WenQuanYi Micro Hei [Scale=0.9]WenQuanYi Micro Hei Mono song-WenQuanYi Micro Hei sfWenQuanYi Micro Hei "zh" = 0pt plus 1pt

ãĂŁLPython CookbookãĂŃçňňäÿL'çL'Ĺ

åŕŚåÿČ 3.0.0

çĘŁèČ¡

2018 åźť 03 æIJĹ 24 æŮě

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http://oreilly.com/catalog/errata.csp?isbn=9781449340377

2 åĽ■èÍĂ

2.1 éąźçŻőäÿżéąţ

https://github.com/yidao620c/python3-cookbook

2.2 èŕŚèĂĚçŽĎèŕİ

äžžçŤ§èŃęç§■ïijŇæĹŚçŤÍ Pythonïij Ą

èŕŚèĂĚäÿĂçŻťåİŽæŇĄä¡£çŤÍ Python 3ïijŇåŻääÿžåőČäżčèąĺäžĘ Python çŽĎæIJłæİěãĂĆèŹ¡çĎűåŘŚåŘŐåĚijåőźæŸŕåőČçŽĎçąñäijďïijŇä¡ĘæŸŕè£ŹäÿłåśĂéİćè£§æŮĺ¨äijŽæŤźåŔŸçŽ èĂŇäÿŤ Python 3 çŽĎæIJłæİěéIJĂèęĄæŕŔäÿłäžžçŽĎåÿőåŁĺ¨åŠŇæŤŕæŇĄãĂĆ çŻőåĽ■åÿĆéİćäÿŁçŽĎæŢŹçÍŃäźęçś■ïijŇç¡Śäÿ ŁçŽĎæĽŃåĘŇåď ğéČĺåĹĘå§žæIJńéČ¡æŸŕ 2.x çşżåĹŮçŽĎïijŇäÿŞéŮĺå§žäžŐ 3.x çşżåĹŮçŽĎäźęçś■åřŚçŽĎåŔŕæĂIJãĂĆ

æIJĂè£ŚçIJŃåĹřäÿĂæIJñãĂŁPython CookbookãĂŃ3rd Edi-tionïijŇåőŇåĚĺå§žäžŐ Python 3ïijŇåĘŹçŽĎäź§å¿Ĺäÿ■éŤŹãĂĆ äÿžäžĘ Python 3 çŽĎæŹőåŔŁïijŇæĹŚäź§äÿ■èĞłéĞŔåŁŻïijŇæČşåĄŽçĆźäżĂäźĹäžŃæČĚãĂĆäžŐæŸŕäźŐïijŇåřśæIJL'äžĘç£ è£Źäÿ■æŸŕäÿĂéąźè¡żæİ¿çŽĎåůěä¡IJïijŇå■ť'æŸŕäÿĂäżűåĂijå¿ŮåĄŽçŽĎåůěä¡IJïijŽäÿ■äżĚæŰźä¿£äžĘåĹńä

èŕŚèĂĚäijŽåİŽæŇĄåŕźèĞłåůśæŕŔäÿĂåŔěçŽĎç£żèŕŚèť§èť čïijŇåŁŻæśĆéńŸèť'léĞŔãĂĆä¡ĘåŔŮèČ¡åŁŽ åęĆæđIJèŕŚæŰĞäÿ■æIJL'äžĂäźĹéŤŹæijŔçŽĎåIJřæŰźèŕůåď ğåőűèğĄèŕËïijŇäź§æňćè£Őåď ğåőűéŽŔæŮűæŇ yidao620@gmail.com

2.3 ä¡IJèĂĚçŽĎèŕİ

èĞłäžŐ 2008 åźť'äžěæİěïijŇPython 3 æĺłçl'žåĞžäÿŰåźűæĚćæĚćè£ŻåŇŰãĂĆPython 3 çŽĎætĄèąŇäÿĂçŻť'ècńèőd'äÿžéIJĂèęĄå¿ĹéŢ£äÿĂæőţæŮűéŮťãĂĆ äžŃåődäÿŁïijŇåĽřæĹŚåĘŹè£ŹæIJñäźęçŽĎ 2013 åźť'ïijŇçżİåď ğéČĺåĹĘçŽĎ Python çÍŃåžŔåŚŸäż■çĎűåIJÍçŤ§äžğçŐŕåćČäÿ■ä¡£çŤÍçŽĎæŸŕçL'ĹæIJñ 2 çşżåĹŮïijŇ æIJĂäÿżèęĄæŸŕåŻääÿž Python 3 äÿ■åŘŚåŘŐåĚijåőźãĂĆæŕńæŮăçŰŚéŰőïijŇåŕźäžŐåůěä¡IJåIJÍéĄŮçŢŹäżčç ä¡ĘæŸŕæŤ¿çIJijæIJłæİěïijŇä¡ăåŕśäijŽåŔŚçŐř Python 3 çżŹä¡ăåÿęæİěäÿ■äÿĂæăůçŽĎæČŁåŰIJãĂĆ

æ■čåęĆ Python 3 äžčèąĺæIJłæİěäÿĂæăůïijŇæŰřçŽĎãĂŁPython Cook-bookãĂŃçL'ĹæIJñçŻÿæŕŤè¿ČäźŃåL'■çŽĎçL'ĹæIJñæIJL'äžĘäÿĂäÿłåĚĺæŰřçŽĎæŤźåŔŸãĂĆ éęŰåĚĹïijŇäź§æŸŕæIJĂéĞ■èęĄçŽĎïijŇè£ŹæĎŘåŠşçİĂæIJñäźęæŸŕäÿĂæIJñéİđåÿÿåL'■æš£çŽĎåŔĆèĂČäź Python 3.3 çL'ĹæIJñäÿŃéİćçijŰåĘŹåŠŇætŃèŕŢçŽĎïijŇ åźűæšąæIJL'èĂČèŹŠäźŃåL'■èĂĄçL'ĹæIJñçŽĎåĚijå ä¡ĘæŸŕæĹŠäžňæIJĂçżĹçŽĎçŻőçŽĎæŸŕåĘŹäÿĂæIJñåőŇåĚĺå§žäžŐçŐřäžčåůěåĚůåŠŇèŕ■èĺĂçŽĎäźęçś■ãĂ æĹŠäžňåÿŇæIJŻæIJñäźęèČ¡åď §æŇĞåŕijäžžäžňä¡£çŤÍ Python 3 çijŰåĘŹæŰřçŽĎäžčçăĄæĹŰèĂĚå■ĞçžğäźŃåL'■çŽĎéĄŮçŢŹäžčçăĄãĂĆ

æŕńæŮăçŰŚéŮőïijŇçijŰåĘŹäÿĂæIJñè£ŹæăůçŽĎäźęçżŹçijŰè¿Śåůěä¡IJåÿęæİěäÿĂåőŽçŽĎæŇŚæĹŸãĂ Python çğŸçś■çŽĎèŕİïijŇäijŽåIJĺèŕÿåęĆ ActiveStateâĂŹs Python recipes æĹŰèĂĚ Stack Overflow çŽĎç¡ŚçńŹäÿŁæŘIJåĹřæŢřäžěå■Čè őąçŽĎæIJL'çŤĺçŽĎçğŸçś■ïijŇä¡ĘæŸŕåĚűäÿ■çżİåď ğéČĺåĹĘéČ è£ŹäžŽçğŸçś■éŹď äžĘæŸŕå§žäžŐ Python 2 çijŰåĘŹäźŃåď ŰïijŇåŔŕèČ¡è£ŸæIJL'å¿Låď Žèğčå Eşæ Ű źæąĹåIJ ïijĹæŕŤåęĆ 2.3 åŠŇ 2.4 çL'ĹæIJñïijL'ãĂĆ åŘęåď ŰïijŇåőČäžňè£ŸäijŽçżŔåÿÿä¡£çŤÍäÿĂäžŻè£ĞæŮűçŽĎæĹA

Python 3.3 éĞŇéÍćåŐżäžĘãĂĆårżæL’¿åőŇåĚĺå§žäžŐ Python 3 çŽĎçğŸçś■çIJ§çŽĎéŽ¿äÿŁåŁăéŽ¿åŢŁãĂĆ

è£ŹæIJñäźęçŽĎæL’ĂæIJL’äÿżécŸéČ¡æŸŕå§žäžŐåůšçżŔå■ŸåIJÍçŽĎäżčçăĄåŠŇæŁĂæIJfŕijŇèĂŇäÿ■æ
Python 3 çL’źæIJL’çŽĎçğŸçś■ãĂĆ åIJÍåŐ§æIJL’äžčçăĄå§žçąĂäÿŁïijŇæĹŚäżňåőŇåĚĺä¡£çŤÍæIJĂæŰřçŽĎ
Python æŁĂæIJŕåŐżæŤźéĂãăĂĆ æL’Ăäžěïij Ňäżżä¡ŢæČşä¡£çŤÍæIJĂæŰřæŁĂæIJŕçijŰåĘŹäżčçăĄçŽĎçÍŃåž

åIJÍéĂL’æŃl’èęĄåŇĚåŔńåŞłäžŽçğŸçś■æŰźéİćïijŇå¿ĹæŸŐæŸ¿äÿ■åŔŕèČ¡çijŰåĘŹäÿĂæIJñäźęåŻŁæŃ
Python écĘå§§æL’ĂæIJL’çŽĎäÿIJèě£ãĂĆ åŻăæ■d’ïijŇæĹŚäżňäijŸåĚĹéĂL’æŃl’äžĘ Python
èŕ■èÍĂæäÿå£ČéČÍåĹĘïijŇäżěåŔŁéĆčäžŻæIJL’çİĂåź£æşŻåžŢçŤÍéćĘå§§çŽĎéŰőécŸãĂĆ
åŔęåd’ŰïijŇåĚűäÿ■æIJL’å¿Ĺåd’ŽçğŸçś■çŤÍæİěåśŢçd’ž Python 3 çŽĎæŰřçL’źæĂğïijŇ
è£Źåŕźäžőå¿Ĺåd’Žäžžæİěèŕť’æŸŕæŕŤè¿ČéŹŇçŤ§çŽĎïijŇåŞłæĂŢæŸŕä¡£çŤÍ
Python èĂĄçL’ĹæIJňçŽĎçżŔélŇäÿřárŇçŽĎçÍŃåžŔåŚŸãĂĆ
è£ŹäžŻçd’žä¿ŃçÍŃåžŔäź§äijŽåĄŔåŘäžŐåśŢçd’žäÿĂäžŻæIJL’çİĂåź£æşŻåžŢçŤÍçŽĎçijŰçÍŃæŁĂæIJŕ
ïijĹå■şçijŰçÍŃæÍąåijŔïijL’ïijŇ èĂŇäÿ■æŸŕäžĚäžĚåőŻä¡■åIJÍäÿĂäžŻåĚůä¡ŞçŽĎéŰőécŸäÿŁãĂĆår¡çőąäź§æ
Python èŕ■èÍĂæäÿå£ČåŠŇæăĞåĞĘåžŞãĂĆ

2.4 è£ŹælJňäźęéĂĆåŘĹèřĄ

è£ŹæIJñäźęçŽĎçŻőæăĞèŕżèĂĚæŸŕéĆčäžŻæČşæůśåĚěçŘĘèğč Python
èŕ■èÍĂæIJžåĹűåŠŇçŐřäżčçijŰçÍŃéčŐæăijçŽĎæIJL’çżŔélŇçŽĎ Python çÍŃåžŔåŚŸãĂĆ
æIJñäźęåd’ğéČÍåĹĘåĘĚåőźéŻĘäÿ■äžŐåIJÍæăĞåĞĘåžŞïijŇæąĘæđűåŠŇåžŢçŤÍçÍŃåžŔäÿ■åź£æşŻä¡£çŤÍçŽĎe
æIJñäźęæL’ĂæIJL’çd’žä¿ŃåİĞåĄĞèő¿èŕżèĂĚåĚůæIJL’äÿĂåőŽçŽĎçijŰçÍŃèČŇæŹŕåźűäÿŤåŘŕäżěèŕżæĞĆçŻ
ïijĹæŕŤåęĆå§žæIJñçŽĎèőąçőŮæIJžçğŚå■ęç§ěèŕĘïijŇæŢřæ■őçżŞædĎç§ěèŕĘïijŇçőŮæşŢåd’■æİĆåžęïijŇçşżç
èŕ■èÍĂçijŰçÍŃç■L’ïijL’ãĂĆ åŔęåd’ŰïijŇæŕŔäÿłçd’žä¿ŃéČ¡åŘłæŸŕäÿĂäÿłåĚěéŮÍæŇĞåŕijïijŇåęĆædIJèŕżèĂĚ
æĹŚäżňåĄĞåőŽèŕżèĂĚåŘŕäżěå¿ĹçĘ§çżČçŽĎä¡£çŤÍæŘIJçt’ćåijŢæŞŐäżěåŘŁç§ěéĄŞæĂŐæăůæ§ěèŕćåIJÍçž£
Python æŰĞæąčĂĆ

æIJL’äÿĂäžŻæŽt’åŁăéńŸçžğçŽĎçğŸçś■ïijŇåęĆædIJèĂŘå£ČéŸĚèŕżïijŇårĘæIJL’åŁl’äžŐçŘĘèğč
Python åžŢåśĆçŽĎåůěä¡IJåŐ§çŘĘãĂĆ äžŐäÿ■ä¡ăårĘå■ęåĹřäÿĂäžŻæŰřçŽĎæŁĂåůğåŠŇæŁĂæIJfŕijŇåźűåž

2.5 è£ŹælJňäźęäÿ■éĂĆåŘĹèřĄ

è£ŹæIJñäźęäÿ■éĂĆåŘĹ Python çŽĎåĹİå■ęèĂĚãĂĆäžŃåőđäÿŁïijŇæIJñäźęåĄĞåőŽèŕżèĂĚåĚůæIJL’
Python æŢŹçÍŃæĹŮåĚěéŮÍäźęçś■äÿ■æL’ĂæŢŹæŐĹçŽĎå§žçąĂç§ěèŕĘãĂĆ
æIJñäźęäź§äÿ■æŸŕéČčçğ■å£ńéĂ§åŔĆèĂČæL’ŃåĘŇ ïijĹä¿ŃåęĆå£ńéĂ§æ§ěèŕćæ§ŘäÿłæĺąåİŮäÿŇçŽĎæ§Řä
æIJñäźęæŮĺåIJÍèĄŽçĎęåĞääÿłæIJĂéĞ■èęĄçŽĎäÿżécŸïijŇæijŤçd’žåĞăçğ■åŔŕèČ¡çŽĎèğčåĘşæŰźæąĹïijŇ
æŔŘä¿Żäÿääÿłèůşæİ£åijŢåŕijèŕżèĂĚè£ŻåĚěäÿĂäžŻæŻt’éńŸçžğçŽĎåĘĚåőźïijĹè£ŹäžŻåŔŕäżěåIJÍç¡Śäÿ ŁæĹ

2.6 åIJÍçž£çd’žä¿Ńäżčçă Ą

æIJñäźęåĞääźŐæL’ĂæIJL’æžŘäżčçăĄåİĞåŔŕäżěåIJÍ http://github.com/dabeaz/python-cookbook äÿŁéİćæL’¿åĹřãĂĆ ä¡IJèĂĚæńćè£ŐåŘĎä¡■èŕżèĂĚä£őæ■č bugïijŇæŤźè£Żäżčçă ĄåŠŇèŕĎèőžãĂĆ

2.7 ä¡£çŤÍçď'žä¿ŃäžčçăĄ

æIJňäźęářśæŸŕåÿőåŁľ'ä¡ăåőŇæĹŘä¡ăçŽĎåůěä¡IJçŽĎãĂĆ
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éŹď'éİđä¡ăä¡£çŤÍäžĘåď'ğéĞŔçŽĎäžčçăĄïijŇåŘęåĹŹäÿ■éIJĂèęĄåŘŚæĹŚäžňçŤşèřůèőÿåŔŕãĂĆ
ä¿ŃåęĆïijŇä¡£çŤÍåĞăäÿłäžčçăĄçL'Ğæőţå0žåőŇæĹŘäÿĂäÿłçÍŃåžŔäÿ■éIJĂèęĄèőÿåŔŕïijŇèt'l'å■ŰæĹŰèĂĚ
åijŢçŤÍæIJňäźęåŠŇçď'žä¿ŃäžčçăĄåŐžç¡ŚäÿŁåŻđç■ŤäÿĂäÿłéŮőécŸäÿ■éIJĂèęĄèőÿåŔŕïijŇä¡ĘæŸŕåŘĹåźűå

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åijŢçŤÍéĂŽåÿÿåŇĚåŘńæăĞécŸïijŇä¡IJèĂĚïijŇåĞžçL'Ĺçď¿ïijŇISBNãĂĆ ä¿ŃåęĆïijŽ*Python Cookbook*, 3rd edition, by David Beazley and Brian K. Jones (OâĂŹReilly). Copyright 2013 David Beazley and Brian Jones, 978-1-449-34037-7.

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2.8 èĄŢçşżæĹŚäžň

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2.9 èĞťèřć

æĹŚäžňèąůå£ČæĎ§èřćæIJňäźęçŽĎæŁĂæIJŕæăąåőąäžžåŚŸ Jake Vanderplasïij ŇRobert Kern åŠŇ Andrea Crotti éİđåÿÿæIJL’çŤĺçŽĎèŕĎèőžåŠŇåžžèőőïijŇ è£ŸæIJL’ Python çd’¿åŇžçŽĎåÿőåŁl’åŠŇéijŞåŁśãĂĆæĹŚäžňåŘŇæăůæĎ§èřćäÿŁäÿĂäÿłçL’ĹæIJňçŽĎçijŰè¿Ś Alex MartelliïijŇAnna Ravenscroft åŠŇ David AscherãĂĆ åř¡çőąè£Źäÿłçl’ĹæIJňæŸŕæŰřåĹŻä¡IJçŽĎïijŇä¡ĘæŸŕåL’■äÿĂäÿłçL’ĹæIJňäÿžæIJňäźęæŔŘä¿ŻäžĘäÿĂäÿłæŇ æIJĂåŘŐäź§æŸŕæIJĂéĞ■èęĄçŽĎïijŇæĹŚäžňèęĄæĎ§èřćæL’ĂæIJL’æŮl’æIJ§écĎèğĹçL’ĹæIJňçŽĎèŕżèĂĚïi

3 çňňäÿĂçńăïijŽæŢřæ■őçżŞæđĎåŠŇçőŮæşŢ

Python æŔŘä¿ŻäžĘåd’ğéĞŔçŽĎåĘĚç¡őæŢřæ■őçżŞæđĎïijŇåŇĚæŃňåĹŮèąĺïijŇéŻĘåŘĹäžěåŘŁå■ŮåĚ ä¡ĘæŸŕïijŇæĹŚäžňäź§äijŽçżŔåÿÿçćřåĹřåĹřěŕÿåęĆæ§ěèŕćïijŇæŐŠåžŔåŠŇè£Ğæżd’ç■L’ç■L’è£ŹäžŻæŹőéĄ■ åŻăæ■d’ïijŇè£ŹäÿĂçńăçŽĎçŻőçŽĎářśæŸŕèőĺèőžè£ŹäžŻæŕŤè¿Čåÿÿè ğĄçŽĎéŮőécŸåŠŇçőŮæşŢãĂĆ åŔęåd’ŰïijŇæĹŚäžňäź§äijŽçżŹåĞžåIJĺéŻĘåŘĹæĺąåİŮ `collections` å¡Şäÿ■æŞ■ä¡IJè£ŹäžŻæŢřæ■őçżŞæđĎçŽĎæŰźæşŢãĂĆ

3.1 1.1 èğčåŐŃåžŔåĹŮèţŃåĂijçżŹåd’ŽäÿłåŔŸéĞŔ

éŮőécŸ

çŐřåIJĺæIJL’äÿĂäÿłåŇĚåŘń N äÿłåĚČçt’ăçŽĎåĚČçżĎæĹŰèĂĚæŸŕåžŔåĹŮïijŇæĂŐæăůårĘåőČéĞŇéİc N äÿłåŔŸéĞŔïij§

èğčåĘşæŰźæąĹ

äžża¡ŢçŽĎåžŔåĹŮïijĹæĹŰèĂĚæŸŕåŔŕè£■äžčårźèśąïijL’åŔŕäžěéĂŽè£ĞäÿĂäÿłçőĂå■ŢçŽĎèţŃåĂijèŕ■å åŤŕäÿĂçŽĎåL’■æŘŘårśæŸŕåŔŸéĞŔçŽĎæŢřéĞŔå£Ěéążèů§åžŔåĹŮåĚČçt’ăçŽĎæŢřéĞŔæŸŕäÿĂæăůçŽĎã

äžčçăĄçd’žä¿ŃïijŽ

```
>>> p = (4, 5)
>>> x, y = p
>>> x
4
>>> y
5
>>>
>>> data = [ 'ACME', 50, 91.1, (2012, 12, 21) ]
>>> name, shares, price, date = data
>>> name
'ACME'
>>> date
(2012, 12, 21)
>>> name, shares, price, (year, mon, day) = data
```

```
>>> name
'ACME'
>>> year
2012
>>> mon
12
>>> day
21
>>>
```

åęĆædIJåŔŸéĞŔäÿłæŢřåŠŇåžŔåĹŮåĚČçť ăçŽĎäÿłæŢřäÿ■åŇźéĚ■ïijŇäijŽäžğçŤ§äÿĂäÿłåijĆåÿÿãĂĆ

äżčçăĄçď žä¿ŃïijŽ

```
>>> p = (4, 5)
>>> x, y, z = p
Traceback (most recent call last):
File "<stdin>", line 1, in <module>
ValueError: need more than 2 values to unpack
>>>
```

èőÍèőž

åőđéŹĚäÿŁïijŇè£Źçğ■èğčåŐŃètŃåĂijåŔŕäžěçŤĺåIJÍäżżä¡ŢåŔŕè£■äžčåŕźèśąäÿŁéİćïijŇèĂŇäÿ■äżĚäżĚæåŇĚæŃňå■ŮçňęäÿšïijŇæŰĞäżűåŕźèśąïijŇè£■äžčåŹĺåŠŇçŤ§æĹŘåŹĺãĂĆ

äżčçăĄçď žä¿ŃïijŽ

```
>>> s = 'Hello'
>>> a, b, c, d, e = s
>>> a
'H'
>>> b
'e'
>>> e
'o'
>>>
```

æIJL'æŮűåĂŹïijŇä¡ăåŔŕèČ¡åŔłæČşèğčåŐŃäÿĂéČĺåĹĘïijŇäÿćåijČåĚűäżŰçŽĎåĂijãĂĆåŕźäžŐè£Źçğ■a
Python åźűæšąæIJL'æŘŘä¿ŻçL'źæőŁçŽĎèí■æşŢãĂĆ ä¡ĘæŸŕä¡ăåŔŕäžěä¡£çŤĺäżżæĎŔåŘŸéĞŔåŘ■åŐżå■ää¡

äżčçăĄçď žä¿ŃïijŽ

```
>>> data = [ 'ACME', 50, 91.1, (2012, 12, 21) ]
>>> _, shares, price, _ = data
>>> shares
50
>>> price
91.1
>>>
```

ä¡åå£Ëéążä£ÌèŕĄä¡ăéĂL’çŤĺçŽĎéĆčäžŻå■ăä¡■åŔŸéĞŔåŘ■åIJĺåËűäžŰåIJřæŰźæšąèćńä¡£çŤĺåĹřãĂĆ

3.2 1.2 èğčåŐŃåŘŕè£■äžčåŕźèśąèţŃåĂijçżŹåď̌ŽäÿłåŔŸéĞŔ

éŮőécŸ

åęĆæđIJäÿĂäÿłåŔŕè£■äžčåŕźèśąçŽĎåËČçţ̌ääÿłæŢřèűËè£ĞåŔŸéĞŔäÿłæŢřæŮűïijÑäijŽæŁŻåĞžäÿĂäÿł
`ValueError` ãĂĆ éĆčäźĹæĂŐæåůæL’■èČ¡äžŐè£ŹäÿłåŔŕè£■äžčåŕźèśąäÿ■èğčåŐŃåĞž N
äÿłåËČçţ̌ääĞžæÌěïij§

èğčåEşæŰźæąĹ

Python çŽĎæŸ§åŘůèąĺè¿¿åijŔåŔŕäžěçŤĺæÌěèğčåEşè£ŹäÿłéŮőécŸãĂĆæŕŤåęĆïijÑä¡ääIJĺå■ęäźääÿĂéŮĺ
ä¡ăæČşçż§èőąäÿŃåőűåž■ä¡IJäÿŽçŽĎåźşåİĞæĹŘçżl’ïijÑä¡EæŸŕæŐŠéŹď̌æŐL’çňňäÿĂäÿłåŠÑæIJĂåŘŐäÿĂä
ä¡Ęåę ĆæđIJæIJL’ 24 äÿłåŚćïij§è£ŹæŮűåĂŹæŸ§åŘůèąĺè¿¿åijŔåřśæť¿äÿŁçŤĺåIJžäžEïijŽ

```
def drop_first_last(grades):
    first, *middle, last = grades
    return avg(middle)
```

åŘęåď̌ŰäÿĂçğ■æČĚåEţïijÑåĄĞèő¿ä¡ăçŐřåIJĺæIJL’äÿĂäžŻçŤĺæĹůçŽĎèőřå¡ŢåĹŮèąĺïijÑærŔæİąèőřå¡Ţ
ä¡ääŔŕäžěåČŔäÿŃéÌćè£ŹæăůåĹEèğčè£ŹäžŻèőřå¡Ţïij Ž

```
>>> record = ('Dave', 'dave@example.com', '773-555-1212', '847-555-
↪1212')
>>> name, email, *phone_numbers = record
>>> name
'Dave'
>>> email
'dave@example.com'
>>> phone_numbers
['773-555-1212', '847-555-1212']
>>>
```

åĂijå¿ŮæşĺæĎŔçŽĎæŸŕäÿŁéÌćèğčåŐŃåĞžçŽĎ `phone_numbers`
åŔŸéĞŔæřÿè£IJéČ¡æŸŕåĹŮèąĺçśžåđŃïijÑäÿ■çőąèğčåŐŃçŽĎçŢţèŕİåŔůçăĄæŢřéĞŔæŸŕåď̌ŽåřŠïijĹåŃĚæŃ
0 äÿłïijL’ãĂĆ æL’Ăäžěïij Ñäżżä¡Ţä¡£çŤĺåĹř `phone_numbers`
åŔŸéĞŔçŽĎäžčçăĄåřśäÿ■éIJĂèęĄåĄŽåď̌Žä¡ŹçŽĎçśžåđŃæčĂæ§ěåŐżçąőèőď̌åőČæŸŕåŘęæŸŕåĹŮèąĺçśžåđ

æŸ§åŘůèąĺè¿¿åijŔäźş§èČ¡çŤĺåIJĺåĹŮèąĺçŽĎåijĂåğŃéČĺåĹĘãĂĆæŕŤåęĆïijÑä¡ăæIJL’äÿĂäÿłåĚñåŔŷåL’■
8 äÿłæIJĹéŤĂåŤőæŢřæ■őçŽĎåžŔåĹŮïijÑ ä¡EæŸŕä¡ăæČşçIJŃäÿŃæIJĂè£ŠäÿĂäÿłæIJĹæŢřæ■őåŠŃåL’■éÌć
7 äÿłæIJĹçŽĎåźşåİĞåĂijçŽĎåŕźæŕŤãĂĆä¡ääŔŕäžěè£ŹæăůåĄŽïijŽ

```
*trailing_qtrs, current_qtr = sales_record
trailing_avg = sum(trailing_qtrs) / len(trailing_qtrs)
return avg_comparison(trailing_avg, current_qtr)
```

äÿŃéÌćæŸŕåIJĺ Python èğčéĞŁåŹĺäÿ■æL’ğèąŇçŽĎçżŞædIJïijŽ

```
>>> *trailing, current = [10, 8, 7, 1, 9, 5, 10, 3]
>>> trailing
[10, 8, 7, 1, 9, 5, 10]
>>> current
3
```

èőÍèőž

æĽľåśŢçŽĎè£■äžčèğčåŐŃèŕ■æşŢæŸŕäÿŞéŮĺäÿžèğčåŐŃäÿ■çąőåőŽäÿłæŢřæĹŰäżżæĎŔäÿłæŢřåĚČçť
éĂŽåÿÿijŇè£ŹäžŽåŔŕè£■äžčåŕźèśąçŽĎåĚČçť ăçżŞæđĎæIJĽçąőåőŽçŽĎèğĎåĹŹïijĹæŕŤåęĆçňň
1 äÿłåĚČçť ăåŘŐéÍćéČ¡æŸŕçŢţèŕÍåŔůçăĄïijĽ ïijŇ æŸ§åŔůèąÍè¿¿åijŔèőľåijĂåŔŚäžžåŚŸåŔŕäżěå¿ĹåőźæŸ§ç
èĂŇäÿ■æŸŕéĂŽè£ĞäÿĂäžŻæŕŤè¿Čåď■æÍĆçŽĎæĽŃæőţåŐżèŐůåŔŰè£ŹäžŽåĚşèĄŢçŽĎåĚČçť ăåĂijãĂĆ

åĂijå¿ŮæşÍæĎŘçŽĎæŸŕïijŇæŸ§åŔůèąÍè¿¿åijŔåIJÍè£■äžčåĚČçť ăäÿžåŔŕåŘŸéŢ£åĚČçżĎçŽĎåžŘåĹŮæ
æŕŤåęĆïijŇäÿŃéÍćæŸŕäÿĂäÿłåÿęæIJĽæăĞç■¿çŽĎåĚČçżĎåžŘåĹŮïijŽ

```
records = [
    ('foo', 1, 2),
    ('bar', 'hello'),
    ('foo', 3, 4),
]

def do_foo(x, y):
    print('foo', x, y)

def do_bar(s):
    print('bar', s)

for tag, *args in records:
    if tag == 'foo':
        do_foo(*args)
    elif tag == 'bar':
        do_bar(*args)
```

æŸ§åŔůèğčåŐŃèŕ■æşŢåIJÍå■ŮçňęäÿšæŞ■ä¡IJçŽĎæŮűåĂŹäź§äijŽå¿ĹæIJĽçŤĺïijŇæŕŤåęĆå■Ůçňęäÿšç

äžčçăĄçď žä¿ŃïijŽ

```
>>> line = 'nobody:*:-2:-2:Unprivileged User:/var/empty:/usr/bin/
↪false'
>>> uname, *fields, homedir, sh = line.split(':')
>>> uname
'nobody'
>>> homedir
'/var/empty'
>>> sh
'/usr/bin/false'
>>>
```

æIJL'æŮűåĂŹïijÑä¡ăæČşèğčåŐŃäÿĂäžŻåĚČçť'ååŘŐäÿćåijČåőČäžňïijÑä¡ăäÿ■èČ¡çőĂå■Ţåřśä¡£çŤÍ
* ïijÑ ä¡ĘæŸŕä¡ăåŔŕäžěä¡£çŤĺäÿĂäÿłæŹőéĂŽçŽĎåž§åijČåŘ■çğřïijÑæŕŤåęĆ _ æĹŰèĂĚ
ign ïijĹignoreïijL'ãĂĆ

äžčçăĄçď'žä¿ŃïijŽ

```
>>> record = ('ACME', 50, 123.45, (12, 18, 2012))
>>> name, *_, (*_, year) = record
>>> name
'ACME'
>>> year
2012
>>>
```

åIJĺå¿Ĺåď'ŽåĞ¡æŢřåijŔèŕ■èĺĂäÿ■ïijÑæŸ§åŔůèğčåŐŃèŕ■æşŢèů§åĹŰèąĺåď'ĎçŘĘæIJL'èőÿåď'ŽçŻÿäijijä
ä¡ăåŔŕäžěå¿ĹåőźæŸŞçŽĎåřĘåőČåĹĘåL'šæĹŘåL'■åŘŐäÿď'éČĺåĹĘïijŽ

```
>>> items = [1, 10, 7, 4, 5, 9]
>>> head, *tail = items
>>> head
1
>>> tail
[10, 7, 4, 5, 9]
>>>
```

åęĆæđIJä¡ăåď'§èĄłæŸŐçŽĎèŕİïijÑè£ŸèČ¡çŤĺè£Źçğ■åĹĘåL'šèŕ■æşŢåŐżåůğåęŹçŽĎåőđçŐřéĂŠå¡ŠçőŮ

```
>>> def sum(items):
...     head, *tail = items
...     return head + sum(tail) if tail else head
...
>>> sum(items)
36
>>>
```

çĎűåŘŐïijÑçŤśäžŐèŕ■èĺĂåśĆéİćçŽĎéŹŘåĹűïijÑéĂŠå¡Šåźűäÿ■æŸŕ Python
æŞĚéŢ£çŽĎãĂĆ åŽäæ■d'ïijÑæIJĂåŘŐéĆčäÿłéĂŠå¡ŠæijŤçď'žäžĚäžĚæŸŕäÿłåě¡åěĞçŽĎæŐćçť'éç¡ćäžĘïijÑå

3.3 1.3 ä£İçŢŹælJĂåŘŐ N äÿłåĚČçť'ă

éŮőécŸ

åIJĺè£■äžčæŞ■ä¡IJæĹŰèĂĚåĚűäžŰæŞ■ä¡IJçŽĎæŮűåĂŹïijÑæĂŐæăůåŔłä£İçŢŹæIJĂåŘŐæIJL'éŹŘåĞă

èğčåĘşæŰźæąĹ

ä£İçŢŹæIJL'éŹŘåŐĘåŔšèőřå¡Ţæ■čæŸŕ `collections.deque`
åď'ğæŸ¿èžńæL'ŃçŽĎæŮűåĂŹãĂĆærŤåęĆïijÑäÿŃéİćçŽĎäžčçăĄåIJĺåď'ŽèąŇäÿŁéİćåĄŽçőĂå■ŢçŽĎæŰĞæ
åźűè£ŤåŽđåŇźéĚ■æL'ĂåIJĺèąÑçŽĎæIJĂåŘŐNèąÑïijŽ

```
from collections import deque


def search(lines, pattern, history=5):
    previous_lines = deque(maxlen=history)
    for line in lines:
        if pattern in line:
            yield line, previous_lines
        previous_lines.append(line)

# Example use on a file
if __name__ == '__main__':
    with open(r'../../cookbook/somefile.txt') as f:
        for line, prevlines in search(f, 'python', 5):
            for pline in prevlines:
                print(pline, end='')
            print(line, end='')
            print('-' * 20)
```

èőÍèőž

æĹŚäžňåIJĺåEŹæ§ěèřćåĚČçť ăçŽĎäžčçăĄæŮűïijŇéĂŽåÿÿäijŽä¡£çŤĺåŇĚåŘń `yield` èąĺè¿¿åijŔçŽĎçŤ§æĹŘåŹĺåĞ¡æŢřïijŇäź§åřśæŸřæĹŚäžňäÿŁéĺćçď žä¿ŇäžčçăĄäÿ■çŽĎéĆčæăůãĂĆ è£ŹæăůåŔřäžěåřĘæŘIJçť ćè£ĞçĺŇäžčçăĄåŠŇä¡£çŤĺæŘIJçť ćçżŞædIJäžčçăĄèğčèĂęãĂĆåęĆædIJä¡ăè£Ÿäÿ■a 4.3 èŁĆãĂĆ

ä¡£çŤĺ `deque(maxlen=N)` ædĎéĂăåĞ¡æŢřäijŽæŰřåžžäÿĂäÿłåŽžåőŽåď ğåřŔçŽĎéŸ§åĹŮãĂĆå¡ŞæŰ æIJĂèĂĄçŽĎåĚČçť ăäijŽèĞłåŁĺèćńçğžéŹď æŐĽ˜ãĂĆ

äžčçăĄçď žä¿ŇïijŽ

```
>>> q = deque(maxlen=3)
>>> q.append(1)
>>> q.append(2)
>>> q.append(3)
>>> q
deque([1, 2, 3], maxlen=3)
>>> q.append(4)
>>> q
deque([2, 3, 4], maxlen=3)
>>> q.append(5)
>>> q
deque([3, 4, 5], maxlen=3)
```

ař¡çőąä¡ăäź§åŘřäžěæĽ˜ŃåŁĺåIJĺäÿĂäÿłåĹŮèąĺäÿŁåődçŐřè£ŹäÿĂçŽĎæŞ■ä¡IJïijĹærŤåęĆåćđåŁăãĂĄåĹ

æŻť äÿĂèĹńçŽĎïijŇ `deque` çśžåŘřäžěèćńçŤĺåIJĺäżžä¡Ţä¡ääŘłéIJĂèęĄäÿĂäÿłçőÅå■ŢéŸ§åĹŮæŢřæ■őç åęĆædIJä¡ääÿ■èő¿ç¡őæIJĂåď ğéŸ§åĹŮåď ğåřŔïijŇéĆčäźĹářšäijŽå¿ŮåĹřäÿĂäÿłæŮăéŹŘåď ğåřŔéŸ§åĹŮïijŇ

äžčçăĄçď žä¿ŇïijŽ

```
>>> q = deque()
>>> q.append(1)
>>> q.append(2)
>>> q.append(3)
>>> q
deque([1, 2, 3])
>>> q.appendleft(4)
>>> q
deque([4, 1, 2, 3])
>>> q.pop()
3
>>> q
deque([4, 1, 2])
>>> q.popleft()
4
```

åIJÍéŸ§åĹŮäÿď'çńŕæŔŠåĚěæĹŰåĹăéŹď'åĚČçţ'ăæŮűéŮţ'åď'■æİĆåžęéČ¡æŸŕ O(1) ïijŇåŇžåĹńäžŐåĹŮèąĺïijŇåIJÍåĹŮèąĺçŽĎåijÄåď'ţ'æŔŠåĚěæĹŰåĹăéŹď'åĚČçţ'ăçŽĎæŮűéŮţ'åď'■æİĆåžęäÿž O(N) ãĂĆ

3.4 1.4 æ§ěæĽ¿ælJĂåď'ğæĹŰælJĂåřŔçŽĎ N äÿłåĚČçţ'ă

éŮőécŸ

æĂŐæăůäżŐäÿĂäÿłéŻĘåŘĹäÿ■èŐůå¿ŮælJĂåď'ğæĹŰèĂĚælJĂåřŔçŽĎ N äÿłåĚČçţ'ăåĹŮèąĺïij§

èğčåĘşæŰźæąĹ

heapq æĺąåİŮælJL'äÿď'äÿłåĞ¡æŢřïijŽnlargest() åŠŇ nsmallest() åŘŕäžěåőŇç¿Őèğčåĕşè£ŹäÿłéŮőécŸãĂĆ

```
import heapq
nums = [1, 8, 2, 23, 7, -4, 18, 23, 42, 37, 2]
print(heapq.nlargest(3, nums)) # Prints [42, 37, 23]
print(heapq.nsmallest(3, nums)) # Prints [-4, 1, 2]
```

äÿď'äÿłåĞ¡æŢřéČ¡èČ¡æŐěåŘŮäÿĂäÿłåĚşéŤőå■ŮåŘĆæŢřïijŇçŤĺäžŐæŻţ'åď'■æİĆçŽĎæŢřæ■őçżŞædĎă

```
portfolio = [
    {'name': 'IBM', 'shares': 100, 'price': 91.1},
    {'name': 'AAPL', 'shares': 50, 'price': 543.22},
    {'name': 'FB', 'shares': 200, 'price': 21.09},
    {'name': 'HPQ', 'shares': 35, 'price': 31.75},
    {'name': 'YHOO', 'shares': 45, 'price': 16.35},
    {'name': 'ACME', 'shares': 75, 'price': 115.65}
]
```

```
cheap = heapq.nsmallest(3, portfolio, key=lambda s: s['price'])
expensive = heapq.nlargest(3, portfolio, key=lambda s: s['price'])
```

èřŚèĂĚæşÍïijŽäÿŁéÍćäžčçăĄåIJĺářźæřŔäÿłåĚČçť'äè£ŻèąŇářźæřŤçŽĎæŮűåĂŹïijŇäijŽäžě price çŽĎåĂijè£ŻèąŇærŤè¿ČãĂĆ

èőÍèőž

åęĆæđIJä¡ăæČşåIJĺäÿĂäÿłéŻĘåŘĹäÿ■æ§ěæL'¿æIJĂářŔæĹŰæIJĂåď'ğçŽĎ N äÿłåĚČçť'ăïijŇåźűäÿŤ N åřŔäžŐéŻĘåŘĹåĚČçť'äæŢřéĞŔïijŇéĆčäźĹè£ŹäžŻåĞ¡æŢřæŔŘä¿ŻäžĘå¿Ĺåě¡çŽĎæ åŻääÿžåIJĺážŢåśĆåőđçŐřéĞŇéÍćïijŇéęŰåĚĹäijŽåĚĹářĘéŻĘåŘĹæŢřæ■ős£ŻèąŇääĘæŐŠåžŔåŘŐæŤ¿åĚěäÿ

```
>>> nums = [1, 8, 2, 23, 7, -4, 18, 23, 42, 37, 2]
>>> import heapq
>>> heap = list(nums)
>>> heapq.heapify(heap)
>>> heap
[-4, 2, 1, 23, 7, 2, 18, 23, 42, 37, 8]
>>>
```

åäĘæŢřæ■őçżŞædĎæIJĂéĞ■èęĄçŽĎçL'źå¿ĄæŸý heap[0] æřÿè£IJæŸýæIJĂářŔçŽĎåĚČçť'ăãĆĆåźűäÿŤåL'l'ä¡ŹçŽĎåĚČçť'ăåŔýäžěå¿ĹåőźæŸ§çŽĎéĂŽè£ĞèřČçŤÍ heapq.heappop() æŰźæşŢå¿ŮåĹřïijŇ èřěæŰźæşŢäijŽåĚĹářĘçňňäÿĂäÿłåĚČçť'ăåijźåĞžæÍěïijŇçĎűåŘŐ O(log N)ïijŇN æŸýåäĘåď'ğářŔïijL'ãĂĆ æřŤåęĆïijŇåęĆædIJæČşèęĄæ§ěæL'¿æIJĂářŔçŽĎ 3 äÿłåĚČçť'ăïijŇä¡ăåŔýäžěè£ŹæăůåĄŽïijŽ

```
>>> heapq.heappop(heap)
-4
>>> heapq.heappop(heap)
1
>>> heapq.heappop(heap)
2
```

å¡ŞèęĄæ§ěæL'¿çŽĎåĚČçť'ääÿłæŢřçŻÿåŕźæřŤè¿ČářŔçŽĎæŮűåĂŹïijŇåĞ¡æŢř nlargest() åŠŇ nsmallest() æŸýå¿ĹåŘĹéĂĆçŽĎãĂĆ åęĆædIJä¡ääžĚäžĚæČşæ§ěæL'¿åŤýäŸĂçŽĎæIJĂářŔæĹŰæIJĂåď'ğïijĹN=1ïijL'çŽĎåĚČçť'ăçŽĎèřÍïijŇéĆčäźÍ min() åŠŇ max() åĞ¡æŢřäijŽæŻť'å£ńäžŽãĂĆ çśžäijijçŽĎïijŇåęĆædIJ N çŽĎåď'ğářŔåŠŇéŻĘåŘĹåď'ğářŔæŐèè£ŠçŽĎæŮűåĂŹïijŇéĂŽåÿÿåĚĹæŐŠåžŔè£ŹäÿłéŻĘåŘĹçĎűåŘŐåĘ■ä¡ ïijĹ sorted(items)[:N] æĹŰèĂĚæŸý sorted(items)[-N:] ïijL'ãĂĆ éIJĂèęĄåIJĺæ■čçąőåIJžåŘĹä¡£çŤĺåĞ¡æŢř nlargest() åŠŇ nsmallest() æL'■èČ¡åŔŠæŇěåőČäžňçŽĎäijŸå£ ïijĹåęĆædIJ N å£ńæŐèè£ŠéŻĘåŘĹåď'ğářŔäžĘïijŇéĆčäźĹä¡£çŤĺæŐŠåžŔæŞ■ä¡IJäijŽæŻť'åě¡äžŻïijL'ãĂĆ

år¡çőąä¡ăæšąæIJL'å£ĚèęĄäÿĂåőŽä¡£çŤĺè£ŹéĞŇçŽĎæŰźæşŢïijŇä¡ĘæŸýåäĘæŢřæ■őçżŞædĎçŽĎåőđçĆ å§žæIJñäÿłåŔłèęĄæŸýæŢřæ■őçżŞædĎåŠŇçőŮæşŢäźęçś■éĞŇéÍćéČ¡äijŽæIJL'æŔŘåŔłåĹřãĂĆ heapq æÍąåİŮçŽĎåőŸæŰźæŰĞæąčéĞŇéÍćäź§èŕęçżĘçŽĎäżŃçż■äžĘåäĘæŢřæ■őçżŞædĎåžŢåśĆçŽĎåőđçĆ

3.5 1.5 åőđçŐřäÿĂäÿłäijŸåĚĹçžğéŸ§åĹŮ

éŮőécŸ

æĂŐæăůåőđçŐřäÿĂäÿłæŇL'äijŸåĚĹçžğæŐŠåžŔçŽĎéŸ§åĹŮïij§åźűäÿŤåIJĺè£ŹäÿłéŸ§åĹŮäÿŁéÍćæŕŔæňą pop æŞ■ä¡IJæĂżæŸŕè£ŤåŽđäijŸåĚĹçžğæIJĂéńŸçŽĎéĆčäÿłåĚČçt

èğčåĘşæŰźæąĹ

äÿŃéÍćçŽĎçśżåĹl'çŤÍ heapq æĺąåİŮåőđçŐřäžĘäÿĂäÿłçőĂå■ŢçŽĎäijŸåĚĹçžğéŸ§åĹŮïijŽ

```
import heapq

class PriorityQueue:
    def __init__(self):
        self._queue = []
        self._index = 0

    def push(self, item, priority):
        heapq.heappush(self._queue, (-priority, self._index, item))
        self._index += 1

    def pop(self):
        return heapq.heappop(self._queue)[-1]
```

äÿŃéÍćæŸŕåőČçŽĎä¡£çŤÍæŰźåijŔïijŽ

```
>>> class Item:
...     def __init__(self, name):
...         self.name = name
...     def __repr__(self):
...         return 'Item({!r})'.format(self.name)
...
>>> q = PriorityQueue()
>>> q.push(Item('foo'), 1)
>>> q.push(Item('bar'), 5)
>>> q.push(Item('spam'), 4)
>>> q.push(Item('grok'), 1)
>>> q.pop()
Item('bar')
>>> q.pop()
Item('spam')
>>> q.pop()
Item('foo')
>>> q.pop()
Item('grok')
>>>
```

äžŤçżĘèğĆåŕ§åŔŕäžěåŔŚçŐřïijŇçňňäÿĂäÿł pop() æŞ■ä¡IJè£ŤåŽđäijŸåĚĹçžğæIJĂéńŸçŽĎåĚČçt'ããĂ

åŔęåď ŰæşÍæĎŔåĹřåęĆæđIJäÿď äÿłæIJL’çİĂçŻÿåŘŇäijŸåĚĹçžğçŽĎåĚČçť ăïijĹ `foo` åŠŇ `grok` ïijL’ïijŇpop æŞ■ä¡IJæŇL’çĚğåőČäžňèćńæŔŠåĚèåĹřéŸ§åĹŮçŽĎéąžåžŔè£ŤåŻđçŽĎãĂĆ

èőÍèőž

è£ŹäÿĂåřŔèŁĆæĹŚäžňäÿžèęĄåĚşæşÍ `heapq` æĺąåİŮçŽĎä¡£çŤĺãĂĆ åĞ¡æŢř `heapq.heappush()` åŠŇ `heapq.heappop()` åĹĘåĹńåIJĺéŸ§åĹŮ `_queue` äÿŁæŔŠåĚèåŠŇåĹäéŹď’çňňäÿĂäÿłåĚČçť ăïijŇ åźűäÿŤéŸ§åĹŮ `_queue` ä£ÌèŕĄçňňäÿĂäÿłåĚČçť ăæŃěæIJL’æIJĂéńŸäijŸåĚĹçžğïijĹ 1.4 èŁĆåůšçżŔèőÍèőžè£Ğè£ŹäÿłéŮőécŸïijL’ãĂĆ `heappop()` åĞ¡æŢřæĂżæŸŕè£ŤåŻđâĂİæIJĂåřŔçŽĎâĂİçŽĎåĚČçť ăïijŇè£ŹåřśæŸŕä£ÌèŕĄéŸ§åĹŮpopæŞ■ä¡IJè£ŤåŻđæ åŔęåď ŰïijŇçŤśäžŐ push åŠŇ pop æŞ■ä¡IJæŮűéŮť åď■æİĆåžęäÿž O(log N)ïijŇåĚűäÿ■ N æŸŕåăĘçŽĎåď ğåřŔïijŇåŻăæ■d’åřśőŮæŸŕ N å¿Ĺåď ğçŽĎæŮűåĂŹåőČäžňè£ŘèąŇéĂ§åžęäź§ä¿İæŮğå¿Ĺå£ńãĂĆ

åIJĺäÿŁéİćäžčçăĄäÿ■ïijŇéŸ§åĹŮåŇĚåŘńäžĘäÿĂäÿł `(-priority, index, item)` çŽĎåĚČçżĎãĂĆ äijŸåĚĹçžğäÿžèť §æŢřçŽĎçŽőçŽĎæŸŕä¡£å¿ŮåĚČçť ăæŇL’çĚğäijŸåĚĹçžğäžŐéńŸè£Źäÿłèů§æŹőéĂŽçŽĎæŇL’äijŸåĚĹçžğäžŐä¡ŐåĹřéńŸæŐŠåžŔçŽĎåăĘæŐŠåžŔæĄřåůğçŽÿåŔ■ãĂĆ

`index` åŔŸéĞŔçŽĎä¡IJçŤĺæŸŕä£ÌèŕĄåŘŇç■L’äijŸåĚĹçžğåĚČçť ăçŽĎæ■čçąőæŐŠåžŔãĂĆ éĂŽè£Ğä£İå■ŸäÿĂäÿłäÿ■æŰ■áćđåŁăçŽĎ `index` äÿŃæăĞåŔŸéĞŔïijŇåŔŕäžěçąőä£İåĚČçť ăæŇL’çĚğåőČäź èĂŇäÿŤïijŇ `index` åŔŸéĞŔäź§åIJĺçŻÿåŘŇäijŸåĚĹçžğåĚČçť ăæŕŤè¿ČçŽĎæŮűåĂŹètůåĹřéĞ■èęĄä¡IJçŤĺã

äÿžäžĘéŸŘæŸŐè£ŹäžŻïijŇåĚĹåĄĞåőŽ `Item` åðđä¿ŃæŸŕäÿ■æŤŕæŇĄæŐŠåžŔçŽĎïijŽ

```
>>> a = Item('foo')
>>> b = Item('bar')
>>> a < b
Traceback (most recent call last):
File "<stdin>", line 1, in <module>
TypeError: unorderable types: Item() < Item()
>>>
```

åęĆæđIJä¡ăä¡£çŤĺåĚČçżĎ `(priority, item)` ïijŇåŔłèęĄäÿď äÿłåĚČçť ăçŽĎäijŸåĚĹçžğäÿ■åŘŇår ä¡ĘæŸŕåęĆæđIJäÿď äÿłåĚČçť ăäijŸåĚĹçžğäÿĂæăůçŽĎèŕİïijŇéĆčäźĹærŤè¿ČæŞ■ä¡IJårśäijŽèů§äźŇåL’■äÿĂ

```
>>> a = (1, Item('foo'))
>>> b = (5, Item('bar'))
>>> a < b
True
>>> c = (1, Item('grok'))
>>> a < c
Traceback (most recent call last):
File "<stdin>", line 1, in <module>
TypeError: unorderable types: Item() < Item()
>>>
```

éĂŽè£ĞåijŢåĚèåŔęåď ŰçŽĎ `index` åŔŸéĞŔçżĎæĹŘäÿL’åĚČçżĎ `(priority, index, item)` ïijŇårśèČ¡å¿Ĺåě¡çŽĎéĄ£åĚ■äÿŁéİćçŽĎéŤŹèŕŕïijŇ åŽăäÿžäÿ■åŔŕèČ¡æIJL’äÿď äÿłåĚČçť ăæIJL’çŽÿåŘŇçŽĎ `index` åĂijãĂĆPython

åIJÍåĄŽåĚČçżĎæŕŤè¿ČæŮűåĂŹïijŇåęĆæđIJåĽ■éÍćçŽĎæŕŤè¿ČåůšçżŕåŕŕäžěçąőåőŽçżŞæđIJäžĘïijŇ
åŘŐéÍćçŽĎæŕŤè¿ČæŞ■ä¡IJåřśäÿ■äijŽåŔŠçŤ§äžĘïijŽ

```
>>> a = (1, 0, Item('foo'))
>>> b = (5, 1, Item('bar'))
>>> c = (1, 2, Item('grok'))
>>> a < b
True
>>> a < c
True
>>>
```

åęĆæđIJä¡ăæČşåIJÍåd'Žäÿłçž£çÍŃäÿ■ä¡£çŤÍåŘŇäÿĂäÿłéŸ§åĹŮïijŇéĆčäźĹä¡ăéIJĂèęĄåćđåŁăéĂĆå¡ŞçŽ
åŔŕäžěæ§ěçIJŃ 12.3 åřŔèŁĆçŽĎä¿Ńå■ŘæijŤçd'žæŸŕæĂŐæăůåĄŽçŽĎãĂĆ

heapq æÍąåİŮçŽĎåőŸæŰźæŰĞæąčæIJĽæŻt'èŕęçżEçŽĎä¿Ńå■ŘçÍŃåžŔäžěåŘŁåŕźäžŐåäEçŘĘèőžåŘŁ

3.6 1.6 å■ŮåĚÿäÿ■çŽĎéŤőæŸăåřĎåd'ŽäÿłåĂij

éŮőécŸ

æĂŐæăůåőđçŐřäÿĂäÿłéŤőåŕźåžŤåd'ŽäÿłåĂijçŽĎå■ŮåĚÿïijĹäź§åŔń
multidictïijL'ïij§

èğčåEşæŰźæąĹ

äÿĂäÿłå■ŮåĚÿåřśæŸŕäÿĂäÿłéŤőåŕźåžŤäÿĂäÿłå■ŢåĂijçŽĎæŸăåřĎãĂĆåęĆæđIJä¡ăæČşèęĄäÿĂäÿłéŤőá
æŕŤåęĆåĹŮèąĺæĹŰèĂĚéŽĘåŘĹéĞŃéÍćãĂĆæŕŤåęĆïijŇä¡ăåŔŕäžěåČŔäÿŃéÍćè£ŹæăůæđĎéĂăè£ŹæăůçŽĎå

```
d = {
    'a' : [1, 2, 3],
    'b' : [4, 5]
}
e = {
    'a' : {1, 2, 3},
    'b' : {4, 5}
}
```

éĂĽ'æŃl'ä¡£çŤÍåĹŮèąĺè£ŸæŸŕéŽĘåŘĹåŘŰåEşäžŐä¡ăçŽĎåőđéŽĚéIJĂæśĆãĂĆåęĆæđIJä¡ăæČşä£ÍæŇA
åęĆæđIJæČşåŐżæŐL'éĞ■åd'■åĚČçť'ăărśä¡£çŤĺéŽĘåŘĹïijĹåźűäÿŤäÿ■åĚşå£ČåĚČçť'ăçŽĎéąžåžŔéŮőécŸïijL

ä¡ăåŔŕäžěå¿ĹæŰźä¿£çŽĎä¡£çŤÍ collections æÍąåİŮäÿ■çŽĎ
defaultdict æÍěæđĎéĂăè£ŹæăůçŽĎå■ŮåĚÿãĂĆ defaultdict
çŽĎäÿĂäÿłçL'źå¿ĄæŸŕåőČäijŽèĞłåŁĺåĹÍåğŇåŇŰærŔäÿł key
åĹŽåijÅåğŇåŕźåžŤçŽĎåĂijïijŇæL'Ăäžěä¡ăåŔłéIJĂèęĄåĚşæşĺæůżåŁăåĚČçť'ăæŞ■ä¡IJäžĘãĂĆærŤåęĆïijŽ

```
from collections import defaultdict

d = defaultdict(list)
```

```
d['a'].append(1)
d['a'].append(2)
d['b'].append(4)

d = defaultdict(set)
d['a'].add(1)
d['a'].add(2)
d['b'].add(4)
```

éIJÄèęĄæşÍæĎŘçŽĎæŸřïijŇ `defaultdict` äijŽèĞłåŁÍäÿžåřĘèęĄèő£éŮőçŽĎéŤőïijĹåřśçőŮçŻőåL'■å åęĆæđIJä¡ääźűäÿ■éIJÄèęĄè£ŹæăůçŽĎçL'źæĂğïijŇä¡ääŘŕäżěåIJĺäÿĂäÿłæŹőéĂŽçŽĎå■ŮåĚÿäÿŁä¡£çŤÍ `setdefault()` æŰźæşŢæİěäżčæŻ£ãĂĆæŕŤåęĆïijŽ

```
d = {} # äÿĂäÿłæŹőéĂŽçŽĎå■ŮåĚÿ
d.setdefault('a', []).append(1)
d.setdefault('a', []).append(2)
d.setdefault('b', []).append(4)
```

ä¡ĘæŸŕå¿Ĺåď'ŽçÍŃåžŘåŚŸèğL'å¿Ů `setdefault()` çŤÍèţůæİěæIJL'çĆźåĹńæL'■ãĂĆåŻääÿžæŕŘæňąèř `[]` ïijL'ãĂĆ

èőÍèőž

äÿĂèĹňæİěèőšïijŇåĹŻåżžäÿĂäÿłåď'ŽåĂijæŸăářĎå■ŮåĚÿæŸŕå¿ĹçőĂå■ŢçŽĎãĂĆä¡ĘæŸŕïijŇåęĆæđIJä ä¡ăåŘŕèČ¡äijŽåČŘäÿŃéİćè£ŹæăůæİěåőđçŐřïijŽ

```
d = {}
for key, value in pairs:
    if key not in d:
        d[key] = []
    d[key].append(value)
```

åęĆæđIJä¡£çŤÍ `defaultdict` çŽĎèŕİäżčçăĄåřśæŻť'åŁăçőĂæť'ĄäžĘïijŽ

```
d = defaultdict(list)
for key, value in pairs:
    d[key].append(value)
```

è£ŹäÿĂåřŘèŁĆæL'Ăèőĺèőžç ŽĎéŮőécŸèů§æŢřæ■őåď'ĎçŘĘäÿ■çŽĎèőřå¡Ţå¡ŠçśżéŮőécŸæIJL'åď'ğçŽĎ 1.15 åřŘèŁĆçŽĎä¿Ńå■ŘãĂĆ

3.7 1.7 å■ŮåĚÿæŐŠåžŘ

éŮőécŸ

ä¡ăæČşåĹŻåżžäÿĂäÿłå■ŮåĚÿïijŇåźűäÿŤåIJĺè£■äżčæĹŰåžŘåĹŮåŇŰè£ŹäÿłåŮåĚÿçŽĎæŮűåĂŹèČ¡åd

èğčåĘşæŰźæąĹ

äÿžäžĘèČ¡æŐğåĹűäÿĂäÿłå■ŮåĚÿäÿ■åĚČçť'äçŽĎéąžåžŔïijŇä¡ääŔŕäžěä¡£çŤÍ collections æÍąåİŮäÿ■çŽĎ OrderedDict çśžãĂĆ åIJĺè£■äžčæŞ■ä¡IJçŽĎæŮűåĂŹåőČäijŽä£İæŇĄåĚČçť'äèćńæŔŠåĚěæŮűçŽĎéąžåžŔïijŇçď'žä¿ŃåęĆäÿŃïijŽ

```
from collections import OrderedDict

d = OrderedDict()
d['foo'] = 1
d['bar'] = 2
d['spam'] = 3
d['grok'] = 4
# Outputs "foo 1", "bar 2", "spam 3", "grok 4"
for key in d:
    print(key, d[key])
```

å¡Şä¡äæČşèęĄæđĎåžžäÿĂäÿłåřĘæİěéIJĂèęĄåžŔåĹŮåŇŰæĹŰçijŰçăĄæĹŘåĚűäžŰæäijåijŔçŽĎæŸäåřł OrderedDict æŸŕéİđåÿÿæIJL'çŤÍçŽĎãĂĆ æŕŤåęĆïijŇä¡äæČşçš¿çąőæŐğåĹűäžě JSON çijŰçăĄåŘŐå■Ůæőţç ŽĎéąžåžŔïijŇä¡ääŔŕäžěåĚĹä¡£çŤÍ OrderedDict æİěæđĎåžžè£ŹæäůçŽĎæŢřæ■őïijŽ

```
>>> import json
>>> json.dumps(d)
'{"foo": 1, "bar": 2, "spam": 3, "grok": 4}'
>>>
```

èőÍèőž

OrderedDict åĘĚéČÍçżť'æŁď'çİĂäÿĂäÿłæäźæ■őéŤőæŔŠåĚěéąžåžŔæŐŠåžŔçŽĎåŔŇåŘŠéŞ¿èąĺãĂĆ åőČäijŽèćńæŤ¿åĹřéŞ¿èąĺçŽĎår¿éČÍãĂĆårźäžŐäÿĂäÿłåůšçżŔå■ŸåIJÍçŽĎéŤőçŽĎéĞ■åď'■ètŇåĂijäÿ■äijŽæŤ

éIJĂèęĄæşĺæĎŔçŽĎæŸŕïijŇäÿĂäÿł OrderedDict çŽĎåď'ğårŔæŸŕäÿĂäÿłæŹőéĂŽå■ŮåĚÿçŽĎäÿď'å æĽĂäżěåęĆædIJä¡äèęĄædĎåžžäÿĂäÿłéIJĂèęĄåď'ğéĞŔ OrderedDict åőđä¿ŃçŽĎæŢřæ■őçżŞædĎçŽĎæŮűåĂŹïijĹærŤåęĆèŕžåŔŰ 100,000 èąŇ CSV æŢřæ■őåĹřäÿĂäÿł OrderedDict åĹŮèąĺäÿ■åŐżïijL'ïijŇ éČčäźĹä¡ääřšå¿ŮäžŤçżĘæİČèąąäÿĂäÿŃæŸŕåŘęä¡£çŤÍ OrderedDict åÿęæİěçŽĎåě¡åď'ĎèęĄåď'ğè£ĞéčÍåď'ŰåĘĚå■ŸæűĹèĂŮçŽĎå¡šåŞ■ãĂĆ

3.8 1.8 å■ŮåĚÿçŽĎè£ŘçőŮ

éŮőécŸ

æĂŐæăůåIJĺæŢřæ■őå■ŮåĚÿäÿ■æĽğèąŇäÿĂäžŻèőąçőŮæŞ■ä¡IJïijĹærŤåęĆæśĆæIJĂåřŔåĂijãĂĄæIJĂå

èğčåEşæŰźæąĹ

èĂČèŹŚäÿŃéİćçŽĎèĆąçěĺåŘ■åŠŇäžůæäijæŸăářĎå■ŮåĚÿïijŽ

```
prices = {
    'ACME': 45.23,
    'AAPL': 612.78,
    'IBM': 205.55,
    'HPQ': 37.20,
    'FB': 10.75
}
```

äÿžäžĘářźå■ŮåĚÿåĂijæĽğèąŇèőąçőŮæŞ■ä¡IJïijŇéĂŽåÿÿéIJĂèęĄä¡£çŤÍ zip() åĞ¡æŢřåĚĹářĘéŤőåŠŇåĂijåŘ■è¡ňè£ĞæİěãĂĆ æŕŤåęĆïijŇäÿŃéİćæŸŕæ§ěæĽ¿æIJĂåřŔåŠŇæIJĂåd'ğèĆąçěĺ

```
min_price = min(zip(prices.values(), prices.keys()))
# min_price is (10.75, 'FB')
max_price = max(zip(prices.values(), prices.keys()))
# max_price is (612.78, 'AAPL')
```

çśżäijijçŽĎïijŇåŔŕäżěä¡£çŤÍ zip() åŠŇ sorted() åĞ¡æŢřæİěæŐŠåĹŮå■ŮåĚÿæŢřæ■őïijŽ

```
prices_sorted = sorted(zip(prices.values(), prices.keys()))
# prices_sorted is [(10.75, 'FB'), (37.2, 'HPQ'),
#                   (45.23, 'ACME'), (205.55, 'IBM'),
#                   (612.78, 'AAPL')]
```

æĽğèąŇè£ŹäžŻèőąçőŮçŽĎæŮűåĂŹïijŇéIJĂèęĄæşĺæĎŘçŽĎæŸŕ zip() åĞ¡æŢřåĹŻåżžçŽĎæŸŕäÿĂäÿłåŘłèČ¡èő£éŮőäÿĂæňąçŽĎè£■äžčåŹĺãĂĆ æŕŤåęĆïijŇäÿŃéİćçŽĎäžčçăĄåŕšäijŽäžğçŤ§éŤŹèŕŕïijŽ

```
prices_and_names = zip(prices.values(), prices.keys())
print(min(prices_and_names)) # OK
print(max(prices_and_names)) # ValueError: max() arg is an empty␣
↪sequence
```

èőĺèőž

åęĆæđIJä¡ăåIJĺäÿĂäÿłå■ŮåĚÿäÿŁæĽğèąŇæŹőéĂŽçŽĎæŢřå■ęè£ŘçőŮïijŇä¡ääijŽåŔŚçŐřåőČäžňäžĚäž

```
min(prices) # Returns 'AAPL'
max(prices) # Returns 'IBM'
```

è£ŹäÿłçżŞæđIJåźűäÿ■æŸŕä¡äæČşèęĄçŽĎïijŇåŻääÿžä¡äæČşèęĄåIJĺå■ŮåĚÿçŽĎåĂijéŻĘåŘĹäÿŁæĽğèą æĹŰèőÿä¡ääijŽářİèŕŢçİĂä¡£çŤĺå■ŮåĚÿçŽĎ values() æŰźæşŢæİèèğčåĘşè£ŹäÿłéŮőécŸïijŽ

```
min(prices.values()) # Returns 10.75
max(prices.values()) # Returns 612.78
```

äÿ■åźÿçŽĎæŸŕïijŇéĂŽåÿÿè£Źäÿłçżş æđIJåŘŇæăůäź§äÿ■æŸŕä¡ăæČşèęĄçŽĎãĂĆ
ä¡ăåŔŕèČ¡è£ŸæČşèęĄç§ěéĄŞåŕźåžŤçŽĎéŤőçŽĎä£ąæĄŕïijĹæŕŤåęĆéĆČçğ■èĆąçĚĺäžůæăijæŸŕæIJĂä¡ŐçŽĎï

ä¡ăåŔŕäżěåIJÍ `min()` åŠŇ `max()` åĞ¡æŢřäÿ■æŘŘä¿Ż `key` åĞ¡æŢřåŔĆæŢřæİěèŐůåŘŰæIJĂåřŔåĂijæĹŰæIJĂåď ğåĂijåŕźåžŤçŽĎéŤőçŽĎä£ąæĄŕãĂĆæŕŤåęĆïijŽ

```
min(prices, key=lambda k: prices[k]) # Returns 'FB'
max(prices, key=lambda k: prices[k]) # Returns 'AAPL'
```

ä¡ĘæŸŕïijŇåęĆæđIJè£ŸæČşèęĄå¿ŮåĹřæIJĂåřŔåĂijïijŇä¡ăåŔĹå¿ŮæĽ ğèąŇäÿĂæňąæ§ěæĽ¿æŞ■ä¡IJãĂ

```
min_value = prices[min(prices, key=lambda k: prices[k])]
```

åĽ■éİćçŽĎ `zip()` åĞ¡æŢřæŰźæąĹéĂŽè£ĞåřĘå■ŮåĚÿâĂİåŔ■è¡ňâĂİäÿž (åĂijïijŇéŤő) åĚČçżĎåžŔåĹŮæİèèğčåĘşäžĘäÿŁè£řéŮőécŸãĂĆ
å¡ŞæŕŤè¿Čäÿď äÿłåĚČçżĎçŽĎæŮűåĂŹïijŇåĂijäijŽåĚĹè£ŻèąŇæŕŤè¿ČïijŇçĎűåŘŐæĽ■æŸŕéŤőãĂĆ
è£ŹæăůçŽĎèŕİä¡ăåřśèČ¡éĂŽè£ĞäÿĂæİąçőĂå■ŢçŽĎèŕ■åŔěåřśèČ¡å¿Ĺè¡żæİ¿çŽĎåőđçŐřåIJĺå■ŮåĚÿäÿŁçŽĎ

éIJĂèęĄæşĺæĎŘçŽĎæŸŕåIJĺèőąçőŮæŞ■ä¡IJäÿ■ä¡£çŤĺåĹřäžĘ (åĂijïijŇéŤő) åŕźãĂĆå¡Şåď Žäÿłåőđä¡ŞæŃěæIJL çŽÿåŘŇçŽĎåĂijçŽĎæŮűåĂŹïijŇéŤőäijŽåĘşåőŽè£ŤåŻđçżŞæđIJãĂĆ
æŕŤåęĆïijŇåIJĺæĽ ğèąŇ `min()` åŠŇ `max()` æŞ■ä¡IJçŽĎæŮűåĂŹïijŇåęĆæđIJæĄŕåůğæIJĂåřŔæĹŰæIJĂåď

```
>>> prices = { 'AAA' : 45.23, 'ZZZ': 45.23 }
>>> min(zip(prices.values(), prices.keys()))
(45.23, 'AAA')
>>> max(zip(prices.values(), prices.keys()))
(45.23, 'ZZZ')
>>>
```

3.9 1.9 æ§ěæĽ¿äÿď å■ŮåĚÿçŽĎçŻÿåŘŇçĆź

éŮőécŸ

æĂŐæăůåIJĺäÿď äÿłå■ŮåĚÿäÿ■årźårżæĽ¿çŻÿåŘŇçĆźïijĹæŕŤåęĆçŻÿåŘŇçŽĎéŤőãĂĄçŻÿåŘŇçŽĎåĂij

èğčåĘşæŰźæąĹ

èĂČèŹŚäÿŃéİćäÿď äÿłå■ŮåĚÿïijŽ

```
a = {
    'x' : 1,
    'y' : 2,
    'z' : 3
}

b = {
    'w' : 10,
    'x' : 11,
```

```
    'y' : 2
}
```

äÿžäžĘåŕżæĽ¿äÿďäÿłå■ŮåĚÿçŽĎçŻÿåŘŇçĆźïijŇåŔŕäžěçőĂå■ŢçŽĎåIJÍäÿďå■ŮåĚÿçŽĎ `keys()` æĹŰèĂĚ `items()` æŰźæşŢè£ŤåŻđçżŞæđIJäÿŁæĽğèąŇéŻĘåŘĹæŞ■ä¡IJãĂĆæŕŤåęĆïijŽ

```
# Find keys in common
a.keys() & b.keys() # { 'x', 'y' }
# Find keys in a that are not in b
a.keys() - b.keys() # { 'z' }
# Find (key,value) pairs in common
a.items() & b.items() # { ('y', 2) }
```

è£ŹäžŻæŞ■ä¡IJäź§åŔŕäžěçŢĺäžŐä£őæŢźæĹŰèĂĚè£ĞæżďåŮåĚÿåĚČçťăãĂĆ æŕŤåęĆïijŇåĄĞåęĆä¡ăæČşäžěçŐřæIJL'å■ŮåĚÿæđĎéĂääÿĂäÿłæŐŠéŹďåĞăäÿłæŇĞåőŽéŤőçŽĎæŰřå■ŮåĚÿäÿŇéÍćåĹl'çŢĺå■ŮåĚÿæŐĺåŕijæÍěåðđçŐřè£Źæăůç ŽĎéIJĂæśĆïijŽ

```
# Make a new dictionary with certain keys removed
c = {key:a[key] for key in a.keys() - {'z', 'w'}}
# c is {'x': 1, 'y': 2}
```

èőÍèőž

äÿĂäÿłå■ŮåĚÿåŕśæŸŕäÿĂäÿłéŤőéŻĘåŘĹäÿŐåĂijéŻĘåŘĹçŽĎæŸăåřĎåĚşçşżãĂĆ å■ŮåĚÿçŽĎ `keys()` æŰźæşŢè£ŤåŻđäÿĂäÿłåśŢçŐřéŤőéŻĘåŘĹçŽĎéŤőèğĘåŻ¿åŕźèśąãĂĆ éŤőèğĘåŻ¿çŽĎäÿĂäÿłå¿ĹåřŚèćńäžĘèğčçŽĎçĽźæĂğåřśæŸŕåőČäžňäź§æŤŕæŇĄéŻĘåŘĹæŞ■ä¡IJïijŇæŕŤåęĆ æĽĂäżěïijŇåęĆæđIJä¡ăæČşåŕźéŻĘåŘĹçŽĎéŤőæĽğèąŇäÿĂäžŻæŹőéĂŽçŽĎéŻĘåŘĹæŞ■ä¡IJïijŇåŔŕäžěçŻťsetãĂĆ

å■ŮåĚÿçŽĎ `items()` æŰźæşŢè£ŤåŻđäÿĂäÿłåŇĚåŘń (éŤőïijŇåĂij) åŕźçŽĎåĚČçťăèğĘåŻ¿åŕźèśąãĂĆ è£ŹäÿłåŕźèśąåŘŇæăůäź§æŤŕæŇĄéŻĘåŘĹæŞ■ä¡IJïijŇåźűäÿŤåŔŕäžěèćńçŤ

år¡çőąå■ŮåĚÿçŽĎ `values()` æŰźæşŢäź§æŸŕçśżäijijïijŇä¡ĘæŸŕåőČåźűäÿ■æŤŕæŇĄè£ŹéĞŇäżŃçż■ç æ§Řçğ■çÍŃåžęäÿŁæŸŕåŻăäÿžåĂijèğĘåŻ¿äÿ■èČ¡ä£ÌèŕĄæĽĂæIJL'çŽĎåĂijäžŠäÿ■çŻÿåŘŇïijŇè£ŹæăůäijŽår äÿ■è£ĞïijŇåęĆæđIJä¡ăçąňèęĄåIJÍåĂijäÿŁéÍćæĽğèąŇè£ŹäžŹéŻĘåŘĹæŞ■ä¡IJçŽĎèŕÍïijŇä¡ääŔŕäžěåĚĹářĘåĂ setïijŇçĎűåŘŐåĘ■æĽğèąŇéŻĘåŘĹè£ŘçőŮářśèąŇäžĘãĂĆ

3.10 1.10 åĹăéŹď åžŔåĹŮçŻÿåŘŇåĚČçťăåźűä£ÌæŇĄéąžåžŔ

éŮőécŸ

æĂŐæăůåIJÍäÿĂäÿłåžŔåĹŮäÿŁéÍćä£ÌæŇĄåĚČçťăéąžåžŔçŽĎåŘŇæŮűæűĹéŹď éĞ■ådˇ■çŽĎåĂijïij§

èğčåĘşæŰźæąĹ

åęĆæđIJåžŔåĹŮäÿŁçŽĎåĂijéČ¡æŸŕ `hashable` çśżåđŃïijŇéĆčäźĹåŔŕäžěå¿ĹçőĂå■ŢçŽĎåĹl'çŤĺéŻĘå

```
def dedupe(items):
    seen = set()
    for item in items:
        if item not in seen:
            yield item
            seen.add(item)
```

äÿŃéİćæŸŕä¡£çŤĺäÿŁè£ŕåĞ¡æŢřçŽĎä¿Ńå■ŘïijŽ

```
>>> a = [1, 5, 2, 1, 9, 1, 5, 10]
>>> list(dedupe(a))
[1, 5, 2, 9, 10]
>>>
```

è£ŹäÿłæŰźæşŢäżĚäżĚåIJĺåžŔåĹŮäÿ■åĚČçť´ääÿž hashable çŽĎæŮűåĂŹæL'■çőąçŤĺãĂĆ åęĆæđIJä¡ăæČşæűĹéŹď´åĚČçť´ääÿ■åŔŕåŞĹåÿŃïijĹæŕŤåęĆ dict çśżåđŃïijL'çŽĎåžŔåĹŮäÿ■éĞ■åď'■åĚČçť´ăçŽĎèŕĺïijŇä¡ăéIJĂèęĄåřĘäÿŁè£ŕäžčçăĄçÍ■å¿őæŤźåŔŸäÿĂ

```
def dedupe(items, key=None):
    seen = set()
    for item in items:
        val = item if key is None else key(item)
        if val not in seen:
            yield item
            seen.add(val)
```

è£ŹéĞŃçŽĎkeyåŔĆæŢřæŇĞåőŽäžĘäÿĂäÿłåĞ¡æŢřïijŇåřĘåžŔåĹŮåĚČçť´ăè¡ňæ■ćæĹŘ hashable çśżåđŃãĂĆäÿŃéİćæŸŕåőČçŽĎçŤĺæşŢçď'žä¿ŃïijŽ

```
>>> a = [ {'x':1, 'y':2}, {'x':1, 'y':3}, {'x':1, 'y':2}, {'x':2, 'y
↪':4}]
>>> list(dedupe(a, key=lambda d: (d['x'],d['y'])))
[{'x': 1, 'y': 2}, {'x': 1, 'y': 3}, {'x': 2, 'y': 4}]
>>> list(dedupe(a, key=lambda d: d['x']))
[{'x': 1, 'y': 2}, {'x': 2, 'y': 4}]
>>>
```

åęĆæđIJä¡ăæČşå§žäžŐå■Ţäÿłå■Ůæőţã´ĂĄåśđæĂğæĹŰèĂĚæ§ŘäÿłæŻť´åď'ğçŽĎæŢřæ■őçżŞæđĎæİěæű

èőĺèőž

åęĆæđIJä¡ääżĚäżĚåřśæŸŕæČşæűĹéŹď´éĞ■åď'■åĚČçť´äïijŇéĂŽåÿÿåŔŕäžěçőĂå■ŢçŽĎæđĎéĂääÿĂäÿłé

```
>>> a
[1, 5, 2, 1, 9, 1, 5, 10]
>>> set(a)
{1, 2, 10, 5, 9}
>>>
```

çĎűèĂŇïijŇè£Źçğ■æŰźæşŢäÿ■èČ¡çżť´æŁď´åĚČçť´äçŽĎéąžåžŔïijŇçŤ§æĹŘçŽĎçżŞæđIJäÿ■çŽĎåĚČçť

åIJÍæIJňèŁĆäÿ■æĹŚäžňä¡£çŤÍäžĘçŤ§æĹŘåŹÍåĞ¡æŢřèőľæĹŚäžňçŽĎåĞ¡æŢřæŻť'åŁäéĂŽçŤÍïijÑäÿ■äż
ærŤåęĆïijÑåęĆæđIJåęĆæđIJä¡ăæČşèŕżåŔŰäÿĂäÿłæŰĞäžűïijÑæűĹéŹď'éĞ■åď'■èąÑïijÑä¡ăåŔŕäżěå¿Ĺåőźæ

```
with open(somefile,'r') as f:
for line in dedupe(f):
    ...
```

äÿŁè£řkeyåĞ¡æŢřåŔĆæŢřæĺąäż£äžĘ sorted() , min() åŠŇ max() ç■L'åĘĚç¡őåĞ¡æŢřçŽĎçŻÿäijijåŁ§èČ¡ãĂĆ åŔŕäżěåŔĆèĂČ 1.8 åŠŇ 1.13 åřŔèŁĆäžĘèğčæŻť'åď'ŽãĂĆ

3.11 1.11 åŚ¡åŘ■åĹĞçL'Ğ

éŮőécŸ

ä¡ăçŽĎçÍŇåžŔåůšçżŔåĞžçŐřäÿĂåď'ğåäĘåůšæŮăæşŢçŻť'èğĘçŽĎçąňçijŰçăĄåĹĞçL'ĞäÿŃæăĞïijŇçĎű

èğčåĘşæŰźæąĹ

åĄĞåőŽä¡ăæIJL'äÿĂæőţäżčçăĄèęĄäżŐäÿĂäÿłèőřå¡Ţå■Ůçňęäÿšäÿ■åĞääÿłåŻžåőŽä¡■ç¡őæŔŘåŔŰåĞžç

```
######                                                                  ␣
↪01234567890123456789012345678901234567890123456789012345678901234567890'
record = '.....................100 .......513.25 ..........'
cost = int(record[20:23]) * float(record[31:37])
```

äÿŐåĚűéĆčæăůåĘŹïijÑäÿžäżĂäźĹäÿ■æČşè£ŹæăůåŚ¡åŘ■åĹĞçL'ĞåŚćïijŽ

```
SHARES = slice(20, 23)
PRICE = slice(31, 37)
cost = int(record[SHARES]) * float(record[PRICE])
```

çňňäžŇçğ■çL'ĹæIJňäÿ■ïijÑä¡ăéĄ£åĚ■äžĘåď'ğéĞŔæŮăæşŢçŘĘèğčçŽĎçąňçijŰçăĄäÿŃæăĞïijÑä¡£å¿Ůă

èőĺèőž

äÿĂèĹňæİěèőšïijÑäżčçăĄäÿ■åęĆæđIJåĞžçŐřåď'ğéĞŔçŽĎçąňçijŰçăĄäÿŃæăĞåĂijäijŽä¡£å¿ŮåŔŕèŕżæ
ærŤåęĆïijÑåęĆæđIJä¡ăåŻđè£ĞæİěçIJŇçIJŇäÿĂåźť'åL'■ä¡ăåĘŹçŽĎäžčçăĄïijÑä¡ääijŽæŠÿçİĂèĎŠècŃæČşéĆ
è£ŹéĞŇçŽĎèğčåĘşæŰźæąĹæŸŕäÿĂäÿłå¿ĹçőĂå■ŢçŽĎæŰźæşŢèőľä¡ăæŻť'åŁäæÿĚæŹŕçŽĎèąĺè¿¿äżčçăĄåĹ

åĘĚç¡őçŽĎ slice() åĞ¡æŢřåĹŻåżžäžĘäÿĂäÿłåĹĞçL'ĞåŕźèśąïijŇåŔŕäżěèćńçŤĺåIJĺäżżä¡ŢåĹĞçL'ĞåĚ

```
>>> items = [0, 1, 2, 3, 4, 5, 6]
>>> a = slice(2, 4)
>>> items[2:4]
[2, 3]
>>> items[a]
```

```
[2, 3]
>>> items[a] = [10,11]
>>> items
[0, 1, 10, 11, 4, 5, 6]
>>> del items[a]
>>> items
[0, 1, 4, 5, 6]
```

åęĆæđIJä¡ăæIJL'äÿĂäÿłåĹĞçL'ĞåŕźèśąaïijŇä¡ăåŔŕäžěåĹĘåĹńèřČçŤĺåőČçŽĎ `a.start`,`a.stop`,`a.step` åśđæĂğæİěèŐůåŔŰæŻt'åd'ŽçŽĎä£ąæĄŕãĂĆæŕŤåęĆïijŽ

```
>>> a = slice(5, 50, 2)
>>> a.start
5
>>> a.stop
50
>>> a.step
2
>>>
```

åŔęåd'ŰïijŇä¡ăè£ŸèČ¡éĂŽè£ĞèřČçŤĺåĹĞçL'ĞçŽĎ `indices(size)` æŰźæşŢåřĘåőČæŸăåřĎåĹřäÿĂäÿłçąőåőŽåd'ğåřŔçŽĎåžŔåĹŮäÿŁïijŇ è£ŹäÿłæŰźæşŢè£ŤåŻđäÿĂäÿłäÿL'åĚČçżĎ `(start, stop, step)` ïijŇæL'ĂæIJL'åĂijéČ¡äijŽèćńåŘĹéĂĆçŽĎçjl'åřŔäžěæżąèűşè¿źçŢŇéŹŘåĹűïijŇ äžŐèĂŇä¡£çŤĺçŽĎæŮűåĂŹéĄ£åĚ■åĞžçŐř `IndexError` åijĆåÿÿãĂĆæŕŤåęĆïijŽ

```
>>> s = 'HelloWorld'
>>> a.indices(len(s))
(5, 10, 2)
>>> for i in range(*a.indices(len(s))):
...     print(s[i])
...
W
r
d
>>>
```

3.12 1.12 åžŔåĹŮäÿ■åĞžçŐřæňąæŢřæIJĂåd'ŽçŽĎåĚČçt'ă

éŮőécŸ

æĂŐæăůæL'¿åĞžäÿĂäÿłåžŔåĹŮäÿ■åĞžçŐřæňąæŢřæIJĂåd'ŽçŽĎåĚČçt'ăåŚćïij§

èğčåĘşæŰźæąĹ

`collections.Counter` çśżåřśæŸŕäÿŞéŮĺäÿžè£ŹçśżéŮőécŸèĂŇèő¿èőąçŽĎïijŇ åőČçŤŽèĞşæIJL'äÿĂäÿłæIJL'çŤĺçŽĎ `most_common()` æŰźæşŢçŻt'æŐěçżŹäžĘä¡äç■ŤæąĹãĂĆ

äÿžäžĘæijŤçď žïijŇåĚĹåĄĜèő¿ä¡ăæIJL’äÿĂäÿłå■Ţèŕ■åĹŮèąĺåźűäÿŤæČşæL’¿åĞžåŞłäÿłå■Ţèŕ■åĞžçŐřé

```
words = [
    'look', 'into', 'my', 'eyes', 'look', 'into', 'my', 'eyes',
    'the', 'eyes', 'the', 'eyes', 'the', 'eyes', 'not', 'around',
↪'the',
    'eyes', "don't", 'look', 'around', 'the', 'eyes', 'look', 'into
↪',
    'my', 'eyes', "you're", 'under'
]
from collections import Counter
word_counts = Counter(words)
# åĞžçŐřéćŚçŐĞæIJĂéńŸçŽĎ3äÿłå■Ţèŕ■
top_three = word_counts.most_common(3)
print(top_three)
# Outputs [('eyes', 8), ('the', 5), ('look', 4)]
```

èőĺèőž

ä¡IJäÿžè¿ŞåĚëïijŇ `Counter` åŕźèśąåŔŕäżěæŐěåŔŮäżżæĎŔçŽĎçŤśåŔŕåŞĹåÿŇïijĹhashableïijL’åĚČ
åIJĺåžŢåśĆåőđçŐřäÿŁïijŇäÿĂäÿł `Counter` åŕźèśąåřśæŸŕäÿĂäÿłå■ŮåĚÿïijŇåřĘåĚČçť’ăæŸăåřĎåĹřåőČåĞžç

```
>>> word_counts['not']
1
>>> word_counts['eyes']
8
>>>
```

åęĆæđIJä¡ăæČşæL’ŃåŁĺåćđåŁăèőąæŢřïijŇåŔŕäżěçőĂå■ŢçŽĎçŤĺåŁăæşŢïijŽ

```
>>> morewords = ['why','are','you','not','looking','in','my','eyes']
>>> for word in morewords:
...     word_counts[word] += 1
...
>>> word_counts['eyes']
9
>>>
```

æĹŰèĂĚä¡ăåŔŕäżěä¡£çŤĺ `update()` æŰźæşŢïijŽ

```
>>> word_counts.update(morewords)
>>>
```

`Counter` åőđä¿ŃäÿĂäÿłéšIJäÿžäžžç§ěçŽĎçL’źæĂğæŸŕåőČäżňåŔŕäżěå¿ĹåőźæŸ§çŽĎèů§æŢřå■ęè£Řç

```
>>> a = Counter(words)
>>> b = Counter(morewords)
>>> a
Counter({'eyes': 8, 'the': 5, 'look': 4, 'into': 3, 'my': 3, 'around
↪': 2,
```

```
"you're": 1, "don't": 1, 'under': 1, 'not': 1})
>>> b
Counter({'eyes': 1, 'looking': 1, 'are': 1, 'in': 1, 'not': 1, 'you
 ↪': 1,
'my': 1, 'why': 1})
>>> # Combine counts
>>> c = a + b
>>> c
Counter({'eyes': 9, 'the': 5, 'look': 4, 'my': 4, 'into': 3, 'not':␣
 ↪2,
'around': 2, "you're": 1, "don't": 1, 'in': 1, 'why': 1,
'looking': 1, 'are': 1, 'under': 1, 'you': 1})
>>> # Subtract counts
>>> d = a - b
>>> d
Counter({'eyes': 7, 'the': 5, 'look': 4, 'into': 3, 'my': 2, 'around
 ↪': 2,
"you're": 1, "don't": 1, 'under': 1})
>>>
```

æŕńæŮăçŰŚéŮőïijŇ Counter åŕźèśąåIJĺåĞääźŐæĽĂæIJL'éIJĂèęĄåĹűèąĺæĹŰèĂĚèőąæŢřæŢřæ■őçŽÌ
åIJĺèğčåEşè£ŹçśżéŮőécŸçŽĎæŮűåĂŹä¡ăäžŤèŕěäijŸåĚĹéĂĽ'æŃĺ'åőČïijŇèĂŇäÿ■æŸŕæĽ'ŃåŁĺçŽĎåĹĺ'çŤĺå

3.13 1.13 éĂŽè£Ğæ§ŘäÿłåĚşéŤőå■ŮæŐŠåžŔäÿĂäÿłå■ŮåĚÿåĹŮèąĺ

éŮőécŸ

ä¡ăæIJL'äÿĂäÿłå■ŮåĚÿåĹŮèąĺïijŇä¡ăæČşæäźæ■őæ§ŘäÿłæĹŰæ§ŘåĞääÿłå■ŮåĚÿå■ŮæőţæİěæŐŠåžŔè£

èğčåEşæŰźæąĹ

éĂŽè£Ğä¡£çŤĺ operator æĺąåİŮçŽĎ itemgetter
åĞ¡æŢřïijŇåŔŕäžěéİđåÿÿåőźæŸŞçŽĎæŐŠåžŔè£ŹæăůçŽĎæŢřæ■őçżŞæđĎãĂĆ
åĄĞèő¿ä¡ăäžŐæŢřæ■őåžŞäÿ■æčĂçť'ćåĞžæİěç¡ŚçńŹäijŽåŚŸä£ąæĄŕåĹŮèąĺïijŇåźűäÿŤäžěäÿŃåĹŮçŽĎæŢřa

```
rows = [
    {'fname': 'Brian', 'lname': 'Jones', 'uid': 1003},
    {'fname': 'David', 'lname': 'Beazley', 'uid': 1002},
    {'fname': 'John', 'lname': 'Cleese', 'uid': 1001},
    {'fname': 'Big', 'lname': 'Jones', 'uid': 1004}
]
```

æăźæ■őäżżæĎŔçŽĎå■ŮåĚÿå■ŮæőţæİěæŐŠåžŔè¿ŞåĚěçżŞæđIJèąŇæŸŕå¿Ĺåőźæ ŸŞåőđçŐřçŽĎïijŇäżč

```
from operator import itemgetter
rows_by_fname = sorted(rows, key=itemgetter('fname'))
rows_by_uid = sorted(rows, key=itemgetter('uid'))
```

```
print(rows_by_fname)
print(rows_by_uid)
```

äžčçăĄçŽĎè¿ŞåĞžåęĆäÿŃïijŽ

```
[{'fname': 'Big', 'uid': 1004, 'lname': 'Jones'},
{'fname': 'Brian', 'uid': 1003, 'lname': 'Jones'},
{'fname': 'David', 'uid': 1002, 'lname': 'Beazley'},
{'fname': 'John', 'uid': 1001, 'lname': 'Cleese'}]
[{'fname': 'John', 'uid': 1001, 'lname': 'Cleese'},
{'fname': 'David', 'uid': 1002, 'lname': 'Beazley'},
{'fname': 'Brian', 'uid': 1003, 'lname': 'Jones'},
{'fname': 'Big', 'uid': 1004, 'lname': 'Jones'}]
```

`itemgetter()` åĞ¡æŢřäź§æŤŕæŇĄåď'Žäÿł keysïijŇæŕŤåęĆäÿŃéĺćçŽĎäžčçăĄ

```
rows_by_lfname = sorted(rows, key=itemgetter('lname','fname'))
print(rows_by_lfname)
```

äijŽäžğçŤ§åęĆäÿŃçŽĎè¿ŞåĞžïijŽ

```
[{'fname': 'David', 'uid': 1002, 'lname': 'Beazley'},
{'fname': 'John', 'uid': 1001, 'lname': 'Cleese'},
{'fname': 'Big', 'uid': 1004, 'lname': 'Jones'},
{'fname': 'Brian', 'uid': 1003, 'lname': 'Jones'}]
```

èőÍèőž

åIJÍäÿŁéÍćä¿Ńå■Řäÿ■ïijŇ `rows` èćńäijăéĂŠçžŹæŐěåŔŮäÿĂäÿłåĚşéŤőå■ŮåŔĆæŢřçŽĎ `sorted()` åĘĚç¡őåĞ¡æŢřãĂĆ è£ŹäÿłåŔĆæŢřæŸŕ `callable` çśžåđŃïijŇåźűäÿŤäžŐ `rows` äÿ■æŐěåŔŮäÿĂäÿłå■ŢäÿĂåĚČçť'äïijŇçĎűåŘŐè£ŤåŻđèćńçŤÍæÍěæŐŠåžŘçŽĎåĂijãĂĆ `itemgetter()` åĞ¡æŢřářśæŸŕèť§èť'čåĹŽåžžè£Źäÿłcallable åŕźèśąçŽĎãĂĆ

`operator.itemgetter()` åĞ¡æŢřæIJL'äÿĂäÿłèćń `rows` äÿ■çŽĎèőřå¡ŢçŤÍæÍě§ěæL'¿åĂijçŽĎçť'ćåijŢåŔĆæŢřãĂĆåŔŕäžěæŸŕäÿĂäÿłå■ŮåĚÿéŤőåŘ■çğřïijŇäÿĂäÿłæŢť'å¡ćåĂijæĹŮèĂĚäžża¡ŢèČ¡åď§äijååĚěäÿĂäÿłåŕźèśąçŽĎ `__getitem__()` æŰźæşŢçŽĎåĂijãĂĆ åęĆæđIJä¡ăäijååĚěåď'Žäÿłçť'ćåijŢåŔĆæŢřçżŹ `itemgetter()` ïijŇåőČçŤ§æĹŘçŽĎ `callable` åŕźèśąäijŽè£ŤåŻđäÿĂäÿłåŇĚåŘńæL'ĂæIJL'åĚČçť'ääĂijçŽĎåĚČçżDïijŇåźűäÿŤ `sorted()` åĞ¡æŢřäijŽæăźæ■őè£ŹäÿłåĚČçżDäÿ■åĚČçť'ăéąžåžŘåŐżæŐŠåžŘãĂĆä¡Ęä¡ăæČşèęĄåŘŇæŮűåIJĺåĞăäÿłå■Ůæőţäÿłéĺćè£ŻèąŇæŐŠåžŘïijĹæŕŤåęĆéĂŽè£Ğåğ$åŠŇåŘ■æĺěæŐŠåž

`itemgetter()` æIJL'æŮűåĂŹäź§åŘŕäžěçŤÍ `lambda` èąĺè¿¿åijŔäžčæŻ£ïijŇæŕŤåęĆïijŽ

```
rows_by_fname = sorted(rows, key=lambda r: r['fname'])
rows_by_lfname = sorted(rows, key=lambda r: (r['lname'],r['fname']))
```

è£Źçğ■æŰźæąĹäź§äÿ■éŤŹãĂĆä¡ĘæŸŕïijŇä¡£çŤÍ `itemgetter()` æŰźåijŔäijŽè£ŘèąŇçŽĎçÍ■å¿ő å£ńçĆźãĂĆåŽäæ■d'ïijŇåęĆæđIJä¡ăåŕźæĂğèČ¡èęĄæśĆæŕŤè¿ČéńŸçŽĎèŕÍåřś `itemgetter()` æŰźåijŔãĂĆ

æIJÄåŘŐïijŇäÿ■èęĄå£ŸäžĘè£ŹèŁĆäÿ■åśŢçd'žçŽĎæŁĂæIJŕäź§åŘŇæăůéĂĆçŤĺäžŐ `min()` åŠŇ `max()` ç■L'åĞ¡æŢřãĂĆæŕŤåęĆïijŽ

```
>>> min(rows, key=itemgetter('uid'))
{'fname': 'John', 'lname': 'Cleese', 'uid': 1001}
>>> max(rows, key=itemgetter('uid'))
{'fname': 'Big', 'lname': 'Jones', 'uid': 1004}
>>>
```

3.14 1.14 æŐŠåžŔäÿ■æŤŕæŇĄåŐ§çŢ§æŕŤè¿ČçŽĎåŕźèśą

éŮőécŸ

ä¡ăæČşæŐŠåžŔçśżåđŇçŻÿåŘŇçŽĎåŕźèśąïijŇä¡ĘæŸŕäżŰäžňäÿ■æŤŕæŇĄåŐ§çŢ§çŽĎæŕŤè¿ČæŞ■ä¡IJã

èğčåĘşæŰźæąĹ

åĘĚç¡őçŽĎ `sorted()` åĞ¡æŢřæIJL'äÿĂäÿłåĚşéŤőå■ŮåŔĆæŢř `key` ïijŇåŔŕäżěäijăåĚěäÿĂäÿł `callable` åŕźèśąçżŹåőČïijŇ è£ŹäÿłåĂijïijŇè£ŹäÿłåĂijäijŽèćń `sorted` çŤĺæİěæŐŠåžŔè£ŹäžŻåŕźèśąãĂĆ æŕŤåęĆïijŇåęĆæđIJä¡ăåIJĺåžŢçŤĺçĺŇåžŔéĞŇéİćæIJL'äÿĂäÿł `User` åőđä¿ŃåžŔåĹŮïijŇåźűäÿŤä¡ăåÿŇæIJŻéĂŽè£ĞäżŰäžňçŽĎ `user_id` åśđæĂğè£ŻèąŇæŐŠåžŔïijŇ ä¡ăåŔŕäżěæŔŘä¿ŻäÿĂäÿłäžě `User` åőđä¿Ńä¡IJäÿžè¿ŞåĚěåźűè¿ŞåĞžåŕźåžŤ `user_id` åĂijçŽĎ `callable` åŕźèśąãĂĆæŕŤåęĆïijŽ

```
class User:
    def __init__(self, user_id):
        self.user_id = user_id

    def __repr__(self):
        return 'User({})'.format(self.user_id)


def sort_notcompare():
    users = [User(23), User(3), User(99)]
    print(users)
    print(sorted(users, key=lambda u: u.user_id))
```

åŔęåd'ŰäÿĂçğ■æŰźåijŔæŸŕä¡£çŤĺ `operator.attrgetter()` æİěäžčæŻ£ lambda åĞ¡æŢřïijŽ

```
>>> from operator import attrgetter
>>> sorted(users, key=attrgetter('user_id'))
[User(3), User(23), User(99)]
>>>
```

èőÍèőž

éĂL'æŃl'ä¡£çŤÍ lambda åĞ¡æŢřæĹŰèĂĚæŸŕ `attrgetter()` åŘŕèČ¡åŘŰåĘşäžŐäÿłäžžåŰIJåě¡ãĂĆ ä¡ĘæŸŕïijŇ `attrgetter()` åĞ¡æŢřéĂŽåÿÿäijŽè£ŘèąŇçŽĎå£ńçĆźïijŇåźűäÿŤè£ŸèČ¡åŘŇæŮŰűåĚĄèőÿåd'Žäÿłå■Ůæőţè£ŻèąŇærŤè¿ČãĂ è£Źäÿłèůş `operator.itemgetter()` åĞ¡æŢřä¡IJçŤĺäžŐå■ŮåĚÿçśžåđŃå¿ĹçśżäijijïijĺåŘĆèĂČ1.13åřŘè ä¿ŃåęĆïijŇåęĆæđIJ `User` åőđä¿Ńè£ŸæIJL'äÿĂäÿł `first_name` åŠŇ `last_name` åśđæĂğïijŇéĆčäźĹåŘŕäżěåŘŚäÿŃéÍćè£ŹæăůæŐŠåžŘïijŽ

```
by_name = sorted(users, key=attrgetter('last_name', 'first_name'))
```

åŘŇæăůéIJĂèęĄæşĺæĎŘçŽĎæŸŕïijŇè£ŹäÿĂåřŘèŁĆçŤĺåĹřçŽĎæŁĂæIJŕåŘŇæăůéĂĆçŤĺäžŐåČŘ `min()` åŠŇ `max()` äźŃçśżçŽĎåĞ¡æŢřãĂĆærŤåęĆïijŽ

```
>>> min(users, key=attrgetter('user_id'))
User(3)
>>> max(users, key=attrgetter('user_id'))
User(99)
>>>
```

3.15 1.15 éĂŽè£Ğæ§Řäÿłå■Ůæőţåřęèőřå¡ŢåĹĘçżĎ

éŮőécŸ

ä¡ăæIJL'äÿĂäÿłå■ŮåĚÿæĹŰèĂĚåőđä¿ŃçŽĎåžŘåĹŮïijŇçĎűåŘŐä¡ăæČşæăźæ■őæ§Řäÿłçĺ'źåőŽçŽĎå■Ů `date` æÍěåĹĘçżĎè£■äžčèő£éŮõãĂĆ

èğčåĘşæŰźæąĹ

`itertools.groupby()` åĞ¡æŢřåŕźäžŐè£ŹæăůçŽĎæŢřæ■őåĹĘçżĎæŞ■ä¡IJéÍđåÿÿåőđçŤĺãĂĆ äÿžäžĘæijŤçd'žïijŇåĄĞèő¿ä¡ăåůšçżŘæIJL'äžĘäÿŃåĹŮçŽĎå■ŮåĚÿåĹŮèąĺïijŽ

```
rows = [
    {'address': '5412 N CLARK', 'date': '07/01/2012'},
    {'address': '5148 N CLARK', 'date': '07/04/2012'},
    {'address': '5800 E 58TH', 'date': '07/02/2012'},
    {'address': '2122 N CLARK', 'date': '07/03/2012'},
    {'address': '5645 N RAVENSWOOD', 'date': '07/02/2012'},
    {'address': '1060 W ADDISON', 'date': '07/02/2012'},
    {'address': '4801 N BROADWAY', 'date': '07/01/2012'},
    {'address': '1039 W GRANVILLE', 'date': '07/04/2012'},
]
```

çŐřåIJĺåĄĞèő¿ä¡ăæČşåIJĺæŃL' date åĹĘçżĎåŘŐçŽĎæŢřæ■őåİŮäÿŁè£ŻèąŃè£■äžčãĂĆäÿžäžĘè£ŹæăůåŰ `date`)æŐŠåžŘïijŃ çĎűåŘŐěřČçŤĺ `itertools.groupby()` åĞ¡æŢřïijŽ

```
from operator import itemgetter
from itertools import groupby

# Sort by the desired field first
rows.sort(key=itemgetter('date'))
# Iterate in groups
for date, items in groupby(rows, key=itemgetter('date')):
    print(date)
    for i in items:
        print('  ', i)
```

è£ŘèąŇçżŞædIJïijŽ

```
07/01/2012
  {'date': '07/01/2012', 'address': '5412 N CLARK'}
  {'date': '07/01/2012', 'address': '4801 N BROADWAY'}
07/02/2012
  {'date': '07/02/2012', 'address': '5800 E 58TH'}
  {'date': '07/02/2012', 'address': '5645 N RAVENSWOOD'}
  {'date': '07/02/2012', 'address': '1060 W ADDISON'}
07/03/2012
  {'date': '07/03/2012', 'address': '2122 N CLARK'}
07/04/2012
  {'date': '07/04/2012', 'address': '5148 N CLARK'}
  {'date': '07/04/2012', 'address': '1039 W GRANVILLE'}
```

èőÍèőž

groupby() åĞ¡æŢřæL'ńæŔŕæŢt'äÿłåžŔåĹŮåźűäÿŤæ§ěæL'¿è£đçż■çŻÿåŘŇåĂijïijĹæĹŰèĂĚæăźæ■ő
key åĞ¡æŢřè£ŤåŻđåĂijçŻÿåŘŇïijL'çŽĎåĚČçt'ăåžŔåĹŮãĂĆ
åIJÍæŕŔæňąè£■äžčçŽĎæŮűåĂŹïijŇåőČäijŽè£ŤåŻđäÿĂäÿłåĂijåŠŇäÿĂäÿłè£■äžčåŹÍåŕźèśąïijŇ
è£ŹäÿłèŁ■äžčåŹÍåŕźèśąåŔŕäžěçŢ§æĹŘåĚČçt'ăåĂijåĚÍéČÍç■L'äžŐäÿŁéÍćéĆčäÿłåĂijçŽĎçżĎäÿ■æL'ĂæIJL'åŕ

äÿĂäÿłéÍđåÿÿéĞ■èęĄçŽĎåĞĘåđ'Ğæ■ěélđ'æŸŕèęĄæăźæ■őæŇĞåőŽçŽĎå■ŮæőţåřĕæŢřæ■őæŐŠåžŔãĂ
åŻăäÿž groupby() äžĚäżĚæčĂæ§ěè£đçż■çŽĎåĚČçt'ăïijŇåęĆæđIJäžŃåĚĹåźűæšąæIJL'æŐŠåžŔåőŇæĹŘç

åęĆæđIJä¡ăäżĚäżĚåŔłæŸŕæČşæăźæ■ő date å■ŮæőţåřĕæŢřæ■őåĹĘçżĎåĹřäÿĂäÿłåđ'ğçŽĎæŢřæ■őçżŞ
éĆčäźĹä¡ăæIJĂåě¡ä¡£çŤÍ defaultdict() æÍěæđĎåżžäÿĂäÿłåđ'ŽåĂijå■ŮåĚÿïijŇåĚşäžŐåđ'ŽåĂijå■ŮåĚÿ
1.6 åŕŘèŁĆæIJL'è£ĞèŕęçżĘçŽĎäżŃçż■ãĂĆæŕŤåęĆïijŽ

```
from collections import defaultdict
rows_by_date = defaultdict(list)
for row in rows:
    rows_by_date[row['date']].append(row)
```

è£ŹæăůçŽĎèŕÍä¡ăåŔŕäžěå¿Ĺè¡żæÍ¿çŽĎåŕśèČ¡åŕźæŕŔäÿłæŇĞåőŽæŮěæIJ§èő£éŮőåŕźåžŤçŽĎèőŕå¡Ţïij Ž

```
>>> for r in rows_by_date['07/01/2012']:
...     print(r)
...
```

```
{'date': '07/01/2012', 'address': '5412 N CLARK'}
{'date': '07/01/2012', 'address': '4801 N BROADWAY'}
>>>
```

åIJÍäÿŁéİćè£ŹäÿŁä¿Ńå■Řäÿ■ïijŇæĹŚäżňæšąæIJL'å£ĚèęĄåĚĹårĘèőřå¡ŢæŐŠåžŔãĂĆåŻăæ■d'ïijŇåęĆæđ
è£ŹçğæŰźåijŔäijŽæŕŤåĚĹæŐŠåžŔçĎűåŘŐåĘéĂŽè£Ğ `groupby()`
åĞ¡æŢřè£äżčçŽĎæŰźåijŔè£ŘèąŇå¿Ůå£ńäÿĂäžŽãĂĆ

3.16 1.16 è£Ğæžď åžŔåĹŮåĚČçť ă

éŮőécŸ

ä¡ăæIJL'äÿĂäÿłæŢřæ■őåžŔåĹŮïijŇæČşåĹľçŤĺäÿĂäžŻèğĎåĹŹäżŐäÿ■æŔŘåŔŰåĞžéIJĂèęĄçŽĎåĂijæĺ

èğčåĘşæŰźæąĹ

æIJĂçőĂå■ŢçŽĎè£ĞæžďåžŔåĹŮåĚČçť ăçŽĎæŰźæşŢářśæŸŕă¡£çŤĺåĹŮèąĺæŐĺåŕijãĂĆæŕŤåęĆïijŽ

```
>>> mylist = [1, 4, -5, 10, -7, 2, 3, -1]
>>> [n for n in mylist if n > 0]
[1, 4, 10, 2, 3]
>>> [n for n in mylist if n < 0]
[-5, -7, -1]
>>>
```

ä¡£çŤĺåĹŮèąĺæŐĺåŕijçŽĎäÿĂäÿłæ¡IJåIJÍçijžéŹůåřśæŸŕåęĆæđIJè¿ŞåĚěéİđåÿÿåď ğçŽĎæŮűåĂŹäijŽäžğç
åęĆæđIJä¡ääŕźåĘĚå■ŸæŕŤè¿ČæŢŔæĎ§ïijŇéĆčäźĹä¡ääŔŕäżěä¡£çŤĺçŤ§æĹŘåŹĺèąĺè¿¿åijŔè£■äžčäžğçŤ§è£Ğ

```
>>> pos = (n for n in mylist if n > 0)
>>> pos
<generator object <genexpr> at 0x1006a0eb0>
>>> for x in pos:
... print(x)
...
1
4
10
2
3
>>>
```

æIJL'æŮűåĂŹïijŇè£Ğæžď èğĎåĹŹæŕŤè¿Čåď'■æİĆïijŇäÿ■èČ¡çőĂå■ŢçŽĎåIJĺåĹŮèąĺæŐĺåŕijæĹŰèĂĚç
æŕŤåęĆïijŇåĄĞèő¿è£Ğæžď çŽĎæŰűåĂŹéIJĂèęĄåď ĎçŘĘäÿĂäžŻåijĆåÿÿæĹŰèĂĚåĚűäżŰåď'■æİĆæČĚåĘ
çĎűåŘŐä¡£çŤĺåĘĚåžžçŽĎ `filter()` åĞ¡æŢřãĂĆçď'žä¿ŃåęĆäÿŇïijŽ

```
values = ['1', '2', '-3', '-', '4', 'N/A', '5']
def is_int(val):
```

```
    try:
        x = int(val)
        return True
    except ValueError:
        return False
ivals = list(filter(is_int, values))
print(ivals)
# Outputs ['1', '2', '-3', '4', '5']
```

filter() åĞ¡æŢřåĹŻåžžäžĘäÿĂäÿłè£■äžčåŹĺïijŇåŻäæ■ď'åęĆæđIJä¡ăæČşå¿ŮåĹřäÿĂäÿłåĹŮèąĺçŽĎè
list() åŐżè¡ňæ■ćãĂĆ

èőĺèőž

åĹŮèąĺæŐĺåŕijåšŇçŤ§æĹŘåŹĺèąĺè¿¿åijŔéĂŽåÿÿæČĚåĘţäÿŃæŸŕè£ĞæżďæŢřæ■őæIJĂçőĂå■ŢçŽĎæŰ
åĚűåőđåőČäžňè£ŸèČ¡åIJĺè£ĞæżďçŽĎæŰűåĂŹè¡ňæ■ćæŢřæ■őãĂĆæŕŤåęĆïijŽ

```
>>> mylist = [1, 4, -5, 10, -7, 2, 3, -1]
>>> import math
>>> [math.sqrt(n) for n in mylist if n > 0]
[1.0, 2.0, 3.1622776601683795, 1.4142135623730951, 1.
↪7320508075688772]
>>>
```

è£ĞæżďæŞ■ä¡IJçŽĎäÿĂäÿłåŔŸçğ■åřśæŸŕåřĘäÿ■çňęåŘĹæİąäžűçŽĎåĂijçŤĺæŰřçŽĎåĂijäžčæŻ£ïijŇèĂ
æŕŤåęĆïijŇåIJĺäÿĂåĹŮæŢřæ■őäÿ■ä¡ăåŔŕèČ¡äÿ■äžĚæČşæL'¿åĹřæ■čæŢřïijŇèĂŇäÿŤè£ŸæČşåřĘäÿ■æŸŕæ■
éĂŽè£ĞåřĘè£Ğæżď'æİąäžűæŤ¿åĹřæİąäžűèąĺè¿¿åijŔäÿ■åŐżïijŇåŔŕäžěå¿Ĺåőźæ ŸŞçŽĎèğčåĘşè£ŹäÿłéŮőécŸ

```
>>> clip_neg = [n if n > 0 else 0 for n in mylist]
>>> clip_neg
[1, 4, 0, 10, 0, 2, 3, 0]
>>> clip_pos = [n if n < 0 else 0 for n in mylist]
>>> clip_pos
[0, 0, -5, 0, -7, 0, 0, -1]
>>>
```

åŔęåď'ŰäÿĂäÿłåĂijå¿ŮåĚşæşĺçŽĎè£Ğæżď'åůěåĚůåřśæŸŕ itertools.
compress() ïijŇ åőČäžěäÿĂäÿł iterable åŕźèśąåŠŇäÿĂäÿłçŻÿåŕźåžŤçŽĎ
Boolean éĂL'æŃľåŹĺåžŔåĹŮä¡IJäÿžè¿ŞåĚěåŔĆæŢřãĂĆ çĎűåŘŐè¿ŞåĞž
iterable åŕźèśąäÿ■åŕźåžŤéĂL'æŃľåŹĺäÿž True çŽĎåĚĆçť'ããĂĆ
å¡Şä¡ăéIJĂèęĄçŤĺåŔęåď'ŰäÿĂäÿłçŻÿåĚşèĄŢçŽĎåžŔåĹŮæİèè£Ğæżď'æ§ŔäÿłåžŕåĹŮçŽĎæŮűåĂŹïijŇè£Źä
æŕŤåęĆïijŇåĄĞåęĆçŐřåIJĺä¡ăæIJL'äÿŃéİćäÿď'åĹŮæŢřæ■őïijŽ

```
addresses = [
    '5412 N CLARK',
    '5148 N CLARK',
    '5800 E 58TH',
    '2122 N CLARK',
    '5645 N RAVENSWOOD',
```

```
    '1060 W ADDISON',
    '4801 N BROADWAY',
    '1039 W GRANVILLE',
]
counts = [ 0, 3, 10, 4, 1, 7, 6, 1]
```

çŐřåIJÍä¡ăæČşåřĘéĆčäžŻåŕźåžŤ count åĂijåď ğäžŐ5çŽĎåIJřåİĂåĚÍéČÍè¿ŞåĞžïijŇéĆčäźĹä¡ăåŔŕäżèè£

```
>>> from itertools import compress
>>> more5 = [n > 5 for n in counts]
>>> more5
[False, False, True, False, False, True, True, False]
>>> list(compress(addresses, more5))
['5800 E 58TH', '1060 W ADDISON', '4801 N BROADWAY']
>>>
```

è£ŹéĞŇçŽĎåĚşéŤőçĆźåIJÍäžŐåĚĹåĹŻåżžäÿĂäÿł Boolean åžŔåĹŮïijŇæŇĞçď´žåŞłäžŻåĚČçť´ăçňęåŘĹæİąäżűãĂĆ çĎűåŘŐ compress() åĞ¡æŢřæäźæ■ős£ŹäÿłåžŔåĹŮåŐžéĂĽ´æŃľè¿ŞåĞžåŕźåžŤä¡■ç¡őäÿž True çŽĎåĚČçť´ăãĂĆ

åŠŇ filter() åĞ¡æŢřçśżäijijïijŇ compress() äźş§æŸŕè£ŤåŻđçŽĎäÿĂäÿłè£■äżčåŹĺãĂĆåŻäæ■d'ïij éĆčäźĹä¡ăéIJĂèęĄä¡£çŤÍ list() æİěåřĘçżŞæđIJè¡ňæ■ćäÿžåĹŮèąÍçśżåđŃãĂĆ

3.17 1.17 äżŐå■ŮåĚÿäÿ■æŔŘåŔŰå■ŘéŻĘ

éŮőécŸ

ä¡ăæČşæđĎéĂăäÿĂäÿłå■ŮåĚÿïijŇåőČæŸŕåŘęåď´ŰäÿĂäÿłå■ŮåĚÿçŽĎå■ŘéŻĘãĂĆ

èğčåĘşæŰźæąĹ

æIJĂçőĂå■ŢçŽĎæŰźåijŔæŸŕä¡£çŤĺå■ŮåĚÿæŐĺåŕijãĂĆærŤåęĆïijŽ

```
prices = {
    'ACME': 45.23,
    'AAPL': 612.78,
    'IBM': 205.55,
    'HPQ': 37.20,
    'FB': 10.75
}
# Make a dictionary of all prices over 200
p1 = {key: value for key, value in prices.items() if value > 200}
# Make a dictionary of tech stocks
tech_names = {'AAPL', 'IBM', 'HPQ', 'MSFT'}
p2 = {key: value for key, value in prices.items() if key in tech_
↪names}
```

èőÍèőž

åď ğåď ŽæŢřæČĚåĘţäÿŃå■ŮåĚÿæŐÍåřijèČ¡åĄŽåĹřçŽĎïijŇéĂŽè£ĞåĹŻåžžäÿĂäÿłåĚČçżĎåžŔåĹŮçĎű
dict() åĞ¡æŢřäź§èČ¡åőđçŐřãĂĆæŕŤåęĆïijŽ

```
p1 = dict((key, value) for key, value in prices.items() if value >␣
↪200)
```

ä¡ĘæŸŕïijŇå■ŮåĚÿæŐÍåřijæŰźåijŔèąÍæĎŔæŻť æÿĚæŹřïijŇåźűäÿŤåőđéŹĚäÿŁäź§äijŽè£ŘèąŇçŽĎæŻť
ïijĹåIJÍè£ŹäÿłäżŃå■ŘäÿïijŇåőđéŹĚæţŃèŕŢåĞääźŐæŕŤ dcit()
åĞ¡æŢřæŰźåijŔå£ńæŢť æŢť äÿĂåĂ■ïijĽ ãĂĆ

æIJL' æŮűåĂŹåőŇæĹŘåŘŇäÿĂäżűäžŇäijŽæIJL' åď Žçğ■æŰźåijŔãĂĆæŕŤåęĆïijŇçňňäžŇäÿłä¿Ńå■ŘçÍŃ

```
# Make a dictionary of tech stocks
tech_names = { 'AAPL', 'IBM', 'HPQ', 'MSFT' }
p2 = { key:prices[key] for key in prices.keys() & tech_names }
```

ä¡ĘæŸŕïijŇè£ŘèąŇæŮűéŮť æţŃèŕŢçżŞæđIJæŸ¿çď žè£Źçğ■æŰźæąĹåď ğæęĆæŕŤçňňäÿĂçğ■æŰźæąĹæ
1.6 åĂ■ãĂĆ åęĆæđIJåŕźçÍŃåžŔè£ŘèąŇæĂğèČ¡èęĄæśĆæŕŤè¿ČéńŸçŽĎèŕİïijŇéIJĂèęĄèŁśçĆźæŮűéŮť åŐż
åĚşäžŐæŻť åď Žèőąæ ŮűåŠŇæĂğèČ¡æţŃèŕŢïijŇåŔŕäžěåŔĆèĂČ 14.13 åřŔèŁĆãĂĆ

3.18 1.18 æŸäåřĎåŘ■çğŕåĹřåžŔåĹŮåĚČçť ă

éŮőécŸ

ä¡ăæIJL' äÿĂæőţéĂŽè£ĞäÿŃæăĞèő£éŮőåĹŮèąÍæĹŰèĂĚåĚČçżĎäÿ■åĚČçť ăçŽĎäžčçăĄïijŇä¡ĘæŸŕè£Ź
äžŐæŸŕä¡ăæČşéĂŽè£ĞåŘ■çğŕæİèèő£éŮőåĚČçť ããĂĆ

èğčåĘşæŰźæąĹ

collections.namedtuple() åĞ¡æŢřéĂŽè£Ğä¡£çŤĺäÿĂäÿłæŹőéĂŽçŽĎåĚČçżĎårźèśąæİěåÿőä¡ă
è£ŹäÿłåĞ¡æŢřåőđéŹĚäÿŁæŸŕäÿĂäÿłè£ŤåŽđ Python äÿ■æăĞåĞĘåĚČçżĎçśžåđŇå■ŘçśžçŽĎäÿĂäÿłåůěåŐĆ
ä¡ăéIJĂèęĄäijăéĂŠäÿĂäÿłçśžåđŇåŘ■åŠŇä¡ăéIJĂèęĄçŽĎå■ŮæőţçżŹåőČïijŇçĎűåŘŐåőČårśäijŽè£ŤåŽđäÿĂ
äžčçăĄçď žä¿ŃïijŽ

```
>>> from collections import namedtuple
>>> Subscriber = namedtuple('Subscriber', ['addr', 'joined'])
>>> sub = Subscriber('jonesy@example.com', '2012-10-19')
>>> sub
Subscriber(addr='jonesy@example.com', joined='2012-10-19')
>>> sub.addr
'jonesy@example.com'
>>> sub.joined
'2012-10-19'
>>>
```

åř¡çőą `namedtuple` çŽĎåőđä¿ŃçIJŃèţůæİěåČŕäÿĂäÿłæŹőéĂŽçŽĎçśžåőđä¿ŃïijŇä¡ĘæŸŕåőČèů§åĚČ
ærŤåęĆïijŽ

```
>>> len(sub)
2
>>> addr, joined = sub
>>> addr
'jonesy@example.com'
>>> joined
'2012-10-19'
>>>
```

åŠ¡åŘ■åĚČçżĎçŽĎäÿĂäÿłäÿżèęĄçŤĺéĂŤæŸŕåřĘä¡ăçŽĎäżčçăĄäžŐäÿŃæăĞæŞ■ä¡IJäÿ■èğčèĎśåĞžæİě
åŻăæ■ď¨ïijŇåęĆædIJä¡ăäžŐæŢřæ■őåžŞèřČçŤĺäÿ■è£ŤåŻđäžĘäÿĂäÿłå¿Ĺåď¨ğçŽĎåĚČçżĎåĹÙèąĺïijŇéĂŽè£Ğ
å¡Şä¡ăåIJĺèąĺäÿ■æůżåŁäžĘæŰřçŽĎåĹÙçŽĎæÙűåĂŹä¡ăçŽĎäżčçăĄåŘŕèČ¡åŕšäijŽåĞžéŤŹäžĘãĆä¡ĘæŸŕå

äÿžäžĘèŕť¨æŸŐæÿĚæěŽïijŇäÿŃéİćæŸŕä¡£çŤĺæŹőéĂŽåĚČçżĎçŽĎäżčçăĄïijŽ

```
def compute_cost(records):
    total = 0.0
    for rec in records:
        total += rec[1] * rec[2]
    return total
```

äÿŃæăĞæŞ■ä¡IJéĂŽåÿÿäijŽèől¨äžčçăĄèąĺæĎŔäÿ■æÿĚæŹřijŇåźűäÿŤéİđåÿÿä¿ÌèţŰèőřå¡ŢçŽĎçżŞæđĎ
äÿŃéİćæŸŕä¡£çŤĺåŠ¡åŘ■åĚČçżĎçŽĎçL¨ĹæIJñïijŽ

```
from collections import namedtuple

Stock = namedtuple('Stock', ['name', 'shares', 'price'])
def compute_cost(records):
    total = 0.0
    for rec in records:
        s = Stock(*rec)
        total += s.shares * s.price
    return total
```

èőÍèőž

åŠ¡åŘ■åĚČçżĎåŕęäÿĂäÿłçŤĺéĂŤåřśæŸŕä¡IJäÿžå■ŮåĚÿçŽĎæŻ£äžčijŇåŻääÿžå■ŮåĚÿå■ŸåĆĺéIJĂèęĄ
åęĆædIJä¡ăéIJĂèęĄæđĎåżžäÿĂäÿłéİđåÿÿåď¨ğçŽĎåŇĚåŘńå■ŮåĚÿçŽĎæŢřæ■őçżŞæđĎïijŇéĆčäźĹä¡£çŤĺåŠ¡
ä¡ĘæŸŕéIJĂèęĄæşĺæĎŔçŽĎæŸŕïijŇäÿ■åČŔå■ŮåĚÿéĆčæăůïijŇäÿĂäÿłåŠ¡åŘ■åĚČçżĎæŸŕäÿ■åŘŕæŻť¨æŤźç

```
>>> s = Stock('ACME', 100, 123.45)
>>> s
Stock(name='ACME', shares=100, price=123.45)
>>> s.shares = 75
Traceback (most recent call last):
File "<stdin>", line 1, in <module>
```

```
AttributeError: can't set attribute
>>>
```

åęĆæđIJä¡ăçIJ§çŽĎéIJĂèęĄæŤźåŔŸåśđæĂğçŽĎåĂijïijŇéĆčäźĹåŔŕäżěä¡£çŤĺåŚ¡åŘ■åĚČçżĎåőđä¿Ńç
`_replace()` æŰźæşŢïijŇ åőČäijŽåĹŻåżžäÿĂäÿłåĚĺæŰřçŽĎåŚ¡åŘ■åĚČçżĎåźűåřĘåŕźåžŤçŽĎå■Ůæőţçĺa

```
>>> s = s._replace(shares=75)
>>> s
Stock(name='ACME', shares=75, price=123.45)
>>>
```

`_replace()` æŰźæşŢè£ŸæIJĽäÿĂäÿłå¿ĹæIJĽçŤĺçŽĎçĽźæĂğåřśæŸŕå¡Şä¡ăçŽĎåŚ¡åŘ■åĚČçżĎæŃě
åőČæŸŕäÿĂäÿłéİđåÿÿæŰźä¿£çŽĎåąńåĚĚæŢřæ■őçŽĎæŰźæşŢãĂĆ
ä¡ăåŔŕäżěåĚĹåĹŻåżžäÿĂäÿłåŇĚåŘńçijžçIJĄåĂijçŽĎåŐ§åđŃåĚČçżĎïijŇçĎűåŘŐä¡£çŤĺ
`_replace()` æŰźæşŢåĹŻåżžæŰřçŽĎåĂijèćńæŻť æŰřè£ĞçŽĎåőđä¿ŃãĂĆæŕŤåęĆïijŽ

```
from collections import namedtuple

Stock = namedtuple('Stock', ['name', 'shares', 'price', 'date',
 ↪'time'])

# Create a prototype instance
stock_prototype = Stock('', 0, 0.0, None, None)

# Function to convert a dictionary to a Stock
def dict_to_stock(s):
    return stock_prototype._replace(**s)
```

äÿŃéİćæŸŕåőČçŽĎä¡£çŤĺæŰźæşŢïijŽ

```
>>> a = {'name': 'ACME', 'shares': 100, 'price': 123.45}
>>> dict_to_stock(a)
Stock(name='ACME', shares=100, price=123.45, date=None, time=None)
>>> b = {'name': 'ACME', 'shares': 100, 'price': 123.45, 'date':
 ↪'12/17/2012'}
>>> dict_to_stock(b)
Stock(name='ACME', shares=100, price=123.45, date='12/17/2012',␣
 ↪time=None)
>>>
```

æIJĂåŘŐèęĄèŕť çŽĎæŸŕïijŇåęĆæđIJä¡ăçŽĎçŻőæăĞæŸŕåőŽäźĽäÿĂäÿłéIJĂèęĄæŻť æŰřå¿Ĺåď Žåőđä¿
è£ŹæŮűåĂŹä¡ăåžŤèŕěèĂČèŹŚåőŽäźĽäÿĂäÿłåŇĚåŘń `__slots__`
æŰźæşŢçŽĎçśżïijĹåŔĆèĂČ8.4åřŔèŁĆïijĽãĂĆ

3.19 1.19 è¡ňæ■ćåźűåŘŇæŮűèőąçőŮæŢřæ■ő

éŮőécŸ

ä¡ăéIJĂèęĄåIJĺæŢřæ■őåžŔåĹŮäÿŁæL'ğèąŇèĄŽéŻĘåĞ¡æŢřïijĹæŕŤåęĆ `sum()`,`min()`,`max()` ïijL'ïijŇ ä¡ĘæŸŕéęŰåĚĹä¡ăéIJĂèęĄåĚĹè¡ňæ■ćæĹŰèĂĚè£Ğæżđ'æŢřæ■ő

èğčåĘşæŰźæąĹ

äÿĂäÿłéİđåÿÿäijŸéŻĚçŽĎæŰźåijŔåŐżçżŞåŘĹæŢřæ■ôèőąçőŮäÿŐè¡ňæ■ćåřśæŸŕä¡£çŤĺäÿĂäÿłçŤ§æĹŘæŕŤåęĆïijŇåęĆæđIJä¡ăæČşèőąçőŮåźşæŰźåŠŇïijŇåŘŕäžěåČŔäÿŃéİćè£ŹæăůåĄŽïijŽ

```
nums = [1, 2, 3, 4, 5]
s = sum(x * x for x in nums)
```

äÿŃéİćæŸŕæŻt'åđ'ŽçŽĎä¿Ńå■ŘïijŽ

```
# Determine if any .py files exist in a directory
import os
files = os.listdir('dirname')
if any(name.endswith('.py') for name in files):
    print('There be python!')
else:
    print('Sorry, no python.')
# Output a tuple as CSV
s = ('ACME', 50, 123.45)
print(','.join(str(x) for x in s))
# Data reduction across fields of a data structure
portfolio = [
    {'name':'GOOG', 'shares': 50},
    {'name':'YHOO', 'shares': 75},
    {'name':'AOL', 'shares': 20},
    {'name':'SCOX', 'shares': 65}
]
min_shares = min(s['shares'] for s in portfolio)
```

èőÍèőž

äÿŁéİćçŽĎçđ'žä¿ŃåŘŚä¡ăæijŤçđ'žäžĘå¡ŞçŤ§æĹŘåŹÍèąÍè¿¿åijŔä¡IJäÿžäÿĂäÿłå■ŢçŃňåŔĆæŢřäijăéĂŠçæŕŤåęĆïijŇäÿŃéİćè£ŹäžŻèŕ■åŘěæŸŕç■Ľ'æŢĹçŽĎïijŽ

```
s = sum((x * x for x in nums)) #␣
↪æŸ¿çd'žçŽĎäijăéĂŠäÿĂäÿłçŤ§æĹŘåŹÍèąÍè¿¿åijŔårźèśą
s = sum(x * x for x in nums) #␣
↪æŻt'åŁääijŸéŻĚçŽĎåőđçŐřæŰźåijŔïijŇçIJĄçŢěäžĘæŃňåŔů
```

ä¡£çŤĺäÿĂäÿłçŤ§æĹŘåŹÍèąÍè¿¿åijŔä¡IJäÿžåŔĆæŢřäijŽæŕŤåĚĹåĹŻåžžäÿĂäÿłäÿť'æŮűåĹŮèąÍæŻť'åŁăéŕæŕŤåęĆïijŇåęĆæđIJä¡ăäÿ■ä¡£çŤĺçŤ§æĹŘåŹÍèąÍè¿¿åijŔçŽĎèŕÏïijŇä¡ăåŘŕèČ¡äijŽèĂČèŹŚä¡£çŤĺäÿŃéİćçŽĎå

```
nums = [1, 2, 3, 4, 5]
s = sum([x * x for x in nums])
```

è£Źçğ■æŰźåijŔåŘŇæăůåŘŕäžěè¿¿åĹřæČşèęĄçŽĎæŢĹæđIJïijŇä¡ĘæŸŕåőČäijŽåď'ŽäÿĂäÿłæ■ěéłď'ïijŇå
åŕźäžŐåřŘåđŃåĹŮèąĺåŘŕèČ¡æšąäżĂäźĹåĚşçşżïijŇä¡ĘæŸŕåęĆæđIJåĚČçť'ăæŢřéĞŔéİđåÿÿåď'ğçŽĎæŮűåĂŹi
åőČäijŽåĹŻåžžäÿĂäÿłåůĺåď'ğçŽĎäžĚäžĚèćńä¡£çŤĺäÿĂæňąåřśèćńäÿćåijČçŽĎäÿt'æŮűæŢřæ■őçżŞæđĎãĂĆè

åIJĺä¡£çŤĺäÿĂäžŽèĄŽéŻĘåĞ¡æŢřæŕŤåęĆ `min()` åŠŇ `max()` çŽĎæŮűåĂŹä¡ăåŔŕèČ¡æŻt'åŁăåĂ¿åŘŚäžŐä¡£çŤĺçŤ§æĹŘåŹĺçL'ĹæIJňïijŇ
åőČäžňæŐěåŔŮçŽĎäÿĂäÿł key åĚşéŤőå■ŮåŘĆæŢřæĹŰèőÿåŕźä¡ăå¿ĹæIJL'åÿőåŁl'ãĂĆ
æŕŤåęĆïijŇåIJĺäÿŁéİćçŽĎèŕĄåĹÿä¿Ńå■Řäÿ■ïijŇä¡ăåŔŕèČ¡äijŽèĂČèŹŠäÿŃéİćçŽĎåőđçŐřçL'ĹæIJňïijŽ

```
# Original: Returns 20
min_shares = min(s['shares'] for s in portfolio)
# Alternative: Returns {'name': 'AOL', 'shares': 20}
min_shares = min(portfolio, key=lambda s: s['shares'])
```

3.20 1.20 åŘĹåźűåď'Žäÿłå■ŮåĚÿæĹŰæŸăåřĎ

éŮőécŸ

çŐřåIJĺæIJL'åď'Žäÿłå■ŮåĚÿæĹŰèĂĚæŸăåřĎïijŇä¡ăæČşåřĘåőČäžňäžŐéĂżè¿ŚäÿŁåŘĹåźűäÿžäÿĂäÿłå■
æŕŤåęĆæ§ěæL'¿åĂijæĹŰèĂĚæčĂæ§ěæ§ŘäžŹéŤőæŸŕåŘęå■ŸåIJĺãĂĆ

èğčåĘşæŰźæąĹ

åĄĞåęĆä¡ăæIJL'åęĆäÿŃäÿď'äÿłå■ŮåĚÿ:

```
a = {'x': 1, 'z': 3 }
b = {'y': 2, 'z': 4 }
```

çŐřåIJĺåĄĞèő¿ä¡ăå£Ěéążå IJĺäÿď'äÿłå■ŮåĚÿäÿ■æL'ğèąŇæ§ěæL'¿æŞ■ä¡IJïijĹæŕŤåęĆåĚĹäžŐ
`a` äÿ■æL'¿ïijŇåęĆædIJæL'¿äÿ■åĹřåĘ■åIJĺ `b` äÿ■æL'¿ïijL'ãĂĆ
äÿĂäÿłéİđåÿÿçőĂå■ŢçŽĎèğčåĘşæŰźæąĹåřśæŸŕä¡£çŤĺ `collections` æĺąåİŮäÿ■çŽĎ
`ChainMap` çśžãĂĆæŕŤåęĆïijŽ

```
from collections import ChainMap
c = ChainMap(a,b)
print(c['x']) # Outputs 1 (from a)
print(c['y']) # Outputs 2 (from b)
print(c['z']) # Outputs 3 (from a)
```

èőĺèőž

äÿĂäÿł `ChainMap` æŐěåŘŮåď'Žäÿłå■ŮåĚÿåźűåřĘåőČäžňåIJĺéĂżè¿ŚäÿŁåŘŸäÿžäÿĂäÿłå■ŮåĚÿãĂĆ
çĎűåŘŐïijŇè£ŹäžŻå■ŮåĚÿåźűäÿ■æŸŕçIJ§çŽĎåŘĹåźűåIJĺäÿĂèţůäžĘïijŇ `ChainMap`

çśżåŔłæŸŕåIJĺåĘĚéČĺåĹŻåżžäžĘäÿĂäÿłåőźçžşè£ŹäžŻå■ŮåĚÿçŽĎåĹŮèąĺ
åźűéĞ■æŰřåőŽäźL’äžĘäÿĂäžŻåÿÿèğAçŽĎå■ŮåĚÿæŞ■ä¡IJæİěéĄ■åŐĘè£ŹäÿłåĹŮèąĺãĂĆåď’ğéČĺåĹĘå■ŮåĚ

```
>>> len(c)
3
>>> list(c.keys())
['x', 'y', 'z']
>>> list(c.values())
[1, 2, 3]
>>>
```

åęĆædIJåĞžçŐřéĞ■åď’■éŤőïijŇéĆčäźĹçňňäÿĂæňąåĞžçŐřçŽĎæŸäářĎåĂijäijŽèćńè£ŤåŻđãĂĆ
åŻăæ■d’ïijŇä¿Ńå■ŘçÍŃåžŔäÿ■çŽĎ `c['z']` æĂżæŸŕäijŽè£ŤåŻđå■ŮåĚÿ `a`
äÿ■ářźåžŤçŽĎåĂijïijŇèĂŇäÿ■æŸŕ `b` äÿ■ářźåžŤçŽĎåĂijãĂĆ

åŕźäžŐå■ŮåĚÿçŽĎæŻt’æŰřæĹŰåĹăéŹd’æŞ■ä¡IJæĂżæŸŕå¡śåŞ■çŽĎæŸŕåĹŮèąĺäÿ■çňňäÿĂäÿłå■ŮåĚÿă

```
>>> c['z'] = 10
>>> c['w'] = 40
>>> del c['x']
>>> a
{'w': 40, 'z': 10}
>>> del c['y']
Traceback (most recent call last):
...
KeyError: "Key not found in the first mapping: 'y'"
>>>
```

`ChainMap` åŕźäžŐçijŰçÍŃèŕ■èÍĂäÿ■çŽĎä¡IJçŤĺèŇČåŻt’åŔŸéĞŔïijĹæŕŤåęĆ
`globals` , `locals` ç■L’ïijL’æŸŕéÍđåÿÿæIJL’çŤĺçŽĎãĂĆ
äžŃåőđäÿŁïijŇæIJL’äÿĂäžŻæŰźæşŢåŔŕäžëä¡£åőČåŔŸå¿ŮçőĂå■Ţïij Ž

```
>>> values = ChainMap()
>>> values['x'] = 1
>>> # Add a new mapping
>>> values = values.new_child()
>>> values['x'] = 2
>>> # Add a new mapping
>>> values = values.new_child()
>>> values['x'] = 3
>>> values
ChainMap({'x': 3}, {'x': 2}, {'x': 1})
>>> values['x']
3
>>> # Discard last mapping
>>> values = values.parents
>>> values['x']
2
>>> # Discard last mapping
>>> values = values.parents
>>> values['x']
```

```
1
>>> values
ChainMap({'x': 1})
>>>
```

ä¡IJäÿž `ChainMap` çŽĎæŻ£äżčïijŇä¡ăåŔŕèČ¡äijŽèĂČèŹŚä¡£çŢĺ `update()` æŰźæşŢåřĘäÿď'äÿłå■ŮåĚÿåŘĹåźűãĂĆæŕŤåęĆïijŽ

```
>>> a = {'x': 1, 'z': 3 }
>>> b = {'y': 2, 'z': 4 }
>>> merged = dict(b)
>>> merged.update(a)
>>> merged['x']
1
>>> merged['y']
2
>>> merged['z']
3
>>>
```

è£Źæăůäź§èČ¡èąŇå¿ŮéĂŽïijŇä¡ĘæŸŕåőĆéIJĂèęĄä¡ăåĹŻåżžäÿĂäÿłåőŇåĚĺäÿ■åŘŇçŽĎå■ŮåĚÿåŕźèśąï
åŘŇæŮűïijŇåęĆæđIJåŐ§å■ŮåĚÿåĄŽäžĘæŻť'æŰřïijŇè£Źçğ■æŤźåŔŸäÿ■äijŽåŔ■äžŤåĹřæŰřçŽĎåŘĹåźűå■Ů

```
>>> a['x'] = 13
>>> merged['x']
1
```

`ChainMap` ä¡£çŤĺåŐ§æİěçŽĎå■ŮåĚÿïijŇåőČèĞłåůśäÿ■åĹŻåżžæŰřçŽĎå■ŮåĚÿãĂĆæĽĂäžěåőČåźűäÿ

```
>>> a = {'x': 1, 'z': 3 }
>>> b = {'y': 2, 'z': 4 }
>>> merged = ChainMap(a, b)
>>> merged['x']
1
>>> a['x'] = 42
>>> merged['x'] # Notice change to merged dicts
42
>>>
```

4 çňňäžŇçńäïijŽå■ŮçňęäÿšåŠŇæŰĞælJň

åĞääźŐæĽĂæIJĽæIJĽçŤĺçŽĎçĺŇåžŔéČ¡äijŽæűĽåŔŁåĹřæ§ŘäžŽæŰĞæIJňåď'ĎçŘĘïijŇäÿ■çőąæŸŕèğ
è£ŹäÿĂçńäářĘéĞ■çĆźåĚşæşĺæŰĞæIJňçŽĎæŞ■ä¡IJåď'ĎçŘĘïijŇæŕŤåęĆæŔŘåŔŰå■ŮçňęäÿšïijŇæŘIJçť'ćïijŇ
åď'ğéČĺåĹęçŽĎéŮőécŸéČ¡èČ¡çőĂå■ŢçŽĎèřČçŤĺå■ŮçňęäÿšçŽĎåĘĚåžžæŰźæşŢåőŇæĹŘãĂĆ
ä¡ĘæŸŕïijŇäÿĂäžŽæŽť'äÿžåď'■æİĆçŽĎæŞ■ä¡IJåŔŕèČ¡éIJĂèęĄæ■čåĹŹèąĺè¿¿åijŔæĹŰèĂĚåijžåď'ğçŽĎèğčæ
åźűäÿŤåIJĺæŞ■ä¡IJUnicodeæŮűåĂŹçćřåĹřçŽĎäÿĂäžŽæčŸæĽŃçŽĎéŮőécŸåIJĺè£ŹéĞŇäź§äijŽèćńæŔŘåŔ

Contents:

4.1 2.1 ä¡£çŤÍåď'Žäÿłç˘ŇåőŽçňęåĹĘåĽ'šå■Ůçňęäÿš

éŮőécŸ

ä¡ăéIJĂèęĄåřĘäÿĂäÿłå■Ůçňęäÿšå[ĹĘåĽ'šäÿžåď'Žäÿłå■Ůæőţ˙ijÑä¡ĘæŸŕåĹĘéŽŤçňę(è£ŸæIJL'åŚÍåŻť'çŽĹ

èğčåĘşæŰźæąĹ

`string` åŕźèśąçŽĎ `split()` æŰźæşŢåŔłéĂĆåžŤäžŐéÍđåÿÿçőĂå■ŢçŽĎå■Ůçňęäÿšå[ĹĘåĽ'šæČĚå¡ć˙ïij
åőČåźűäÿ■åĚĄèőÿæIJL'åď'Žäÿłå[ĹĘéŽŤçňęæĹŰèĂĚæŸŕåĹĘéŽŤçňęåŚÍåŻť'äÿ■çąőåőŽçŽĎçl'žæăijãĂĆ
å¡Şä¡ăéIJĂèęĄæŻť'åŁăçĄţæť'żçŽĎåĹĞåĽ'šå■Ůçňęäÿšç˘ŽĎæŮűåĂŹ˙ijÑæIJĂåě¡ä¡£çŤÍ `re.split()` æŰźæşŢ˙ijŽ

```
>>> line = 'asdf fjdk; afed, fjek,asdf, foo'
>>> import re
>>> re.split(r'[;,\s]\s*', line)
['asdf', 'fjdk', 'afed', 'fjek', 'asdf', 'foo']
```

èőÍèőž

åĞ¡æŢř `re.split()` æŸŕéÍđåÿÿåőđçŤÍçŽĎ˙ijÑåŻääÿžåőČåĚĄèőÿä¡ääÿžåĹĘéŽŤçňęæŇĞåőŽåď'Žäÿł
æŕŤåęĆ˙ijÑåIJÍäÿŁéÍćçŽĎä¿Ńå■Řäÿ■˙ijÑåĹĘéŽŤçňęåŔŕäžěæŸŕéĂŮåŔů˙ijÑåĹĘåŔůæĹŰèĂĚæŸŕçl'žæăijï˙ij
åŔłèęĄè£Źäÿłæĺąåij˙ŘèćńæĽ'¿åĹŕ˙ijÑéĆčäźĹåŇźéĚ■çŽĎåĹĘéŽŤçňęäÿď'è¿źçŽĎåőđä¡ŞéČ¡äijŽèćńå¡ŞæĹŘæ
è£ŤåŻđçżŞæđIJäÿžäÿĂäÿłå■Ůæőţ˙åĹŮèąĺ˙ijÑè£Źäÿłèů§ `str.split()`
è£ŤåŻđåĂijçśžåđŇæŸŕäÿĂæăůçŽĎãĂĆ

å¡Şä¡ää¡£çŤÍ `re.split()` åĞ¡æŢřæŮűåĂŹ˙ijÑéIJĂèęĄçL'źåĹńæşĺæĎŔçŽĎæŸŕæ■čåĹŹèąĺè¿¿åijŔäÿ
åęĆæđIJä¡£çŤÍäžĘæ■ŢèŐůåĹĘçżĎ˙ijÑéĆčäźĹèćńåŇźéĚ■çŽĎæŰĞæIJñäź§ářĘåĞžçŐřåIJÍçżŞæđIJåĹŮèąĺäÿ

```
>>> fields = re.split(r'(;|,|\s)\s*', line)
>>> fields
['asdf', ' ', 'fjdk', ';', 'afed', ',', 'fjek', ',', 'asdf', ',',
↪'foo']
>>>
```

èŐůåŔŰåĹĘåĽ'šå■Ůçňęåij Íæ§ŘäžZæČĚåĘţäÿŇäź§æŸŕæIJL'çŤÍçŽĎãĂĆ
æŕŤåęĆ˙ijÑä¡ăåŔŕèČ¡æČşä£ÍçŢŹåĹĘåĽ'šå■Ůçňęäÿš˙ijÑçŤÍæÍěåIJÍåŘŐéÍćéĞ■æŰřæđĎéĂääÿĂäÿłæŰřçŽĎè

```
>>> values = fields[::2]
>>> delimiters = fields[1::2] + ['']
>>> values
['asdf', 'fjdk', 'afed', 'fjek', 'asdf', 'foo']
>>> delimiters
[' ', ';', ',', ',', ',', '']
>>> # Reform the line using the same delimiters
>>> ''.join(v+d for v,d in zip(values, delimiters))
'asdf fjdk;afed,fjek,asdf,foo'
>>>
```

åęĆædIJä¡ăäÿ■æČşä£ÍçŢŹåĹĘåL'šå■Ůçňęäÿšå Ĺřçżşædl Jå ĹŮèąĺäÿ■åŐżïijŇä¡Ęäż■çĎűéIJÄèęÄä¡£çŤĺåĺçąőä£Íä¡ăçŽĎåĹEçżĎæŸŕéIđæ■ŢèŐůåĹEçżĎïijŇå¡ćåęĆ `(?:...)` ãĂĆærŤåęĆïijŽ

```
>>> re.split(r'(?:,|;|\s)\s*', line)
['asdf', 'fjdk', 'afed', 'fjek', 'asdf', 'foo']
>>>
```

4.2 2.2 å■ŮçňęäÿšåijĂåď'æĹŰçżŞář¿åŇźéĚ■

éŮőécŸ

ä¡ăéIJĂèęĄéĂŽè£ĞæŇĞåőŽçŽĎæŰĞæIJňæĺąåijŔåŐżæčĂæ§ěå■ŮçňęäÿšçŽĎåijĂåď'æĹŰèĂĚçżŞář¿ŞSchemeç■L'ç■L'ãĂĆ

èğčåĘşæŰźæąĹ

æčĂæ§ěå■ŮçňęäÿšåijĂåď'æĹŰçżŞář¿çŽĎäÿĂäÿłçőĂå■ŢæŰźæşŢæŸŕä¡£çŤĺ `str.startswith()` æĹŰèĂĚæŸŕ `str.endswith()` æŰźæşŢãĂĆærŤåęĆïijŽ

```
>>> filename = 'spam.txt'
>>> filename.endswith('.txt')
True
>>> filename.startswith('file:')
False
>>> url = 'http://www.python.org'
>>> url.startswith('http:')
True
>>>
```

åęĆædIJä¡ăæČşæčĂæ§ěåď'Žçğ■åŇźéĚ■åŔŕèČ¡ïijŇåŔłéIJĂèęĄåřĘæL'ĂæIJL'çŽĎåŇźéĚ■éąźæŤ¿åĚěåĹçĎűåŘŐäijăçżŹ `startswith()` æĹŰèĂĚ `endswith()` æŰźæşŢïijŽ

```
>>> import os
>>> filenames = os.listdir('.')
>>> filenames
[ 'Makefile', 'foo.c', 'bar.py', 'spam.c', 'spam.h' ]
>>> [name for name in filenames if name.endswith(('.c', '.h')) ]
['foo.c', 'spam.c', 'spam.h'
>>> any(name.endswith('.py') for name in filenames)
True
>>>
```

äÿŃéÍćæŸŕåŔęäÿĂäÿłä¿Ńå■ŘïijŽ

```
from urllib.request import urlopen
```

```
def read_data(name):
    if name.startswith(('http:', 'https:', 'ftp:')):
        return urlopen(name).read()
    else:
        with open(name) as f:
            return f.read()
```

åěĞæĂłçŽĎæŸŕïijŇè£ŹäÿłæŰźæşŢäÿ■å£Ěéążèę Ąè¿ŞåĚěäÿĂäÿłåĚČçżĎä¡IJäÿžåŔĆæŢřãĂĆ åęĆæđIJä¡ăæĄřåůğæIJL'äÿĂäÿł list æĹŰèĂĚ set çśżåđŃçŽĎéĂL'æŃl'éąźïijŇ èęĄçąőä£Ïäijăé ĂŠåŔĆæŢřåL'■åĚĹèřČçŤÍ tuple() åřĘåĚűè¡ñæ■ćäÿžåĚČçżĎçśżåđŃãĂĆæŕŤåęĆïijŽ

```
>>> choices = ['http:', 'ftp:']
>>> url = 'http://www.python.org'
>>> url.startswith(choices)
Traceback (most recent call last):
File "<stdin>", line 1, in <module>
TypeError: startswith first arg must be str or a tuple of str, not␣
 ↪list
>>> url.startswith(tuple(choices))
True
>>>
```

èőÍèőž

startswith() åŠŇ endswith() æŰźæşŢæŔŘä¿ŻäžĘäÿĂäÿłéÍđåÿÿæŰźä¿£çŽĎæŰźåijŔåŐżåĄŽå çśżäijijçŽĎæŞ■ä¡IJäź§åŔŕäžěä¡£çŤĺåĹĞçL'ĞæÍěåőđçŐřïijŇä¡ĘæŸŕäžčçăĄçIJŃèţůæÍěæšąæIJL'éĆčäźĹäijŸé

```
>>> filename = 'spam.txt'
>>> filename[-4:] == '.txt'
True
>>> url = 'http://www.python.org'
>>> url[:5] == 'http:' or url[:6] == 'https:' or url[:4] == 'ftp:'
True
>>>
```

ä¡ăåŔŕäžěèČ¡è£ŸæČşä¡£çŤĺæ■čåĹŹèąĺè¿¿åijŔåŐżåőđçŐřïijŇæŕŤåęĆïijŽ

```
>>> import re
>>> url = 'http://www.python.org'
>>> re.match('http:|https:|ftp:', url)
<_sre.SRE_Match object at 0x101253098>
>>>
```

è£Źçğ■æŰźåijŔäź§èąŇå¿ŮéĂŽïijŇä¡ĘæŸŕåŕźäžŐçőĂå■ŢçŽĎåŇźéĚ■åőđåIJĺæŸŕæIJL'çĆźåŕŔæİŘåđ'ğ

æIJĂåŘŐæŔŘäÿĂäÿŃïijŇå¡ŞåŠŇåĚűäżŰæŞ■ä¡IJæŕŤåęĆæŹőéĂŽæŢřæ■őèĄŽåŘĹçŻÿçżŞåŘĹçŽĎæŮú startswith() åŠŇ endswith() æŰźæşŢæŸŕå¿Ĺäÿ■éŤŹçŽĎãĂĆ æŕŤåęĆïijŇäÿŃéİćè£Źäÿłèŕ■åŘëæčĂæ§ëæ§ŘäÿłæŰĞäžűåđ'źäÿ■æŸŕåŘęå■ŸåIJĺæŇĞåőŽçŽĎæŰĞäžűçśżåđ

```
if any(name.endswith(('.c', '.h')) for name in listdir(dirname)):
...
```

4.3 2.3 çŤÍShelléĂŽéĚ■çňęåŇźéĚ■å■Ůçňęäÿš

éŮőécŸ

ä¡ăæČşä¡£çŤÍ **Unix Shell** äÿ■åÿÿçŤÍçŽĎéĂŽéĚ■çňę(æŕŤåęĆ `*.py`,`Dat[0-9]*.csv` ç■L')åŐżåŇźéĚ■æŰĞæIJňå■Ůçňęäÿš

èğčåĘşæŰźæąĹ

`fnmatch` æĺąåİŮæŔŘä¿ŻäžĘäÿd'äÿłåĞ¡æŢřâĂŤâĂŤ `fnmatch()` åŠŇ `fnmatchcase()` ïijŇåŔŕäžěçŤÍæİěåőđçŐřè£Źæăůç˝ŽĎåŇźéĚ■ãĂĆçŤÍæşŢåęĆäÿŃïijŽ

```
>>> from fnmatch import fnmatch, fnmatchcase
>>> fnmatch('foo.txt', '*.txt')
True
>>> fnmatch('foo.txt', '?oo.txt')
True
>>> fnmatch('Dat45.csv', 'Dat[0-9]*')
True
>>> names = ['Dat1.csv', 'Dat2.csv', 'config.ini', 'foo.py']
>>> [name for name in names if fnmatch(name, 'Dat*.csv')]
['Dat1.csv', 'Dat2.csv']
>>>
```

`fnmatch()` åĞ¡æŢřä¡£çŤÍåžŢåśĆæŞ■ä¡IJçşżçż§çŽĎåd'ğåřŔåĘŹæŢŔæĎ§èğĎåĹŹ(äÿ■åŘńçŽĎçşżçż§

```
>>> # On OS X (Mac)
>>> fnmatch('foo.txt', '*.TXT')
False
>>> # On Windows
>>> fnmatch('foo.txt', '*.TXT')
True
>>>
```

åęĆædIJä¡ăåŕźè£ŹäÿłåŇžåĹńå¿ĹåIJĺæĎŔïijŇåŔŕäžěä¡£çŤÍ `fnmatchcase()` æİěäżčæŻ£ãĂĆåőČåőŇåĚĺä¡£çŤÍä¡ăçŽĎæĺąåijŔåd'ğåřŔåĘŹåŇźéĚ■ãĂĆæŕŤåęĆïijŽ

```
>>> fnmatchcase('foo.txt', '*.TXT')
False
>>>
```

è£Źäÿd'äÿłåĞ¡æŢřéĂŽåÿÿäijŽèćńå£¡çŢěçŽĎäÿĂäÿłçL'źæĂğæŸŕåIJĺåd'ĎçŘEéİđæŰĞäžűåŘ■çŽĎå■Ůç
æŕŤåęĆïijŇåĄĞèő¿ä¡ăæIJL'äÿĂäÿłèąÛéĄŞåIJřåİĂçŽĎåĹÛèąĺæŢřæ■őïijŽ

```
addresses = [
    '5412 N CLARK ST',
    '1060 W ADDISON ST',
    '1039 W GRANVILLE AVE',
    '2122 N CLARK ST',
    '4802 N BROADWAY',
]
```

ä¡ăåŔŕäžěåČŔè£ŹæăůåĘŹåĹŮèąĺæŐĺåŕijïijŽ

```
>>> from fnmatch import fnmatchcase
>>> [addr for addr in addresses if fnmatchcase(addr, '* ST')]
['5412 N CLARK ST', '1060 W ADDISON ST', '2122 N CLARK ST']
>>> [addr for addr in addresses if fnmatchcase(addr, '54[0-9][0-9]␣
↪*CLARK*')]
['5412 N CLARK ST']
>>>
```

èőÍèőž

fnmatch() åĞ¡æŢřåŇźéĚ■èČ¡åŁŻäżŇäžŐçőĂå■ŢçŽĎå■ŮçňęäÿšæŰźæşŢåŠŇåijžåď ğçŽĎæ■čåĹŹèą åęĆæđIJåIJÍæŢřæ■őåď ĎçŘĘæŞ■ä¡IJäÿ■åŔłéIJĂèęĄçőĂå■ŢçŽĎéĂŽéĚ■çňęářśèČ¡åőŇæĹŘçŽĎæŮűåĂŹïijŇ

åęĆæđIJä¡ăçŽĎäžčçăĄéIJĂèęĄåĄŽæŰĞäžűåŘ■çŽĎåŇźéĚ■ïijŇæIJĂåě¡ä¡£çŤÍ glob æĺąåİŮãĂĆåŔĆèĂČ5.13ářŔèŁĆãĂĆ

4.4 2.4 å■Ůçňęäÿšå ŇźéĚ■åŠŇæŘIJçť ć

éŮőécŸ

ä¡ăæČşåŇźéĚ■æĹŰèĂĚæŘIJçť ćçL´źåőŽæĺąåijŔçŽĎæŰĞæIJň

èğčåĘşæŰźæąĹ

åęĆæđIJä¡ăæČşåŇźéĚ■çŽĎæŸŕå■Ůéİćĺ■ŮçňęäÿšïijŇéĆčäźĹä¡ăéĂŽåÿÿåŔłéIJĂèęĄèřČçŤĺå§žæIJňå■Ů æŕŤåęĆ str.find() , str.endswith() , str.startswith() æĹŰèĂĚçśžäijijçŽĎæŰźæşŢïijŽ

```
>>> text = 'yeah, but no, but yeah, but no, but yeah'
>>> # Exact match
>>> text == 'yeah'
False
>>> # Match at start or end
>>> text.startswith('yeah')
True
>>> text.endswith('no')
```

```
False
>>> # Search for the location of the first occurrence
>>> text.find('no')
10
>>>
```

åŕźäžŐåď■æİĆçŽĎåŇźéĚ■éIJĂèęĄä¡£çŤĺæ■čåĹŹèąĺè¿¿åijŔåŠŇ `re` æĺąåİŮãĂĆ äÿžäžEèğčéĞŁæ■čåĹŹèąĺè¿¿åijŔçŽĎå§žæIJňåŐ§çŘĘïijŇåĄĞèő¿ä¡ăæČşåŇźéĚ■æŢřå■Ůæăijåij ŔçŽĎæŮěæ `11/27/2012` ïijŇä¡ääŔŕäžěè£ŹæăůåĄŽïijŽ

```
>>> text1 = '11/27/2012'
>>> text2 = 'Nov 27, 2012'
>>>
>>> import re
>>> # Simple matching: \d+ means match one or more digits
>>> if re.match(r'\d+/\d+/\d+', text1):
... print('yes')
... else:
... print('no')
...
yes
>>> if re.match(r'\d+/\d+/\d+', text2):
... print('yes')
... else:
... print('no')
...
no
>>>
```

åęĆæđIJä¡ăæČşä¡£çŤĺåŘŇäÿĂäÿłæĺąåijŔåŐżåĄŽåď'ŽæňąåŇźéĚ■ïijŇä¡ääžŤèŕěåĚĹåřĘæĺąåijŔå■Ůçňęä

```
>>> datepat = re.compile(r'\d+/\d+/\d+')
>>> if datepat.match(text1):
... print('yes')
... else:
... print('no')
...
yes
>>> if datepat.match(text2):
... print('yes')
... else:
... print('no')
...
no
>>>
```

`match()` æĂżæŸŕäžŐå■ŮçňęäÿšåijĂåğŇåŐżåŇźéĚ■ïijŇåęĆæđIJä¡ăæČşæ§ěæL'¿å■ŮçňęäÿšäżżæĎŔé ä¡£çŤĺ `findall()` æŰźæşŢåŐżäžčæŽ£ãĂĆæŕŤåęĆïijŽ

```
>>> text = 'Today is 11/27/2012. PyCon starts 3/13/2013.'
>>> datepat.findall(text)
['11/27/2012', '3/13/2013']
>>>
```

åIJÍåőŽäźL’æ■čåĹŹåijŔçŽĎæŮűåĂŹïijŇéĂŽåÿÿäijŽåĹľçŤÍæŃňåŔůåŐżæ■ŢèŐůåĹĘçżĎãĂĆæŕŤåęĆïij

```
>>> datepat = re.compile(r'(\d+)/(\d+)/(\d+)')
>>>
```

æ■ŢèŐůåĹĘçżĎåŔŕäżěä¡£å¿ŮåŘŐéİćçŽĎåd’ĎçŘĘæŻt’åŁăçőĂå■ŢïijŇåŻääÿžåŔŕäżěåĹĘåĹńářĘæŕŔäÿ

```
>>> m = datepat.match('11/27/2012')
>>> m
<_sre.SRE_Match object at 0x1005d2750>
>>> # Extract the contents of each group
>>> m.group(0)
'11/27/2012'
>>> m.group(1)
'11'
>>> m.group(2)
'27'
>>> m.group(3)
'2012'
>>> m.groups()
('11', '27', '2012')
>>> month, day, year = m.groups()
>>>
>>> # Find all matches (notice splitting into tuples)
>>> text
'Today is 11/27/2012. PyCon starts 3/13/2013.'
>>> datepat.findall(text)
[('11', '27', '2012'), ('3', '13', '2013')]
>>> for month, day, year in datepat.findall(text):
...     print('{}-{}-{}'.format(year, month, day))
...
2012-11-27
2013-3-13
>>>
```

`findall()` æŰźæşŢäijŽæŘIJçt’ćæŰĞæIJňåźűäžěåĹÙèąĺå¡ćåijŔè£ŤåŻđæL’ĂæIJL’çŽĎåŇźéĚ■ãĂĆ åęĆæđIJä¡ăæČşäžěè£■äžčæŰźåijŔè£ŤåŻđåŇźéĚ■ïijŇåŔŕäżěä¡£çŤÍ `finditer()` æŰźæşŢæİěäžčæŻ£ïijŇæŕŤåęĆïijŽ

```
>>> for m in datepat.finditer(text):
...     print(m.groups())
...
('11', '27', '2012')
('3', '13', '2013')
>>>
```

èőÍèőž

åĚşäžŐæ■čåĹŹèąĺè¿¿åijŔçŘĘèőžçŽĎæŢŹçÍŃåůšçżŔèűĚåĞžäžĘæIJňäźęçŽĎèŇČåŻťãĂĆ äÿ■è£ĞïijŇè£ŹäÿĂèŁĆéŸŘè£řäžĘä¡£çŤÍreæĺąåİŮè£ŻèąŇåŇźéĚ■åŠŇæŘIJçťćæŰĞæIJňçŽĎæIJĂå§žæIJňæ æäÿå£Čæ■ěéłd'åřśæŸŕåĚĹä¡£çŤÍ `re.compile()` çijŰèŕŚæ■čåĹŹèąĺè¿¿åijŔå■ŮçňęäÿšïijŇ çĎűåŘŐä¡£çŤÍ `match()`, `findall()` æĹŰèĂĚ `finditer()` ç■L'æŰźæşŢãĂĆ

å¡ŞåĘŹæ■čåĹŹåijŔå■Ůçňęäÿšç ŽĎæŮűåĂŹïijŇçŻÿåŕźæŹőéĄ■çŽĎåĄŽæşŢæŸŕä¡£çŤÍåŐ§ågŇå■Ůçňęä `r'(\d+)/(\d+)/(\d+)'` ãĂĆ è£Źçğ■å■Ůçňęäÿšår Ęäÿ■åŐżèğčæđŘåŔ■æŰIJæİäïijŇè£ŹåIJÍæ■čåĹŹèąĺè åęĆæđIJäÿ■è£ŹæăůåĄžçŽĎèŕİïijŇä¡ăå£Ěéążä¡£çŤÍäÿd'äÿłåŔ■æŰIJæİäïijŇçšžäijij `'(\\d+)/(\\d+)/(\\d+)'` ãĂĆ

éIJĂèęĄæşÍæĎŘçŽĎæŸŕ `match()` æŰźæşŢäžĚäžĚæčĂæ§ěå■Ůçňęäÿšç ŽĎåijĂågŇéČÍåĹĘãĂĆåőČçŽ

```
>>> m = datepat.match('11/27/2012abcdef')
>>> m
<_sre.SRE_Match object at 0x1005d27e8>
>>> m.group()
'11/27/2012'
>>>
```

åęĆæđIJä¡ăæČşçš¿çąőåŇźéĚ■ïijŇçąőä£İä¡ăçŽĎæ■čåĹŹèąĺè¿¿åijŔäžě$çżŞář¿ïijŇářšåČŔè£ŹäźĹè£Źæă

```
>>> datepat = re.compile(r'(\d+)/(\d+)/(\d+)$')
>>> datepat.match('11/27/2012abcdef')
>>> datepat.match('11/27/2012')
<_sre.SRE_Match object at 0x1005d2750>
>>>
```

æIJĂåŘŐïijŇåęĆæđIJä¡ääžĚäžĚæŸŕåĄžäÿĂæňąçőĂå■ŢçŽĎæŰĞæIJňåŇźéĚ■/æŘIJçťćæŞ■ä¡IJçŽĎèŕİ `re` æĺąåİŮçžğåĹńçŽĎåĞ¡æŢřãĂĆærŤåęĆïijŽ

```
>>> re.findall(r'(\d+)/(\d+)/(\d+)', text)
[('11', '27', '2012'), ('3', '13', '2013')]
>>>
```

ä¡ĘæŸŕéIJĂèęĄæşÍæĎŘçŽĎæŸŕïijŇåęĆæđIJä¡ăæL'ŞçőŮåĄŽåď'ğéĞŘçŽĎåŇźéĚ■åŠŇæŘIJçť'ćæŞ■ä¡IJ æĺąåİŮçžğåĹńçŽĎåĞ¡æŢřäijŽårĘæIJĂè£ŚçijŰèŕŚè£ĞçŽĎæĺąåijŘçijŞå■Ÿè̯ůæİěïijŇåŻăæ■d'åźűäÿ■äijŽæűĹ ä¡ĘæŸŕåęĆæđIJä¡£çŤÍéćĎçijŰèŕŚæĺąåijŘçŽĎèŕİïijŇä¡ăårĘäijŽåĞŘårŚæ§ěæL'¿åŠŇäÿĂäžŽéćÍåd'ŰçŽĎåd'Ď

4.5 2.5 å■ŮçňęäÿšæŘIJçť'ćåŠŇæŻ£æ■ć

éŮőécŸ

ä¡ăæČşåIJÍå■Ůçňęäÿšäÿ■æŘIJçť'ćåŠŇåŇźéĚ■æŇĞåőŽçŽĎæŰĞæIJňæĺąåijŘ

èğčåĘşæŰźæąĹ

åŕźäžŐçőĂå■ŢçŽĎå■ŮéİćæĺąåijŔïijŇçŻťæŐëä¡£çŤĺ `str.replace()` æŰźæşŢå■şåŔŕïijŇæŕŤåęĆïijŽ

```
>>> text = 'yeah, but no, but yeah, but no, but yeah'
>>> text.replace('yeah', 'yep')
'yep, but no, but yep, but no, but yep'
>>>
```

åŕźäžŐåď■æİĆçŽĎæĺąåijŔïijŇèŕůä¡£çŤĺ `re` æĺąåİŮäÿ■çŽĎ `sub()` åĞ¡æŢřãĂĆ äÿžäžĘèŕťæŸŐè£ŹäÿłïijŇåĄĞèő¿ä¡ăæČşåřĘå¡ćåijŔäÿž `11/27/2012` çŽĎæŮěæIJ§å■ŮçňęäÿšæŤźæĹŘ `2012-11-27` ãĂĆçđ'žä¿ŇåęĆäÿŇïijŽ

```
>>> text = 'Today is 11/27/2012. PyCon starts 3/13/2013.'
>>> import re
>>> re.sub(r'(\d+)/(\d+)/(\d+)', r'\3-\1-\2', text)
'Today is 2012-11-27. PyCon starts 2013-3-13.'
>>>
```

`sub()` åĞ¡æŢřäÿ■çŽĎçňňäÿĂäÿłåŔĆæŢřæŸŕèćńåŇźéĚ■çŽĎæĺąåijŔïijŇçňňäžŇäÿłåŔĆæŢřæŸŕæŻ£æ
`\3` æŇĞåŘŠåĽ■éİćæĺąåijŔçŽĎæ■ŢèŐůçżĎåŔůãĂĆ

åęĆæđIJä¡ăæĽŞçőŮçŤĺçŻÿåŘŇçŽĎæĺąåijŔåĄŽåď'Žæňąæ£æ■ćïijŇèĂČèŹŠåĚĹçijŰèŕŠåőČæİěæŔŘå

```
>>> import re
>>> datepat = re.compile(r'(\d+)/(\d+)/(\d+)')
>>> datepat.sub(r'\3-\1-\2', text)
'Today is 2012-11-27. PyCon starts 2013-3-13.'
>>>
```

åŕźäžŐæŻť'åŁååď■æİĆçŽĎæŻ£æ■ćïijŇåŔŕäžěäijăéĂŠäÿĂäÿłæŻ£æ■ćåŻđèřČåĞ¡æŢřæİěäžčæŻ£ïijŇæŕ

```
>>> from calendar import month_abbr
>>> def change_date(m):
... mon_name = month_abbr[int(m.group(1))]
... return '{} {} {}'.format(m.group(2), mon_name, m.group(3))
...
>>> datepat.sub(change_date, text)
'Today is 27 Nov 2012. PyCon starts 13 Mar 2013.'
>>>
```

äÿĂäÿłæŻ£æ■ćåŻđèřČåĞ¡æŢřçŽĎåŔĆæŢřæŸŕäÿĂäÿł `match` åŕźèśąïijŇäźş§åřśæŸŕ `match()` æĹŰèĂĚ `find()` è£ŤåŻđçŽĎåŕźèśąãĂĆ ä¡£çŤĺ `group()` æŰźæşŢæİěæŔŘåŔŰçĽźåőŽçŽĎåŇźéĚ■éČĺåĹĘãĂĆåŻđèřČåĞ¡æŢřæIJĂåŘŐè£ŤåŻđæŻ£æ■ćå■Ůçňęäÿšã

åęĆæđIJéŹď'äžĘæŻ£æ■ćåŘŐçŽĎçżŞæđIJåď'ŰïijŇä¡ăè£ŸæČşç§ěéĄŞæIJĽåď'ŽåřŚæŻ£æ■ćåŔŚçŢ§äžĘ
`re.subn()` æİěäžčæŻ£ãĂĆæŕŤåęĆïijŽ

```
>>> newtext, n = datepat.subn(r'\3-\1-\2', text)
>>> newtext
```

```
'Today is 2012-11-27. PyCon starts 2013-3-13.'
>>> n
2
>>>
```

èőÍèőž

åĚşäžŐæ■čåĹŹèąÍè¿¿åijŔæŘIJçť ćåŠŇæŻ£æ■ćïijŇäÿŁéİćæijŤçď žçŽĎ sub() æŰźæşŢå§žæIJňåůšçżŔæűţçŻŰäžĘæĽ ĂæIJL ãĂĆ åĚűåőđæIJĂéŽ¿çŽĎéČĺåĹĘářśæŸŕçijŰåĘŹæ■čåĹŹèąÍè¿¿

4.6 2.6 å■Ůçňęäÿšå£¡çŢěåď ğářŔåĘŹçŽĎæŘIJçť ćæŻ£æ■ć

éŮőécŸ

ä¡ăéIJĂèęĄäžěå£¡çŢěåď ğářŔåĘŹçŽĎæŰźåijŔæŘIJçť ćäÿŐæŻ£æ■ćæŰĞæIJňå■Ůçňęäÿš

èğčåĘşæŰźæąĹ

äÿžäžĘåIJÍæŰĞæIJňæŞ■ä¡IJæŮűå£¡çŢěåď ğářŔåĘŹïijŇä¡ăéIJĂèęĄåIJÍä¡£çŤÍ re æÍąåİŮçŽĎæŮűåĂŹçżŹè£ŹäžŻæŞ■ä¡IJæŔŘä¿Ż re.IGNORECASE æăĞå£ŮåŔĆæŢřăĂĆæŕŤåęĆïijŽ

```
>>> text = 'UPPER PYTHON, lower python, Mixed Python'
>>> re.findall('python', text, flags=re.IGNORECASE)
['PYTHON', 'python', 'Python']
>>> re.sub('python', 'snake', text, flags=re.IGNORECASE)
'UPPER snake, lower snake, Mixed snake'
>>>
```

æIJĂåŘŐçŽĎéĆčäÿłä¿Ńå■ŘæŔ■çď žäžĘäÿĂäÿłářŔçijžéŹůïijŇæŻ£æ■ćå■Ůçňęäÿšåźűäÿ■äijŽèĞłåŁÍèů§äÿžäžĘä£őåď ■è£ŹäÿłïijŇä¡ăåŔŕèČ¡éIJĂèęĄäÿĂäÿłè¿ĚåŁľåĞ¡æŢřïijŇářšåČŔäÿŃéİćçŽĎè£ŹæăůïijŽ

```
def matchcase(word):
    def replace(m):
        text = m.group()
        if text.isupper():
            return word.upper()
        elif text.islower():
            return word.lower()
        elif text[0].isupper():
            return word.capitalize()
        else:
            return word
    return replace
```

äÿŃéİćæŸŕä¡£çŤÍäÿŁè£ŕåĞ¡æŢřçŽĎæŰźæşŢïijŽ

```
>>> re.sub('python', matchcase('snake'), text, flags=re.IGNORECASE)
'UPPER SNAKE, lower snake, Mixed Snake'
>>>
```

èґŚèĂĚæşÍïijŽ `matchcase('snake')` è£ŤåŻđäžĘäÿĂäÿłåŻđèřČåĞ¡æŢř(åŔĆæŢřå£ĚéążæŸŕ `match` åŕźèśą)ïijŇåL'■éİćäÿĂèŁĆæŔŘåĹřè£ĞïijŇ `sub()` åĞ¡æŢřéŹď'äžĘæŐěåŔŮæŻ£æ■ćå■Ůçňęäÿšåď'ŰïijŇè£ŸèČ¡æŐěåŔŮäÿĂäÿłåŻđèřČåĞ¡æŢřãĂĆ

èőÍèőž

åŕźäžŐäÿĂèĹňçŽĎå£¡çŢěåď'ğåřŔåĘŹçŽĎåŇźéĚ■æŞ■ä¡IJïijŇçőĂå■ŢçŽĎäijåéĂŠäÿĂäÿł `re.IGNORECASE` æăĞå£ŮåŔĆæŢřåřśåůšçżŔèűşåď'§äžĘãĂĆ ä¡ĘæŸŕéIJĂèęĄæşÍæĎŔçŽĎæŸŕïijŇè£ŹäÿłåŕźäžŐæ§ŘäžŻéIJĂèęĄåď'ğåřŔåĘŹè¡ñæ■ćçŽĎUnicodeåŇźéĚ■å åŔĆèĂČ2.10åřŔèŁĆäžĘèğčæŻt'åď'ŽçżĘèŁĆãĂĆ

4.7 2.7 æIJĂç§■åŇźéĚ■æÍąåijŔ

éŮőécŸ

ä¡ăæ■čåIJÍèŕŢçİĂçŤÍæ■čåĹŹèąÍè¿¿åijŔåŇźéĚ■æ§ŘäÿłæŰĞæIJñæÍąåijŔïijŇä¡ĘæŸŕåőČæL'¿åĹřçŽĎæŸ èĂŇä¡ăæČşä£őæŤźåőČåŔŸæĹŘæ§ěæL'¿æIJĂç§■çŽĎåŔŕèČ¡åŇźéĚ■ãĂĆ

èğčåĘşæŰźæąĹ

è£ŹäÿłéŮőécŸäÿĂèĹňåĞžçŐřåIJÍéIJĂèęĄåŇźéĚ■äÿĂåŕźåĹĘéŽŤçňęäźŃéŮt'çŽĎæŰĞæIJňçŽĎæŮűåĂ äÿžäžĘèŕt'æŸŐæÿĚæěŽïijŇèĂČèŹŚåęĆäÿŃçŽĎä¿Ńå■ŘïijŽ

```
>>> str_pat = re.compile(r'"(.*)"')
>>> text1 = 'Computer says "no."'
>>> str_pat.findall(text1)
['no.']
>>> text2 = 'Computer says "no." Phone says "yes."'
>>> str_pat.findall(text2)
['no." Phone says "yes.']
>>>
```

åIJÍè£ŹäÿłäżÑå■ŘäÿïijŇæÍąåijŔ `r'\"(.*)\"'` çŽĎæĎŔåŻ¿æŸŕåŇźéĚ■èćńåŔŇåijŢåŔůåŇĚåŘńçŽĎ ä¡ĘæŸŕåIJÍæ■čåĹŹèąÍè¿¿åijŔäÿ■*æŞ■ä¡IJçňęæŸŕèt'łåľłçŽĎïijŇåŻăæ■d'åŇźéĚ■æŞ■ä¡IJäijŽæ§ěæL'¿æIJĂéŢ äžŐæŸŕåIJÍçňňäžŇäÿłäżÑå■ŘäÿïæŘIJçt'ć `text2` çŽĎæŮűåĂŹè£ŤåŻđçżŞæđIJåźűäÿ■æŸŕæĹŚäžňæČşèęĄç

äÿžäžĘä£őæ■čè£ŹäÿłéŮőécŸïijŇåŔŕäžěåIJÍæÍąåijŔäÿ■çŽĎ*æŞ■ä¡IJçňęåŘŐéİćåŁääÿŁ?ä£őéěřçňęïijŇå

```
>>> str_pat = re.compile(r'"(.*?)"')
>>> str_pat.findall(text2)
['no.', 'yes.']
>>>
```

è£Źæăůářšä¡£å¿ŮåŇźéĚ■åŔŸæĹŘéİđèť'łăl'łæĺąåijŔïijŇäžŐèĂŇå¿ŮåĹřæIJĂç§■çŽĎåŇźéĚ■ïijŇäź§ářšä

èőÍèőž

è£ŹäÿĂèŁĆåśŢçd'žäžĘåIJÍåĘŹåŇĚåŘńçĆź(.)å■Ůçňęç ŽĎæ■čåĹŹèąÍè¿¿åijŔçŽĎæŮűåĂŹéĄĞåĹřçŽĎäÿ
åIJÍäÿĂäÿłæĺąåijŔå■Ůçňęäÿšäÿ■ïijŇçĆź(.)åŇźéĚ■éŹd'äžĘæ■ćèąŇåd'ŰçŽĎäżżä¡Ţå■Ůçňęã ĂĆ
çĎűèĂŇïijŇåęĆæđIJä¡ăářĘçĆź(.)åŔůæŤ¿åIJÍåijĂåğŇäÿŐçżŞæİ§çňę(ærŤåęĆåijŢåŔů)äźŃéÚť'çŽĎæŮűåĂŹi
è£ŹæăůéĂŽåÿÿäijŽářijèĞť'å¿Ĺåd'Žäÿ■éÚť'çŽĎèćńåijĂåğŇäÿŐçżŞæİ§çňęåŇĚåŘńçŽĎæŰĞæIJňèćńå£¡çŢěæ
éĂŽè£ĞåIJÍ * æĹŰèĂĚ + è£ŹæăůçŽĎæŞ■ä¡IJçňęåŘŐéİćæůżåŁääÿĂäÿł ?
åŘŕäžěåijżåĹűåŇźéĚ■çőŮæşŢæŤźæĹŘåŕżæL'¿æIJĂç§■çŽĎåŔŕèČ¡åŇźéĚ■ãĂĆ

4.8 2.8 åď'ŽèąŇåŇźéĚ■æĺąåijŔ

éŮőécŸ

ä¡ăæ■čåIJÍèŕŢçİĂä¡£çŤÍæ■čåĹŹèąÍè¿¿åijŔåŐżåŇźéĚ■äÿĂåd'ğåİŮçŽĎæŰĞæIJňïijŇèĂŇä¡äéIJĂèęĄèůİ

èğčåĘşæŰźæąĹ

è£ŹäÿłéŮőécŸå¿ĹåĚÿåđŃçŽĎåĞžçŐřåIJÍå¡Şä¡ăçŤÍçĆź(.)åŐżåŇźéĚ■äżżæĎŔå■Ůçňęç ŽĎæŮűåĂŹïijŇa
ærŤåęĆïijŇåĄĞèő¿ä¡ăæČşèŕŢçİĂåŐżåŇźéĚ■Cèŕ■èÍĂåĹĘåL'šçŽĎæşÍéĞŁïijŽ

```
>>> comment = re.compile(r'/\*(.*?)\*/')
>>> text1 = '/* this is a comment */'
>>> text2 = '''/* this is a
... multiline comment */
... '''
>>>
>>> comment.findall(text1)
[' this is a comment ']
>>> comment.findall(text2)
[]
>>>
```

äÿžäžĘä£őæ■čè£ŹäÿłéŮőécŸïijŇä¡ăåŔŕäžěä£őæŤźæĺąåijŔå■ŮçňęäÿšïijŇåćđåŁåářźæ■ćèąŇçŽĎæŤŕæŇ

```
>>> comment = re.compile(r'/\*((?:.|\n)*?)\*/')
>>> comment.findall(text2)
[' this is a\n multiline comment ']
>>>
```

åIJÍè£ŹäÿłæĺąåijŔäÿ■ïijŇ (?:.|\n) æŇĞåőŽäžĘäÿĂäÿłéİđæ■ŢèŐůçżĎ
(äź§ářšæŸŕåőČåőŽäźĽäžĘäÿĂäÿłäžĚäżĚçŤÍæĺěåĄŽåŇźéĚ■ïijŇèĂŇäÿ■èČ¡éĂŽè£Ğå■ŢçŃňæ■ŢèŐůæĹŰèĂ

èőÍèőž

re.compile() åĞ¡æŢřæŐěåŔŮäÿĂäÿłæăĞå£ŮåŔĆæŢřåŔń re.DOTALL ïijŇåIJÍè£ŹéĞŇéÍđåÿÿæIJL'çŤÍãĂĆ åőČåŔŕäžěèől'æ■čåĹŹèąÍè¿¿åijŔäÿ■çŽĎçĆź(.)åŇźéĚ■åŇĚæŃňæ■ćèąŇ

```
>>> comment = re.compile(r'/\*(.*?)\*/', re.DOTALL)
>>> comment.findall(text2)
[' this is a\n multiline comment ']
```

åŕźäžŐçőĂå■ŢçŽĎæČĚåĘţä¡£çŤÍ re.DOTALL æăĞèőřåŔĆæŢřåůěä¡IJçŽĎå¿Ĺåě¡ïijŇ ä¡ĘæŸŕåęĆæđIJæĺąåijŔéÍđåÿÿåd'■æÍĆæĹŰèĂĚæŸŕäÿžäžĘæđĎéĂăå■Ůçňęäÿšäžd'çL'ŇèĂŇåřĘåd'Žäÿłæĺąåi è£ŹæŮűåĂŹä¡£çŤÍè£ŹäÿłæăĞèőřåŔĆæŢřåřšåŔŕèČ¡åĞžçŐřäÿĂäžŻéŮőécŸãĂĆ åęĆæđIJèől'ä¡ăéĂL'æŃl'çŽĎèŕÍïijŇæIJĂåě¡è£ŸæŸŕåőŽäźL'èĞłåůšçŽĎæ■čåĹŹèąÍè¿¿åijŔæĺąåijŔïijŇè£Źæăů

4.9 2.9 åřĘUnicodeæŰĞælJňæăĞåĞĘåŇŰ

éŮőécŸ

ä¡ăæ■čåIJÍåd'ĎçŘĘUnicodeå■ŮçňęäÿšïijŇéIJĂèęAçąőä£ÍæL'ĂæIJL'å■ŮçňęäÿšåIJÍåžŢåśĆæIJL'çŻÿåŘŇ

èğčåĘşæŰźæąĹ

åIJÍUnicodeäÿ■ïijŇæ§ŘäžŻå■Ůçňęè Č¡åd'§çŤÍåd'Žäÿłå ŘĹæşŢçŽĎçijŰçăĄèąÍçd'žãĂĆäÿžäžĘèŕt'æŸŐïij

```
>>> s1 = 'Spicy Jalape\u00f1o'
>>> s2 = 'Spicy Jalapen\u0303o'
>>> s1
'Spicy JalapeÃ±o'
>>> s2
'Spicy JalapeÃ±o'
>>> s1 == s2
False
>>> len(s1)
14
>>> len(s2)
15
>>>
```

è£ŹéĞŇçŽĎæŰĞæIJňâĂİSpicy JalapeÃ±oâĂİä¡£çŤÍäžĘäÿd'çğ■å¡ćåijŔæİěèąÍçd'žãĂĆ çňňäÿĂçğ■ä¡£çŤÍæŢt'ä¡Şå■Ůçňęâ ĂİÃ±âĂİ(U+00F1)ïijŇçňňäžŇçğ■ä¡£çŤÍæŃL'äÿĄå■Ůæŕ■âĂİnâĂİåŘŐéÍć

åIJÍéIJĂèęĄæŕŤè¿Čå■ŮçňęäÿšçŽĎçÍŃåžŔäÿ■ä¡£çŤÍå■ŮçňęçŽĎåd'Žçğ■èąÍçd'žäijŽäžğçŤ§éŮőécŸãĂĆ äÿžäžĘä£őæ■čè£ŹäÿłéŮőécŸïijŇä¡ăåŔŕäžěä¡£çŤÍunicodedataæÍąåİŮåĚĹårĘæŰĞælJňæăĞåĞĘåŇŰïijŽ

```
>>> import unicodedata
>>> t1 = unicodedata.normalize('NFC', s1)
>>> t2 = unicodedata.normalize('NFC', s2)
>>> t1 == t2
```

```
True
>>> print(ascii(t1))
'Spicy Jalape\xf1o'
>>> t3 = unicodedata.normalize('NFD', s1)
>>> t4 = unicodedata.normalize('NFD', s2)
>>> t3 == t4
True
>>> print(ascii(t3))
'Spicy Jalapen\u0303o'
>>>
```

normalize() çňňäÿĂäÿłåŔĆæŢřæŇĞåőŽå■ŮçňęäÿšæăĞåĞĘåŇŰçŽĎæŰźåijŔãĂĆ NFCèąĺçď'žå■ŮçňęåžŤèŕěæŸŕæŢt'ä¡ŞçżĎæĹŘ(æŕŤåęĆåŔŕèČ¡çŽĎèŕÍåřśä¡£çŤĺå■ŢäÿĂçijŰçăA)ïijŇèĂŇNFI

PythonåŘŇæăůæŤŕæŇĄæĽľ'åśŢçŽĎæăĞåĞĘåŇŰå¡ćåijŔNFKCåŠŇNFKDïijŇåőČäžňåIJÍåď'ĎçŘĘæ§Ř

```
>>> s = '\ufb01' # A single character
>>> s
'ïňĄ'
>>> unicodedata.normalize('NFD', s)
'ïňĄ'
# Notice how the combined letters are broken apart here
>>> unicodedata.normalize('NFKD', s)
'fi'
>>> unicodedata.normalize('NFKC', s)
'fi'
>>>
```

èőÍèőž

æăĞåĞĘåŇŰåŕźäžŐäżä¡ŢéIJĂèęĄäžěäÿĂèĞt'çŽĎæŰźåijŔåď'ĎçŘĘUnicodeæŰĞæIJňçŽĎçÍŃåžŔéČ¡å¡Şåď'ĎçŘĘæÍèèĞłçŤÍæĹůè¿ŞåĚěçŽĎå■Ůçňęäÿšè ĂŇä¡ăå¿ĹéŽ¿åÖżæŐğåĹűçijŰçăĄçŽĎæŮűåĂŹårď'åĚűåę

åIJÍæÿĚçŘĘåŠŇè£Ğæżď'æŰĞæIJňçŽĎæŮűåĂŹå■ŮçňęçŽĎæăĞåĞĘåŇŰäź§æŸŕå¿ĹéĞ■èęĄçŽĎãĂĆ æŕŤåęĆïijŇåĄĞèő¿ä¡ăæČşæÿĚéŹď'æŐL'äÿĂäžŻæŰĞæIJňäÿŁéİćçŽĎåŔŸé§şçňęçŽĎæŮűåĂŹ(åŔŕèČ¡æŸŕäÿ

```
>>> t1 = unicodedata.normalize('NFD', s1)
>>> ''.join(c for c in t1 if not unicodedata.combining(c))
'Spicy Jalapeno'
>>>
```

æIJĂåŘŐäÿĂäÿłä¿Ńå■ŘåśŢçď'žäžĘ unicodedata æĺąåİŮçŽĎåŘęäÿĂäÿłéĞ■èęĄæŰźéİćïijŇäź§ářśæ combining() åĞ¡æŢřåŔŕäžěæţŃèŕŢäÿĂäÿłå■ŮçňęæŸŕåŘęäÿžåŠŇé§şå■Ůçňęã ĂĆ åIJÍè£ŹäÿłæĺąåİŮäÿ■è£ŸæIJL'åĚűäžŰåĞ¡æŢřçŤÍäžŐæ§ěæL'¿å■ŮçňęçśžåĹńïijŇæţŃèŕŢæŸŕåŘęäÿžæŢřå■Ůå

UnicodeæŸ¿çĎűæŸŕäÿĂäÿłå¿Ĺåď'ğçŽĎäÿżéćŸãĂĆåęĆæđIJæČşæŻt'æůśåĚěçŽĎäžĘèğčåĚşäžŐæăĞåČ èŕůçIJŃèĂČ UnicodeåőŸç¡Śäÿ■åĚşäžŐè£ŹéČĺåĹęçŽĎèŕt'æŸŐ Ned BatchelderåIJÍ äžŰçŽĎç¡ŚçńŹ äÿŁåŕźPythonçŽĎUnicodeåď'ĎçŘĘéŮőécŸäź§æIJL'äÿĂäÿłå¿Ĺåě¡çŽĎäżŃçż■ãĂĆ

4.10 2.10 åIJÍæ■čåĹŹåijŔäÿ■ä¡£çŤÍUnicode

éŮőécŸ

ä¡ăæ■čåIJÍä¡£çŤÍæ■čåĹŹèąĺè¿¿åijŔåd'ĎçŘĘæŰĞæIJñïijÑä¡ĘæŸŕåĚşæşÍçŽĎæŸŕUnicodeå■Ůçňęåd'Ďç

èğčåĘşæŰźæąĹ

éžŸèőd'æČĚåĘţäÿŃ re æÍąåİŮåůšçżŔåŕźäÿĂäžŻUnicodeå■Ůçňęçśżæ IJL'äžĘå§žæIJñçŽĎæŤŕæŇĄãĂĆ æŕŤåęĆïijŇ \\d åůšçżŔåŇźéĚ■äżżæĎŔçŽĎunicodeæŢřå■Ůå■Ůçňęäžĕïijž

```
>>> import re
>>> num = re.compile('\d+')
>>> # ASCII digits
>>> num.match('123')
<_sre.SRE_Match object at 0x1007d9ed0>
>>> # Arabic digits
>>> num.match('\u0661\u0662\u0663')
<_sre.SRE_Match object at 0x101234030>
>>>
```

åęĆæđIJä¡ăæČşåIJÍæĺąåijŔäÿ■åŇĚåŘńæŇĞåőŽçŽĎUnicodeå■ŮçňęïijŇä¡ääŔŕäżěä¡£çŤÍUnicodeå■Ůçň \uFFF æĹŰèĂĚ \UFFFFFFF)ãĂĆ æŕŤåęĆïijŇäÿŃéİćæŸŕäÿĂäÿłåŇźéĚ■åĞăäÿłäÿ■åŘŇéŸ£æŃL'äijŕçijŰç

```
>>> arabic = re.compile('[\u0600-\u06ff\u0750-\u077f\u08a0-\u08ff]+
↪')
>>>
```

å¡ŞæL'ğèąŇåŇźéĚ■åŠŇæŘIJçt'ćæŞ■ä¡IJçŽĎæŮűåĂŹïijŇæIJĂåě¡æŸŕåĚĹæăĞåĞĘåŇŰåźűäÿŤæÿĚçŘĚ ä¡ĘæŸŕåŘŇæăůäź§åžŤèŕěæşÍæĎŔäÿĂäžŻçL'źæőŁæČĚåĘţïijŇærŤåęĆåIJÍå£¡çŢěåd'ğářŔåĘŹåŇźéĚ■åŠŇåd'

```
>>> pat = re.compile('stra\u00dfe', re.IGNORECASE)
>>> s = 'straÃ§e'
>>> pat.match(s) # Matches
<_sre.SRE_Match object at 0x10069d370>
>>> pat.match(s.upper()) # Doesn't match
>>> s.upper() # Case folds
'STRASSE'
>>>
```

èőÍèőž

æůůåŘĹä¡£çŤÍUnicodeåŠŇæ■čåĹŹèąĺè¿¿åijŔéĂŽåÿÿäijŽèőľ'ä¡ăæŁŞçŃĆãĂĆ åęĆæđIJä¡ăçIJ§çŽĎæL'ŞçőŮè£ŹæăůåĄŽçŽĎèŕĺïijŇæIJĂåě¡èĂČèŹŚäÿŇåőL'èčĚçňňäÿL'æŰźæ■čåĹŹåijŔåžŞ åőČäžňäijŽäÿžUnicodeçŽĎåd'ğářŔåĘŹè¡ňæ■ćåŠŇåĚűäżŰåd'ğéĞŔæIJL'èűčçL'źæĂğæŔŘä¿ŻåĚĺéİćçŽĎæŤŕ

4.11 2.11 åĹǎéŹďå■Ůçňęäÿšäÿ■äÿ■éIJÄèęĄçŽĎå■Ůçňę

éŮőécŸ

ä¡ăæČşåŐżæŐĽ'æŰĞæIJňå■Ůçňęäÿšåij Ăåď't'ïijŇçżŞář¿æĹŰèĂĚäÿ■éŮt'äÿ■æČşèęĄçŽĎå■Ůçňęïij Ňæŕ

èğčåĘşæŰźæąĹ

strip() æŰźæşŢèČ¡çŤĺäžŐåĹǎéŹď'åijĂåğŃæĹŰçżŞář¿çŽĎå■Ůçňęã ĂĆ lstrip() åŠŇ rstrip() åĹĘąĹńäżŐåůęåŠŇäżŐåŔşæL'ğèąŇåĹǎéŹď'æŞ■ä¡IJãĂĆ éżŸèŏď'æČĚåĘţäÿŃïijŇè£ŹäžŻæŰźæşŢäijŽåŐżéŹď'çl'žçŹ¡å■Ůçňęïij Ňä¡ĘæŸŕä¡ääź§åŔŕäžěæŇĞåőŽåĚűäżŰ

```
>>> # Whitespace stripping
>>> s = ' hello world \n'
>>> s.strip()
'hello world'
>>> s.lstrip()
'hello world \n'
>>> s.rstrip()
' hello world'
>>>
>>> # Character stripping
>>> t = '-----hello====='
>>> t.lstrip('-')
'hello====='
>>> t.strip('-=')
'hello'
>>>
```

èőÍèőž

è£ŹäžŻ strip() æŰźæşŢåIJÍèŕżåŔŰåŠŇæÿĚçŘĘæŢřæ■őäžěåď'ĞåŘŐçż■åď'ĎçŘĘçŽĎæŮűåĂŹæŸŕç æŕŤåęĆïijŇä¡ääŔŕäžěçŤÍåőČäžňæÌěåŐżæŐĽ'çl'žæăijïijŇåijŢåŔůåŠŇåőŇæĹŘåĚűäżŰäżżåŁąãĂĆ

ä¡ĘæŸŕéIJÄèęĄæşÍæĎŔçŽĎæŸŕåŐżéŹď'æŞ■ä¡IJäÿ■äijŽåŕźå■ŮçňęäÿšçŽĎäÿ■éŮt'çŽĎæŰĞæIJňäžğçŤ

```
>>> s = ' hello      world \n'
>>> s = s.strip()
>>> s
'hello      world'
>>>
```

åęĆædIJä¡ăæČşåď'ĎçŘĘäÿ■éŮt'çŽĎçl'žæăijïijŇéĆčäźĹä¡ăéIJÄèęĄæśĆåŁl'åĚűäžŰæŁĂæIJŕãĂĆæŕŤåę replace() æŰźæşŢæĹŰèĂĚæŸŕçŤÍæ■čåĹŹèąÍè¿¿åijŔæŽ£æ■ćãĂĆçď'žä¿ŃåęĆäÿŃïijŽ

```
>>> s.replace(' ', '')
'helloworld'
>>> import re
```

```
>>> re.sub('\s+', ' ', s)
'hello world'
>>>
```

éĂŽåÿÿæČĚåĘţäÿŃä¡ăæČşåřĘå■Ůçňęäÿš strip æŞ■ä¡IJåŠŇåĚűäżŰè£■äžčæŞ■ä¡IJçŻÿçżŞåŘĹïijŇæŕ
åęĆæđIJæŸŕè£ŹæăůçŽĎèŕÏïijŇéĆčäźĹçŤ§æĹŘåŹĺèąĺè¿¿åijŔåřśåŔŕäžěåď˙ğæŸ¿èžńæĽ'ŇäžĘãĂĆæŕŤåęĆïijŽ

```
with open(filename) as f:
    lines = (line.strip() for line in f)
    for line in lines:
        print(line)
```

åIJĺè£ŹéĞŇïijŇèąĺè¿¿åijŔ lines = (line.strip() for line in f)
æĽ˙ğèąŇæŢřæ■őè¡ňæ■ćæŞ■ä¡IJãĂĆ è£Źçğ■æŰźåijŔéÏđåÿÿéńŸæŢĹïijŇåŽääÿžåőČäÿ■éIJĂèęĄécĎåĚĹèŕżåĿ
åőČäžĚäżĚåŔłæŸŕåĹŻåžžäÿĂäÿłçŤ§æĹŘåŹĺïijŇåźűäÿŤæŕŔæňąè£ŤåŽđèąŇäźŇåL'■äijŽåĚĹæL'ğèąŇ
strip æŞ■ä¡IJãĂĆ

åŕźäžŐæŽt'énŸéŸűçŽĎstripïijŇä¡ăåŔŕèČ¡éIJĂèęĄä¡£çŤĺ translate()
æŰźæşŢãĂĆèŕůåŔĆéŸĚäÿŃäÿĂèŁĆäžĘèğčæŽt'åď˙ŽåĚşäžŐå■ŮçňęäÿšæÿĚçŘĘçŽĎåĘĚåőźãĂĆ

4.12 2.12 åőąææ§ěæÿĚçŘĘæŰĞælJňå■Ůçňęäÿš

éŮőécŸ

äÿĂäžŻæŮăèĄŁçŽĎåźijçĺŽéżŠåőćåIJĺä¡ăçŽĎç¡ŚçńŹéąţéÍćèąĺå■Ţäÿ■è¿ŞåĚěæŰĞælJňâĂİpÃ¡tÄěÃűÃś

èğčåĘşæŰźæąĹ

æŰĞælJňæÿĚçŘĘéŮőécŸäijŽæűĽ'åŔŁåĹřåŇĚæŃňæŰĞælJňèğčæđŘäÿŐæŢřæ■őåď˙ĎçŘĘç■Ľ'äÿĂçşżå
åIJĺéÍđåÿÿçőĂå■ŢçŽĎæČĚå¡ćäÿŃïijŇä¡ăåŔŕèČ¡äijŽéĂĽ'æŃľä¡£çŤĺå■Ůçňęäÿšå Ğ¡æŢř(æŕŤåęĆ
str.upper() åŠŇ str.lower())åřĘæŰĞælJňè¡ňäÿžæăĞåĞĘæäijåijŔãĂĆ ä¡£çŤĺ
str.replace() æĹŰèĂĚ re.sub() çŽĎçőĂå■ŢæŻ£æ■ćæŞ■ä¡IJèČ¡åĹăéŹď˙æĹŰèĂĚæŤźåŔŸæŇĞåőŽ
ä¡ăåŘŇæăůè£Ÿåŕźäžěä¡£çŤĺ2.9åřŔèŁĆçŽĎ unicodedata.normalize()
åĞ¡æŢřåřĘunicodeæŰĞælJňæăĞåĞĘåŇŰãĂĆ

çĎűåŘŐïijŇæIJĽ'æŮűåĂŹä¡ăåŔŕèČ¡è£ŸæČşåIJĺæÿĚçŘĘæŞ■ä¡IJäÿŁæŻt'è£ŻäÿĂæ■ěãĂĆæŕŤåęĆïijŇä¡
äÿžäžĘè£ŹæăůåĄŽïijŇä¡ăåŔŕäžěä¡£çŤĺçżŔåÿÿäijŽècńå£¡èğĘçŽĎ str.translate()
æŰźæşŢãĂĆ äÿžäžĘæijŤçď˙žïijŇåĄĞèő¿ä¡äçŐřåIJĺæIJĽ'äÿŃéÍćè£ŹäÿłåĞŇäźśçŽĎå■ŮçňęäÿšïijŽ

```
>>> s = 'pÃ¡tÄěÃűÃś\fis\tawesome\r\n'
>>> s
'pÃ¡tÄěÃűÃś\x0cis\tawesome\r\n'
>>>
```

çňňäÿĂæ■ěæŸŕæÿĚçŘĘçľ˙žçŹ¡å■ŮçňęäĉäÿžäžĘè£ŹæăůåĄŽïijŇåĚĹåĹŻåžžäÿĂäÿłářŔçŽĎè¡ňæ■ćèąĺ
translate() æŰźæşŢïijŽ

```
>>> remap = {
...     ord('\t') : ' ',
...     ord('\f') : ' ',
...     ord('\r') : None # Deleted
... }
>>> a = s.translate(remap)
>>> a
'pÃ¡tÄëÃűÃś is awesome\n'
>>>
```

æ■čåęĆä¡äçIJŃçŽĎéĆčæăůïijŇçľžçŹ¡å■Ůçňę \t åŠŇ \f åůšçżŔèćńéĞ■æŰřæŸăářĎåĹřäÿĂäÿłçľžæăijãĂĆåŻđè¡ęå■ŮçňęrçŻť'æŐěèćńåĹăéŹď'ãĂĆ

ä¡ăåŔŕäžěäžěè£Źäÿłèąĺæăijäÿžå§žçąÀè£ŻäÿĂæ■éæđĎåžžæŻť'åď'ğçŽĎèąĺæăijãĂĆæŕŤåęĆïijŇèőľ'æĹŚä

```
>>> import unicodedata
>>> import sys
>>> cmb_chrs = dict.fromkeys(c for c in range(sys.maxunicode)
...                          if unicodedata.combining(chr(c)))
...
>>> b = unicodedata.normalize('NFD', a)
>>> b
'pÃ¡tÄëÃűÃś is awesome\n'
>>> b.translate(cmb_chrs)
'python is awesome\n'
>>>
```

äÿŁéİćä¿Ńå■Řäÿ■ïijŇéĂŽè£Ğä¡£çŤĺ dict.fromkeys() æŰźæşŢæđĎéĂăäÿĂäÿłå■ŮåĚÿïijŇæŕŔäÿłUnicodeåŠŇé§şçňęä¡IJäÿžéŤőïijŇåŕźåžŤçŽĎåĂijåĚĺéČĺäÿž None ãĂĆ

çĎűåŘŐäj£çŤĺ unicodedata.normalize() åřĘåŐ§åğŃè¿ŞåĚěæăĞåĞĘåŇŰäÿžåĹĘèğčå¡ćåijŔå■Ů çĎűåŘŐåĘ■èřČçŤĺ translate åĞ¡æŢřåĹăéŹď'æĽ'ĂæIJL'éĞ■é§şçňęãĂĆ åŘŇæăůçŽĎæŁĂæIJŕäź§åŔŕäžěèćńçŤĺæİěåĹăéŹď'åĚűäžŰçśžåđŃçŽĎå■Ůçňę(æŕŤåęĆæŐğåĹűå■Ůçňęç■Ĺ')ã

ä¡IJäÿžåŘęäÿĂäÿłä¿Ńå■ŘïijŇè£ŹéĞŇæđĎéĂăäÿĂäÿłåřĘæĽ'ĂæIJL'UnicodeæŢřå■Ůå■ŮçňęæŸăářĎåĹi

```
>>> digitmap = { c: ord('0') + unicodedata.digit(chr(c))
...           for c in range(sys.maxunicode)
...           if unicodedata.category(chr(c)) == 'Nd' }
...
>>> len(digitmap)
460
>>> # Arabic digits
>>> x = '\u0661\u0662\u0663'
>>> x.translate(digitmap)
'123'
>>>
```

åŘęäÿĂçğ■æÿĚçŘĘæŰĞæIJňçŽĎæŁĂæIJŕæűL'åŔŁåĹřI/Oèğčçă Ąäÿ Őçij Ůçă Ąåğ¡æŢřãĂĆè£ŹéĞŇçŽĎ çĎűåŘŐåĘ■çżŞåŘĹ encode() æĹŰèĂĚ decode() æŞ■ä¡IJæİěæÿĚéŹď'æĹŰä£őæŤźåőČãĂĆæŕŤåęĆïijŽ

```
>>> a
'pÃ¡tÄëÃűÃś is awesome\n'
>>> b = unicodedata.normalize('NFD', a)
>>> b.encode('ascii', 'ignore').decode('ascii')
'python is awesome\n'
>>>
```

è£ŹéĞŇçŽĎæăĞåĞĘåŇŰæŞ■ä¡IJåřĘåŐ§æİěçŽĎæŰĞæIJňåĹĘèğčäÿžå■ŢçŃňçŽĎåŠŇé§şçňęãĂĆæŐěă
å¡ŞçĎűïijŇè£Źçğ■æŰźæşŢäžĔäžĔåŔłåIJĺæIJĂåŘŐçŽĎçŻőæăĞåřśæŸŕèŐůåŘŰåĹřæŰĞæIJňåŕźåžŤACSIIèą

èőĺèőž

æŰĞæIJňå■Ůçňęæÿ̆ĔçŘĔäÿĂäÿłæIJĂäÿżèęĄçŽĎéŮőécŸåžŤèřěæŸŕè£ŘèąŇçŽĎæĂğèČ¡ãĂĆäÿĂèĹňæ
åŕźäžŐçőĂå■ŢçŽĎæŻ£æ■ćæŞ■ä¡IJïijŇ `str.replace()` æŰźæşŢéĂŽåÿÿæŸŕæIJĂå£ńçŽĎïijŇçŤŽèĞşåIJ
æŕŤåęĆïijŇäÿžäžĘæÿĔçŘĔçl'žçŹ¡å■ŮçňęïijŇä¡ăåŘŕäžěè£ŹæăůåĄŽïijŽ

```
def clean_spaces(s):
    s = s.replace('\r', '')
    s = s.replace('\t', ' ')
    s = s.replace('\f', ' ')
    return s
```

åęĆæđIJä¡ăåŐżæţŃèŕŢçŽĎèŕÍïijŇä¡ăåřśäijŽåŘŞçŐřè£Źçğ■æŰźåijŔäijŽæŕŤä¡£çŤĺ
`translate()` æĹŰèĂĔæ■čåĹŹèąĺè¿¿åijŔèęĄå£ńå¿Ĺåď'ŽãĂĆ

åŘęäÿĂæŰźéİćïijŇåęĆæđIJä¡ăéIJĂèęĄæL'ğèąŇäżżä¡Ţåď'■æİĆå■Ůçňęåŕźå■Ůçňę çŽĎéĞ■æŰřæŸăåřĎæ
`tanslate()` æŰźæşŢäijŽéİđåÿÿçŽĎå£ńãĂĆ

äžŐåď'ğçŽĎæŰźéİćæİěèőšïijŇåŕźäžŐä¡ăçŽĎåžŤçŤĺçĺŃåžŘæİěèŕť'æĂğèČ¡æŸŕä¡ääÿ■å¿Ůäÿ■åŐżèĞłåů
äÿ■åźÿçŽĎæŸŕïijŇæĹŚäžňäÿ■åŘŕèČ¡çżŹä¡ăåżžèőőäÿĂäÿłçL'źåőŽçŽĎæŁĂæIJŕïijŇä¡£åőČèČ¡åď'§éĂĆåžŤa
åŻäæ■ď'åőđéŹĔæČĔåĘţäÿ■éIJĂèęĄä¡ăèĞłåůšåŐżåŕİèŕŢäÿ■åŘŇçŽĎæŰźæşŢåźűèŕĎäijřåőČãĂĆ

år¡çőąè£ŹäÿĂèŁĆéŻĘäÿ■èőĺèőžçŽĎæŸŕæŰĞæIJňïijŇä¡ĘæŸŕçśżäijijçŽĎæŁĂæIJŕäź§åŘŕäžěéĂĆçŤĺäž

4.13 2.13 å■Ůçňęäÿšåŕźé¡Ř

éŮőécŸ

ä¡ăæČşéĂŽè£Ğæ§Řçğ■åŕźé¡ŘæŰźåijŔæİěæäijåijŔåŇŰå■Ůçňęäÿš

èğčåĘşæŰźæąĹ

åŕźäžŐå§žæIJňçŽĎå■Ůçňęäÿšåŕźé¡ŘæŞ■ä¡IJïijŇåŘŕäžěä¡£çŤĺå■ŮçňęäÿšçŽĎ `ljust()`
, `rjust()` åŠŇ `center()` æŰźæşŢãĂĆæŕŤåęĆïijŽ

```
>>> text = 'Hello World'
>>> text.ljust(20)
```

```
'Hello World          '
>>> text.rjust(20)
'          Hello World'
>>> text.center(20)
'    Hello World     '
>>>
```

æL’ĂæIJL’è£ŹäžŻæŰźæşŢéČ¡èČ¡æŐěåŔŮäÿĂäÿłåŘŕéĂL’çŽĎåąńåĚĚå■Ůçňęã ĂĆæŕŤåęĆïijŽ

```
>>> text.rjust(20,'=')
'==========Hello World'
>>> text.center(20,'*')
'****Hello World*****'
>>>
```

åĞ¡æŢř format() åŘŇæăůåŔŕäžěçŤĺæİěå¿Ĺåőźæ ŸŞçŽĎåŕźé¡Řå■Ůçňęäÿšã ĂĆ ä¡ăèęĄåĄŽçŽĎåřśæŸŕä¡£çŤĺ <, > æĹŰèĂĚ ^ å■Ůçňęå ŘŐéİćçť ğèů§äÿĂäÿłæŇĞåőŽçŽĎåő¡åžęã ĂĆæŕŤåęĆ

```
>>> format(text, '>20')
'          Hello World'
>>> format(text, '<20')
'Hello World          '
>>> format(text, '^20')
'    Hello World     '
>>>
```

åęĆæđIJä¡ăæČşæŇĞåőŽäÿĂäÿłéİđçl’žæăijçŽĎåąńåĚĚå■Ůçňęïij ŇårĘåőČåĘŹåĹřåŕźé¡Řå■Ůçňęç ŽĎåL’■

```
>>> format(text, '=>20s')
'==========Hello World'
>>> format(text, '*^20s')
'****Hello World*****'
>>>
```

å¡Şæăijåij ŔåŇŰåd’Žäÿłå Ăijç ŽĎæŮűåĂŹïijŇè£ŹäžŻæăijåijŔäžčçăĄäź§åŔŕäžěèćńçŤĺåIJÍ format() æŰźæşŢäÿ■ãĂĆæŕŤåęĆïijŽ

```
>>> '{:>10s} {:>10s}'.format('Hello', 'World')
'     Hello      World'
>>>
```

format() åĞ¡æŢřçŽĎäÿĂäÿłåě¡åd’ĎæŸŕåőČäÿ■äžĚéĂĆçŤĺäžŐå■Ůçňęäÿšã ĂĆåőČåŔŕäžěçŤĺæİěæăij æŕŤåęĆïijŇä¡ååŔŕäžěçŤĺåőČæİěæăijåijŔåŇŰæŢřå■ŮïijŽ

```
>>> x = 1.2345
>>> format(x, '>10')
'    1.2345'
>>> format(x, '^10.2f')
'   1.23   '
>>>
```

èőÍèőž

åIJÍèĂĄçŽĎäžčçăĄäÿ■ïijŇä¡ăçżŔåÿÿäijŽçIJŃåĹřèćńçŤÍæİěæäijåijŔåŇŰæŰĞæIJňçŽĎ % æŞ■ä¡IJçňęãĂĆærŤåęĆïijŽ

```
>>> '%-20s' % text
'Hello World          '
>>> '%20s' % text
'          Hello World'
>>>
```

ä¡ĘæŸŕïijŇåIJÍæŰřçĽĹæIJňäžčçăĄäÿ■ïijŇä¡ăåžŤèŕěäijŸåĚĹéĂĽ'æŃľ format() åĞ¡æŢřæĹŰèĂĚæŰźæşŢãĂĆ format() èęĄærŤ % æŞ■ä¡IJçňęçŽĎåŁ§èČ¡æŻť'äÿžåijžåď'ğãĂĆ åźűäÿŤ format() äź§ærŤä¡£çŤÍ ljust() , rjust() æĹŰ center() æŰźæşŢæŻť'éĂŽçŤÍïijŇ åŻääÿžåőČåŔŕäžěçŤÍæİěæäijåijŔåŇŰäżżæĎŔåŕźèśąïijŇèĂŇäÿ■äžĚäżĚæŸŕå■Ůçňęäÿšã ĂĆ

åęĆæđIJæČşèęĄåőŇåĚÍäžĘèğč format() åĞ¡æŢřçŽĎæIJL'çŤÍçL'źæĂğïijŇ èŕůåŔĆèĂČ åIJÍçž£PythonæŰĞæąč

4.14 2.14 åŘĹåźűæŃijæŐěå■Ůçňęäÿš

éŮőécŸ

ä¡ăæČşåřĘåĞääÿłåřŔçŽĎå■Ůçňęäÿšå ŘĹåźűäÿžäÿĂäÿłåď'ğçŽĎå■Ůçňęäÿš

èğčåĘşæŰźæąĹ

åęĆæđIJä¡ăæČşèęĄåŘĹåźűçŽĎå■Ůçňęäÿšæ ŸŕåIJÍäÿĂäÿłåžŔåĹŮæĹŰèĂĚ iterable äÿ■ïijŇéĆčäźĹæIJĂå£nçŽĎæŰźåijŔåřśæŸŕä¡£çŤÍ join() æŰźæşŢãĂĆærŤåęĆïijŽ

```
>>> parts = ['Is', 'Chicago', 'Not', 'Chicago?']
>>> ' '.join(parts)
'Is Chicago Not Chicago?'
>>> ','.join(parts)
'Is,Chicago,Not,Chicago?'
>>> ''.join(parts)
'IsChicagoNotChicago?'
>>>
```

åĹİçIJŃètůæİěïijŇè£Źçğ■èŕ■æşŢçIJŃäÿŁåŐżäijŽærŤè¿ČæĂłïijŇä¡ĘæŸŕ join() èćńæŇĞåőŽäÿžå■Ůçňęäÿšç ŽĎäÿĂäÿłæŰźæşŢãĂĆ è£Źæăůå ĄŽçŽĎéČĺåĹĘåŐ§åŻăæŸŕä¡ăæČşåŐżè£đæŐěçŽĎåŕźèśąåŔŕèČ¡æİěèĞłåŘĎçğ■äÿ■åŘŇçŽĎæŢŕæ■ åęĆæđIJåIJÍæĽĂæIJL'è£ŹäžŽåŕźèśąäÿŁéČ¡åőŽäźĽäÿĂäÿł join() æŰźæşŢæŸŐæŸ¿æŸŕåĘŮä¡ŹçŽĎãĂĆ åŻăæ■d'ä¡ăåŘłéIJĂèęĄæŇĞåőŽä¡ăæČşèęĄçŽĎåĹĘåĽšå■Ůçňęäÿšåź join() æŰźæşŢåŐżåřĘæŰĞæIJňçĽĞæőţçżĎåŘĹètůæİěãĂĆ

åęĆæđIJä¡ăäżĚäżĚåŘłæŸŕåŘĹåźűåřŚæŢřåĞääÿłå■ŮçňęäÿšïijŇä¡£çŤĺåŁăåŔů(+)éĂŽåÿÿåůšçżŔèűşåď'§ă

```
>>> a = 'Is Chicago'
>>> b = 'Not Chicago?'
>>> a + ' ' + b
'Is Chicago Not Chicago?'
>>>
```

åŁääŔů(+)æŞ■ä¡IJçňęåIJĺä¡IJäÿžäÿĂäžŻåď■æİĆå■ŮçňęäÿšæäijåijŔåŇŰçŽĎæŻ£äžčæŰźæąĹçŽĎæŮűå

```
>>> print('{} {}'.format(a,b))
Is Chicago Not Chicago?
>>> print(a + ' ' + b)
Is Chicago Not Chicago?
>>>
```

åęĆæđIJä¡ăæČşåIJĺæžŘçăĄäÿ■årĘäÿd'äÿłå■ŮéİĆå■Ůçňęäÿšå ŘĹåźűètůæİěïijŇä¡ääŔłéIJÄèęĄçőÄå■ŢçŽ

```
>>> a = 'Hello' 'World'
>>> a
'HelloWorld'
>>>
```

èőĺèőž

å■Ůçňęäÿšå ŘĹåźűåŔŕèČ¡çIJŃäÿŁåŐżåźűäÿ■éIJÄèęĄçŤĺäÿĂæŢt'èŁĆæİěèőĺèőžãĂĆ
ä¡ĘæŸŕäÿ■åžŤèŕêårŘçIJŃè£ŹäÿłéŮőécŸïijŇçĺŃåžŔåŚŸéĂŽåÿÿåIJĺå■ŮçňęäÿšæäijåijŔåŇŰçŽĎæŮűåĂŹåŻ

æIJĂéĞ■èęĄçŽĎéIJÄèęĄåijŢètůæşĺæĎŘçŽĎæŸŕïijŇå¡ŞæĹŚäżňä¡£çŤĺåŁääŔů(+)æŞ■ä¡IJçňęåŐżè£đæ
åŻääÿžåŁääŔůè£đæŐëäijŽåijŢètůåĘĚå■Ÿåď■åĹűäžëåŘŁåđČåIJ¿åŻđæŤűæŞ■ä¡IJãĂĆ
çL'źåĹńçŽĎïijŇä¡ăæřÿè£IJéČ¡äÿ■åžŤåČŘäÿŃéİcè£ŹæăůåĘŹå■Ůçňęäÿšè£đæŐëäžčçăĄïijŽ

```
s = ''
for p in parts:
    s += p
```

è£Źçğ■åĘŹæşŢäijŽæŕŤä¡£çŤĺ `join()` æŰźæşŢè£ŘèąŇçŽĎèęĄæĚćäÿĂäžŻïijŇåŻääÿžæŕŘäÿĂæňąæL'
ä¡ăæIJĂåě¡æŸŕåĚĹæŤűéŻĘæL'ĂæIJL'çŽĎå■Ůçňęäÿšçl'ĞæőţçĎűåŘŐåĘ■ářĘåőČäžňè£đæŐëèţůæİěãĂĆ

äÿĂäÿłçŻÿåŕźæŕŤè¿ČèĄłæŸŐçŽĎæŁĂåůğæŸŕåĹl'çŤĺçŤ§æĹŘåŹĺèąĺè¿¿åijŔ(åŔĆèĂČ1.19ářŘèŁĆ)è¡ňa

```
>>> data = ['ACME', 50, 91.1]
>>> ','.join(str(d) for d in data)
'ACME,50,91.1'
>>>
```

åŘŇæăůè£Ÿå¿ŮæşĺæĎŘäÿ■å£ĚèęĄçŽĎå■Ůçňęäÿšè£đæŐëæŞ■ä¡IJãĂĆæIJL'æŮűåĂŹçĺŃåžŔåŚŸåIJĺæ

```
print(a + ':' + b + ':' + c) # Ugly
print(':'.join([a, b, c])) # Still ugly
print(a, b, c, sep=':') # Better
```

å¡Şæůůå ŘĹä¡£çŤÍI/OæŞ■ä¡IJåŠŇå■Ůçňęäÿšè£đæŐěæŞ■ä¡IJçŽĎæŮűůåĂŹïijŇæIJL’æŮűůåĂŹéIJÄèęĄäżŤ
ærŤåęĆïijŇèĂČèŹŚäÿŃéİćçŽĎäÿď’çńŕäžčçăĄçL’Ğæőţïijž

```
# Version 1 (string concatenation)
f.write(chunk1 + chunk2)

# Version 2 (separate I/O operations)
f.write(chunk1)
f.write(chunk2)
```

åęĆæđIJäÿď’äÿłå■Ůçňęäÿšå¿ĹářŕïijŇéĆčäźĹçňňäÿĂäÿłçL’ĹæIJňæĂğèČ¡äijŽæŻť’åě¡äžŻïijŇåŻääÿžI/Oç
åŔęåď’Űäÿ ĂæŰźéİćïijŇåęĆæđIJäÿď’äÿłå■Ůçňęäÿšå¿Ĺåď’ğïijŇéĆčäźĹçňňäžŇäÿłçL’ĹæIJňåŔŕèČ¡äijŽæŻť’åŁä
åŻääÿžåőČéĄ£åĚ■äžĘąĹŻåžžäÿĂäÿłå¿Ĺåď’ğçŽĎäÿť’æŮűçżŞæđIJåźűäÿŤèęĄåď’■åĹűåď’ğéĞŔçŽĎåĘĚå■Ÿå
è£ŸæŸŕéĆčåŔěèŕÏïijŇæIJL’æŮűåĂŹæŸŕéIJÄèęĄæäźæ■őä¡äçŽĎåžŤçŤÍçÍŃåžŔçL’źçĆźæİěåĘşåőŽåžŤèŕěä¡£

æIJĂåŘŐèřĹäÿĂäÿŃïijŇåęĆæđIJä¡ääĞĘåď’ĞçijŮåĘŹæđĎåžžåď’ğéĞŔåřŔå■Ůçňęäÿšç ŽĎè¿ŞåĞžäžčçăA
ä¡ăæIJĂåě¡èĂČèŹŚäÿŃä¡£çŤÍçŤ§æĹŘåŹÍåĞ¡æŢřïijŇåĹl’çŤÍyieldèŕ■åŔěäžğçŤ§è¿ŞåĞžçL’Ğæőţã ĆæŕŤåęĆ

```
def sample():
    yield 'Is'
    yield 'Chicago'
    yield 'Not'
    yield 'Chicago?'
```

è£ŹçğæŰźæşŢäÿĂäÿłæIJL’èűčçŽĎæŰźéİćæŸŕåőČåźűæšąæIJL’åŕźè¿ŞåĞžçL’Ğæőţå Ľřåž ŢèęĄæĂŐæăů
ä¿ŃåęĆïijŇä¡ääŘŕäžěçőĂå■ŢçŽĎä¡£çŤÍ `join()` æŰźæşŢårĘè£ŹäžŻçL’Ğæőţå ŘĹåźűèţůæİěïijž

```
text = ''.join(sample())
```

æĹŰèĂĚä¡ääź§åŘŕäžěårĘå■Ůçňęäÿšç L’Ğæőţé Ğ■åőŽåŘŠåĽřI/Oïijž

```
for part in sample():
    f.write(part)
```

åĘ■æĹŰèĂĚä¡äè£ŸåŘŕäžěåĘŹåĞžäÿĂäžŻçżŞåŘĹI/OæŞ■ä¡IJçŽĎæůůåŘĹæŰźæąĹïijž

```
def combine(source, maxsize):
    parts = []
    size = 0
    for part in source:
        parts.append(part)
        size += len(part)
        if size > maxsize:
            yield ''.join(parts)
            parts = []
            size = 0
        yield ''.join(parts)

# çżŞåŘĹæŰĞäżűæŞ■ä¡IJ
with open('filename', 'w') as f:
    for part in combine(sample(), 32768):
        f.write(part)
```

è£ŹéĞŇçŽĎåĚşéŤőçĆźåIJÍäžŐåŐ§ågŃçŽĎçŤ§æĹŘåŹÍåĞ¡æŢřåźűäÿ■éIJĂèęAç§ěéĄŞä¡£çŤÍçżĘèŁĆïij

4.15 2.15 å■Ůçňęäÿšäÿ■æŔŠåĚěåŔŸéĞŔ

éŮőécŸ

ä¡ăæČşåĹŻåžžäÿĂäÿłåĘĚåţŇåŔŸéĞŔçŽĎå■ŮçňęäÿšïijŇåŔŸéĞŔèćńåőČçŽĎåĂijæĽĂèąÍçď žçŽĎå■Ů

èğčåĘşæŰźæąĹ

PythonåźűæšąæIJL'åŕźåIJÍå■Ůçňęäÿšäÿ■çőĂå■ŢæŻ£æ■ćåŔŸéĞŔåĂijæŔŘä¿ŻçŻť'æŐěçŽĎæŤŕæŇĄãĂ
ä¡ĘæŸŕéĂŽè£Ğä¡£çŤÍå■Ůçňęäÿšç ŽĎ `format()` æŰźæşŢæİěèğčåĘşè£ŹäÿłéŮőécŸãĂĆærŤåęĆïijŽ

```
>>> s = '{name} has {n} messages.'
>>> s.format(name='Guido', n=37)
'Guido has 37 messages.'
>>>
```

æĹŰèĂĚïijŇåęĆæđIJèęĄèćńæŻ£æ■ćçŽĎåŔŸéĞŔèČ¡åIJÍåŔŸéĞŔå§§äÿ■æL'¿åĹřïijŇ
éĆčäźĹä¡ääŔŕäžěçżŞåŘĹä¡£çŤÍ `format_map()` åŠŇ `vars()`
ãĂĆåřśåČŔäÿŃéÍćè£ŹæăůïijŽ

```
>>> name = 'Guido'
>>> n = 37
>>> s.format_map(vars())
'Guido has 37 messages.'
>>>
```

`vars()` è£ŸæIJL'äÿĂäÿłæIJL'æĎŔæĂİçŽĎçL'źæĂğåřśæŸŕåőČäź§éĂĆçŤÍäžŐåŕźèśąåőđä¿ŃãĂĆærŤå

```
>>> class Info:
...     def __init__(self, name, n):
...         self.name = name
...         self.n = n
...
>>> a = Info('Guido',37)
>>> s.format_map(vars(a))
'Guido has 37 messages.'
>>>
```

`format` åŠŇ `format_map()` çŽĎäÿĂäÿłçijžéŹůåřśæŸŕåőČäžňåźűäÿ■èČ¡å¿Ĺåě¡çŽĎåď ĎçŘĘåŔŸéĞ

```
>>> s.format(name='Guido')
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
KeyError: 'n'
>>>
```

äÿĂçğ■éĄ£åĚ■è£Źçğ■éŤŹèŕŕçŽĎæŰźæşŢæŸŕåŔęåď Ůåő ŽäźĽäÿĂäÿłåŘńæIJĽ __missing__() æŰźæşŢçŽĎå■ŮåĚÿåŕźèśąïijŇåřšåČŔäÿŃéİćè£Źæăůïijž

```
class safesub(dict):
"""éŸšæ■ćkeyæL'¿äÿ■åĹř"""
def __missing__(self, key):
    return '{' + key + '}'
```

çŐřåIJĺä¡ăåŔŕäżěåĹľçŤĺè£ŹäÿłçśżåŇĚèčĚè¿ŞåĚěåŘŐäijăéĂŠçžŹ format_map() ïijž

```
>>> del n # Make sure n is undefined
>>> s.format_map(safesub(vars()))
'Guido has {n} messages.'
>>>
```

åęĆæđIJä¡ăåŔŠçŐřèĞłåůśåIJĺäżčçăĄäÿ■éćŠçźĄçŽĎæL'ğèąŇè£ŹäžŻæ■ěéłď'ïijŇä¡ăåŔŕäżěåřĘåŔŸéĞŔa

```
import sys

def sub(text):
    return text.format_map(safesub(sys._getframe(1).f_locals))
```

çŐřåIJĺä¡ăåŔŕäżěåČŔäÿŃéİćè£ŹæăůåĘŹäžĘïijž

```
>>> name = 'Guido'
>>> n = 37
>>> print(sub('Hello {name}'))
Hello Guido
>>> print(sub('You have {n} messages.'))
You have 37 messages.
>>> print(sub('Your favorite color is {color}'))
Your favorite color is {color}
>>>
```

èőĺèőž

åď Žåźť äżěæİěçŤśäžŐPythonçijžäźŔåŕźåŔŸéĞŔæŻ£æ■ćçŽĎåĘĚç¡őæŤŕæŇĄèĂŇåŕijèĞť äžĘåŘĎçğ■äÿ ä¡IJäÿžæIJňèŁĆäÿ■åśŢçď žçŽĎäÿĂäÿłåŔŕèČ¡çŽĎèğčåĘşæŰźæąĹïijŇä¡ăåŔŕäżěæIJĽæŮűåĂŹäijŽçIJŃåĹřåČ

```
>>> name = 'Guido'
>>> n = 37
>>> '%(name) has %(n) messages.' % vars()
'Guido has 37 messages.'
>>>
```

ä¡ăåŔŕèČ¡è£Ÿäij ŽçIJŃåĹřå■Ůçňęäÿšæĺąæİ£çŽĎä¡£çŤĺïijž

```
>>> import string
>>> s = string.Template('$name has $n messages.')
>>> s.substitute(vars())
'Guido has 37 messages.'
>>>
```

çĎűèĂŇïijŇ `format()` åŠŇ `format_map()` çŻÿæŕŤè¿ČäÿŁéİćè£ŹäžŻæŰźæąĹèĂŇåůšæŻť åŁăåĚĹ ä¡£çŢĺ `format()` æŰźæşŢè£ŸæIJL'äÿĂäÿłåě¡åď'ĎåŕśæŸŕä¡ăåŔŕäżěèŐůå¿ŮåŕźåŋŰçňęäÿšæäijåijŔåŇŰçŽĎ èĂŇè£ŹäžŻçL'źæĂğæŸŕä¡£çŢĺåČŔæĹąæİ£åŋŰçňęäÿšäźŃçśżçŽĎæŰźæąĹäÿŋåŔŕèČ¡èŐůå¿ŮçŽĎãĂĆ

æIJňæIJžè£ŸéČĺåĹĘäżŃçż■äžĘäÿĂäžŻéńŸçžğçL'źæĂğãĂĆæŸăåřĎæĹŰèĂĚå■ŮåĚÿçśžäÿ■éšIJäÿžäžž `__missing__()` æŰźæşŢåŔŕäžěèől'ä¡ăåőŽäźL'åęĆä¡Ţåď'ĎçŘĘçijžåď'śçŽĎåĂijãĂĆ åIJĺ `SafeSub` çśżäÿ■ïijŇè£ŹäÿłæŰźæşŢèćńåőŽäźL'äÿžåŕźçijžåď'śçŽĎåĂijè£ŤåŻđäÿĂäÿłå■ää¡■çňęãĂĆ ä¡ăåŔŕäžěåŔŚçŐřçijžåď'śçŽĎåĂijäijŽåĞžçŐřåIJĺçżŞæđIJå■Ůçňęäÿšäÿ■(åIJĺèřČèŕŢçŽĎæŮűåĂŹåŔŕèČ¡å¿Ĺa `KeyError` åijĆåÿÿãĂĆ

`sub()` åĞ¡æŢřä¡£çŢĺ `sys._getframe(1)` è£ŤåŻđèřČçŢĺèĂĚçŽĎæăĹåÿğãĂĆåŔŕäžěäžŐäÿ■èő£éŮ `f_locals` æİèèŐůå¿ŮåśĂéČĺåŔŸéĞŔãĂĆ æńńæŮăçŰŚéŮőçżİåď'ğéČĺåĹĘæČĚåĘţäÿŇåIJĺäžčçăĄäÿ■åŐżç ä¡ĘæŸŕijŇåŕźäžŐåČŔå■ŮçňęäÿšæŻ£æ■ćåůěåĚůåĞ¡æŢřèĂŇèĺĂåőČæŸŕéİđåÿÿæIJL'çŢĺçŽĎãĂĆ åŔęåď'ŰïijŇåĂijå¿ŮæşĺæĎŔçŽĎæŸŕ `f_locals` æŸŕäÿĂäÿłåď'■åĹűèřČçŢĺåĞ¡æŢřçŽĎæIJňåIJŕåŔŸéĞŔçŽ åř¡çőąä¡ăåŔŕäžěæŤźåŔŸ `f_locals` çŽĎåĘĚåőźïijŇä¡ĘæŸŕè£ŹäÿłâŁőæŤźåŕźäžŐåŘŐéİćçŽĎåŔŸéĞŔèő£é æĽĂäżěïijŇèŹ¡èŕť'èő£éŮőäÿĂäÿłæăĹåÿğçIJŃäÿŁåŐżå¿ĹéĆłæĄűïijŇä¡ĘæŸŕåŕźåőČçŽĎäżżä¡ŢæŞ■ä¡IJäÿ■ä

4.16 2.16 äžěæŇĞåőŽåĹŮåő¡æăijåijŔåŇŰå■Ůçňęäÿš

éŮőécŸ

ä¡ăæIJL'äÿĂäžŻéŢ£å■ŮçňęäÿšïijŇæČşäžěæŇĞåőŽçŽĎåĹŮåő¡åřĘåőČäżňéĞ■æŰřæăijåijŔåŇŰãĂĆ

èğčåĘşæŰźæąĹ

ä¡£çŢĺ `textwrap` æĺąåİŮæİěæăijåijŔåŇŰå■ŮçňęäÿšçŽĎè¿ŞåĞžãĂĆærŤåęĆïijŇåĄĞåęĆä¡ăæIJL'äÿŇå

```
s = "Look into my eyes, look into my eyes, the eyes, the eyes, \
the eyes, not around the eyes, don't look around the eyes, \
look into my eyes, you're under."
```

äÿŇéİćæijŤçď'žä¡£çŢĺ `textwrap` æăijåijŔåŇŰå■ŮçňęäÿšçŽĎåď'Žçğ■æŰźåijŕïijŽ

```
>>> import textwrap
>>> print(textwrap.fill(s, 70))
Look into my eyes, look into my eyes, the eyes, the eyes, the eyes,
not around the eyes, don't look around the eyes, look into my eyes,
you're under.

>>> print(textwrap.fill(s, 40))
Look into my eyes, look into my eyes,
the eyes, the eyes, the eyes, not around
```

```
the eyes, don't look around the eyes,
look into my eyes, you're under.

>>> print(textwrap.fill(s, 40, initial_indent='    '))
    Look into my eyes, look into my
eyes, the eyes, the eyes, the eyes, not
around the eyes, don't look around the
eyes, look into my eyes, you're under.

>>> print(textwrap.fill(s, 40, subsequent_indent='    '))
Look into my eyes, look into my eyes,
    the eyes, the eyes, the eyes, not
    around the eyes, don't look around
    the eyes, look into my eyes, you're
    under.
```

èőÍèőž

textwrap æÍąåİŮåŕźäžŐå■ŮçňęäÿšæĽŞå■řæŸŕéİđåÿÿæIJĽçŤÍçŽĎïijŇçĽźåĹńæŸŕå¡Şä¡ăåÿŇæIJŻè¿Ş
ä¡ăåŔŕäžěä¡£çŤÍ os.get_terminal_size() æŰźæşŢæİèèŐůåŔŰçżĹçńŕçŽĎåď ğářŔářžåŕÿãĂĆærŤåęĆ

```
>>> import os
>>> os.get_terminal_size().columns
80
>>>
```

fill() æŰźæşŢæŐěåŔŮäÿĂäžŻåĚűäžŰåŔŕéĂĽåŔĆæŢřæİěæŐğåĹűtabïijŇèŕ■åŔěçżŞář¿ç■L'ãĂĆ
åŔĆéŸĚ textwrap.TextWrapperæŰĞæąč èŐůåŔŰæŻť åď ŽåĘĚåőźãĂĆ

4.17 2.17 åIJĺå■Ůçňęäÿšäÿ■åď ĎçŘĘhtmlåŠŇxml

éŮőécŸ

ä¡ăæČşářĘHTMLæĹŰèĂĚXMLåőđä¡ŞåęĆ &entity; æĹŰ &#code;
æŻ£æ■ćäÿžářźåžŢçŽĎæŰĞæIJñãĂĆ åĘ■èĂĚïijŇä¡ăéIJĂèęĄè¡ňæ■ćæŰĞæIJñäÿ■çĽźáőŽçŽĎå■Ůçňę(ærŤåę
>, æĹŰ &)ãĂĆ

èğčåĘşæŰźæąĹ

åęĆæđIJä¡ăæČşæŻ£æ■ćæŰĞæIJňå■Ůçňęäÿšäÿ■çŽĎ âĂŸ<âĂŹ æĹŰèĂĚ âĂŸ>âĂŹ
ïijŇä¡£çŤÍ html.escape() åĞ¡æŢřåŔŕäžěå¿ĹåőźæŸ§çŽĎåőŇæĹŘãĂĆærŤåęĆïijŽ

```
>>> s = 'Elements are written as "<tag>text</tag>".'
>>> import html
>>> print(s)
Elements are written as "<tag>text</tag>".
```

```
>>> print(html.escape(s))
Elements are written as &quot;&lt;tag&gt;text&lt;/tag&gt;&quot;.

>>> # Disable escaping of quotes
>>> print(html.escape(s, quote=False))
Elements are written as "&lt;tag&gt;text&lt;/tag&gt;".
>>>
```

åęĆæđIJä¡ăæ■čåIJĺåď ĎçŘĘçŽĎæŸŕASCIIæŰĞæIJňïijŇåźűäÿŤæČşåřĘéİđASCIIæŰĞæIJňåŕźåžŤçŽĎç
åŔŕäžěçżŹæ§ŘäžŻI/OåĞ¡æŢřäijăéĂŠåŔĆæŢř `errors='xmlcharrefreplace'`
æİěè¿¿åĹřè£ŹäÿłçŻőãĂĆæŕŤåęĆïijŽ

```
>>> s = 'Spicy JalapeÃśo'
>>> s.encode('ascii', errors='xmlcharrefreplace')
b'Spicy Jalape&#241;o'
>>>
```

äÿžäžĘæŻ£æ■ćæŰĞæIJňäÿ■çŽĎçijŰçăĄåőđä¡ŞïijŇä¡ăéIJĂèęĄä¡£çŤĺåŔęåď ŰäÿĂçğ■æŰźæşŢãĂĆ
åęĆæđIJä¡ăæ■čåIJĺåď ĎçŘĘHTMLæĹŰèĂĚXMLæŰĞæIJňïijŇèŕŢçİĂåĚĹä¡£çŤĺäÿĂäÿłåŘĹéĂĆçŽĎHTML
éĂŽåÿÿæČĚåĘţäÿŃïijŇè£ŹäžŻåůěåĚůäijŽèĞłåŁĺæŻ£æ■ćè£ŹäžŻçijŰçăĄåĂijïijŇä¡ăæŮăéIJĂæŃĚå£ČãĂĆ

æIJL'æŮűåĂŹïijŇåęĆæđIJä¡ăæŐěæŤűåĹřäžĘäÿĂäžŻåŘńæIJL'çijŰçăĄåĂijçŽĎåŐ§ågŃæŰĞæIJňïijŇél
éĂŽåÿÿä¡ăåŘłéIJĂèęĄä¡£çŤÍHTMLæĹŰèĂĚXMLèğčæđŘåŹÍçŽĎäÿĂäžŻçŻÿåĚşåůěåĚůåĞ¡æŢř/æŰźæşŢå■

```
>>> s = 'Spicy &quot;Jalape&#241;o&quot.'
>>> from html.parser import HTMLParser
>>> p = HTMLParser()
>>> p.unescape(s)
'Spicy "JalapeÃśo".'
>>>
>>> t = 'The prompt is &gt;&gt;&gt;'
>>> from xml.sax.saxutils import unescape
>>> unescape(t)
'The prompt is >>>'
>>>
```

èőÍèőž

åIJÍçŤ§æĹŘHTMLæĹŰèĂĚXMLæŰĞæIJňçŽĎæŮűåĂŹïijŇåęĆæđIJæ■čçąőçŽĎè¡ñæ■ćçL'źæőŁæăĞèć
çL'źåĹńæŸŕå¡Şä¡ăä¡£çŤÍ `print()` åĞ¡æŢřæĹŰèĂĚåĚűäžŰå■ŮçňęäÿšæăijåijŘåŇŰæİěäžğçŤ§è¿ŞåĞžçŽĎa
ä¡£çŤĺåČŔ `html.escape()` çŽĎåůěåĚůåĞ¡æŢřåŕŕäžěå¿Ĺåőźæ ŸŞçŽĎèğčåĘşè£ŹçśźéŮőécŸãĂĆ

åęĆæđIJä¡ăæČşäžěåĚűäžŰæŰźåijŔåď ĎçŘĘæŰĞæIJňïijŇè£ŸæIJL'äÿĂäžŻåĚűäžŰçŽĎåůěåĚůåĞ¡æŢřa
`xml.sax.saxutils.unescape()` åŔŕäžěåÿőåŁľä¡ăãĂĆ
çĎűěĂŇïijŇä¡ăåžŤèŕěåĚĹèŕČçăŤæÿĚæěŽæĂŐæăůä¡£çŤĺäÿĂäÿłåŘĹéĂĆçŽĎèğčæđŘåŹĺãĂĆ
æŕŤåęĆïijŇåęĆæđIJä¡ăåIJĺåď ĎçŘĘHTMLæĹŰXMLæŰĞæIJňïijŇ
ä¡£çŤĺæ§ŘäÿłèğčæđŘæĺąåİŮæŕŤåęĆ `html.parse` æĹŰ `xml.etree.ElementTree`
åůšçżŔåÿőä¡ăèĞłåŁĺåď ĎçŘĘäžĘçŻÿåĚşçŽĎæŻ£æ■ćçżĘèŁĆãĂĆ

4.18 2.18 å■Ůçňęäÿšäžď'çĽŇèğčæđŘ

éŮőécŸ

ä¡ăæIJL'äÿĂäÿłå■ŮçňęäÿšïijŇæČşäžŐåůęèĞşåŘşåřĘåĚűèğčæđŘäÿžäÿĂäÿłäžď'çL'ŇæţĄãĂĆ

èğčåĘşæŰźæąĹ

åĄĞåęĆä¡ăæIJL'äÿŃéÍćè£Źæăůäÿ Ääÿłæ ŰĞæIJňå■ŮçňęäÿšïijŽ

```
text = 'foo = 23 + 42 * 10'
```

äÿžäžĘäžď'çL'ŇåŇŰå■ŮçňęäÿšïijŇä¡ääÿ■äžĚéIJÄèęĄåŇźéĚ■æĺąåijŔïijŇè£Ÿå¿ŮæŇĞåőŽæĺąåijŔçŽĎç
ærŤåęĆïijŇä¡ääŘŕèČ¡æČşářĘå■Ůçňęäÿšå ČŔäÿŃéÍćè£Źæăůè¡ňæ■ćäÿžäžŘåĹŮářźïijŽ

```
tokens = [('NAME', 'foo'), ('EQ','='), ('NUM', '23'), ('PLUS','+'),
          ('NUM', '42'), ('TIMES', '*'), ('NUM', '10')]
```

äÿžäžĘæL'ğèąŇè£Źæăůç ŽĎåĹĞåĹĘïijŇçňňäÿĂæ■ěářśæŸŕåČŔäÿŃéÍćè£Źæăůå Ĺl'çŤĺåŠ¡åŘ■æ■ŢèŐůçż

```
import re
NAME = r'(?P<NAME>[a-zA-Z_][a-zA-Z_0-9]*)'
NUM = r'(?P<NUM>\d+)'
PLUS = r'(?P<PLUS>\+)'
TIMES = r'(?P<TIMES>\*)'
EQ = r'(?P<EQ>=)'
WS = r'(?P<WS>\s+)'

master_pat = re.compile('|'.join([NAME, NUM, PLUS, TIMES, EQ, WS]))
```

åIJÍäÿŁéÍćçŽĎæĺąåijŔäÿ■ïijŇ `?P<TOKENNAME>` çŤĺäžŐçżŹäÿĂäÿłæĺąåijŔåŚ¡åŘ■ïijŇä¿ŻåŘŐéÍćä¡£çŤ

äÿŇäÿĂæ■ěïijŇäÿžäžĘäžď'çL'ŇåŇŰïijŇä¡£çŤĺæĺąåijŔåŕźèśąå¿ĹåřŚèćńäžžç§ěéĄŞçŽĎ
`scanner()` æŰźæşŢãĂĆ è£ŹäÿłæŰźæşŢäijŽåĹŻåžžäÿĂäÿł
`scanner` åŕźèśąïijŇ åIJÍè£ŹäÿłåŕźèśąäÿŁäÿ■æŰ■çŽĎèřČçŤÍ `match()`
æŰźæşŢäijŽäÿĂæ■ěæ■ěçŽĎæL'ńæŔŘçŽőæĂĞæŰŰĞæIJňïijŇærŔæ■ěäÿĂäÿłåŇźéĚ■ãĂĆ
äÿŃéÍćæŸŕæijŤçď'žäÿĂäÿł `scanner` åŕźèśąåęĆä¡Ţåůěä¡IJçŽĎäžď'äžŠåijŔä¿Ńå■ŘïijŽ

```
>>> scanner = master_pat.scanner('foo = 42')
>>> scanner.match()
<_sre.SRE_Match object at 0x100677738>
>>> _.lastgroup, _.group()
('NAME', 'foo')
>>> scanner.match()
<_sre.SRE_Match object at 0x100677738>
>>> _.lastgroup, _.group()
('WS', ' ')
>>> scanner.match()
<_sre.SRE_Match object at 0x100677738>
```

```
>>> _.lastgroup, _.group()
('EQ', '=')
>>> scanner.match()
<_sre.SRE_Match object at 0x100677738>
>>> _.lastgroup, _.group()
('WS', ' ')
>>> scanner.match()
<_sre.SRE_Match object at 0x100677738>
>>> _.lastgroup, _.group()
('NUM', '42')
>>> scanner.match()
>>>
```

åőđéŹĚä¡£çŤÍè£Źçğ■æŁĂæIJŕçŽĎæŮűåĂŹïijŇåŔŕäžěå¿Ĺåőźæ ŸŞçŽĎåČŔäÿŃéİćè£ŹæăůåřĘäÿŁè£ŕäž

```
def generate_tokens(pat, text):
    Token = namedtuple('Token', ['type', 'value'])
    scanner = pat.scanner(text)
    for m in iter(scanner.match, None):
        yield Token(m.lastgroup, m.group())

# Example use
for tok in generate_tokens(master_pat, 'foo = 42'):
    print(tok)
# Produces output
# Token(type='NAME', value='foo')
# Token(type='WS', value=' ')
# Token(type='EQ', value='=')
# Token(type='WS', value=' ')
# Token(type='NUM', value='42')
```

åęĆæđIJä¡ăæČşè£ĞæżđʼäżđʼçĽŇæţĄïijŇä¡ăåŔŕäžěåőŽäźĽæŻtʼåđʼŽçŽĎçŤ§æĹŘåŹĺåĞ¡æŢřæĹŰèĂĚä¡æŕŤåęĆïijŇäÿŃéİćæijŤçđʼžæĂŐæăůè£ĞæżđʼæĽĂæIJĽçŽĎçlʼžçŹ¡äżđʼçĽŇïijŽ

```
tokens = (tok for tok in generate_tokens(master_pat, text)
          if tok.type != 'WS')
for tok in tokens:
    print(tok)
```

èőÍèőž

éĂŽåÿÿæİěèőšäžđʼçĽŇåŇŰæŸŕå¿ĹåđʼŽéńŸçžğæŰĞæIJňèğčæđŘäÿŐåđʼĎçŘĘçŽĎçňňäÿĂæ■ěãĂĆ äÿžäžĘä¡£çŤÍäÿŁéİćçŽĎæĽńæŔŘæŰźæşŢïijŇä¡ăéIJĂèęĄèőřä¡Ŕè£ŹéĞŇäÿĂäžŻéĞ■èęĄçŽĎåĞäçĆźãĂĆ çňňäÿĂçĆźåřśæŸŕä¡ăå£Ěéążçąõèőđʼä¡ăä¡£çŤÍæ■čåĹŹèąÍè¿¿åijŔæŇĞåőŽäžĘæĽĂæIJĽè¿ŞåĚěäÿ■åŔŕèČ¡åĞ åęĆæđIJæIJĽäżżä¡Ţäÿ■åŔŕåŇźéĚ■çŽĎæŰĞæIJňåĞžçŐřäžĘïijŇæĽńæŔŘåřśäijŽçŻtʼæŐěåĄIJæ■ćãĂĆè£Źä

äžđʼçĽŇçŽĎéąžåžŔäź§æŸŕæIJĽå¡śåŞ■çŽĎãĂĆ `re` æĺąåİŮäijŽæŇĽʼçĚğæŇĞåőŽåě¡çŽĎéąžåžŔåŐżåĄ åŻäæ■đʼïijŇåęĆæđIJäÿĂäÿłæĺąåijŔæĄřåě¡æŸŕåŔęäÿĂäÿłæŻtʼéŢ£æĺąåijŔçŽĎå■Řå■ŮçňęäÿšïijŇéĆčäźĹä¡ăé

```
LT = r'(?P<LT><)'
LE = r'(?P<LE><=)'
EQ = r'(?P<EQ>=)'

master_pat = re.compile('|'.join([LE, LT, EQ])) # Correct
# master_pat = re.compile('|'.join([LT, LE, EQ])) # Incorrect
```

çñňäžŇäÿłæĺąåijŕæŸŕéŤŹçŽĎïijŇåŻääÿžåőČäijŽåřĘæŰĞæIJň<=åŇźéĚ■äÿžäžd'çL'ŇLTçť ğèů§çİĂEQi

æIJĂåŘŐïijŇä¡ăéIJĂèęĄçŢŹæĎŕäÿŃå■Řå■Ůçňęäÿšå¡ćåijŔçŽĎæĺąåijŔãĂĆæŕŤåęĆïijŇåĄĞèő¿ä¡ăæIJI

```
PRINT = r'(?P<PRINT>print)'
NAME = r'(?P<NAME>[a-zA-Z_][a-zA-Z_0-9]*)'

master_pat = re.compile('|'.join([PRINT, NAME]))

for tok in generate_tokens(master_pat, 'printer'):
    print(tok)

# Outputs :
# Token(type='PRINT', value='print')
# Token(type='NAME', value='er')
```

åĚşäžŐæŻť'énŸéŸűçŽĎäžd'çL'ŇåŇŰæŁĂæIJŕïijŇä¡ăåŔŕèČ¡éIJĂèęĄæ§ěçIJŃ PyParsing æĹÚèĂĚ PLY åŇĚãĂĆ äÿĂäÿłèřČçŤÍPLYçŽĎä¿Ńå■ŘåIJĺäÿŃäÿĂèŁĆäijŽæIJL'æijŤçd'žãĂĆ

4.19 2.19 åőđçŐřäÿĂäÿłçőÅå■ŢçŽĎéĂŠå¡ŠäÿŃéŹ■åĹĘæđŘåŹĺ

éŮőécŸ

ä¡ăæČşæăźæ■őäÿĂçżĎèŕ■æşŢèğĎåĹŹèğčæđŘæŰĞæIJňåźűæL'ğèąŇåŚ¡äžd'ïijŇæĹŰèĂĚæđĎéĂăäÿĂäj
åęĆæđIJèŕ■æşŢéİđåÿÿçőÅå■ŢïijŇä¡ăåŔŕäžěèĞłåůśåĘŹè£ŹäÿłèğčæđŘåŹĺïijŇèĂŇäÿ■æŸŕä¡£çŤĺäÿĂäžŻæąĘ

èğčåĘşæŰźæąĹ

åIJĺè£ŹäÿłéŮőécŸäÿ■ïijŇæĹŚäžňéŽĘäÿ■èőĺèőžæăźæ■őçL'źæőŁèŕ■æşŢåŐżèğčæđŘæŰĞæIJňçŽĎéŮőé
äÿžäžĘè£ŹæăůåĄŽïijŇä¡ăéęŰåĚĹèęĄäžěBNFæĹŰèĂĚEBNFå¡ćåijŔæŇĞåőŽäÿĂäÿłæăĞåĞĘèŕ■æşŢãĂĆ
æŕŤåęĆïijŇäÿĂäÿłçőÅå■ŢæŢřå■ęèąĺè¿¿åijŔèŕ■æşŢåŔŕèČ¡åČŔäÿŃéİćè£Źæăůïijž

```
expr ::= expr + term
    |    expr - term
    |    term

term ::= term * factor
    |    term / factor
    |    factor
```

```
factor ::= ( expr )
    |   NUM
```

æĹŰèĂĚïijÑäžěEBNFå¡ćåijŔïijŽ

```
expr ::= term { (+|-) term }*

term ::= factor { (*|/) factor }*

factor ::= ( expr )
    |   NUM
```

åIJÍEBNFäÿ■ïijÑèćńåŇĚåŘńåIJÍ { . . . }* äÿ■çŽĎèğĎåĹŹæŸŕåŘŕéĂL'çŽĎãĂĆ*äžčèąĺ0æňąæĹŰåď'Žæ

çŐřåIJÍïijÑåęĆæđIJä¡ăåŕźBNFçŽĎåůěä¡IJæIJžåĹűè£Ÿäÿ■æŸŕå¿ĹæŸŐçŹ¡çŽĎèŕİïijÑåřśæŁŁåőČå¡ŞåĄ
äÿĂèĹňæİěëőšïijÑèğčæđŘçŽĎåŐ§çŘĘåřśæŸŕä¡ăåĹl'çŤÍBNFåőŇæĹŘåď'Žäÿ łæŻ£æ■ćåŠŇæL'l'åśŢäžěåŇźéĚ
äÿžäžĘæijŤçď'žïijÑåĄĞèő¿ä¡ăæ■čåIJÍèğčæđŘå¡ćåęĆ 3 + 4 * 5 çŽĎèąĺè¿¿åijŔãĂĆ
è£Źäÿłèąĺè¿¿åijŔåĚĹèęĄéĂŽè£Ğä¡£çŤÍ2.18èŁĆäÿ■äžŃçż■çŽĎæŁĂæIJŕåĹĘèğčäÿžäÿĂçżĎäžď'çL'ŇæţĄãĂ
çżŞæđIJåŘŕèČ¡æŸŕåČŔäÿŃåĹŮè£ŹæăůçŽĎäžď'çL'ŇåžŘåĹŮïijŽ

```
NUM + NUM * NUM
```

åIJÍæ■d'å§žçąĂäÿŁïijÑ èğčæđŘåŁÍä¡IJäijŽèŕŢçİĂåŐžéĂŽè£ĞæŻ£æ■ćæŞ■ä¡IJåŇźéĚ■èŕ■æşŢåĹřè¿ŞåĚ

```
expr
expr ::= term { (+|-) term }*
expr ::= factor { (*|/) factor }* { (+|-) term }*
expr ::= NUM { (*|/) factor }* { (+|-) term }*
expr ::= NUM { (+|-) term }*
expr ::= NUM + term { (+|-) term }*
expr ::= NUM + factor { (*|/) factor }* { (+|-) term }*
expr ::= NUM + NUM { (*|/) factor}* { (+|-) term }*
expr ::= NUM + NUM * factor { (*|/) factor }* { (+|-) term }*
expr ::= NUM + NUM * NUM { (*|/) factor }* { (+|-) term }*
expr ::= NUM + NUM * NUM { (+|-) term }*
expr ::= NUM + NUM * NUM
```

äÿŇéİćæL'ĂæIJL'çŽĎèğčæđŘæ■ěéłď'åŘŕèČ¡éIJĂèęĄèŁśçĆźæŮűéŮt'åijĎæŸŐçŹ¡ïijÑä¡ĘæŸŕåőČäžňåĆ
çňňäÿĂäÿłè¿ŞåĚěäžď'çL'ŇæŸŕfNUMïijÑåŽăæ■d'æŻ£æ■ćéęŰåĚĹäijŽåŇźéĚ■éĆčäÿłéČĺåĹĘãĂĆ
äÿĂæŮęåŇźéĚ■æĹŘåŁ§ïijÑåřśäijŽè£ŽåĚěäÿŇäÿĂäÿłäžď'çL'Ň+ïijÑäžěæ■d'çśźæŐĺãĂĆ
å¡ŞåůšçżŕçąőåőŽäÿ■èČ¡åŇźéĚ■äÿŇäÿĂäÿłäžď'çL'ŇçŽĎæŮűåĂŹïijÑåŘşè¿źçŽĎéČĺåĹĘ(æŕŤåęĆ
{ (*/) factor }*)åřśäijŽèćńæÿĚçŘĘæŐL'ãĂĆ åIJĺäÿĂäÿłæĹŘåŁ§çŽĎèğčæđŘäÿ■ïijÑæŢt'äÿłåŘşè¿źé

æIJL'äžĘåL'■éİćçŽĎç§ěèŕĘèČŇæŹŕïijÑäÿŇéİćæĹŚäžňäÿ¿äÿĂäÿłçŐÅå■Ţçď'žä¿ŇæİěåśŢçď'žåęĆä¡Ţæđĺ

```
#!/usr/bin/env python
# -*- encoding: utf-8 -*-
"""
Topic: äÿŃéŹ■èğčæđŘåŹĺ
Desc :
"""
```

```
import re
import collections

# Token specification
NUM = r'(?P<NUM>\d+)'
PLUS = r'(?P<PLUS>\+)'
MINUS = r'(?P<MINUS>-)'
TIMES = r'(?P<TIMES>\*)'
DIVIDE = r'(?P<DIVIDE>/)'
LPAREN = r'(?P<LPAREN>\()'
RPAREN = r'(?P<RPAREN>\))'
WS = r'(?P<WS>\s+)'

master_pat = re.compile('|'.join([NUM, PLUS, MINUS, TIMES,
                                  DIVIDE, LPAREN, RPAREN, WS]))
# Tokenizer
Token = collections.namedtuple('Token', ['type', 'value'])


def generate_tokens(text):
    scanner = master_pat.scanner(text)
    for m in iter(scanner.match, None):
        tok = Token(m.lastgroup, m.group())
        if tok.type != 'WS':
            yield tok


# Parser
class ExpressionEvaluator:
    '''
    Implementation of a recursive descent parser. Each method
    implements a single grammar rule. Use the ._accept() method
    to test and accept the current lookahead token. Use the ._
↪expect()
    method to exactly match and discard the next token on on the␣
↪input
    (or raise a SyntaxError if it doesn't match).
    '''

    def parse(self, text):
        self.tokens = generate_tokens(text)
        self.tok = None  # Last symbol consumed
        self.nexttok = None  # Next symbol tokenized
        self._advance()  # Load first lookahead token
        return self.expr()

    def _advance(self):
        'Advance one token ahead'
        self.tok, self.nexttok = self.nexttok, next(self.tokens,␣
↪None)
```

```
    def _accept(self, toktype):
        'Test and consume the next token if it matches toktype'
        if self.nexttok and self.nexttok.type == toktype:
            self._advance()
            return True
        else:
            return False

    def _expect(self, toktype):
        'Consume next token if it matches toktype or raise␣
↪SyntaxError'
        if not self._accept(toktype):
            raise SyntaxError('Expected ' + toktype)

    # Grammar rules follow
    def expr(self):
        "expression ::= term { ('+'|'-') term }*"
        exprval = self.term()
        while self._accept('PLUS') or self._accept('MINUS'):
            op = self.tok.type
            right = self.term()
            if op == 'PLUS':
                exprval += right
            elif op == 'MINUS':
                exprval -= right
        return exprval

    def term(self):
        "term ::= factor { ('*'|'/') factor }*"
        termval = self.factor()
        while self._accept('TIMES') or self._accept('DIVIDE'):
            op = self.tok.type
            right = self.factor()
            if op == 'TIMES':
                termval *= right
            elif op == 'DIVIDE':
                termval /= right
        return termval

    def factor(self):
        "factor ::= NUM | ( expr )"
        if self._accept('NUM'):
            return int(self.tok.value)
        elif self._accept('LPAREN'):
            exprval = self.expr()
            self._expect('RPAREN')
            return exprval
        else:
            raise SyntaxError('Expected NUMBER or LPAREN')
```

```
def descent_parser():
    e = ExpressionEvaluator()
    print(e.parse('2'))
    print(e.parse('2 + 3'))
    print(e.parse('2 + 3 * 4'))
    print(e.parse('2 + (3 + 4) * 5'))
    # print(e.parse('2 + (3 + * 4)'))
    # Traceback (most recent call last):
    #   File "<stdin>", line 1, in <module>
    #   File "exprparse.py", line 40, in parse
    #   return self.expr()
    #   File "exprparse.py", line 67, in expr
    #   right = self.term()
    #   File "exprparse.py", line 77, in term
    #   termval = self.factor()
    #   File "exprparse.py", line 93, in factor
    #   exprval = self.expr()
    #   File "exprparse.py", line 67, in expr
    #   right = self.term()
    #   File "exprparse.py", line 77, in term
    #   termval = self.factor()
    #   File "exprparse.py", line 97, in factor
    #   raise SyntaxError("Expected NUMBER or LPAREN")
    #   SyntaxError: Expected NUMBER or LPAREN


if __name__ == '__main__':
    descent_parser()
```

èőÍèőž

æŰĞæIJňèğčæđŘæŸŕäÿĂäÿłå¿Ĺåď´ğçŽĎäÿžéćŸïijŇ äÿĂèĹňäijŽå■ăçŤĺå■ęçŤ§å■ęäźăçijŰèŕŚèŕ¿çÍŃæŮ
åęĆæđIJä¡ăåIJÍæL’¿åŕżåĚşäžŐèŕ■æşŢïijŇèğčæđŘçőŮæşŢç■L’çŻÿåĚşçŽĎèČŇæŹŕç§ěèŕEçŽĎèŕÍïijŇä¡ăåžŤèŕ
å¿ĹæŸ¿çĎűïijŇåĚşäžŐè£ŹæŰźéÍćçŽĎåĘĚåőźåď’łåď’ŽïijŇäÿ■åŘŕèČ¡åIJÍè£ŹéĞŇåĚĺéČĺĺśŢåijĂãĂĆ

åř¡çőąåęĆæ■d’ïijŇçijŰåĘŹäÿĂäÿłéĂŠå¡ŠäÿŃéŹ■èğčæđŘåŹÍçŽĎæŢť’ä¡ŞæĂÌèůŕæŸŕæŕŤè¿ČçőĂå■ŢçŽ
åijĂåğŃçŽĎæŮűůåĂŹïijŇä¡ăåĚĹèŐůå¿ŮæL’ĂæIJL’çŽĎèŕ■æşŢèğĎåĹŹïijŇçĎűåŘŐářĘåĚűè¡ňæ■ćäÿžäÿĂäÿ
åŽăæ■d’åęĆæđIJä¡ăçŽĎèŕ■æşŢçśżäijijè£Źæăůïijž

```
expr ::= term { ('+'|'-') term }*

term ::= factor { ('*'|'/') factor }*

factor ::= '(' expr ')'
    | NUM
```

ä¡ăåžŤèŕěéęŰåĚĹářĘåőČäżňè¡ňæ■ćæĹŘäÿĂçžĎåČŔäÿŃéÍćè£ŹæăůçŽĎæŰźæşŢïijž

```
class ExpressionEvaluator:
    ...
    def expr(self):
    ...
    def term(self):
    ...
    def factor(self):
    ...
```

æŕŘäÿłæŰźæşŢèęĄåőŇæĹŘçŽĎäżżåŁąå¿ĹçőĂå■Ţ - åőČå£ĚéążäżŐåůęèĞşåŔşéĄ■åŐĘèŕ■æşŢèğĎåĹŹäžŐæ§ŘçğæĎŔäźĽäÿŁèőšïijŇæŰźæşŢçŽĎçŻőçŽĎåřśæŸŕèęĄäźĹåď˙ĎçŘĘåőŇèŕ■æşŢèğĎåĹŹïijŇèęĄäźĹäÿžäžĘè£ŹæăůåĄŽïijŇéIJĂéĞĞçŤĺäÿŇéÍćçŽĎè£ŹäžŽåőđçŐřæŰźæşŢïijŽ

- åęĆæđIJèğĎåĹŹäÿ■çŽĎäÿŇäÿłçňęåŘůæŸŕåŔęåď˙ŰäÿĂäÿłèŕ■æşŢèğĎåĹŹçŽĎåŘ■å■Ů(æŕŤåęĆtermæ
  è£ŹåřśæŸŕèŕěçőŮæşŢäÿ■âĂÍäÿŇéŹ■âĂÍçŽĎçŤśæÍě -
  æŐğåĹűäÿŇéŹ■åĹřåŔęäÿĂäÿłèŕ■æşŢèğĎåĹŹäÿ■åŐżãĂĆ
  æIJL˙æŰűåĂŹèğĎåĹŹäijŽèřČçŤĺåůšçżŔæL˙ğèąŇçŽĎæŰźæşŢ(æŕŤåęĆïijŇåIJÍ
  `factor ::= '('expr ')'` äÿ■åŕźexprçŽĎèřČçŤĺ)ãĂĆ
  è£ŹåřśæŸŕçőŮæşŢäÿ■âĂÍéĂŠå¡ŠâĂÍçŽĎçŤśæÍěãĂĆ
- åęĆæđIJèğĎåĹŹäÿ■äÿŇäÿĂäÿłçňęåŘůæŸŕäÿłçL˙źæőŁçňęåŘů(æŕŤåęĆ()ïijŇä¡åå¿Ůæ§ěæL˙¿äÿŇäÿĂäÿ
  åęĆæđIJäÿ■åŇźéĚ■ïijŇåřśäžğçŤ§äÿĂäÿłèŕ■æşŢéŤŹèŕŕãĂĆè£ŹäÿĂèŁĆäÿ■çŽĎ
  `_expect()` æŰźæşŢåřśæŸŕçŤĺæÍěåĄŽè£ŹäÿĂæ■ěçŽĎãĂĆ
- åęĆæđIJèğĎåĹŹäÿ■äÿŇäÿĂäÿłçňęåŘůäÿžäÿĂäžŽåŘŕèČ¡çŽĎéĂL˙æŃľéąź(æŕŤåęĆ +
  æĹŰ -)ïijŇ ä¡åå£ĚéążåŕźæŕŘäÿĂçğ■åŘŕèČ¡æČĚåĘţæčĂæ§ěäÿŇäÿĂäÿłäžď˙çL˙ŇïijŇåŘłæIJL˙å¡ŞåőČåŇ
  è£ŹäźŞæŸŕæIJňèŁĆçď˙žä¿Ňäÿ■ `_accept()` æŰźæşŢçŽĎçŻőçŽĎãĂĆ
  åőČçŻÿå¡ŞäžŐ_expect()æŰźæşŢçŽĎåijśåŇŰçL˙ĹæIJňïijŇåŽääÿžåęĆæđIJäÿĂäÿłåŇźéĚ■æL˙¿åĹřäžĘå
  ä¡ĘæŸŕåęĆæđIJæšąæL˙¿åĹřïijŇåőČäÿ■äijŽäžğçŤ§éŤŹèŕŕèĂŇæŸŕåŽđæżŽ(åĚĄèőÿåŘŐçż■çŽĎæčĂæ§
- åŕźäžŐæIJL˙éĞ■åď˙■éČĺåĹĘçŽĎèğĎåĹŹ(æŕŤåęĆåIJÍèğĎåĹŹèąÍè¿¿åijŔ `::= term {
  ('+'|'-') term }*` äÿ■)ïijŇ éĞ■åď˙■åŁÍä¡IJéĂŽè£ĞäÿĂäÿłwhileå¿łçŐŕæÍěåőđçŐřãĂĆ
  å¿łçŐŕäÿżä¡ŞäijŽæŤűéŽĘæĹŰåď˙ĎçŘĘæL˙ĂæIJL˙çŽĎéĞ■åď˙■åĚČçt˙ăçŽt˙åĹřæšąæIJL˙åĚűäžŰåĚČçt˙ă
- äÿĂæŮęæŢt˙äÿłèŕ■æşŢèğĎåĹŹåď˙ĎçŘĘåőŇæĹŘïijŇæŕŘäÿłæŰźæşŢäijŽè£ŤåŽđæ§Řçğ■çżŞæđIJçżŹè
  è£ŹåřśæŸŕåIJÍèğčæđŘè£ĞçÍŃäÿ■åĂijæŸŕæĂŐæăůçt˙ŕåŁăçŽĎåŐ§çŘĘãĂĆ
  æŕŤåęĆïijŇåIJÍèąÍè¿¿åijŔæśĆåĂijçÍŃåžŘäÿ■ïijŇè£ŤåŽđåĂijäžčèąÍèąÍè¿¿åijŔèğčæđŘåŘŐçŽĎéĆĺåĹĘç
  æIJĂåŘŐæL˙ĂæIJL˙åĂijäijŽåIJÍæIJĂéąűåśĆçŽĎèŕ■æşŢèğĎåĹŹæŰźæşŢäÿ■åŘĹázűètůæÍěãĂĆ

åř¡çőąåŘŚä¡ăæijŤçď˙žçŽĎæŸŕäÿĂäÿłçőĂå■ŢçŽĎä¿Ńå■ŘïijŇéĂŠå¡ŠäÿŇéŹ■èğčæđŘåŹĺåŔŕäžěçŤÍæÍěå
æŕŤåęĆïijŇPythonèŕ■èÍĂæIJňèžńářśæŸŕéĂŽè£ĞäÿĂäÿłéĂŠå¡ŠäÿŇéŹ■èğčæđŘåŹĺåŐżèğčéĞŁçŽĎãĂĆ
åęĆæđIJä¡ăářźæ■ď˙æĎ§åĚt˙èűčïijŇä¡ăåŔŕäžěéĂŽè£ĞæŞěçIJŃPythonæžŘçăĄæŰĞäžűGrammar/GrammaræÍ
çIJŃåőŇä¡ăäijŽåŘŚçŐřïijŇéĂŽè£ĞæL˙ŃåŁÍæŰźåijŔåŐżåőđçŐřäÿĂäÿłèğčæđŘåŹĺåĚűåőđäijŽæIJL˙å¿Ĺåď˙Žç

åĚűäÿ■äÿĂäÿłåśĂéŹŘåřśæŸŕåőČäžňäÿ■èČ¡èćńçŤÍäžŐåŇĚåŘńäżżä¡ŢåůęéĂŠå¡ŞçŽĎèŕ■æşŢèğĎåĹŹäÿ

```
items ::= items ',' item
    | item
```

äÿžäžĘè£ŹæăůåĄŽïijŇä¡ăåŔŕèČ¡äijŽåČŔäÿŇéÍćè£ŹæăůäĄ£çŤÍ `items()` æŰźæşŢïijŽ

```
def items(self):
    itemsval = self.items()
    if itemsval and self._accept(','):
        itemsval.append(self.item())
    else:
        itemsval = [ self.item() ]
```

åŤŕäÿĂçŽĎéŮőéćŸæŸŕè£ŹäÿłæŰźæşŢæăźæIJňäÿ■èČ¡åůěä¡IJïijŇäžŃåőđäÿŁïijŇåőČäijŽäžğçŤ§äÿĂäÿ

åĚşäžŐèŕ■æşŢèğĎåĹŹæIJňèžńä¡ăåŔŕèČ¡äź§äijŽçćřåĹřäÿĂäžŻæčŸæL’ŃçŽĎéŮőéćŸãĂĆ æŕŤåęĆïijŇä¡ăåŔŕèČ¡æČşç§ěéĄŞäÿŃéİćè£ŹäÿłçőĂå■ŢæL’ijèŕ■æşŢæŸŕåŘęèąĺè£řå¿Ůå¡Şïijž

```
expr ::= factor { ('+'|'-'|'*'|'/') factor }*

factor ::= '(' expression ')'
    | NUM
```

è£Źäÿłèŕ■æşŢçIJŃäÿŁåŐżæšąåŢěéŮőéćŸïijŇä¡ĘæŸŕåőČå■t’äÿ■èČ¡åŕ§ègL’åĹřæăĞåĞĘåŻŻåĹŹè£ŘçőŮ æŕŤåęĆïijŇèąĺè¿¿åijŔ "3 + 4 * 5" äijŽå¿ŮåĹř35èĂŇäÿ■æŸŕæIJ§æIJŻçŽĎ23. åĹĘåijĂä¡£çŤĺâĂİexprâĂİåŠŇâĂİtermâĂİèğĎåĹŹåŔŕäžěèőľ’åőČæ■čçąőçŽĎåůěä¡IJãĂĆ

åŕźäžŐåď■æİĆçŽĎèŕ■æşŢïijŇä¡ăæIJĂåě¡æŸŕéĂL’æŃľæ§ŘäÿłèğčæđŘåůěåĚůæŕŤåęĆPyParsingæĹŰèĂ äÿŃéİćæŸŕä¡£çŤĺPLYæİěéĞ■åĘŹèąĺè¿¿åijŔæśĆåĂijçĺŃåžŔçŽĎäžčçăĄïijž

```
from ply.lex import lex
from ply.yacc import yacc

# Token list
tokens = [ 'NUM', 'PLUS', 'MINUS', 'TIMES', 'DIVIDE', 'LPAREN',
↪'RPAREN' ]
# Ignored characters
t_ignore = ' \t\n'
# Token specifications (as regexs)
t_PLUS = r'\+'
t_MINUS = r'-'
t_TIMES = r'\*'
t_DIVIDE = r'/'
t_LPAREN = r'\('
t_RPAREN = r'\)'

# Token processing functions
def t_NUM(t):
    r'\d+'
    t.value = int(t.value)
    return t

# Error handler
def t_error(t):
    print('Bad character: {!r}'.format(t.value[0]))
    t.skip(1)
```

```
# Build the lexer
lexer = lex()

# Grammar rules and handler functions
def p_expr(p):
    '''
    expr : expr PLUS term
         | expr MINUS term
    '''
    if p[2] == '+':
        p[0] = p[1] + p[3]
    elif p[2] == '-':
        p[0] = p[1] - p[3]


def p_expr_term(p):
    '''
    expr : term
    '''
    p[0] = p[1]


def p_term(p):
    '''
    term : term TIMES factor
    | term DIVIDE factor
    '''
    if p[2] == '*':
        p[0] = p[1] * p[3]
    elif p[2] == '/':
        p[0] = p[1] / p[3]

def p_term_factor(p):
    '''
    term : factor
    '''
    p[0] = p[1]

def p_factor(p):
    '''
    factor : NUM
    '''
    p[0] = p[1]

def p_factor_group(p):
    '''
    factor : LPAREN expr RPAREN
    '''
    p[0] = p[2]
```

```
def p_error(p):
    print('Syntax error')

parser = yacc()
```

è£ŹäÿłçÍŃåžŔäÿ■ïijŇæĽĂæIJL’äžčçăĄéČ¡ä¡■äžŐäÿĂäÿłæŕŤè¿ČéńŸçŽĎåśĆæňąãĂĆä¡ååŔłéIJĂèęĄäÿ
èĂŇåőđéŹĚçŽĎè£Řèą Ňèğčæđ ŘåŹĺïijŇæŐěåŔŮäžď’çĽŇç■Ľ’ç■Ľ’åžŢåśĆåŁĺä¡IJåůšçżŔèćńåžŞåĞ¡æŢřåőđçĆ

äÿŃéİćæŸŕäÿĂäÿłæĂŐæăůä¡£çŤĺå¿ŮåĹřçŽĎèğčæđŘåŕźèśąçŽĎä¿Ńå■ŘïijŽ

```
>>> parser.parse('2')
2
>>> parser.parse('2+3')
5
>>> parser.parse('2+(3+4)*5')
37
>>>
```

åęĆæđIJä¡ăæČşåIJĺä¡ăçŽĎçijŰçÍŃè£ĞçÍŃäÿ■æİěçĆźæŇŚæĹŸåŠŇåĹžæ£ĂïijŇçijŰåĘŹèğčæđŘåŹĺåŠŇ
åĘ■æňąïijŇäÿĂæIJňçijŰèŕŚåŹÍçŽĎäźęçś■äijŽåŇĚåŘńå¿Ĺåď’ŽåžŢåśĆçŽĎçŘĘèőžç§ěèŕĘãĂĆäÿ■è£Ğå¿Ĺåď’
PythonèĞłåůšçŽĎastæĺąåİŮäź§åĂijå¿ŮåŐžçIJŃäÿĂäÿŃãĂĆ

4.20 2.20 å■ŮèŁĆå■Ůçňęäÿšäÿ ŁçŽĎå■ŮçňęäÿšæŞ■ä¡IJ

éŮőéćŸ

ä¡ăæČşåIJĺå■ŮèŁĆå■Ůçňęäÿšäÿ ŁæĽğèąŇæŹőéĂŽçŽĎæŰĞæIJňæŞ■ä¡IJ(æŕŤåęĆçğżéŹď’ijjŇæŘIJçť’ćå

èğčåĘşæŰźæąĹ

å■ŮèŁĆå■ŮçňęäÿšåŘŇæăůäź§æŤŕæŇĄåď’ğéČĺåĹĘåŠŇæŰĞæIJňå■Ůçňęäÿšäÿ ĂæăůçŽĎåĘĚç¡őæŞ■ä¡

```
>>> data = b'Hello World'
>>> data[0:5]
b'Hello'
>>> data.startswith(b'Hello')
True
>>> data.split()
[b'Hello', b'World']
>>> data.replace(b'Hello', b'Hello Cruel')
b'Hello Cruel World'
>>>
```

è£ŹäžŻæŞ■ä¡IJåŘŇæăůäź§éĂĆçŤĺäžŐå■ŮèŁĆæŢřçżĎãĂĆæŕŤåęĆïijŽ

```
>>> data = bytearray(b'Hello World')
>>> data[0:5]
bytearray(b'Hello')
```

```
>>> data.startswith(b'Hello')
True
>>> data.split()
[bytearray(b'Hello'), bytearray(b'World')]
>>> data.replace(b'Hello', b'Hello Cruel')
bytearray(b'Hello Cruel World')
>>>
```

ä¡ăåŔŕäžěä¡£çŤĺæ■čåĹŹèąĺè¿¿åijŔåŇźéĚ■å■ŮèŁĆå■ŮçňęäÿšïijŇä¡ĘæŸŕæ■čåĹŹèąĺè¿¿åijŔæIJňèžńå£Ě

```
>>>
>>> data = b'FOO:BAR,SPAM'
>>> import re
>>> re.split('[:,]',data)
Traceback (most recent call last):
File "<stdin>", line 1, in <module>
File "/usr/local/lib/python3.3/re.py", line 191, in split
return _compile(pattern, flags).split(string, maxsplit)
TypeError: can't use a string pattern on a bytes-like object
>>> re.split(b'[:,]',data) # Notice: pattern as bytes
[b'FOO', b'BAR', b'SPAM']
>>>
```

èőÍèőž

åď ğåď ŽæŢřæČĚåĘţäÿŃïijŇåIJĺæŰĞæIJňå■Ůçňęäÿšäÿ ŁçŽĎæŞ■ä¡IJåİĞåŔŕçŤĺäžŐå■ŮèŁĆå■Ůçňęäÿš
çĎűčèĂŇïijŇè£ŹéĞŇäź§æIJL’äÿĂäžŻéIJĂèęĄæşĺæĎŔçŽĎäÿ■åŘŇçĆźãĂĆéęŰåĚĹïijŇå■ŮèŁĆå■Ůçňęäÿšç

```
>>> a = 'Hello World' # Text string
>>> a[0]
'H'
>>> a[1]
'e'
>>> b = b'Hello World' # Byte string
>>> b[0]
72
>>> b[1]
101
>>>
```

è£Źçğ■èŕ■äźL’äÿŁçŽĎåŇžåĹńäijŽåŕźäžŐåď ĎçŘĘéİćåŘŠå■ŮèŁĆçŽĎå■ŮçňęæŢřæ■őæIJL’å¡śåŞ■ãĂĆ

çňňäžŇçĆźïijŇå■ŮèŁĆå■Ůçňęäÿšäÿ■äijŽæŔŘä¿ŻäÿĂäÿłç¿ŐèğĆçŽĎå■Ůçňęäÿšèąĺçd’žïijŇäź§äÿ■èČ¡å

```
>>> s = b'Hello World'
>>> print(s)
b'Hello World' # Observe b'...'
>>> print(s.decode('ascii'))
Hello World
>>>
```

çśżäijijçŽĎïijŇäź§äÿ■å■ŸåIJÍäżżä¡ŢéĂĆçŤÍäžŐå■ŮèŁĆå■Ůçňęäÿšç ŽĎæäijåijŔåŇŰæŞ■ä¡IJïijŽ

```
>>> b'%10s %10d %10.2f' % (b'ACME', 100, 490.1)
Traceback (most recent call last):
    File "<stdin>", line 1, in <module>
TypeError: unsupported operand type(s) for %: 'bytes' and 'tuple'
>>> b'{} {} {}'.format(b'ACME', 100, 490.1)
Traceback (most recent call last):
    File "<stdin>", line 1, in <module>
AttributeError: 'bytes' object has no attribute 'format'
>>>
```

åęĆæđIJä¡ăæČşæäijåijŔåŇŰå■ŮèŁĆå■ŮçňęäÿšïijŇä¡åå¿ŮåĚĹä¡£çŤÍæăĞåĞĘçŽĎæŰĞæIJňå■Ůçňęäÿš

```
>>> '{:10s} {:10d} {:10.2f}'.format('ACME', 100, 490.1).encode(
 ↪'ascii')
b'ACME 100 490.10'
>>>
```

æIJĂåŘŐéIJĂèęĄæşÍæĎŔçŽĎæŸŕïijŇä¡£çŤÍå■ŮèŁĆå■Ůçňęäÿšå ŔŕèČ¡äijŽæŤźåŔŸäÿĂäžŻæŞ■ä¡IJçŽÌ
æŕŤåęĆïijŇåęĆæđIJä¡ää¡£çŤÍäÿĂäÿłçijŰçăĄäÿžå■ŮèŁĆçŽĎæŰĞäžűåŘ■ïijŇèĂŇäÿ■æŸŕäÿĂäÿłæŹőéĂŽçŽ

```
>>> # Write a UTF-8 filename
>>> with open('jalape\xf1o.txt', 'w') as f:
...     f.write('spicy')
...
>>> # Get a directory listing
>>> import os
>>> os.listdir('.') # Text string (names are decoded)
['jalapeÃ±o.txt']
>>> os.listdir(b'.') # Byte string (names left as bytes)
[b'jalapen\xcc\x83o.txt']
>>>
```

æşÍæĎŔä¿Ńå■Řäÿ■çŽĎæIJĂåŘŐéČÍåĹĘçżŹçŻőå¡ŢåŘ■äijăéĂŠäÿĂäÿłå■ŮèŁĆå■ŮçňęäÿšæŸŕæĂŐæă
åIJÍçŻőå¡Ţäÿ■çŽĎæŰĞäžűåŘ■åŇĚåŘńåŐ§ågŃçŽĎUTF-8çijŰçăĄãĂĆ
åŔĆèĂČ5.15ařŔèŁĆèŐůåŔŰæŻť'åď'ŽæŰĞäžűåŘ■çŻÿåĚşçŽĎåĘĚåőźãĂĆ

æIJĂåŘŐæŔŘäÿĂçĆźïijŇäÿĂäžŻçÍŃåžŔåŚŸäÿžäžĘæŔŘå■ĞçÍŃåžŔæĽğèąŇçŽĎéĂ§åžęäijŽåĂ¿åŘŚäž
ař¡çőąæŞ■ä¡IJå■ŮèŁĆå■ŮçňęäÿšçąőåőđäijŽæŕŤæŰĞæIJňæŻť'åŁăéńŸæŢĹ(åŽăäÿžåď'ĎçŘĘæŰĞæIJňåŽžæI
è£Źæăůå ĄŽéĂŽåÿÿäijŽåŕijèĞť'éİđåÿÿæİĆäźśçŽĎäžčçăĄãĂĆä¡ääijŽçżŔåÿÿåŘŚçŐŕå■ŮèŁĆå■Ůçňęäÿšåźűäÿ
åźűäÿŤä¡ăè£Ÿå¿ŮæĽŃåŁĺåď'ĎçŘĘæĽĂæIJĽçŽĎçijŰçăĄ/èğčçăĄæŞ■ä¡IJãĂĆ
åİęçŹ¡ëőšïijŇåęĆæđIJä¡ääIJĺåď'ĎçŘĘæŰĞæIJňçŽĎèŕÏïijŇářśçŻť'æŐëåIJÍçÍŃåžŔäÿ■ä¡£çŤÍæŹőéĂŽçŽĎæŰĆ

5 çňňäÿĽçńäïijŽæŢřå■ŮæŮěæIJ§åŠŇæŮűéŮť

åIJÍPythonäÿ■æĽğèąŇæŢť'æŢřåŠŇæţőçĆźæŢřçŽĎæŢřå■ęè£ŘçőŮæŮűå¿ĹçőĂå■ŢçŽĎãĂĆ
ař¡çőąåęĆæ■ď'ïijŇåęĆæđIJä¡ăéIJĂèęĄæĽğèąŇåĹĘæŢřãĂĄæŢřçżĎæĹŰèĂĚæŸŕæŮěæIJ§åŠŇæŮűéŮť'çŽĎ

æIJňçńäéŻĘäÿ■èőÍèőžçŽĎåřśæŸŕè£ŹäžŻäÿżéćŸãĂĆ

Contents:

5.1 3.1 æŢřå■ŮçŽĎåŻŻèĹ■äžŤåĚě

éŮőécŸ

ä¡ăæČşåŕźæţőçĆźæŢřæĽğèąŇæŇĞåőŽçš¿åžęçŽĎèĹ■åĚěè£ŘçőŮãĂĆ

èğčåĘşæŰźæąĹ

åŕźäžŐçőĂå■ŢçŽĎèĹ■åĚěè£ŘçőŮïijŇä¡£çŤĺåĘĚç¡őçŽĎ `round(value, ndigits)` åĞ¡æŢřå■şåŔŕãĂĆærŤåęĆïijŽ

```
>>> round(1.23, 1)
1.2
>>> round(1.27, 1)
1.3
>>> round(-1.27, 1)
-1.3
>>> round(1.25361,3)
1.254
>>>
```

å¡ŞäÿĂäÿłåĂijåĹŽåě¡åIJÍäÿď äÿłè¿źçŢŇçŽĎäÿ■éŮť çŽĎæŮűåĂŹïijŇ `round` åĞ¡æŢřè£ŤåŻđçężåőČæIJĂè£ŚçŽĎåĄűæŢřãĂĆ äź§åŕśæŸŕèŕťïijŇåŕź1.5æĹŰèĂĚ2.5çŽĎèĹ■åĚěè£ŘçőŮéČ¡

äijăçżŹ `round()` åĞ¡æŢřçŽĎ `ndigits` åŔĆæŢřåŔŕäžěæŸŕèť§æŢřïijŇè£Źçğ■æČĚåĘţäÿŃïijŇèĹ■åĚěè£ŘçőŮäijŽä¡IJçŤĺåIJĺå■Ąä¡■ãĂĄçŹ¿ä¡■ãĂĄå■Čä¡■ç■Ľäÿ£éÍćãĂĆærŤåęĆïijŽ

```
>>> a = 1627731
>>> round(a, -1)
1627730
>>> round(a, -2)
1627700
>>> round(a, -3)
1628000
>>>
```

èőÍèőž

äÿ■èęĄåřĘèĹ■åĚěåŠŇæăijåijŔåŇŰè¿ŞåĞžæŘđæůûæůĘäžĘãĂĆ åęĆæđIJä¡ăçŽĎçŻőçŽĎåŔłæŸŕçőĂå■ŢçŽĎè¿ŞåĞžäÿĂåőŽåő¡åžęçŽĎæŢřïijŇä¡ăäÿ■éIJĂèęĄä¡£çŤÍ `round()` åĞ¡æŢřãĂĆ èĂŇäžĚäžĚåŔłéIJĂèęĄåIJÍæăijåijŔåŇŰçŽĎæŮűåĂŹæŇĞåőŽçš¿åžęå■şåŔŕãĂĆærŤ

```
>>> x = 1.23456
>>> format(x, '0.2f')
'1.23'
>>> format(x, '0.3f')
'1.235'
>>> 'value is {:0.3f}'.format(x)
'value is 1.235'
>>>
```

åŘŇæăůïijŇäÿ■èęĄèŕŢçİĂåŐżèĹ■åĚěæţőçĆźåĂijæİěâĂİä£őæ■čâĂİèąĺéİćäÿŁçIJŃèţůæİěæ■čçąőçŽĎéŮ

```
>>> a = 2.1
>>> b = 4.2
>>> c = a + b
>>> c
6.300000000000001
>>> c = round(c, 2) # "Fix" result (???)
>>> c
6.3
>>>
```

åŕźäžŐåď ğåď ŽæŢřä¡£çŤĺåĹřæţőçĆźçŽĎçĺŃåžŔïijŇæšąæIJL’å£ĚèęĄäź§äÿ■æŐÍè■Řè£ŹæăůåĄŽãĂĆ
åř¡çőąåIJÍèőąçőŮçŽĎæŮűůåĂŹäijŽæIJL’äÿĂçĆźçĆźåřŔçŽĎèŕřåůőïijŇä¡ĘæŸŕè£ŹäžŻåřŔçŽĎèŕřåůőæŸŕèČ¡è
åęĆæđIJäÿ■èČ¡åĚĄèőÿè£ŹæăůçŽĎåřŔèŕřåůő(æŕŤåęĆæűĽ’åŔŁåĹřéĞŚèđ■éćĘå§§)ïijŇéĆčäźĹåřšå¿ŮèĂČèŹ
`decimal` æÍąåİŮäžĘïijŇäÿŃäÿĂèŁĆæĹŚäžňäijŽèŕęçżĘèŐÍèőžãĂĆ

5.2 3.2 æĽ’ğèąŇçš¿çąőçŽĎæţőçĆźæŢřè£ŘçőŮ

éŮőécŸ

ä¡ăéIJĂèęĄåŕźæţőçĆźæŢřæL’ğèąŇçš¿çąőçŽĎèőąçőŮæŞ■ä¡IJïijŇåźűäÿŤäÿ■åÿŃæIJŻæIJL’äżżä¡ŢåřŔèŕŕ

èğčåĘşæŰźæąĹ

æţőçĆźæŢřçŽĎäÿĂäÿłæŹőéĄ■éŮőécŸæŸŕåőČäžňåźűäÿ■èČ¡çš¿çąőçŽĎèąĺçď žå■Ąè£ŻåĹűæŢřãĂĆ
åźűäÿŤïijŇå■şä¡£æŸŕæIJĂçőĂå■ŢçŽĎæŢřå■ęè£ŘçőŮäź§äijŽäžğçŤ§åřŔçŽĎèŕřåůőïijŇæŕŤåęĆïijŽ

```
>>> a = 4.2
>>> b = 2.1
>>> a + b
6.300000000000001
>>> (a + b) == 6.3
False
>>>
```

è£ŹäžŻéŤŹèŕŕæŸŕçŤśåžŢåśĆCPUåŠŇIEEE 754æăĞåĞĘéĂŽè£ĞèĞłåůśçŽĎæţőçĆźå■Ţä¡■åŐżæL’ğèąŇ
çŤśäžŐPythonçŽĎæţőçĆźæŢřæ■őçśżåđŃä¡£çŤĺåžŢåśĆèąĺçď žå■ŸåĆĺæŢřæ■őïijŇåŽăæ■d’ä¡ăęšąåŁđæşŢåŐ

åęĆædIJä¡ăæČşæŻťˇåŁăçš¿çąő(åźűèČ¡åőźå£■äÿĂåőŽçŽĎæĂğèČ¡æ■§èĂŮ)ïijŇä¡ăåŔŕäžěä¡£çŤÍ decimal æÍąåİŮïijŽ

```
>>> from decimal import Decimal
>>> a = Decimal('4.2')
>>> b = Decimal('2.1')
>>> a + b
Decimal('6.3')
>>> print(a + b)
6.3
>>> (a + b) == Decimal('6.3')
True
```

åĹİçIJŃèţůæİěïijŇäÿŁéİćçŽĎäžčçăĄåě¡åČŔæIJL’çĆźåěĞæĂłïijŇæŕŤåęĆæĹŚäžňçŤĺå■ŮçňęäÿšæİěèąÍçơ
çĎűèĂŇïijŇ Decimal åŕźèśąäijŽåČŔæŹőéĂŽæţőçĆźæŢřäÿĂæăůçŽĎåůěä¡IJ(æŤŕæŇĄæL’ĂæIJL’çŽĎåÿÿç
åęĆædIJä¡ăæL’Şå■řáőČäžňæĹŰèĂĚåIJÍå■ŮçňęäÿšæăijåijŔåŇŰåĞ¡æŢřäÿ■ä¡£çŤĺáőČäžňïijŇçIJŃèţůæİěèů§a

decimal æÍąåİŮçŽĎäÿĂäÿłäÿżèęĄçL’źå¿ĄæŸŕåĚĄèőÿä¡ăæŐğåĹűèőąçőŮçŽĎæŕŔäÿĂæŰźéİćïijŇåŇ
äÿžäžEè£ŹæăůåĄŽïijŇä¡ăåĚĹå¿ŮåĹŻåžžäÿĂäÿłæIJňåIJřäÿŁäÿŃæŰĞåźűæŻťˇæŤźáőČçŽĎèő¿ç¡őïijŇæŕŤåęĆ

```
>>> from decimal import localcontext
>>> a = Decimal('1.3')
>>> b = Decimal('1.7')
>>> print(a / b)
0.76470588235294117647058823 53
>>> with localcontext() as ctx:
...     ctx.prec = 3
...     print(a / b)
...
0.765
>>> with localcontext() as ctx:
...     ctx.prec = 50
...     print(a / b)
...
0.76470588235294117647058823529411764705882352941176
>>>
```

èőÍèőž

decimal æÍąåİŮåőđçŐřäžĘIBMçŽĎâĂİéĂŽçŤÍåřŔæŢřè£ŘçőŮèğĎèŇČâĂİãĂĆäÿ■çŤÍèŕťˇïijŇæIJL’å¿

PythonæŰřæL’ŃäijŽåĂ¿åŘŠäžŐä¡£çŤÍ decimal æÍąåİŮæİěåď’ĎçŘĘæţőçĆźæŢřçŽĎçš¿çąőè£ŘçőŮãĂ
çĎűèĂŇïijŇåĚĹçŘĘèğčä¡ăçŽĎåžŤçŤÍçÍŃåžŔçŻőçŽĎæŸŕéİđåÿÿéĞ■èęĄçŽĎãĂĆ
åęĆædIJä¡ăæŸŕåIJÍåĄŽçğŠå■ęèőąçőŮæĹŰåůěçÍŃécĘå§§çŽĎèőąçőŮãĂĄçŤţèĎŠçżŸåŻ¿ïijŇæĹŰèĂĚæŸŕç
éĆčäźĹä¡£çŤÍæŹőéĂŽçŽĎæţőçĆźçśžåđŇæŸŕæŕŤè¿ČæŹőéĄ■çŽĎåĄŽæşŢãĂĆ
åĚűäÿ■äÿĂäÿłåŐ§åŻăæŸŕïijŇåIJÍçIJ§åőđäÿŰçŢŃäÿ■å¿ĹåŕŠäijŽèęĄæśĆçš¿çąőåĽřæŹőéĂŽæţőçĆźæŢřèČ¡æ
åŽăæ■ď’ïijŇèőąçőŮè£ĞçÍŃäÿ■çŽĎéĆčäźĹäÿĂçĆźçĆźçŽĎèŕŕåůőæŸŕèćńåĚĄèőÿçŽĎãĂĆ
çňňäžŇçĆźåřśæŸŕïijŇåŐ§çŤ§çŽĎæţőçĆźæŢřèőąçőŮèęĄå£ńçŽĎåď’Ž-
æIJL’æŰűåĂŹä¡ăåIJÍæL’ğèąŇåď’ğéĞŔè£ŘçőŮçŽĎæŰűåĂŹéĂ§åžęäź§æŸŕéİđåÿÿéĞ■èęĄçŽĎãĂĆ

å■şä¿£åęĆæ■ď'ïijŇä¡ăå■ť'äÿ■èČ¡åőŇåĚĺå£¡çŢčèŕŕåůőãĂĆæŢřå■ęåőűèŁśäžĘåď'ğéĞŔæŮűéŮť'åŐżçăŤçĺ
ä¡ăäź§å¿ŮæşÍæĎŔäÿŃåĞŔæşŢåĹăéŹď'äžěåŔŁåď'ğæŢřåŠŇåřŔæŢřçŽĎåŁăåĹĘè£ŘçőŮæĽ'ĂåÿęæİěçŽĎå¡šå

```
>>> nums = [1.23e+18, 1, -1.23e+18]
>>> sum(nums) # Notice how 1 disappears
0.0
>>>
```

äÿŁéİćçŽĎéŤŹèŕŕåŔŕäžěåĹl'çŤÍ `math.fsum()` æĽ'ĂæŔŘä¿ŻçŽĎæŻť'çš¿çąőèőąçőŮèČ¡åŁŻæİěèğčåĘ

```
>>> import math
>>> math.fsum(nums)
1.0
>>>
```

çĎűèĂŇïijŇåŕźäžŐåĚűäžŰçŽĎçőŮæşŢïijŇä¡ääžŤèŕěäżŤçżEçăŤçl'űåőČåźűçŘĘèğčåőČçŽĎèŕŕåůőäžğçŤ

æĂżçŽĎæİěèŕť'ïijŇ `decimal` æÍąåİŮäÿżèęĄçŤĺåIJÍæűĽ'åŔŁåĽřéĞŚèđ■çŽĎécĘå§§ãĂĆ
åIJÍè£ŹçśżçÍŃåžŘäÿ■ïijŇåŞłæĂŢæŸŕäÿĂçĆźåřŔåřŘçŽĎèŕŕåůőåIJÍèőąçőŮè£ĞçÍŃäÿ■èŢŞåžűéČ¡æŸŕäÿ■åĚA
åŽăæ■ď'ïijŇ `decimal` æÍąåİŮäÿžèğčåĘşè£ŹçśżéŮőécŸæŔŘä¿ŻäžĘæŰźæşŢãĂĆ
å¡ŞPythonåŠŇæŢřæ■őåžŞæĽ'Şäžď'éĄŞçŽĎæŮűåĂŹäź§éĂŽåÿÿäijŽéĄĞåĹř `Decimal`
åŕźèśąïijŇåźűäÿŤïijŇéĂŽåÿÿäź§æŸŕåIJÍåď'ĎçŘĘéĞŚèđ■æŢřæ■őçŽĎæŮűåĂŹãĂĆ

5.3 3.3 æŢřå■ŮçŽĎæăijåijŔåŇŰè¿ŞåĞž

éŮőécŸ

ä¡ăéIJĂèęĄåřĘæŢřå■ŮæăijåijŕåŇŰåŘŐè¿ŞåĞžïijŇåźűæŐğåĹűæŢřå■ŮçŽĎä¡■æŢřãĂĄåŕźé¡ŘãĂĄå■Č

èğčåĘşæŰźæąĹ

æăijåijŔåŇŰè¿ŞåĞžå■ŢäÿłæŢřå■ŮçŽĎæŮűåĂŹïijŇåŔŕäžěä¡£çŤĺåĘĚç¡őçŽĎ
`format()` åĞ¡æŢřïijŇærŤåęĆïijŽ

```
>>> x = 1234.56789

>>> # Two decimal places of accuracy
>>> format(x, '0.2f')
'1234.57'

>>> # Right justified in 10 chars, one-digit accuracy
>>> format(x, '>10.1f')
'    1234.6'

>>> # Left justified
>>> format(x, '<10.1f')
'1234.6    '
```

```
>>> # Centered
>>> format(x, '^10.1f')
'  1234.6  '

>>> # Inclusion of thousands separator
>>> format(x, ',')
'1,234.56789'
>>> format(x, '0,.1f')
'1,234.6'
>>>
```

åęĆædIJä¡ăæČşä¡£çŤĺæŇĞæŢřèőřæşŢïijŇářĘfæŤźæĹŘeæĹŰèĂĚE(åŔŰåĘşäžŐæŇĞæŢřè¿ŞåĞžçŽĎåd

```
>>> format(x, 'e')
'1.234568e+03'
>>> format(x, '0.2E')
'1.23E+03'
>>>
```

åŘŇæŮűæŇĞåőŽåő¡åžęåŠŇçš¿åžęçŽĎäÿĂèĹňå¡ćåijŔæŸŕ '[<>^]?width[,]?(.digits)?' ïijŇ åĚűäÿ■ width åŠŇ digits äÿžæŢťæŢřïijŇïij§äžčèąĺåŔŕéĂL'éČĺåĹĘãĂĆ åŘŇæăůçŽĎæäijåijŔäź§èćńçŤĺåIJĺå■Ůçňęäÿšç ŽĎ format() æŰźæşŢäÿ■ãĂĆærŤåęĆïijŽ

```
>>> 'The value is {:0,.2f}'.format(x)
'The value is 1,234.57'
>>>
```

èőĺèőž

æŢřå■Ůæäijåijŕ åŇŰè¿ŞåĞžéĂŽåÿÿæŸŕærŤè¿ČçőĂå■ŢçŽĎãĂĆäÿŁéĺćæijŤçď žçŽĎæŁĂæIJŕåŘŇæŮű decimal æĺąåİŮäÿ■çŽĎ Decimal æŢřå■Ůåŕźèśąã ĂĆ

å¡ŞæŇĞåőŽæŢřå■ŮçŽĎä¡■æŢřåŘŐïijŇçžŞæđIJåĂijäijŽæăźæ■ő round() åĞ¡æŢřåŘŇæăůçŽĎèğĎåĹŹè£ŽèąŇåŽŽèĹ■äžŤåĚěåŘŐè£ŤåŽđãĂĆærŤåęĆïijŽ

```
>>> x
1234.56789
>>> format(x, '0.1f')
'1234.6'
>>> format(-x, '0.1f')
'-1234.6'
>>>
```

åŇĚåŘńå■Čä¡■çňęçŽĎæäijåijŔåŇŰèů§æIJňåIJřåŇŰæšąæIJL'åĚşçşžãĂĆ åęĆædIJä¡ăéIJĂèęĄæăźæ■őåIJřåŇžæİěæŸ¿çď žå■Čä¡■çňęïijŇä¡ăéIJĂèęĄèĞłåůśåŐżèřČæ§ěäÿŃ locale æĺąåİŮäÿ■çŽĎåĞ¡æŢřäžĘãĂĆ ä¡ääŘŇæăůäź§åŔŕäżěä¡£çŤĺå■Ůçňęäÿšç ŽĎ translate() æŰźæşŢæİěäžď'æ■ćå■Čä¡■çňęãĂĆærŤåęĆïijŽ

```
>>> swap_separators = { ord('.'):',', ord(','):'.' }
>>> format(x, ',').translate(swap_separators)
'1.234,56789'
>>>
```

åIJÍå¿Ĺåď ŽPythonäžčçăĄäÿ■äijŽçIJŃåĹřä¡£çŤÍ%æİěæäijåijŔåŇŰæŢřå■ŮçŽĎïijŇæŕŤåęĆïijŽ

```
>>> '%0.2f' % x
'1234.57'
>>> '%10.1f' % x
'    1234.6'
>>> '%-10.1f' % x
'1234.6    '
>>>
```

è£Źçğ■æäijåijŔåŇŰæŰźæşŢäź§æŸŕåŔŕèąŇçŽĎïijŇäÿ■è£ĞæŕŤæŻťåŁäåĚĹè£ŻçŽĎ `format()` èęĄåůőäÿĂçĆźãĂĆ æŕŤåęĆïijŇåIJÍä¡£çŤÍ%æŞ■ä¡IJçňęæäijåijŔåŇŰæŢřå■ŮçŽĎæŮűåĂŹïijŇäÿ

5.4 3.4 äžŇåĚńå■ĄåĚ■è£ŻåĹűæŢťæŢř

éŮőécŸ

ä¡ăéIJĂèęĄè¡ňæ■ćæĹŰèĂĚè¿ŞåĞžä¡£çŤÍäžŇè£ŻåĹűïijŇåĚńè£ŻåĹűæĹŰå■ĄåĚ■è£ŻåĹűèąÍçď žçŽĎæŢ

èğčåĘşæŰźæąĹ

äÿžäžĘåřĘæŢťæŢřè¡ňæ■ćäÿžäžŇè£ŻåĹűãĂĄåĚńè£ŻåĹűæĹŰå■ĄåĚ■è£ŻåĹűçŽĎæŰĞæIJňäÿšïijŇ åŔŕäžěåĹĘåĹńä¡£çŤÍ `bin()` , `oct()` æĹŰ `hex()` åĞ¡æŢřïijŽ

```
>>> x = 1234
>>> bin(x)
'0b10011010010'
>>> oct(x)
'0o2322'
>>> hex(x)
'0x4d2'
>>>
```

åŔęåď ŰïijŇåęĆæđIJä¡ääÿ■æČşè¿ŞåĞž `0b` , `0o` æĹŰèĂĚ `0x` çŽĎåL’■çijĂçŽĎèŕÍïijŇåŔŕäžěä¡£çŤÍ `format()` åĞ¡æŢřãĂĆæŕŤåęĆïijŽ

```
>>> format(x, 'b')
'10011010010'
>>> format(x, 'o')
'2322'
>>> format(x, 'x')
'4d2'
>>>
```

æŢťæŢřæŸŕæIJL’çňęåŔůçŽĎïijŇæL’Ăäžěåę Ćæđ IJä¡ăåIJĺåď’ĎçŘĘèť§æŢřçŽĎèŕİïijŇè¿ŞåĞžçżŞæđIJäij

```
>>> x = -1234
>>> format(x, 'b')
'-10011010010'
>>> format(x, 'x')
'-4d2'
>>>
```

åę ĆæđIJä¡ăæČşäžğçŤ§äÿĂäÿłæŮăçňęåŔůåĂijïijŇä¡ăéIJĂèęĄåćđåŁääÿĂäÿłæŇĞçď’žæIJĂåď’ğä¡■éŢ£åž

```
>>> x = -1234
>>> format(2**32 + x, 'b')
'11111111111111111111101100101110'
>>> format(2**32 + x, 'x')
'fffffb2e'
>>>
```

äÿžäžĘäžěäÿ■åŘŇçŽĎè£ŻåĹűè¡ňæ■ćæŢťæŢřå■ŮçňęäÿšïijŇçőĂå■ŢçŽĎä¡£çŤĺåÿęæIJL’è£ŻåĹűçŽĎ `int()` åĞ¡æŢřå■şåŔŕïijŽ

```
>>> int('4d2', 16)
1234
>>> int('10011010010', 2)
1234
>>>
```

èőĺèőž

åď’ğåď’ŽæŢřæČĚåĘţäÿŃåď’ĎçŘĘäžŇè£ŻåĹűãĂĄåĚńè£ŻåĹűåŠŇå■ĄåĚ■è£ŻåĹűæŢťæŢřæŸŕå¿ĹçőĂå
åŘłèęĄèőřä¡Ŕè£ŹäžŻè¡ňæ■ćåśđäžŐæŢťæŢřåŠŇåĚűåŕźåžŤçŽĎæŰĞæIJňèąĺçď’žäźŃéŮťçŽĎè¡ňæ■ćå■şåŔŕã

æIJĂåŘŐïijŇä¡£çŤĺåĚńè£ŻåĹűçŽĎçÍŃåžŔåŚŸæIJL’äÿĂçĆźéIJĂèęĄæşÍæĎŔäÿŃãĂĆ
PythonæŇĞåőŽåĚńè£ŻåĹűæŢřçŽĎèŕ■æşŢèů§åĚűäžŰèŕ■èÍĂçÍ■æIJL’äÿ■åŘŇãĂĆæŕŤåęĆïijŇåęĆæđIJä¡ăåČ

```
>>> import os
>>> os.chmod('script.py', 0755)
    File "<stdin>", line 1
        os.chmod('script.py', 0755)
                              ^
SyntaxError: invalid token
>>>
```

éIJĂçąőä£ÍåĚńè£ŻåĹűæŢřçŽĎåL’■çijĂæŸŕ `0o` ïijŇårśåČŔäÿŃéÍćè£Źæăůïij Ž

```
>>> os.chmod('script.py', 0o755)
>>>
```

5.5 3.5 å■ÙèŁĆåĹřåď ğæŢťæŢřçŽĎæĽŞåŇĚäÿŐèğčåŇĚ

éŮőécŸ

ä¡ăæIJL’äÿĂäÿłå■ÙèŁĆå■ŮçňęäÿšåźűæČşåřĘåőČèğčåŐŃæĹŘäÿĂäÿłæŢť æŢřăĂĆæĹŰèĂĚïijŇä¡ăéIJĂ

èğčåĘşæŰźæąĹ

åĄĞèő¿ä¡ăçŽĎçÍŃåžŔéIJĂèęĄåď ĎçŘĘäÿĂäÿłæŃěæIJL’128ä¡■éŢ£çŽĎ16äÿłåĚČçt’ăçŽĎå■ÙèŁĆå■Ůç

```
data = b'\x00\x124V\x00x\x90\xab\x00\xcd\xef\x01\x00#\x004'
```

äÿžäžĘåřĘbytesèğčæđŘäÿžæŢť æŢřïijŇä¡£çŤÍ `int.from_bytes()` æŰźæşŢïijŇåźűåČŘäÿŃéÍćè£ŹæăůæŇĞåőŽå■ÙèŁĆéąžåžŔïijŽ

```
>>> len(data)
16
>>> int.from_bytes(data, 'little')
69120565665751139577663547927094891008
>>> int.from_bytes(data, 'big')
94522842520747284487117727783387188
>>>
```

äÿžäžĘåřĘäÿĂäÿłåď ğæŢť æŢřè¡ňæ■ćäÿžäÿĂäÿłå■ÙèŁĆå■ŮçňęäÿšïijŇä¡£çŤÍ `int.to_bytes()` æŰźæşŢïijŇåźűåČŘäÿŃéÍćè£ŹæăůæŇĞåőŽå■ÙèŁĆæŢřåŠŇå■ÙèŁĆéąžåžŔïijŽ

```
>>> x = 94522842520747284487117727783387188
>>> x.to_bytes(16, 'big')
b'\x00\x124V\x00x\x90\xab\x00\xcd\xef\x01\x00#\x004'
>>> x.to_bytes(16, 'little')
b'4\x00#\x00\x01\xef\xcd\x00\xab\x90x\x00V4\x12\x00'
>>>
```

èőÍèőž

åď ğæŢť æŢřåŠŇå■ÙèŁĆå■Ůçňęäÿšäź ŃéŮť çŽĎè¡ňæ■ćæŞ■ä¡IJåźűäÿ■åÿÿèğĄãĂĆ çĎűèĂŇïijŇåIJÍäÿĂäžŽåžŤçŤÍécĘå§§æIJL’æŮűåĂŹäź§äijŽåĞžçŐřïijŇæŕŤåęĆåŕĘçăĄå■ęæĹŰèĂĚç¡ŚçżIJã ä¿ŃåęĆïijŇIPv6ç¡ŚçżIJåIJřåİĂä¡£çŤÍäÿĂäÿł128ä¡■çŽĎæŢť æŢřèąÍçď žãĂĆ åęĆæđIJä¡ăèęĄäžŐäÿĂäÿłæŢřæ■őèőřå¡Ţäÿ■æŔŘåŔŰè£ŹæăůçŽĎåĂijçŽĎæŮűåĂŹïijŇä¡ăåřśäijŽéÍćåŕźè£Źa

ä¡IJäÿžäÿĂçğ■æŻ£äžčæŰźæąĹïijŇä¡ăåŔŕèČ¡æČşä¡£çŤÍ6.11åřŔèŁĆäÿ■æL’ĂäżŃçż■çŽĎ `struct` æÍąåİŮæİèèğčåŐŃå■ÙèŁĆãĂĆ è£ŹæăůäźŝèąŇå¿ŮéĂŽïijŇäÿ■è£ĞåĹl’çŤÍ `struct` æÍąåİŮæİèèğčåŐŃåŕźäžŐæŢť æŢřçŽĎåď ğåŕÆŸŕæIJL’éŹŘåĹűçŽĎãĂĆ åŻăæ■d’ïijŇä¡ăåŔŕèČ¡æČşèğčåŐŃåď Žäÿłå■ÙèŁĆäÿšåźűåřĘçżŞædIJåŘĹåźűäÿžæIJĂçżĹçŽĎçżŞædIJïijŇåřś

```
>>> data
b'\x00\x124V\x00x\x90\xab\x00\xcd\xef\x01\x00#\x004'
>>> import struct
```

```
>>> hi, lo = struct.unpack('>QQ', data)
>>> (hi << 64) + lo
94522842520747284487117727783387188
>>>
```

å■ÙèŁĆéąžåžŔèğĎåĹŹ(littleæĹŰbig)äżĚäżĚæŇĞåőŽäžĘæđĎåżžæŢťæŢřæŮűçŽĎå■ÙèŁĆçŽĎä¡Őä¡■æĹŚäžňäżŐäÿŃéİćçš¿å£ČæđĎéĂäçŽĎ16è£ŻåĹűæŢřçŽĎèąÍçď žäÿ■åŔřäžěå¿Ĺåőźæ ŸŞçŽĎçIJŃåĞžæİěïijŽ

```
>>> x = 0x01020304
>>> x.to_bytes(4, 'big')
b'\x01\x02\x03\x04'
>>> x.to_bytes(4, 'little')
b'\x04\x03\x02\x01'
>>>
```

åęĆæđIJä¡ăèŕŢçİĂåřĘäÿĂäÿłæŢťæŢřæL'ŞåŇĚäÿžå■ÙèŁĆå■ŮçňęäÿšïijŇéĆčäźĹåőČåřśäÿ■åŘĹéĂĆäžE
åęĆæđIJéIJĂèęAçŽĎèŕÏïijŇä¡ääŔřäžěä¡£çŤÍ `int.bit_length()`
æŰźæşŢæİěåĘşåőŽéIJĂèęAåď'ŽåřŚå■ÙèŁĆä¡■æİěå■ŸåĆÍè£ŹäÿłåĂijãĂĆ

```
>>> x = 523 ** 23
>>> x
335381300113661875107536852714019056160355655333978849017944067
>>> x.to_bytes(16, 'little')
Traceback (most recent call last):
File "<stdin>", line 1, in <module>
OverflowError: int too big to convert
>>> x.bit_length()
208
>>> nbytes, rem = divmod(x.bit_length(), 8)
>>> if rem:
... nbytes += 1
...
>>>
>>> x.to_bytes(nbytes, 'little')
b'\x03X\xf1\x82iT\x96\xac\xc7c\x16\xf3\xb9\xcf...\xd0'
>>>
```

5.6 3.6 åď■æŢřçŽĎæŢřå■ęè£ŘçőŮ

éŮőécŸ

ä¡ääĘŹçŽĎæIJĂæŰřçŽĎç¡ŚçżIJèőď'èŕĄæŰźæąĹäžčçăĄéĄĞåĹřäžĘäÿĂäÿłéŽ¿écŸïijŇåźűäÿŤä¡ääŤřäÿ
åĘ■æĹŰèĂĚæŸřä¡ääżĚäżĚéIJĂèęAä¡£çŤĺåď'■æŢřæİěæL'ğèąŇäÿĂäžŻèőąçőŮæŞ■ä¡IJãĂĆ

èğčåĘşæŰźæąĹ

åď■æŢřåŔŕäžěçŤĺä¡£çŤĺåĞ¡æŢř `complex(real, imag)` æĹŰèĂĚæŸŕåÿęæIJĽåŘŐçijĂjçŽĎætőçĆźæŢřæİěæŇĞåőŽãĂĆæŕŤåęĆïijŽ

```
>>> a = complex(2, 4)
>>> b = 3 - 5j
>>> a
(2+4j)
>>> b
(3-5j)
>>>
```

åŕźåžŤçŽĎåőđéČĺãĂąèŹŽéČĺåŠŇåĚśè¡■åď■æŢřåŔŕäžěå¿Ĺåőźæ ŸŞçŽĎèŐůåŔŰãĂĆåřśåČŔäÿŃéİćè£Ź

```
>>> a.real
2.0
>>> a.imag
4.0
>>> a.conjugate()
(2-4j)
>>>
```

åŘęåď Űïij ŇæĽĂæIJĽåÿÿèğĄçŽĎæŢřå■ęè£ŘçőŮéČ¡åŕŕäžěåůěä¡IJïijŽ

```
>>> a + b
(5-1j)
>>> a * b
(26+2j)
>>> a / b
(-0.4117647058823529+0.6470588235294118j)
>>> abs(a)
4.47213595499958
>>>
```

åęĆæđIJèęĄæĽğèąŇåĚűäžŰçŽĎåď■æŢřåĞ¡æŢřæŕŤåęĆæ■čåijęãĂĄä¡Źåijęæ ĹŰåźşæŰźæăźïijŇä¡£çŤĺ `cmath` æĺąåİŮïijŽ

```
>>> import cmath
>>> cmath.sin(a)
(24.83130584894638-11.356612711218174j)
>>> cmath.cos(a)
(-11.36423470640106-24.814651485634187j)
>>> cmath.exp(a)
(-4.829809383269385-5.5920560936409816j)
>>>
```

èőÍèőž

Pythonäÿ■åď ğéČÍåĹĘäÿŐæŢřå■ęçŻÿåĚşçŽĎæÍąåİŮéČ¡èČ¡åď ĎçŘĘåď ■æŢřãĂĆ æŕŤåęĆåęĆæđIJä¡ăä¡£çŤÍ numpy ïijŇåŔŕäžěå¿Ĺåőźæ ŸŞçŽĎæđĎéĂääÿĂäÿłåď ■æŢřæŢřçżĎåźűåIJÍè£Źäÿłæ

```
>>> import numpy as np
>>> a = np.array([2+3j, 4+5j, 6-7j, 8+9j])
>>> a
array([ 2.+3.j, 4.+5.j, 6.-7.j, 8.+9.j])
>>> a + 2
array([ 4.+3.j, 6.+5.j, 8.-7.j, 10.+9.j])
>>> np.sin(a)
array([ 9.15449915 -4.16890696j, -56.16227422 -48.50245524j,
        -153.20827755-526.47684926j, 4008.42651446-589.49948373j])
>>>
```

PythonçŽĎæăĞåĞĘæŢřå■ęåĞ¡æŢřçąőåőđæČĚåĘţäÿŃåźűäÿ■èČ¡äžğçŤ§åď ■æŢřåĂijïijŇåŻăæ■ď ä¡ăçŽ

```
>>> import math
>>> math.sqrt(-1)
Traceback (most recent call last):
    File "<stdin>", line 1, in <module>
ValueError: math domain error
>>>
```

åęĆæđIJä¡ăæČşçŤ§æĹŘäÿĂäÿłåď ■æŢřè£ŤåŻđçżŞæđIJïijŇä¡ăå£Ěéążæ Ÿ¿çď žçŽĎä¡£çŤÍ cmath æÍąåİŮïijŇæĹŮèĂĚåIJÍæ§Řäÿłæ ŤŕæŇĄåď ■æŢřçŽĎåžŞäÿ■åčřæ ŸŐåď ■æŢřçśżåđŃçŽĎä¡£çŤÍãĂĆæ

```
>>> import cmath
>>> cmath.sqrt(-1)
1j
>>>
```

5.7 3.7 æŮăçľůåď ğäÿŐNaN

éŮőécŸ

ä¡ăæČşåĹŻåžžæĹŰæţŃèŕŢæ■čæŮăçľůãĂĄèť §æŮăçľůæĹŰNaN(éİđæŢřå■Ů)çŽĎæţőçĆźæŢřãĂĆ

èğčåĘşæŰźæąĹ

PythonåźűæšąæIJL'çL'źæőŁçŽĎèŕ■æşŢæİěèąÍçď žè£ŹäžŻçL'źæőŁçŽĎæţőçĆźåĂijïijŇä¡ĘæŸŕåŔŕäžěä¡£ float() æİěåĹŻåžžåőČäžñãĂĆæŕŤåęĆïijŽ

```
>>> a = float('inf')
>>> b = float('-inf')
>>> c = float('nan')
>>> a
```

```
inf
>>> b
-inf
>>> c
nan
>>>
```

äÿžäžĘæţŃèŕŢè£ŹäžŻåĂijçŽĎå■ŸåIJĺïijŇä¡£çŤĺ `math.isinf()` åŠŇ `math.isnan()` åĞ¡æŢřãĂĆæŕŤåęĆïijŽ

```
>>> math.isinf(a)
True
>>> math.isnan(c)
True
>>>
```

èőĺèőž

æČşäžĘèğčæŻt'åd'Žè£ŹäžŻçL'źæőŁæţőçĆźåĂijçŽĎä£ąæĄŕïijŇåŔŕäžěåŔĆèĂČIEEE 754èğĎèŇČãĂĆ çĎűèĂŇïijŇäź§æIJL'äÿĂäžŻåIJřæŰźéIJĂèęĄä¡ăçL'źåĹńæşĺæĎŔïijŇçL'źåĹńæŸŕèů§æŕŤè¿

æŮăçl'ůåd'ğæŢřåIJĺæL'ğèąŇæŢřå■ęèőąçőŮçŽĎæŮűůåĂŹäijŽäijăæŠ■ïijŇæŕŤåęĆïijŽ

```
>>> a = float('inf')
>>> a + 45
inf
>>> a * 10
inf
>>> 10 / a
0.0
>>>
```

ä¡ĘæŸŕæIJL'äžŻæŞ■ä¡IJæŮűæIJłåőŽäźL'çŽĎåźűäijŽè£ŤåŻđäÿĂäÿłNaNçżŞæđIJãĂĆæŕŤåęĆïijŽ

```
>>> a = float('inf')
>>> a/a
nan
>>> b = float('-inf')
>>> a + b
nan
>>>
```

NaNåĂijäijŽåIJĺæL'ĂæIJL'æŞ■ä¡IJäÿ■äijăæŠ■ïijŇèĂŇäÿ■äijŽäžğçŤ§äijĆåÿÿãĂĆæŕŤåęĆïijŽ

```
>>> c = float('nan')
>>> c + 23
nan
>>> c / 2
nan
```

```
>>> c * 2
nan
>>> math.sqrt(c)
nan
>>>
```

NaNåĂijçŽĎäÿĂäÿłçL'źåĹńçŽĎåIJřæŰźæŮűåőČäžňäźŃéŮt'çŽĎæŕŤè¿ČæŞ■ä¡IJæĂżæŸŕè£ŤåŻđFalseâ

```
>>> c = float('nan')
>>> d = float('nan')
>>> c == d
False
>>> c is d
False
>>>
```

çŤśäžŐè£ŹäÿłåŐ§åŻăïijŇæţŃèŕŢäÿĂäÿłNaNåĂijå¿ŮåŤŕäÿĂåőL'åĚĺçŽĎæŰźæşŢářśæŸŕä¡£çŤÍ `math.isnan()` ïijŇäź§ářśæŸŕäÿŁéİćæijŤçd'žçŽĎéĆčæăůãĂĆ

æIJL'æŮűåĂŹçÍŃåžŔåŚŸæČşæŤźåŔŸPythonézŸèőd'èąŇäÿžïijŇåIJÍè£ŤåŻđæŮăçl'ůåd'ğæĹŰNaNçżŞæ `fpectl` æÍąåİŮåŔŕäžěçŤÍæİěæŤźåŔŸè£Źçğ■èąŇäÿžïijŇä¡ĘæŸŕåőČåIJÍæăĞåĞĘçŽĎPythonæđĎåžžäÿ■åźűâ åźűäÿŤéŠĹářźçŽĎæŸŕäÿŞåőűçžğçÍŃåžŔåŚŸãĂĆåŔŕäžěåŔĆèĂČåIJÍçž£çŽĎPythonæŰĞæąčèŐůåŔŰæŻt'åd

5.8 3.8 åĹĘæŢřè£ŘçőŮ

éŮőécŸ

ä¡ăè£ŻåĚěæŮűéŮt'æIJžåŹÍïijŇçłĄçĎűåŔŚçŐřä¡ăæ■čåIJÍåĄŽářŔå■ęåőűåž■ä¡IJäÿŽïijŇåźűæűL'åŔŁåĹřă æĹŰèĂĚä¡ăåŔŕèČ¡éIJĂèęĄåĘŹäžčçăĄåŐżèőąçőŮåIJÍä¡ăçŽĎæIJÍåůěåůěåŐĆäÿ■çŽĎæţŃéĞŔåĂijãĂĆ

èğčåĘşæŰźæąĹ

`fractions` æÍąåİŮåŔŕäžěèćńçŤÍæİěæL'ğèąŇåŇĚåŘńåĹĘæŢřçŽĎæŢřå■ęè£ŘçőŮãĂĆærŤåęĆïijŽ

```
>>> from fractions import Fraction
>>> a = Fraction(5, 4)
>>> b = Fraction(7, 16)
>>> print(a + b)
27/16
>>> print(a * b)
35/64

>>> # Getting numerator/denominator
>>> c = a * b
>>> c.numerator
35
>>> c.denominator
64
```

```
>>> # Converting to a float
>>> float(c)
0.546875

>>> # Limiting the denominator of a value
>>> print(c.limit_denominator(8))
4/7

>>> # Converting a float to a fraction
>>> x = 3.75
>>> y = Fraction(*x.as_integer_ratio())
>>> y
Fraction(15, 4)
>>>
```

èőÍèőž

åIJÍåď ğåď ŽæŢřçÍŇåžŔäÿ■äÿĂèĹňäÿ■äijŽåĞžçŐřåĹĘæŢřçŽĎèőąçőŮéŮőécŸïijŇä¡ĘæŸŕæIJL’æŮűåĂŹ
æŕŤåęĆïijŇåIJÍäÿĂäÿłåĚĄèőÿæŐěåŔŮåĹĘæŢřå¡ćåijŔçŽĎæţŃèŕŢå■Ţä¡■åźűäżěåĹĘæŢřå¡ćåijŔæL’ğèąŇè£Ř
çŻť’æŐěä¡£çŤĺåĹĘæŢřåŔŕäżěåĞŔåřŚæL’ŇåŁĺè¡ňæ■ćäÿžåřŔæŢřæĹŰæţőçĆźæŢřçŽĎåůěä¡IJãĂĆ

5.9 3.9 åď ğåđŃæŢřçżĎè£ŘçőŮ

éŮőécŸ

ä¡ăéIJĂèęĄåIJÍåď ğæŢřæ■őéŻĘ(æŕŤåęĆæŢřçżĎæĹŰç¡Śæăij)äÿŁéÍćæL’ğèąŇèőąçőŮãĂĆ

èğčåĘşæŰźæąĹ

æűL’åŔŁåĹřæŢřçżĎçŽĎéĞ■éĞŔçžğè£ŘçőŮæŞ■ä¡IJïijŇåŔŕäżěä¡£çŤÍ `NumPy` åžŞãĂĆ
`NumPy` çŽĎäÿĂäÿłäÿżèęĄçL’źå¿ĄæŸŕåőĆäijŽçżŹPythonæŔŘä¿ŻäÿĂäÿłæŢřçżĎåŕźèśąïijŇçŻÿæŕŤæăĞåĞĘ
äÿŃéÍćæŸŕäÿĂäÿłçőĂå■ŢçŽĎåřŔä¿Ńå■ŘïijŇåŘŚä¡ăåśŢçď žæăĞåĞĘåĹŮèąĺåŕźèśąåŠŇ
`NumPy` æŢřçżĎåŕźèśąäźŃéŮt’çŽĎåůőåĹníijŽ

```
>>> # Python lists
>>> x = [1, 2, 3, 4]
>>> y = [5, 6, 7, 8]
>>> x * 2
[1, 2, 3, 4, 1, 2, 3, 4]
>>> x + 10
Traceback (most recent call last):
    File "<stdin>", line 1, in <module>
TypeError: can only concatenate list (not "int") to list
>>> x + y
[1, 2, 3, 4, 5, 6, 7, 8]
```

```
>>> # Numpy arrays
>>> import numpy as np
>>> ax = np.array([1, 2, 3, 4])
>>> ay = np.array([5, 6, 7, 8])
>>> ax * 2
array([2, 4, 6, 8])
>>> ax + 10
array([11, 12, 13, 14])
>>> ax + ay
array([ 6, 8, 10, 12])
>>> ax * ay
array([ 5, 12, 21, 32])
>>>
```

æ■čåęĆæĽĂèğĄïijŇäÿd'çğ■æŰźæąĹäÿ■æŢřçżĎçŽĎå§žæIJňæŢřå■ęè£ŘçőŮçżŞædIJåźűäÿ■çŻÿåŘŇãĂçĽźåĹńçŽĎïijŇ NumPy äÿ■çŽĎæăĞéĞŔè£ŘçőŮ(æŕŤåęĆ ax * 2 æĹŰ ax + 10)äijŽä¡IJçŤĺåIJĺæŕŔäÿĂäÿłåĚČçt'ääÿŁãĂĆ åŘęåd'ŰïijŇå¡Şäÿd'äÿłæŞ■ä¡IJæŢřéČ¡æŸræŢřçżĎçŽĎæŮűåĂŹæĽğèąŇåĚČçt'äåŕźç■Ľä¡■ç¡ôèőąçőŮïijŇåźű

åŕźæŢt'äÿłæŢřçżĎäÿ■æĽĂæIJĽåĚČçt'äåŘŇæŮűæĽğèąŇæŢřå■ęè£ŘçőŮåŔŕäżěä¡£å¿Ůä¡IJçŤĺåIJĺæŢt'ä æŕŤåęĆïijŇåęĆædIJä¡ăæČşèőąçőŮåd'Žéąźåij ŔçŽĎåĂijïijŇåŔŕäżěè£ŹæăůåĄŽïijŽ

```
>>> def f(x):
... return 3*x**2 - 2*x + 7
...
>>> f(ax)
array([ 8, 15, 28, 47])
>>>
```

NumPy è£Ÿäÿžæ ŢřçżĎæŞ■ä¡IJæŔŘä¿ŻäžĘåd'ğéĞŔçŽĎéĂŽçŤĺåĞ¡æŢřïijŇè£ŹäžŻåĞ¡æŢřåŔŕäżěä¡IJäÿ math æĺąåİŮäÿ■çśżäijijåĞ¡æŢřçŽĎæŻ£äžčãĂĆæŕŤåęĆïijŽ

```
>>> np.sqrt(ax)
array([ 1. , 1.41421356, 1.73205081, 2. ])
>>> np.cos(ax)
array([ 0.54030231, -0.41614684, -0.9899925 , -0.65364362])
>>>
```

ä¡£çŤĺè£ŹäžŻéĂŽçŤĺåĞ¡æŢřèęĄæŕŤå¿łçŐŕæŢřçżĎåźűä¡£çŤĺ math æĺąåİŮäÿ■çŽĎåĞ¡æŢřæĽğèąŇèőąçőŮèęĄå£ńçŽĎåd'ŽãĂĆ åŻăæ■d'ïijŇåŔłèęĄæIJĽåŔŕèČ¡çŽĎèŕİår¡éĞŔéĂĽæŃl' NumPy çŽĎæŢřçżĎæŰźæąĹãĂĆ

åžŢåśĆåőđçŐřäÿ■ïijŇ NumPy æŢřçżĎä¡£çŤĺäžĘCæĹŰèĂĚFortranèŕ■èĺĂçŽĎæIJžåĹűåĹĘéĚ■åĘĚå■Ÿãäźş§åřśæŸŕèŕťïijŇåőĆäžňæŸŕäÿĂäÿłéİđåÿÿåd'ğçŽĎè£đçż■çŽĎåźűçŤśåŘŇçśżådŃæŢřæ■őçżĎæĹŘçŽĎåĘĚåæĽĂäżěïijŇä¡ăåŔŕäžěædĎéĂääÿĂäÿłæŕŤæŹőéĂŽPythonåĹŮèąĺåd'ğçŽĎåd'ŽçŽĎæŢřçżĎãĂĆ æŕŤåęĆïijŇåęĆædIJä¡ăæČşædĎéĂääÿĂäÿł10,000*10,000çŽĎæţőçĆźæŢřäžŇçžt'ç¡ŚæäijïijŇå¿Ĺè¡żæİ¿ïijŽ

```
>>> grid = np.zeros(shape=(10000,10000), dtype=float)
>>> grid
    array([[ 0., 0., 0., ..., 0., 0., 0.],
```

```
    [ 0., 0., 0., ..., 0., 0., 0.],
    [ 0., 0., 0., ..., 0., 0., 0.],
    ...,
    [ 0., 0., 0., ..., 0., 0., 0.],
    [ 0., 0., 0., ..., 0., 0., 0.],
    [ 0., 0., 0., ..., 0., 0., 0.]])
>>>
```

æL'ĂæIJL'çŽĎæŹőéĂŽæŞ■ä¡IJè£ŸæŸŕäijŽåŘŇæŮűä¡IJçŤĺåIJĺæL'ĂæIJL'åĚČçť'ääýŁïijŽ

```
>>> grid += 10
>>> grid
array([[ 10., 10., 10., ..., 10., 10., 10.],
    [ 10., 10., 10., ..., 10., 10., 10.],
    [ 10., 10., 10., ..., 10., 10., 10.],
    ...,
    [ 10., 10., 10., ..., 10., 10., 10.],
    [ 10., 10., 10., ..., 10., 10., 10.],
    [ 10., 10., 10., ..., 10., 10., 10.]])
>>> np.sin(grid)
array([[-0.54402111, -0.54402111, -0.54402111, ..., -0.54402111,
        -0.54402111, -0.54402111],
    [-0.54402111, -0.54402111, -0.54402111, ..., -0.54402111,
        -0.54402111, -0.54402111],
    [-0.54402111, -0.54402111, -0.54402111, ..., -0.54402111,
        -0.54402111, -0.54402111],
    ...,
    [-0.54402111, -0.54402111, -0.54402111, ..., -0.54402111,
        -0.54402111, -0.54402111],
    [-0.54402111, -0.54402111, -0.54402111, ..., -0.54402111,
        -0.54402111, -0.54402111],
    [-0.54402111, -0.54402111, -0.54402111, ..., -0.54402111,
        -0.54402111, -0.54402111]])
>>>
```

åĚşäžŐ NumPy æIJL'äÿĂçĆźéIJĂèęĄçL'źåĹńçŽĎäÿżæĎŕïijŇéĆčåřśæŸŕåőČæL'l'åśŢPythonåĹŮèąĺçŽĎ - çL'źåĹńæŸŕåŕźäžŐåď'Žçżť'æŢřçżĎãĂĆ äÿžäžĘèŕť'æŸŐæÿĚæěŽïijŇåĚĹædĎéĂääÿĂäÿłçőĂå■ŢçŽĎäžŇçżt

```
>>> a = np.array([[1, 2, 3, 4], [5, 6, 7, 8], [9, 10, 11, 12]])
>>> a
array([[ 1, 2, 3, 4],
[ 5, 6, 7, 8],
[ 9, 10, 11, 12]])

>>> # Select row 1
>>> a[1]
array([5, 6, 7, 8])

>>> # Select column 1
>>> a[:,1]
array([ 2, 6, 10])
```

```
>>> # Select a subregion and change it
>>> a[1:3, 1:3]
array([[ 6, 7],
       [10, 11]])
>>> a[1:3, 1:3] += 10
>>> a
array([[ 1, 2, 3, 4],
       [ 5, 16, 17, 8],
       [ 9, 20, 21, 12]])

>>> # Broadcast a row vector across an operation on all rows
>>> a + [100, 101, 102, 103]
array([[101, 103, 105, 107],
       [105, 117, 119, 111],
       [109, 121, 123, 115]])
>>> a
array([[ 1, 2, 3, 4],
       [ 5, 16, 17, 8],
       [ 9, 20, 21, 12]])

>>> # Conditional assignment on an array
>>> np.where(a < 10, a, 10)
array([[ 1, 2, 3, 4],
       [ 5, 10, 10, 8],
       [ 9, 10, 10, 10]])
>>>
```

èőÍèőž

NumPy æŸŕPythonécĘå§§äÿ■å¿Ĺåď'ŽçğŚå■ęäÿŐåůěçÍŃåžŞçŽĎå§žçąĂïijŇåŘŇæŮűäź§æŸŕèćńåź£æşŽ
å■şä¿£åęĆæ■ď'ïijŇåIJĺåĹŽåijĂåğŃçŽĎæŮűåĂŹéĂŽè£ĞäÿĂäžŽçőĂå■ŢçŽĎä¿Ńå■ŘåŠŇçŐľ'åĚůçÍŃåžŔäź§

éĂŽåÿÿæĹŚäžňåŕijåĚě NumPy æĺąåİŮçŽĎæŮűåĂŹäijŽä¡£çŤĺèŕ■åŔě import numpy as np ãĂĆ è£ŹæăůçŽĎèŕÍä¡ăåřšäÿ■çŤĺåĘ■ä¡ăçŽĎçÍŃåžŔéĞŇéİćäÿĂéĄ■éĄ■çŽĎæŢšåĚě numpy ïijŇåŘłéIJĂèęĄè¿ŞåĚě np åřśèąŇäžĘïijŇèŁĆçIJĄäžĘäÿ■åřŚæŮűéŮť'ãĂĆ

åęĆæđIJæČşèŐůåŘŰæŻť'åď'ŽçŽĎä£ąæĄŕïijŇä¡ăå¡ŞçĎűå¿ŮåŐż NumPy åőŸç¡ŚéĂŻéĂŻäžĘïijŇç¡ŚåİĂæŸŕïijŽ http://www.numpy.org

5.10 3.10 ç§'éŸţäÿŐçž£æĂğäżčæŢřè£ŘçőŮ

éŮőécŸ

ä¡ăéIJĂèęĄæL'ğèąŇç§l'éŸţåŠŇçž£æĂğäżčæŢřè£ŘçőŮïijŇæŕŤåęĆç§l'éŸţäźŸæşŢãĂĄåŕżæL'¿èąŇåĹŮå

èğčåĘşæŰźæąĹ

NumPy åžŞæIJL'äÿĂäÿłç§l'éŸţåŕźèśąåŔŕäżěçŤĺæİěèğčåĘşè£ŹäÿłéŮőécŸãĂĆ
ç§l'éŸţçśżäijijäžŐ3.9åřŔèŁĆäÿ■æŢřçżĎåŕźèśąïijŇä¡ĘæŸŕéĄţå¿łçž£æĂğäżčæŢřçŽĎèőąçőŮèğĎåĹŹãĂ

```
>>> import numpy as np
>>> m = np.matrix([[1,-2,3],[0,4,5],[7,8,-9]])
>>> m
matrix([[ 1, -2, 3],
        [ 0, 4, 5],
        [ 7, 8, -9]])

>>> # Return transpose
>>> m.T
matrix([[ 1, 0, 7],
        [-2, 4, 8],
        [ 3, 5, -9]])

>>> # Return inverse
>>> m.I
matrix([[ 0.33043478, -0.02608696, 0.09565217],
        [-0.15217391, 0.13043478, 0.02173913],
        [ 0.12173913, 0.09565217, -0.0173913 ]])

>>> # Create a vector and multiply
>>> v = np.matrix([[2],[3],[4]])
>>> v
matrix([[2],
        [3],
        [4]])
>>> m * v
matrix([[ 8],
        [32],
        [ 2]])
>>>
```

åŔŕäżěåIJÍ numpy.linalg å■ŘåŇĚäÿ■æL'¿åĹřæŻt'åď'ŽçŽĎæŞ■ä¡IJåĞ¡æŢřïijŇæŕŤåęĆïijŽ

```
>>> import numpy.linalg

>>> # Determinant
>>> numpy.linalg.det(m)
-229.99999999999983

>>> # Eigenvalues
>>> numpy.linalg.eigvals(m)
array([-13.11474312, 2.75956154, 6.35518158])

>>> # Solve for x in mx = v
>>> x = numpy.linalg.solve(m, v)
```

```
>>> x
matrix([[ 0.96521739],
        [ 0.17391304],
        [ 0.46086957]])
>>> m * x
matrix([[ 2.],
        [ 3.],
        [ 4.]])
>>> v
matrix([[2],
        [3],
        [4]])
>>>
```

èőÍèőž

å¿ÍæŸ¿çĎűçž£æĂğäžčæŢřæŸŕäÿłéÍđåÿÿåď ğçŽĎäÿžécŸïijŇåůšçżŔèűĚåĞžäžĘæIJñäźęèČ¡èőÍèőžçŽĎè
ä¡ĘæŸŕïijŇåęĆæđIJä¡ăéIJĂèęĄæŞ■ä¡IJæŢřçżĎåŠŇåŘŚéĞŔçŽĎèŕÍïijŇ NumPy
æŸŕäÿĂäÿłäÿ■éŤŹçŽĎåĚěåŘčçĆźãĂĆ åŔŕäžěèő£éŮő NumPy åőŸç¡Ś http://www.numpy.org
èŐůåŘŰæŻť åď Žä£ąæĄŕãĂĆ

5.11 3.11 éŽŔælJžéĂĽæŃľ

éŮőécŸ

ä¡ăæČşäżŐäÿĂäÿłåžŔåĹŮäÿ■éŽŔæIJžæŁ¡åŘŰèŃěåźšåĚČçť ăïijŇæĹŰèĂĚæČşçŢ§æĹŘåĞääÿłéŽŔæIJ

èğčåĘşæŰźæąĹ

random æÍąåİŮæIJL'åď ğéĞŔçŽĎåĞ¡æŢřçŤÍæİěäžğçŤ§éŽŔæIJžæŢřåŠŇéŽŔæIJžéĂL'æŃľåĚČçť ăãĂĆ
ærŤåęĆïijŇèęĄæČşäżŐäÿĂäÿłåžŔåĹŮäÿ■éŽŔæIJžçŽĎæŁ¡åŘŰäÿĂäÿłåĚČçť ăïijŇåŔŕäžěä¡£çŤÍ
random.choice() ïijŽ

```
>>> import random
>>> values = [1, 2, 3, 4, 5, 6]
>>> random.choice(values)
2
>>> random.choice(values)
3
>>> random.choice(values)
1
>>> random.choice(values)
4
>>> random.choice(values)
6
>>>
```

äÿžäžĘæŔŘåŔŰåĞžNäÿłäÿ■åŘŇåĚČçť ăçŽĎæăůæIJňçŤÍæİěåĄŽè£ŻäÿĂæ■ěçŽĎæŞ■ä¡IJïijŇåŔŕäżěä¡£ `random.sample()` ïijŽ

```
>>> random.sample(values, 2)
[6, 2]
>>> random.sample(values, 2)
[4, 3]
>>> random.sample(values, 3)
[4, 3, 1]
>>> random.sample(values, 3)
[5, 4, 1]
>>>
```

åęĆæđIJä¡ăäżĚäżĚåŔłæŸŕæČşæĽŞäźśåžŔåĹŮäÿ■åĚČçť ăçŽĎéąžåžŔïijŇåŔŕäżěä¡£çŤÍ `random.shuffle()` ïijŽ

```
>>> random.shuffle(values)
>>> values
[2, 4, 6, 5, 3, 1]
>>> random.shuffle(values)
>>> values
[3, 5, 2, 1, 6, 4]
>>>
```

çŤ§æĹŘéŽŔæIJžæŢť æŢřïijŇèŕůä¡£çŤÍ `random.randint()` ïijŽ

```
>>> random.randint(0,10)
2
>>> random.randint(0,10)
5
>>> random.randint(0,10)
0
>>> random.randint(0,10)
7
>>> random.randint(0,10)
10
>>> random.randint(0,10)
3
>>>
```

äÿžäžĘçŤ§æĹR0åĹř1èŇČåŻť åĘĚåİĞåŇĂåĹĘåÿČçŽĎæţőçĆźæŢřïijŇä¡£çŤÍ `random.random()` ïijŽ

```
>>> random.random()
0.9406677561675867
>>> random.random()
0.133129581343897
>>> random.random()
0.4144991136919316
>>>
```

åęĆædIJèęĄèŐůåŘŰNä¡■éŽŔæIJžä¡■(äžŇè£ŻåĹű)çŽĎæŢt'æŢřïijŇä¡£çŤĺ `random.getrandbits()` ïijŽ

```
>>> random.getrandbits(200)
335837000776573622800628485064121869519521710558559406913275
>>>
```

èőĺèőž

`random` æĺąåİŮä¡£çŤĺ *Mersenne Twister* çőŮæşŢæİěèőąçőŮçŤ§æĹŘéŽŔæIJžæŢřãĂĆè£ŹæŸŕäÿĂäÿłçä¡ĘæŸŕä¡ăåŘŕäžěéĂŽè£Ğ `random.seed()` åĞ¡æŢřä£őæŤźåĹİåğŇåŇŰçğ■å■ŘãĂĆærŤåęĆïijŽ

```
random.seed() # Seed based on system time or os.urandom()
random.seed(12345) # Seed based on integer given
random.seed(b'bytedata') # Seed based on byte data
```

éŹď'äžĘäÿŁè£řäžŇçż■çŽĎåŁ§èČ¡ïijŇrandomæĺąåİŮè£ŸåŇĚåŘńå§žäžŐåİĞåŇĂåĹĘåÿČãĂĄéńŸæŰŕåærŤåęĆïijŇ `random.uniform()` èőąçőŮåİĞåŇĂåĹĘåÿČéŽŔæIJžæŢřïijŇ `random.gauss()` èőąçőŮæ■čæĂĄåĹĘåÿČéŽŔæIJžæŢřãĂĆ åŕźäžŐåĚűäžŰçŽĎåĹĘåÿČæČĚåĘţèŕůåŘĆèĂČåIJĺçž£æŰĞæąčãĂĆ

åIJĺ `random` æĺąåİŮäÿ■çŽĎåĞ¡æŢřäÿ■åžŤèŕěçŤĺåIJĺåŠŇårĘçăĄå■ęçŻÿåĚşçŽĎçĺŃåžŔäÿ■ãĂĆ åęĆædIJä¡ăçąőåődéIJĂèęĄçśżäijijçŽĎåŁ§èČ¡ïijŇåŘŕäžěä¡£çŤĺsslæĺąåİŮäÿ■çŻÿåžŤçŽĎåĞ¡æŢřãĂĆ ærŤåęĆïijŇ `ssl.RAND_bytes()` åŘŕäžěçŤĺæİěçŤ§æĹŘäÿĂäÿłåőĽåĚĺçŽĎéŽŔæIJžå■ŮèŁĆåžŔåĹŮãĂĆ

5.12 3.12 å§žælJńçŽĎæŮěælJ§äÿŐæŮűéŮť'è¡ňæ■ć

éŮőécŸ

ä¡ăéIJĂèęĄæL'ğèąŇçőĂå■ŢçŽĎæŮűéŮť'è¡ňæ■ćïijŇærŤåęĆåd'l'åĽrçğŠïijŇářŔæŮűåĹřåĹĘéŠ§ç■L'çŽĎ

èğčåĘşæŰźæąĹ

äÿžäžĘæL'ğèąŇäÿ■åŘŇæŮűéŮť'å■Ţä¡■çŽĎè¡ňæ■ćåŠŇèőąçőŮïijŇèŕůä¡£çŤĺ `datetime` æĺąåİŮãĂĆ ærŤåęĆïijŇäÿžäžĘèąÍçd'žäÿĂäÿłæŮűéŮť'æőţïijŇåŘŕäžěåĹŻåžžäÿĂäÿł `timedelta` åőđä¿ŃïijŇářšåČŔäÿŃéİćè£Źæăůïijž

```
>>> from datetime import timedelta
>>> a = timedelta(days=2, hours=6)
>>> b = timedelta(hours=4.5)
>>> c = a + b
>>> c.days
2
>>> c.seconds
37800
>>> c.seconds / 3600
10.5
```

```
>>> c.total_seconds() / 3600
58.5
>>>
```

åęĆædIJä¡ăæČşèąÍçd'žæŇĞåőŽçŽĎæŮěæIJ§åŠŇæŮűéŮt'ïijŇåĚĹåĹŻåžžäÿĂäÿł datetime åőđä¿ŃçĎűåŘŐä¡£çŤÍæăĞåĞĘçŽĎæŢřå■ęè£ŘçőŮæİěæŞ■ä¡IJåőČäžñãĂĆærŤåęĆïijŽ

```
>>> from datetime import datetime
>>> a = datetime(2012, 9, 23)
>>> print(a + timedelta(days=10))
2012-10-03 00:00:00
>>>
>>> b = datetime(2012, 12, 21)
>>> d = b - a
>>> d.days
89
>>> now = datetime.today()
>>> print(now)
2012-12-21 14:54:43.094063
>>> print(now + timedelta(minutes=10))
2012-12-21 15:04:43.094063
>>>
```

åIJÍèőąçőŮçŽĎæŮűåĂŹïijŇéIJĂèęĄæşÍæĎŘçŽĎæŸŕ datetime äijŽèĞłåŁÍåd'ĎçŘĘéŮřåźt'ãĂĆærŤåęĆïijŽ

```
>>> a = datetime(2012, 3, 1)
>>> b = datetime(2012, 2, 28)
>>> a - b
datetime.timedelta(2)
>>> (a - b).days
2
>>> c = datetime(2013, 3, 1)
>>> d = datetime(2013, 2, 28)
>>> (c - d).days
1
>>>
```

èőÍèőž

åŕźåd'ğåd'ŽæŢřå§žæIJňçŽĎæŮěæIJ§åŠŇæŮűéŮt'åd'ĎçŘĘéŮőécŸïijŇ datetime æÍąåİŮåůšçżŔèűşåd'§äžĘãĂĆ åęĆædIJä¡ăéIJĂèęĄæL'ğèąŇæŻt'åŁăåd'■æİĆçŽĎæŮěæIJ§æŞ■ä¡IJïijŇærŤåęĆ åŘŕäżěèĂČèŹŚä¡£çŤÍ dateutilæÍąåİŮ

èőÿåd'Žçśżäijijç ŽĎæŮűéŮt'èőąçőŮåŘŕäżěä¡£çŤÍ dateutil.relativedelta() åĞ¡æŢřäžčæŻ£ãĂĆ ä¡ĘæŸŕïijŇæIJL'äÿĂçĆźéIJĂèęĄæşÍæĎŘçŽĎåřśæŸŕïijŇåőČäijŽåIJÍåd'ĎçŘĘæIJĹäż¡(è

```
>>> a = datetime(2012, 9, 23)
>>> a + timedelta(months=1)
```

```
Traceback (most recent call last):
File "<stdin>", line 1, in <module>
TypeError: 'months' is an invalid keyword argument for this function
>>>
>>> from dateutil.relativedelta import relativedelta
>>> a + relativedelta(months=+1)
datetime.datetime(2012, 10, 23, 0, 0)
>>> a + relativedelta(months=+4)
datetime.datetime(2013, 1, 23, 0, 0)
>>>
>>> # Time between two dates
>>> b = datetime(2012, 12, 21)
>>> d = b - a
>>> d
datetime.timedelta(89)
>>> d = relativedelta(b, a)
>>> d
relativedelta(months=+2, days=+28)
>>> d.months
2
>>> d.days
28
>>>
```

5.13 3.13 èőąçőŮæIJĂåŘŐäÿĂäÿłåŚĺäžŤçŽĎæŮěæIJ§

éŮőécŸ

ä¡ăéIJĂèęĄæ§ěæL'¿æŸ§æIJ§äÿ■æ§ŘäÿĂåď'ľæIJĂåŘŐåĞžçŐřçŽĎæŮěæIJ§ïijŇæŕŤåęĆæŸ§æIJ§äžŤãĂ

èğčåĘşæŰźæąĹ

PythonçŽĎ `datetime` æĺąåİŮäÿ■æIJL'åůěåĚůåĞ¡æŢřåŠŇçśżåŔŕäžěåÿőåŁľä¡ăæL'ğèąŇè£ŹæăůçŽĎèőäÿŃéIćæŸŕåŕźçśżäijijè£ŹæăůçŽĎéŮőécŸçŽĎäÿĂäÿłéĂŽçŤĺèğčåĘşæŰźæąĹïijŽ

```
#!/usr/bin/env python
# -*- encoding: utf-8 -*-
"""
Topic: æIJĂåŘŐçŽĎåŚĺäžŤ
Desc :
"""
from datetime import datetime, timedelta

weekdays = ['Monday', 'Tuesday', 'Wednesday', 'Thursday',
            'Friday', 'Saturday', 'Sunday']
```

```
def get_previous_byday(dayname, start_date=None):
    if start_date is None:
        start_date = datetime.today()
    day_num = start_date.weekday()
    day_num_target = weekdays.index(dayname)
    days_ago = (7 + day_num - day_num_target) % 7
    if days_ago == 0:
        days_ago = 7
    target_date = start_date - timedelta(days=days_ago)
    return target_date
```

åIJÍäžď'äžŠåijŔèğčéĞŁåŹÍäÿ■ä¡£çŤÍåęĆäÿŃïijŽ

```
>>> datetime.today() # For reference
datetime.datetime(2012, 8, 28, 22, 4, 30, 263076)
>>> get_previous_byday('Monday')
datetime.datetime(2012, 8, 27, 22, 3, 57, 29045)
>>> get_previous_byday('Tuesday') # Previous week, not today
datetime.datetime(2012, 8, 21, 22, 4, 12, 629771)
>>> get_previous_byday('Friday')
datetime.datetime(2012, 8, 24, 22, 5, 9, 911393)
>>>
```

åŔŕéĂL'çŽĎ `start_date` åŔĆæŢřåŔŕäžěçŤśåŔęåď'ŰäÿĂäÿł `datetime` åőđä¿ŃæÌěæŔŘä¿ŻãĂĆæŕŤåęĆïijŽ

```
>>> get_previous_byday('Sunday', datetime(2012, 12, 21))
datetime.datetime(2012, 12, 16, 0, 0)
>>>
```

èőÍèőž

äÿŁéÌćçŽĎçőŮæşŢåŐ§çŘĘæŸŕè£Źæăůç ŽĎïijŽåĚĹářĘåijĂåğŃæŮěæIJ§åŠŇçŻőæăĞæŮěæIJ§æŸăářĎ çĎűåŘŐéĂŽè£ĞæÍąè£ŘçőÙèőąçőŮåĞžçŻőæăĞæŮěæIJ§èęAçżŔè£Ğåď'ŽářŚåď'l'æL'■èČ¡åĹřè¿¿åijĂåğŃæŮ

åęĆædIJä¡ăèęĄåČŔè£ŹæăůæL'ğèąŇåď'ğéĞŔçŽĎæŮěæIJ§èőąçőŮçŽĎèŕÌïijŇä¡ăæIJĂåě¡åőL'èčĚçňňäÿL `python-dateutil` æÌěäžčæŻ£ãĂĆ æŕŤåęĆïijŇäÿŃéÌćæŸŕæŸŕä¡£çŤÍ `dateutil` æÍąåÌŮäÿ■çŽĎ `relativedelta()` åĞ¡æŢřæL'ğèąŇåŘŇæăůçŽĎèőąçőŮïijŽ

```
>>> from datetime import datetime
>>> from dateutil.relativedelta import relativedelta
>>> from dateutil.rrule import *
>>> d = datetime.now()
>>> print(d)
2012-12-23 16:31:52.718111

>>> # Next Friday
>>> print(d + relativedelta(weekday=FR))
2012-12-28 16:31:52.718111
```

```
>>>

>>> # Last Friday
>>> print(d + relativedelta(weekday=FR(-1)))
2012-12-21 16:31:52.718111
>>>
```

5.14 3.14 èőąçőŮå¡ŞåĽ■æIJĹäż¡çŽĎæŮěæIJ§èŇČåŻť

éŮőécŸ

ä¡ăçŽĎäžčçăĄéIJĂèęĄåIJĺå¡ŞåĽ■æIJĹäż¡äÿ■å¿łçŐŕæŕŔäÿĂåď'ľïijŇæČşæĽ¿åĹřäÿĂäÿłèőąçőŮè£Źäÿłaŕ

èğčåĘşæŰźæąĹ

åIJĺè£Źæăůç ŽĎæŮěæIJ§äÿŁå¿łçŐŕåźűéIJĂèęĄäžŇåĚĹæđĎéĂääÿĂäÿłåŇĚåŘńæĽĂæIJĽæŮěæIJ§çŽĎ
ä¡ääŔŕäžěåĚĹèőąçőŮåĞžåijĂåğŇæŮěæIJ§åŠŇçżŞæİ§æŮěæIJ§ïijŇ
çĎűåŘŐåIJĺä¡ăæ■ěè£ŻçŽĎæŮűåĂŹä¡£çŤÍ `datetime.timedelta`
ářźèśąéĂŠåćđè£ŹäÿłæŮěæIJ§åŔŸéĞŔå■şåŔŕãĂĆ

äÿŇéİćæŸŕäÿĂäÿłæŐěåŘŮäżżæĎŔ `datetime` ářźèśąåźűè£ŤåŻđäÿĂäÿłçŤśå¡ŞåĽ■æIJĹäż¡åijĂåğŇæŮ

```
from datetime import datetime, date, timedelta
import calendar

def get_month_range(start_date=None):
    if start_date is None:
        start_date = date.today().replace(day=1)
    _, days_in_month = calendar.monthrange(start_date.year, start_
↪date.month)
    end_date = start_date + timedelta(days=days_in_month)
    return (start_date, end_date)
```

æIJĽäžĘè£ŹäÿłářśåŔŕäżěå¿ĹåőźæŸŞçŽĎåIJĺè£ŤåŻđçŽĎæŮěæIJ§èŇČåŻťäÿŁéİćåĄŽå¿łçŐŕæŞ■ä¡IJäž

```
>>> a_day = timedelta(days=1)
>>> first_day, last_day = get_month_range()
>>> while first_day < last_day:
...     print(first_day)
...     first_day += a_day
...
2012-08-01
2012-08-02
2012-08-03
2012-08-04
2012-08-05
2012-08-06
```

```
2012-08-07
2012-08-08
2012-08-09
#... and so on...
```

èőÍèőž

äÿŁéİćçŽĎäžčçăĄåĚĹèőąçőŮåĞžäÿĂäÿłåŕźåžŤæIJĹäż¡çňňäÿĂåď'ľçŽĎæŮĕæIJ§ãĂĆ äÿĂäÿłå£ńéĂ§çŽĎæŰźæşŢåřśæŸŕä¡£çŤĺ `date` æĹŰ `datetime` åŕźèśąçŽĎ `replace()` æŰźæşŢçőĂå■ŢçŽĎåřĘ `days` åśđæĂğèő¿ç¡őæĹŘ1å■şåŔŕãĂĆ `replace()` æŰźæşŢäÿĂäÿłåě¡åď'ĎåřśæŸŕåőČäijŽåĹŻåžžåŠŇä¡ăåijĂåğŃäijăåĚěåŕźèśąçśžåđŃçŻÿåŘŇçŽĎåŕźèśąãĂĆ æĽ'Ăäżěïij Ňåę Ćæđ IJè¿ŞåĚěåŔĆæŢřæŸŕäÿĂäÿł `date` åőđä¿Ńïij ŇéĆčäźĹçżŞæđIJäź§æŸŕäÿĂäÿł `date` åőđä¿ŃãĂĆ åŘŇæăůçŽĎïij ŇåęĆæđIJè¿ŞåĚěæŸŕäÿĂäÿł `datetime` åőđä¿Ńïij ŇéĆčäźĹä¡ăå¿ŮåĹřçŽĎåřśæŸŕäÿĂäÿł `datetime` åőđä¿ŃãĂĆ

çĎűåŘŐïij Ňä¡£çŤĺ `calendar.monthrange()` åĞ¡æŢřæİěæĽ'¿åĞžèřěæIJĹçŽĎæĂżåď'ľæŢřãĂĆ äżżä¡ŢæŮűåĂŹåŔłèęĄä¡ăæČşèŐůå¿ŮæŮĕåŐĘä£ąæĄŕïij ŇéĆčäźĹ `calendar` æĺąåİŮåřśéİđåÿÿæIJĽçŤĺäžĘãĂĆ `monthrange()` åĞ¡æŢřäijŽè£ŤåŻđåŇĚåŘńæŸ§æIJ§åŠŇèřěæIJĹåď'ľæŢřçŽĎåĚČçżĎãĂĆ

äÿĂæŮęèřěæIJĹçŽĎåď'ľæŢřåůšç§ëäžĘïij ŇéĆčäźĹçżŞæİ§æŮĕæIJ§åřśåŔŕäżěéĂŽè£ĞåIJĺåijĂåğŃæŮĕæ æIJĽäÿłéIJĂèęĄæşĺæĎŔçŽĎæŸŕçżŞæİ§æŮĕæIJ§åźűäÿ■åŇĚåŘńåIJĺè£ŹäÿłæŮĕæIJ§èŇČåŻť'åĘĚ(äžŇåőđäÿ è£ŹäÿłåŠŇPythonçŽĎ `slice` äÿŐ `range` æŞ■ä¡IJèąŇäÿžä£ÍæŇĄäÿĂèĞť'ïijŇåŘŇæăůäź§äÿ■åŇĚåŘńçżŞåï

äÿžäžĘåIJĺæŮĕæIJ§èŇČåŻť'äÿŁå¿łçŐŕïijŇèęĄä¡£çŤĺåĹřæăĞåĞĘçŽĎæŢřå■ęåŠŇæŕŤè¿ČæŞ■ä¡IJãĂĆ æŕŤåęĆïijŇåŔŕäżěåĹľçŤĺ `timedelta` åőđä¿ŃæÍěéĂŠáćđæŮĕæIJ§ïijŇåřŔäžŐåŔů<çŤĺæÍěæčĂæ§ëäÿĂäÿła

çŘĘæČşæČĚåĘţäÿŃïijŇåęĆæđIJèČ¡äÿžæŮĕæIJ§è£■äżčåĹŻåžžäÿĂäÿłåŘŇåĘĚç¡őçŽĎ `range()` åĞ¡æŢřäÿĂæăůçŽĎåĞ¡æŢřåŕśåě¡äžĘãĂĆ åźÿè£ŘçŽĎæŸŕïijŇåŔŕäżěä¡£çŤĺäÿĂäÿłçŤ§æĹŘåŹĺçŽĎä¿Ńå■ŘïijŽ

```
def date_range(start, stop, step):
    while start < stop:
        yield start
        start += step
```

äÿŃéİćæŸŕä¡£çŤĺè£ŹäÿłçŤ§æĹŘåŹĺçŽĎä¿Ńå■ŘïijŽ

```
>>> for d in date_range(datetime(2012, 9, 1), datetime(2012,10,1),
                        timedelta(hours=6)):
...     print(d)
...
2012-09-01 00:00:00
2012-09-01 06:00:00
2012-09-01 12:00:00
2012-09-01 18:00:00
2012-09-02 00:00:00
2012-09-02 06:00:00
...
>>>
```

è£Źçğ■åőđçŐřäźŃæĽĂäžěè£ŹäźĹçőĂå■ŢïijŇè£Ÿå¿Ůå¡ŠåŁ§äžŐPythonäÿ■çŽĎæŮěæIJ§åŠŇæŮűéŮťć

5.15 3.15 å■Ůçňęäÿšè¡ňæ■ćäÿžæŮěæIJ§

éŮőécŸ

ä¡ăçŽĎåžŤçŤĺçĺŃåžŔæŐěåŔŮå■ŮçňęäÿšæăijåijŔçŽĎè¿ŞåĚěïijŇä¡ĘæŸŕä¡ăæČşářĘåőČäžňè¡ňæ■ćäÿž datetime åŕźèśąäžěä¿£åIJĺäÿŁéÍćæĽğèąŇéİđå■ŮçňęäÿšæŞ■ä¡IJãĂĆ

èğčåĘşæŰźæąĹ

ä¡£çŤĺPythonçŽĎæăĞåĞĘæĺąåİŮ datetime åŔŕäžěå¿ĹåőźæŸ§çŽĎèğčåĘşè£ŹäÿłéŮőécŸãĂĆæŕŤåęĆ

```
>>> from datetime import datetime
>>> text = '2012-09-20'
>>> y = datetime.strptime(text, '%Y-%m-%d')
>>> z = datetime.now()
>>> diff = z - y
>>> diff
datetime.timedelta(3, 77824, 177393)
>>>
```

èőĺèőž

datetime.strptime() æŰźæşŢæŤŕæŇĄå¿Ĺåd'ŽçŽĎæăijåijŔåŇŰäžčçăĄïijŇ æŕŤåęĆ %Y äžčèąĺ4ä¡■æŢřåźt'äž¡ïijŇ %m äžčèąĺäÿd'ä¡■æŢřæIJĹäž¡ãĂĆ è£ŸæIJL'äÿĂçĆźåĂijå¿ŮæşĺæĎŔçŽĎæŸŕè£ŹäžŻæăijåijŔåŇŰå■ăä¡■çňęäź§åŔŕäžěåŔ■è£Ğæĺěä¡£çŤĺïijŇårE

æŕŤåęĆïijŇåĄĞèő¿ä¡ăçŽĎäžčçăĄäÿ■çŤ§æĹŘäžĘäÿĂäÿł datetime åŕźèśąïijŇ ä¡ăæČşářĘåőČæăijåijŔåŇŰäÿžæijĆäžőæŸŞèŕźå¡ćåijŔåŘŐæŤ¿åIJĺèĞłåŁĺçŤ§æĹŘçŽĎä£ąäžűæĹŰèĂĚæŁěå

```
>>> z
datetime.datetime(2012, 9, 23, 21, 37, 4, 177393)
>>> nice_z = datetime.strftime(z, '%A %B %d, %Y')
>>> nice_z
'Sunday September 23, 2012'
>>>
```

è£ŸæIJL'äÿĂçĆźéIJĂèęĄæşĺæĎŔçŽĎæŸŕïijŇ strptime() çŽĎæĂğèČ¡èęĄæŕŤä¡ăæČşèśąäÿ■çŽĎåůőå¿Ĺåd'ŽïijŇ åŻăäÿžåőČæŸŕä¡£çŤĺçžŕPythonåőđçŐřïijŇåźűäÿŤå£Ì åęĆæđIJä¡ăèęĄåIJĺäžčçăĄäÿ■éIJĂèęĄèğčæđŘåd'ğéĞŔçŽĎæŮěæIJ§åźűäÿŤåůšçżŔç§ěéĄŞäžĘæŮěæIJ§å■Ůç æŕŤåęĆïijŇåęĆæđIJä¡ăåůšçżŔç§ěéĄŞæL'ĂäžěæŮěæIJ§æăijåijŔæŸŕ YYYY-MM-DD ïijŇä¡ăåŔŕäžěåČŔäÿŇéİćè£ŹæăůåőđçŐřäÿĂäÿłèğčæđŘåĞ¡æŢřïijŽ

```
from datetime import datetime
def parse_ymd(s):
```

```
    year_s, mon_s, day_s = s.split('-')
    return datetime(int(year_s), int(mon_s), int(day_s))
```

åőđéŹĚæţŃèřŢäÿ■ïijŇè£ŹäÿłåĞ¡æŢřæŕŤ `datetime.strptime()` å£ń7åĂ■åď'ŽãĂĆ
åęĆæđIJä¡ăèęĄåď'ĎçŘĘåď'ğéĞŔçŽĎæűL'åŔŁåĹřæŮĕæIJ§çŽĎæŢřæ■őçŽĎèŕİïijŇéĆčäźĹæIJĂåě¡èĂČèŹŚäÿ

5.16 3.16 çżŞåŘĹæŮűåŇžçŽĎæŮĕæIJ§æŞ■ä¡IJ

éŮőécŸ

ä¡ăæIJL'äÿĂäÿłåőL'æŐŠåIJÍ2012åźť'12æIJĹ21æŮĕæŮl'äÿŁ9:30çŽĎçŤţèŕİäijŽèőőïijŇåIJřçĆźåIJÍèŁİåŁă
èĂŇä¡ăçŽĎæIJŃåŔŃåIJÍå■řåžęçŽĎçŔ■åŁăç¡ŮåřŤïijŇéĆčäźĹäżŰåžŤèŕěåIJÍå¡ŞåIJřæŮűéŮť'åĞăçĆźåŔĆåŁă

èğčåĘşæŰźæąĹ

åŕźåĞääźŐæL'ĂæIJL'æűL'åŔŁåĹřæŮűåŇžçŽĎéŮőécŸïijŇä¡äéČ¡åžŤèŕěä¡£çŤÍ
`pytz` æÍąåİŮãĂĆè£ŹäÿłåŇĚæŔŘä¿ŻäžĘOlsonæŮűåŇžæŢřæ■őåžŞïijŇ
åőČæŸřæŮűåŇžä£qæĄŕçŽĎäžŃåőđäÿŁçŽĎæăĞåĞĘïijŇåIJÍå¿Ĺåď'Žèŕ■èÍĂåŠŇæŞ■ä¡IJçşżç§éĞŇéÍćéČ¡åŔ

`pytz` æÍąåİŮäÿĂäÿłäÿżèęĄçŤÍéĂŤæŸřårĘ `datetime`
åžŞåĹŻåżžçŽĎçőĂå■ŢæŮĕæIJ§årźèśąæIJňåIJřåŇŰãĂĆ ærŤåęĆïijŇäÿŇéÍćåęĆä¡Ţèą[çď'žäÿĂäÿłèŁİåŁääŞěa

```
>>> from datetime import datetime
>>> from pytz import timezone
>>> d = datetime(2012, 12, 21, 9, 30, 0)
>>> print(d)
2012-12-21 09:30:00
>>>

>>> # Localize the date for Chicago
>>> central = timezone('US/Central')
>>> loc_d = central.localize(d)
>>> print(loc_d)
2012-12-21 09:30:00-06:00
>>>
```

äÿĂæŮęæŮĕæIJ§èćńæIJňåIJřåŇŰäžĘïijŇ åőČårśåŔŕäżěè¡ňæ■ćäÿžåĚűäżŰæŮűåŇžçŽĎæŮűéŮť'äžĘąĂĆ
äÿžäžĘå¿ŮåĹřçŔ■åŁăç¡ŮåřŤårźåžŤçŽĎæŮűéŮť'ïijŇä¡ääŔŕäżěè£Źæăůå[ŽïijŽ

```
>>> # Convert to Bangalore time
>>> bang_d = loc_d.astimezone(timezone('Asia/Kolkata'))
>>> print(bang_d)
2012-12-21 21:00:00+05:30
>>>
```

åęĆæđIJä¡ăæL'ŞçőŮåIJÍæIJňåIJřåŇŰæŮĕæIJ§äÿŁæL'ğèąŇèőąçőŮïijŇä¡ăéIJĂèęĄçL'źåĹńæşÍæĎŔåď'Ŕä
ærŤåęĆïijŇåIJÍ2013åźť'ïijŇç¿ŐåŻ¡æăĞåĞĘåď'Ŕäżď'æŮűæŮűéŮť'åijĂågŇäžŐæIJňåIJřæŮűéŮť'3æIJĹ13æŮè
åęĆæđIJä¡ăæ■čåIJÍæL'ğèąŇæIJňåIJřèőąçőŮïijŇä¡ääijŽå¿ŮåĹřäÿĂäÿłéŤŹèŕřãĂĆærŤåęĆïijŽ

```
>>> d = datetime(2013, 3, 10, 1, 45)
>>> loc_d = central.localize(d)
>>> print(loc_d)
2013-03-10 01:45:00-06:00
>>> later = loc_d + timedelta(minutes=30)
>>> print(later)
2013-03-10 02:15:00-06:00 # WRONG! WRONG!
>>>
```

çżŞæđIJéŤŹèŕŕæŸŕåŻääÿžåőČåźűæšąæIJL'èĂČèŹŠåIJÍæIJňåIJřæŮűéŮt'äÿ■æIJL'äÿĂářŔæŮűçŽĎèůşèů äÿžäžĘä£őæ■čè£ŹäÿłéŤŹèŕŕïijŇåŔŕäżčä¡£çŤÍæŮűåŇžářźèšą `normalize()` æŰźæşŢãĂĆæŕŤåęĆïijŽ

```
>>> from datetime import timedelta
>>> later = central.normalize(loc_d + timedelta(minutes=30))
>>> print(later)
2013-03-10 03:15:00-05:00
>>>
```

èőÍèőž

äÿžäžĘäÿ■èől'ä¡äèćnè£ŹäžŻäÿIJäÿIJåijĎçŽĎæŹŢåd'ť'è¡ňåŘŚïijŇåd'ĎçŘĘæIJňåIJřåŇŰæŮěæIJ§çŽĎéĂ åźűçŤÍåőČæİěæL'ğèąŇæL'ĂæIJL'çŽĎäÿ■éŮt'å■ŸåĆÍåŠŇæŞ■ä¡IJãĂĆæŕŤåęĆïijŽ

```
>>> print(loc_d)
2013-03-10 01:45:00-06:00
>>> utc_d = loc_d.astimezone(pytz.utc)
>>> print(utc_d)
2013-03-10 07:45:00+00:00
>>>
```

äÿĂæŮęè¡ňæ■ćäÿžUTCïijÑä¡ăářšäÿ■çŤÍåŐżæŃĚå£Čèů§åd'Ŕäžd'æŮűçŻÿåĚşçŽĎéŮőécŸäžĘãĂĆ åŻăæ■d'ïijÑä¡ăåŔŕäżěèů§äźŃåL'■äÿĂæăůæŤ¿å£ČçŽĎæL'ğèąŇåÿÿèğĄçŽĎæŮěæIJ§èőąçőŮãĂĆ å¡Şä¡ăæČşářĘè¿ŞåĞžåŔŸäÿžæIJňåIJřæŮűéŮt'çŽĎæŮűåĂŹïijÑä¡£çŤÍåŘĹéĂĆçŽĎæŮűåŇžåŐżè¡ňæ■ćäÿŃå

```
>>> later_utc = utc_d + timedelta(minutes=30)
>>> print(later_utc.astimezone(central))
2013-03-10 03:15:00-05:00
>>>
```

å¡ŞæűL'åŔŁåĹřæŮűåŇžæŞ■ä¡IJçŽĎæŮűåĂŹïijÑæIJL'äÿłéŮőécŸåřśæŸŕæĹŚäžňåęĆä¡Ţå¿ŮåĹřæŮűåŇ ærŤåęĆïijŇåIJÍè£ŹäÿŀäżNå■Řäÿ■ïijÑæĹŚäžňåęĆä¡Ţç§ěéĄŞâĂIJAsia/KolkataâĂİåřśæŸŕå■řåžęåŕźåžŤçŽĎæ äÿžäžĘæ§ěæL'¿ïijŇåŔŕäżěä¡£çŤÍISO 3166åŻ¡åőűäžčçăĄä¡IJäÿžåĚşéŤőå■ŮåŐżæ§ěéŸĚå■ŮåĚÿ `pytz.country_timezones` ãĂĆæŕŤåęĆïijŽ

```
>>> pytz.country_timezones['IN']
['Asia/Kolkata']
>>>
```

æşÍïijŽå¡Şä¡ăéŸĚèŕžåĹřè£ŹéĞŇçŽĎæŮűåĂŹïijŇæIJL’åŔŕèČ¡ pytz
æÍąåİŮåůšçżŔäÿ■åĘ■åžžèőőä¡£çŤÍäžĘïijŇåŽääÿžPEP431æŔŘåĞžäžĘæŻt’åĚĹè£ŻçŽĎæŮűåŇžæŤŕæŇĄãĂ
ä¡ĘæŸŕè£ŹéĞŇèŕĹåĹřçŽĎå¿Ĺåd’ŽéŮőécŸè£ŸæŸŕæIJL’åŔĆèĂČäżůåĂijçŽĎ(æŕŤåęĆä¡£çŤÍUTCæŮěæIJ§ç

6 çňňåŻŻçńäïijŽè£■äžčåŹÍäÿŐçŤ§æĹŘåŹÍ

è£■äžčæŸŕPythonæIJĂåijžåd’ğçŽĎåŁ§èČ¡äźŇäÿĂãĂĆåĹİçIJŃèţůæİěŕijŇä¡ăåŔŕèČ¡äijŽçőĂå■ŢçŽĎèőc
çĎűèĂŇïijŇçżÍéİđäžĚäžĚåŕśæŸŕåęĆæ■d’ïijŇè£ŸæIJL’å¿Ĺåd’Žä¡ăåŔŕèČ¡äÿ■ç§ěéĄŞçŽĎïijŇ
æŕŤåęĆåĹŻåžžä¡ăèĞłåůśçŽĎè£■äžčåŹÍåŕźèśąïijŇåIJÍitertoolsæÍąåİŮäÿ■ä¡£çŤÍæIJL’çŤÍçŽĎè£■äžčæÍąåijŔïij
è£ŹäÿĂçńäçŽőçŽĎåŕśæŸŕåŘŚä¡ăåśŢçd’žèů§è£■äžčæIJL’åĚşçŽĎåŘĎçğ■åÿÿèğĄéŮőécŸãĂĆ

Contents:

6.1 4.1 æĽŃåŁÍéĄ■åŐĘè£■äžčåŹÍ

éŮőécŸ

ä¡ăæČşéĄ■åŐĘäÿĂäÿłåŔŕè£■äžčåŕźèśąäÿ■çŽĎæL’ĂæIJL’åĚČçt’ăïijŇä¡ĘæŸŕå■t’äÿ■æČşä¡£çŤÍforå¿łçČ

èğčåĘşæŰźæąĹ

äÿžäžĘæL’ŃåŁÍçŽĎéĄ■åŐĘåŔŕè£■äžčåŕźèśąïijŇä¡£çŤÍ next()
åĞ¡æŢřåźűåIJÍäžčçĂąäÿ■æ■ŢèŐů StopIteration åijĆåÿÿãĂĆ
æŕŤåęĆïijŇäÿŃéİćçŽĎä¿Ńå■ŘæL’ŃåŁÍèŕžåŔŰäÿĂäÿłæŰĞäžűäÿ■çŽĎæL’ĂæIJL’èąŇïijŽ

```
def manual_iter():
    with open('/etc/passwd') as f:
        try:
            while True:
                line = next(f)
                print(line, end='')
        except StopIteration:
            pass
```

éĂŽåÿÿæİěèőšïijŇ StopIteration çŤÍæİěæŇĞçd’žè£■äžčçŽĎçżŞår¿ãĂĆ
çĎűèĂŇïijŇåęĆæđIJä¡ăæL’ŃåŁÍä¡£çŤÍäÿŁéİćæijŢçd’žçŽĎ next()
åĞ¡æŢřçŽĎèŕİïijŇä¡ăè£ŸåŔŕäžééĂŽè£Gè£ŤåŻđäÿĂäÿłæŇĞåőŽåĂijæİěæăĞèőřçżŞår¿ïijŇæŕŤåęĆ
None ãĂĆ äÿŃéİćæŸŕçd’žä¿ŃïijŽ

```
with open('/etc/passwd') as f:
    while True:
        line = next(f, None)
        if line is None:
            break
        print(line, end='')
```

èőÍèőž

åď ğåď ŽæŢřæČĚåĘţäÿŃïijŇæĹŚäžňäijŽä¡£çŤÍ `for` å¿łçŐŕèŕ■åŘěçŤÍæİěéĄ■åŐĘäÿĂäÿłåŘŕè£■äžčåŕźè
ä¡ĘæŸŕïijŇåĄűåřŤäź§éIJĂèęĄåŕźè£■äžčåĄŽæŻť åŁăçš¿çąőçŽĎæŐğåĹűïijŇè£ŹæŮűåĂŹäžĘèğčåžŢåśĆè£■ä

äÿŃéİćçŽĎäžď äžŠçď žä¿ŃåŘŚæĹŚäžňæijŤçď žäžĘè£■äžčæIJ§éŮť æĽĂåŘŚçŤ§çŽĎå§žæIJňçżĘèŁĆïijŽ

```
>>> items = [1, 2, 3]
>>> # Get the iterator
>>> it = iter(items) # Invokes items.__iter__()
>>> # Run the iterator
>>> next(it) # Invokes it.__next__()
1
>>> next(it)
2
>>> next(it)
3
>>> next(it)
Traceback (most recent call last):
    File "<stdin>", line 1, in <module>
StopIteration
>>>
```

æIJňçńăæŐěäÿŃæİěåĞåářŘèŁĆäijŽæŻť æůšåĚěçŽĎèőšèğčè£■äžčçŻÿåĚşæŁĂæIJŕïijŇåĽ■æŘŘæŸŕä¡ăă
æĽĂäżěçąőä£Ia¡ăåůšçżŘæŁŁè£ŹçńăçŽĎåĘĚåőźçĽ ćçĽ ćèőřåIJĺå£ČäÿąãĂĆ

6.2 4.2 äžčçŘĘè£■äžč

éŮőécŸ

ä¡ăæđĎåžžäžĘäÿĂäÿłèĞłåőŽäźĽåőźåŹĺářźèšąïijŇéĞŇéİcåŇĚåŘńæIJĽåĹŮèąĺãĂĄåĚČçżĎæĹŰåĚűäżŮ
ä¡ăæČşçŻť æŐěåIJĺä¡äçŽĎè£ŹäÿłæŰřåőźåŹĺářźèšąäÿŁæĽğèąŇè£■äžčæŞ■ä¡IJãĂĆ

èğčåĘşæŰźæąĹ

åőđéŹĚäÿŁä¡ăåŘłéIJĂèęĄåőŽäźĽäÿĂäÿł `__iter__()`
æŰźæşŢïijŇářĘè£■äžčæŞ■ä¡IJäžčçŘĘåĹřåőźåŹĺåĘĚéČĺçŽĎářźèšąäÿŁåŐżãĂĆæŕŤåęĆïijŽ

```
class Node:
    def __init__(self, value):
        self._value = value
        self._children = []

    def __repr__(self):
        return 'Node({!r})'.format(self._value)

    def add_child(self, node):
        self._children.append(node)
```

```
    def __iter__(self):
        return iter(self._children)

# Example
if __name__ == '__main__':
    root = Node(0)
    child1 = Node(1)
    child2 = Node(2)
    root.add_child(child1)
    root.add_child(child2)
    # Outputs Node(1), Node(2)
    for ch in root:
        print(ch)
```

åIJÍäÿŁéİćäžčçăĄäÿ■ïijŇ __iter__() æŰźæşŢåŔłæŸŕçőĂå■ŢçŽĎåřĘè£■äżčèŕůæśĆäijăéĂŠçżŹåĘĚé _children åśđæĂğãĂĆ

èőÍèőž

PythonçŽĎè£■äżčåŹÍå■ŔèőőéIJĂèęĄ __iter__() æŰźæşŢè£ŤåŻđäÿĂäÿłåőđçŐřäžĘ __next__() æŰźæşŢçŽĎè£■äżčåŹÍåŕźèśąãĂĆ åęĆæđIJä¡ăåŔłæŸŕè£■äżčéĄ■åŐĘåĚűäżŰåőźåŹÍçŽĎåĘĚå

è£ŹéĞŇçŽĎ iter() åĞ¡æŢřçŽĎä¡£çŤÍçőĂåŇŰäžĘäžčçăĄïijŇ iter(s) åŔłæŸŕçőĂå■ŢçŽĎéĂŽè£ĞèřČçŤÍ s.__iter__() æŰźæşŢæİèè£ŤåŻđåŕźåžŤçŽĎè£■äżčåŹÍåŕźèśąïijŇ åřśèů§ len(s) äijŽèřČçŤÍ s.__len__() åŐ§çŘĘæŸŕäÿĂæăůçŽĎãĂĆ

6.3 4.3 ä¡£çŤÍçŤ§æĹŘåŹÍåĹŻåžžæŰřçŽĎè£■äżčæÍąåijŔ

éŮőécŸ

ä¡ăæČşåőđçŐřäÿĂäÿłèĞłåőŽäźL'è£■äżčæÍąåijŔïijŇèů§æŹőéĂŽçŽĎåĘĚç¡őåĞ¡æŢřæŕŤåęĆ range() , reversed() äÿ■äÿĂæăůãĂĆ

èğčåĘşæŰźæąĹ

åęĆæđIJä¡ăæČşåőđçŐřäÿĂçğ■æŰřçŽĎè£■äżčæÍąåijŔïijŇä¡£çŤÍäÿĂäÿłçŤ§æĹŘåŹÍåĞ¡æŢřæİèåőŽäźL'å äÿŃéİćæŸŕäÿĂäÿłçŤ§äžğæ§ŘäÿłèŇČåŻt'åĘĚæţőçĆźæŢřçŽĎçŤ§æĹŘåŹÍïijŽ

```
def frange(start, stop, increment):
    x = start
    while x < stop:
        yield x
        x += increment
```

äÿžäžĘä¡£çŤÍè£ŹäÿłåĞ¡æŢřïijŇ ä¡ăåŔřäžěçŤÍforå¿łçŐřè£■äžčåőČæĹŰèĂĚä¡£çŤÍåĚűäžŰæŐěåŔŮäÿĂä
sum() ,list() ç■Ľ)ãĂĆçď žä¿ŃåęĆäÿŃïijŽ

```
>>> for n in frange(0, 4, 0.5):
...     print(n)
...
0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
>>> list(frange(0, 1, 0.125))
[0, 0.125, 0.25, 0.375, 0.5, 0.625, 0.75, 0.875]
>>>
```

èőÍèőž

äÿĂäÿłåĞ¡æŢřäÿ■éIJĂèęĄæIJL'äÿĂäÿł yield èŕ■åŔěå■şåŔřårĘåĚűè¡ňæ■ćäÿžäÿĂäÿłçŤ§æĹŘåŹÍãĂĆ
èů§æŹőéĂŽåĞ¡æŢřäÿ■åŘŇçŽĎæŸřïijŇçŤ§æĹŘåŹÍåŔłèČ¡çŤÍäžŐè£■äžčæŞ■ä¡IJãĂĆ
äÿŃéÍćæŸŕäÿĂäÿłåőđéłŃïijŇåŘŚä¡ăåśŢçď žè£ŹæăůçŽĎåĞ¡æŢřåžŢåśĆåůěä¡IJæIJžåĹűïijŽ

```
>>> def countdown(n):
...     print('Starting to count from', n)
...     while n > 0:
...         yield n
...         n -= 1
...     print('Done!')
...

>>> # Create the generator, notice no output appears
>>> c = countdown(3)
>>> c
<generator object countdown at 0x1006a0af0>

>>> # Run to first yield and emit a value
>>> next(c)
Starting to count from 3
3

>>> # Run to the next yield
>>> next(c)
2

>>> # Run to next yield
>>> next(c)
1
```

```
>>> # Run to next yield (iteration stops)
>>> next(c)
Done!
Traceback (most recent call last):
    File "<stdin>", line 1, in <module>
StopIteration
>>>
```

äÿĂäÿłçŢ§æĹŘåŹĺåĞ¡æŢřäÿżèęĄçĽźå¿ĄæŸŕåőČåŔłäijŽåŻđåžŢåIJĺè£■äżčäÿ■ä¡£çŢĺåĹřçŽĎ
next æŞ■ä¡IJãĂĆ äÿĂæŮęçŢ§æĹŘåŹĺåĞ¡æŢřè£ŢåŻđéĂĂåĞžïijŇè£■äżčçżĹæ■ćãĂĆæĹŚäžňåIJĺè£■äżčäÿ■é

6.4 4.4 åőđçŐřè£■äżčåŹĺå■Ŕèőő

éŮőécŸ

ä¡ăæČşæđĎåžžäÿĂäÿłèČ¡æŢŕæŇĄè£■äżčæŞ■ä¡IJçŽĎèĞłåőŽäźĽ'åŕźèśąïijŇåźűåÿŇæIJŻæĽ'¿åĹřäÿĂäÿł

èğčåĘşæŰźæąĹ

çŻőåĽ'■äÿžæ■ćïijŇåIJĺäÿĂäÿłåŕźèśąäÿŁåőđçŐřè£■äżčæIJĂçőĂå■ŢçŽĎæŰźåijŔæŸŕä¡£çŢĺäÿĂäÿłçŢ§æ
åIJĺ4.2åřŔèŁĆäÿ■ïijŇä¡£çŢĺNodeçśżæİěèąĺçđ'žæăŚå¡ćæŢřæ■őçżŞæđĎãĂĆä¡ăåŔŕèČ¡æČşåőđçŐřäÿĂäÿłäżěa
äÿŃéİćæŸŕäžčçăĄçđ'žä¿ŃïijŽ

```
class Node:
    def __init__(self, value):
        self._value = value
        self._children = []

    def __repr__(self):
        return 'Node({!r})'.format(self._value)

    def add_child(self, node):
        self._children.append(node)

    def __iter__(self):
        return iter(self._children)

    def depth_first(self):
        yield self
        for c in self:
            yield from c.depth_first()

# Example
if __name__ == '__main__':
    root = Node(0)
    child1 = Node(1)
    child2 = Node(2)
```

```
    root.add_child(child1)
    root.add_child(child2)
    child1.add_child(Node(3))
    child1.add_child(Node(4))
    child2.add_child(Node(5))

    for ch in root.depth_first():
        print(ch)
    # Outputs Node(0), Node(1), Node(3), Node(4), Node(2), Node(5)
```

åIJÍè£Źæőţäžčçă Ąäÿ■ïijŇdepth_first() æŰźæşŢçőĂå■ŢçŻť'èğĆãĂĆ åőČéęŰåĚĹè£ŤåŻđèĞłåůśæIJňèžńåźűè£■äžčæŕŔäÿĂäÿłå■ŘèŁĆçĆźåźű éĂŽè£ĞèřČçŤĺå■ŘèŁĆçĆźçŽĎ depth_first() æŰźæşŢ(ä¡£çŤÍ yield from èŕ■åŘě)è£ŤåŻđåŕźåžŤåĚČçť'ããĂĆ

èőÍèőž

PythonçŽĎè£■äžčå■Ŕèőőèę Ąæś ĆäÿĂäÿł __iter__() æŰźæşŢè£ŤåŻđäÿĂäÿłçL'źæőŁçŽĎè£■äžčåŹĺåŕźèśąïijŇ è£Źäÿłè£■äžčåŹĺåŕźèśąåőđçŐřäžĘ __next__() æŰźæşŢåźűéĂŽè£Ğ StopIteration åijĆåÿÿæăĞèŕĘè£■äžčçŽĎåőŇæĹŘãĂĆ ä¡ĘæŸŕïijŇåőđçŐřè£ŹäžŻéĂŽåÿÿäijŽæŕŤè¿ČçźĄçŘŘãĂĆ äÿŃéİćæĹŚäžňæijŤçd'žäÿŃè£Źçğ■æŰźåijŔïijŇå depth_first() æŰźæşŢïijŽ

```
class Node2:
    def __init__(self, value):
        self._value = value
        self._children = []

    def __repr__(self):
        return 'Node({!r})'.format(self._value)

    def add_child(self, node):
        self._children.append(node)

    def __iter__(self):
        return iter(self._children)

    def depth_first(self):
        return DepthFirstIterator(self)


class DepthFirstIterator(object):
    '''
    Depth-first traversal
    '''

    def __init__(self, start_node):
        self._node = start_node
        self._children_iter = None
```

```
        self._child_iter = None

    def __iter__(self):
        return self

    def __next__(self):
        # Return myself if just started; create an iterator for␣
↪children
        if self._children_iter is None:
            self._children_iter = iter(self._node)
            return self._node
        # If processing a child, return its next item
        elif self._child_iter:
            try:
                nextchild = next(self._child_iter)
                return nextchild
            except StopIteration:
                self._child_iter = None
                return next(self)
        # Advance to the next child and start its iteration
        else:
            self._child_iter = next(self._children_iter).depth_
↪first()
            return next(self)
```

DepthFirstIterator çśżåŠÑäÿŁéÍćä¡£çŤÍçŤ§æĹŘåŹÍçŽĎçL'ĹæIJňåůěä¡IJåŐ§çŘĘçśżäijijïijÑ
ä¡ĘæŸŕåőČåĘŹèţůæÍěå¿ĹçźAçŘŘïijÑåŽääÿžè£■äžčåŹÍå£Ěéążå IJÍè£■äžčåd'ĎçŘĘè£ĞçÍÑäÿ■çżt'æŁd'åd'ğéČ
åÍęçŹ¡æÍěèőšïijÑæšąäžžæĎ£æĎŔåĘŹè£ŹäźĹæŹęæűl'çŽĎäžčçăĄãĂĆåřĘä¡äçŽĎè£■äžčåŹÍåőŽäźL'äÿžäÿĂäÿ

6.5 4.5 åŔ■åŘŚè£■äžč

éŮőécŸ

ä¡ăæČşåŔ■æŰźåŘŚè£■äžčäÿĂäÿłåžŔåĹŮ

èğčåĘşæŰźæąĹ

ä¡£çŤÍåĘĚç¡őçŽĎ `reversed()` åĞ¡æŢřïijÑæŕŤåęĆïijŽ

```
>>> a = [1, 2, 3, 4]
>>> for x in reversed(a):
...     print(x)
...
4
3
2
1
```

åŕ■åŘŝè£■äžčäžĚäžĚå¡Şåŕźèśąçž Ďåď ğåřŕåŕŕéčĎåĚĹçąőåőŽæĹŰèĂĚåŕźèśąåőđçŐřäžĘ
__reversed__() çŽĎçĽźæőŁæŰźæşŢæŮűæĽ■èČ¡çŤ§æŢĹãĂĆ
åęĆæđIJäÿď èĂĚéČ¡äÿ■çňęåŘĹïijŇéĆčä¡ăå£Ěéążå ĚĹåřĘåŕźèśąè¡ňæ■ćäÿžäÿĂäÿłåĹŮèąÍæĽ■èąŇïijŇæŕŤåęĆ

```
# Print a file backwards
f = open('somefile')
for line in reversed(list(f)):
    print(line, end='')
```

èęĄæşÍæĎŘçŽĎæŸŕåęĆæđIJåŘŕè£■äžčåŕźèśąåĚČçť ăå¿Ĺåď ŽçŽĎèŕÍïijŇåřĘåĚűéčĎåĚĹè¡ňæ■ćäÿžäÿĂ

èőÍèőž

å¿Ĺåď ŽçÍŃåžŘåŚŸåźűäÿ■ç§ěéĄŞåŘŕäžěéĂŽè£ĞåIJÍèĞłåőŽäźĽçśžäÿŁåőđçŐř
__reversed__() æŰźæşŢæÌěåőđçŐřåŕ■åŘŚè£■äžčãĂĆæŕŤåęĆïijŽ

```
class Countdown:
    def __init__(self, start):
        self.start = start

    # Forward iterator
    def __iter__(self):
        n = self.start
        while n > 0:
            yield n
            n -= 1

    # Reverse iterator
    def __reversed__(self):
        n = 1
        while n <= self.start:
            yield n
            n += 1

for rr in reversed(Countdown(30)):
    print(rr)
for rr in Countdown(30):
    print(rr)
```

åőŽäźĽäÿĂäÿłåŕ■åŘŚè£■äžčåŹĺåŕŕäžěä¡£å¿ŮäžčçăĄéİđåÿÿçŽĎéńŸæŢĹïijŇ
åŻääÿžåőČäÿ■åĘ■éIJĂèęĄåřĘæŢřæ■őåąńåĚĚåĹřäÿĂäÿłåĹŮèąÍäÿ■çĎűåŘŐåĘ■åŐżåŕ■åŘŚè£■äžčè£ŹäÿłåĹ

6.6 4.6 åÿęæIJĽåď ŰéČÍçŁűæĂĄçŽĎçŤ§æĹŘåŹĺåĞ¡æŢř

éŮőéćŸ

ä¡ăæČşåőŽäźĽäÿĂäÿłçŤ§æĹŘåŹĺåĞ¡æŢřïijŇä¡ĘæŸŕåőČäijŽèřČçŤÍæ§Řäÿłä¡ăæČşæŽť éIJšçżŹçŤÍæĹůă

èğčåĘşæŰźæąĹ

åęĆædIJä¡ăæČşèőľ'ä¡ăçŽĎçŤ§æĹŘåŹĺæŽť'éIJšåď'ŰéČĺçŁűæĂĄçżŹçŤĺæĹůïijŇ
åĹńå£ŸäžĘä¡ăåŔŕäžěçőĂå■ŢçŽĎåřĘåőČåőđçŐřäÿžäÿĂäÿłçśžïijŇçĎűåŘŐæŁŁçŤ§æĹŘåŹĺåĞ¡æŢřæŤ¿åĹř
`__iter__()` æŰźæşŢäÿ■è£ĞåŐżãĂĆæŕŤåęĆïijŽ

```
from collections import deque

class linehistory:
    def __init__(self, lines, histlen=3):
        self.lines = lines
        self.history = deque(maxlen=histlen)

    def __iter__(self):
        for lineno, line in enumerate(self.lines, 1):
            self.history.append((lineno, line))
            yield line

    def clear(self):
        self.history.clear()
```

äÿžäžĘä¡£çŤĺè£ŹäÿłçśžïijŇä¡ăåŔŕäžěåřĘåőČå¡ŞåĄŽæŸŕäÿĂäÿłæŹőéĂŽçŽĎçŤ§æĹŘåŹĺåĞ¡æŢřãĂĆ
çĎűěĂŇïijŇçŤśäžŐåŔŕäžěåĹŻåžžäÿĂäÿłåőđä¿ŃåŕźèśąïijŇäžŐæŸŕä¡ăåŔŕäžěèő£éŮőåĘĚéČĺåšđæĂğåĂijïijŇ
æŕŤåęĆ `history` åšđæĂğæĹŰèĂĚæŸŕ `clear()` æŰźæşŢãĂĆäžčçăĄçď'žä¿ŃåęĆäÿŇïijŽ

```
with open('somefile.txt') as f:
    lines = linehistory(f)
    for line in lines:
        if 'python' in line:
            for lineno, hline in lines.history:
                print('{}:{}'.format(lineno, hline), end='')
```

èőĺèőž

åĚşäžŐçŤ§æĹŘåŹĺïijŇå¿ĹåőźæŸ§æŐL'è£ŻåĞ¡æŢřæŮăæL'Ăäÿ■èČ¡çŽĎéŹůéŸśãĂĆ
åęĆædIJçŤ§æĹŘåŹĺåĞ¡æŢřéIJĂèęĄèů§ä¡ăçŽĎçĺŃåžŘåĚűäžŰéČĺåĹĘæL'Şäžď'éĄŞçŽĎèŕĺ(æŕŤåęĆæŽť'éIJšă
åŘŕèČ¡äijŽåŕijèĞť'ä¡ăçŽĎäžčçăĄåijĆåÿÿçŽĎåď'■æĺĆãĂĆ åęĆædIJæŸŕè£ŹçĞ■æČĚåĘţçŽĎèŕĺïijŇåŘŕäžěèĂĆ
åIJĺ `__iter__()` æŰźæşŢäÿ■åőŽäźL'ä¡ăçŽĎçŤ§æĹŘåŹĺäÿ■äijŽæŤźåŔŸä¡ääżä¡ŢçŽĎçőŮæşŢéĂżè¿ŚãĂĆ
çŤśäžŐåőČæŸŕçśžçŽĎäÿĂéČĺåĹĘïijŇæL'ĂäžěåĚĄèőÿä¡ăåőŽäźL'åŘĎçĞ■åšđæĂğåŠŇæŰźæşŢæÌěä¿ŻçŤĺæĹ

äÿĂäÿłéIJĂèęĄæşĺæĎŔçŽĎåřŔåIJřæŰźæŸŕïijŇåęĆædIJä¡ăåIJĺè£■äžčæŞ■ä¡IJæŮűäÿ■ä¡£çŤĺforå¿łçŐŕè
`iter()` åĞ¡æŢřãĂĆæŕŤåęĆïijŽ

```
>>> f = open('somefile.txt')
>>> lines = linehistory(f)
>>> next(lines)
Traceback (most recent call last):
    File "<stdin>", line 1, in <module>
TypeError: 'linehistory' object is not an iterator
```

```
>>> # Call iter() first, then start iterating
>>> it = iter(lines)
>>> next(it)
'hello world\n'
>>> next(it)
'this is a test\n'
>>>
```

6.7 4.7 è£■äżčåŹĺåĹĞçĽĞ

éŮőécŸ

ä¡ăæČşå¿ŮåĹřäÿĂäÿłçŤśè£■äżčåŹĺçŤ§æĹŘçŽĎåĹĞçĽĞåŕźèśąïijŇä¡ĘæŸŕæăĞåĞĘåĹĞçĽĞæŞ■ä¡IJåź

èğčåĘşæŰźæąĹ

åĞ¡æŢř `itertools.islice()` æ■čåě¡éĂĆçŤĺäžŐåIJĺè£■äżčåŹĺåŠŇçŤ§æĹŘåŹĺäÿŁåĄŽåĹĞçĽĞæ

```
>>> def count(n):
...     while True:
...         yield n
...         n += 1
...
>>> c = count(0)
>>> c[10:20]
Traceback (most recent call last):
    File "<stdin>", line 1, in <module>
TypeError: 'generator' object is not subscriptable

>>> # Now using islice()
>>> import itertools
>>> for x in itertools.islice(c, 10, 20):
...     print(x)
...
10
11
12
13
14
15
16
17
18
19
>>>
```

èőÍèőž

è£■äžčåŹÍåŠÑçŤ§æĹŘåŹÍäÿ■èČ¡ä¡£çŤÍæăĞåĞEçŽĎåĹĞçL'ĞæŞ■ä¡IJïijÑåŻăäÿžåőČäžñçŽĎéŢ£åžęäžÑ
åĞ¡æŢř `islice()` è£ŤåŻđäÿĂäÿłåŘŕäžěçŤ§æĹŘæŇĞåőŽåĚČçť'ăçŽĎè£■äžčåŹÍïijÑåőČéĂŽè£ĞéĄ■åŐEå
çĎűåŘŐæL'■åijĂåğÑäÿĂäÿłäÿłçŽĎè£ŤåŻđåĚČçť'ăïijÑåźűçŻť'åĹŕåĹĞçL'ĞçżŞæİ§çť'ćåijŢä¡■ç¡őãĂĆ

è£ŹéĞŇèęĄçİĂéĞ■åijžèřČçŽĎäÿĂçĆźæŸŕ `islice()`
äijŽæűĹèĂŮæŐL'äijăåĚěçŽĎè£■äžčåŹÍäÿ■çŽĎæŢřæ■őãĂĆ å£Ěéążè ĂČèŹŚåĹřè£■äžčåŹÍæŸŕäÿ■åŘréĂEçŽ
æL'Ăäžěåę ĆæđIJä¡äéIJĂèęĄäźÑåŘŐåE■æñąèő£éŮőè£Źäÿłè£■äžčåŹÍçŽĎèŕİïijÑéĆčä¡ääřšå¿ŮåĚĹářĘåőČéĞ

6.8 4.8 èůşè£ĞåŘŕè£■äžčåŕźèšąçŽĎåijĂåğÑéČĺåĹĘ

éŮőécŸ

ä¡ăæČşéĄ■åŐEäÿĂäÿłåŘŕè£■äžčåŕźèšąïijÑä¡ĘæŸŕåőČåijĂåğÑçŽĎæ§ŘäžŽåĚČçť'ăä¡ääźűäÿ■æĎ§åĚt'è

èğčåĘşæŰźæąĹ

`itertools` æĺąåİŮäÿ■æIJL'äÿĂäžŽåĞ¡æŢřåŘŕäžěåőÑæĹŘè£ŹäÿłäżżåŁąãĂĆ
éęŰåĚĹäžÑçż■çŽĎæŸŕ `itertools.dropwhile()` åĞ¡æŢřãĂĆä¡£çŤÍæŮűïijÑä¡ăçżŹåőČäijăéĂŠäÿĂäÿ
åőČäijŽè£ŤåŻđäÿĂäÿłè£■äžčåŹÍåŕźèšąïijÑäÿćåijČåŐ§æIJL'åžŘåĹŮäÿ■çŻť'åĹřåĞ¡æŢřè£ŤåŻđFlaseäźÑåL'■ç

äÿžäžĘæijŤçđ'žïijÑåĄĞåőŽä¡ăåIJÍèŕżåŘŰäÿĂäÿłåijĂåğÑéČÍåĹĘæŸŕåĞăèąÑæşÍéĞŁçŽĎæžŘæŰĞäžűã

```
>>> with open('/etc/passwd') as f:
...     for line in f:
...         print(line, end='')
...
##
# User Database
#
# Note that this file is consulted directly only when the system is␣
↪running
# in single-user mode. At other times, this information is provided␣
↪by
# Open Directory.
...
##
nobody:*:-2:-2:Unprivileged User:/var/empty:/usr/bin/false
root:*:0:0:System Administrator:/var/root:/bin/sh
...
>>>
```

åęĆæđIJä¡ăæČşèůşè£ĞåijĂåğÑéČÍåĹĘçŽĎæşÍéĞŁèąÑçŽĎèŕİïijÑåŘŕäžěè£ŹæăůåĄŽïijŽ

```
>>> from itertools import dropwhile
>>> with open('/etc/passwd') as f:
...     for line in dropwhile(lambda line: line.startswith('#'), f):
```

```
...         print(line, end='')
...
nobody:*:-2:-2:Unprivileged User:/var/empty:/usr/bin/false
root:*:0:0:System Administrator:/var/root:/bin/sh
...
>>>
```

è£Źäÿłä¿Ńå■ŘæŸŕå§žäžŐæäźæ■őæ§ŘäÿłæţŃèŕŢåĞ¡æŢřèůşè£ĞåijĂåğŃçŽĎåĚČçť ăãĂĆ åęĆæđIJä¡ăåůšçżŔæŸŐçąőç§ěéĄŞäžĘèęĄèůşè£ĞçŽĎåĚČçť ăçŽĎäÿłæŢřçŽĎèŕÍïijŃéĆčäźĹåŔŕäžěä¡£çŤÍ `itertools.islice()` æİěäžčæŻ£ãĂĆæŕŤåęĆïijŽ

```
>>> from itertools import islice
>>> items = ['a', 'b', 'c', 1, 4, 10, 15]
>>> for x in islice(items, 3, None):
...     print(x)
...
1
4
10
15
>>>
```

åIJÍè£Źäÿłä¿Ńå■Řäÿ■ïijŃ `islice()` åĞ¡æŢřæIJĂåŘŐéĆčäÿł `None` åŔĆæŢřæŇĞåőŽäžĘä¡ăèęĄèŐůåŔŰäżŐçňň3äÿłåĹřæIJĂåŘŐçŽĎæL'ĂæIJL'åĚČçť ăïijŃ åęĆæđIJ `None` åŠŇ3çŽĎä¡■ç¡őåŕźèřČïijŃæĎŔæĂİåřśæŸŕäžĚäżĚèŐůåŔŰåL'■äÿL'äÿłåĚČçť ăæĄřæĄřçŻÿåŔ (è£Źäÿłèů§åĹĞçL'ĞçŽĎçŻÿåŔ■æŞ■ä¡IJ `[3:]` åŠŇ `[:3]` åŐ§çŘĘæŸŕäÿĂæăůçŽĎ)ãĂĆ

èőÍèőž

åĞ¡æŢř `dropwhile()` åŠŇ `islice()` åĚűåőđåřśæŸŕäÿd'äÿłåÿőåŁl'åĞ¡æŢřïijŃäÿžçŽĎåřśæŸŕéĄ£ål

```
with open('/etc/passwd') as f:
    # Skip over initial comments
    while True:
        line = next(f, '')
        if not line.startswith('#'):
            break

    # Process remaining lines
    while line:
        # Replace with useful processing
        print(line, end='')
        line = next(f, None)
```

èůşè£ĞäÿĂäÿłåŔŕè£■äžčåŕźèśąçŽĎåijĂåğŃéČĺåĹĘèů§éĂŽåÿÿçŽĎè£ĞæżďæŸŕäÿ■åŘŃçŽĎãĂĆ æŕŤåęĆïijŃäÿŁè£ŕäžčçăĄçŽĎçňňäÿĂäÿłéČĺåĹĘåŔŕèČ¡äijŽè£ŹæăúéĞ■åĘŹïijŽ

```
with open('/etc/passwd') as f:
    lines = (line for line in f if not line.startswith('#'))
```

```
    for line in lines:
        print(line, end='')
```

è£ŹæăůåĘŹçąőåőđåŘŕäžěèůşè£ĞåijĂåğŃéČĺåĹĘçŽĎæşĺéĞŁèąŇïijŇä¡ĘæŸŕåŘŇæăůäź§äijŽèůşè£ĞæŰ
æ■ćåŘěèŕİèőšïijŇæĹŚäžňçŽĎèğčåĘşæŰźæąĹæŸŕäžĚäžĚèůşè£ĞåijĂåğŃéČĺåĹĘæżąèűşæţŃèŕŢæİąäžűçŽĎè

æIJĂåŘŐéIJĂèęĄçİĂéĞ■åijžèřČçŽĎäÿĂçĆźæŸŕïijŇæIJñèŁĆçŽĎæŰźæąĹéĂĆçŤĺäžŐæĽ’ĂæIJL’åŘŕè£
æŕŤåęĆçŤ§æĹŘåŹĺïijŇæŰĞäžűåŘŁåĚűçśžäijijçŽĎåŕźèśąãĂĆ

6.9 4.9 æŐŠåĹŮçżĎåŘĹçŽĎè£■äžč

éŮőécŸ

ä¡ăæČşè£■äžčéĄ■åŐĘäÿĂäÿłéŽĘåŘĹäÿ■åĚČçť ăçŽĎæĽ’ĂæIJL’åŘŕèČ¡çŽĎæŐŠåĹŮæĹŰçżĎåŘĹ

èğčåĘşæŰźæąĹ

itertoolsæĺąåİŮæŔŘä¿ŻäžĘäÿL’äÿłåĞ¡æŢřæİěèğčåĘşè£ŹçśźéŮőécŸãĂĆ
åĚűäÿ■äÿĂäÿłæŸŕ `itertools.permutations()` ïijŇ
åőČæŐěåŘŮäÿĂäÿłéŽĘåŘĹåźűäžğçŢ§äÿĂäÿłåĚČçżĎåžŘåĹŮïijŇæŕŔäÿłåĚČçżĎçŢśéŽĘåŘĹäÿ■æĽ’ĂæIJL’
äź§åřśæŸŕèŕť éĂŽè£ĞæĽ’ŞäźśéŽĘåŘĹäÿ■åĚČçť ăæŐŠåĹŮéąžåžŘçŢ§æĹŘäÿĂäÿłåĚČçżĎïijŇæŕŤåęĆïijŽ

```
>>> items = ['a', 'b', 'c']
>>> from itertools import permutations
>>> for p in permutations(items):
...     print(p)
...
('a', 'b', 'c')
('a', 'c', 'b')
('b', 'a', 'c')
('b', 'c', 'a')
('c', 'a', 'b')
('c', 'b', 'a')
>>>
```

åęĆæđIJä¡ăæČşå¿ŮåĹřæŇĞåőŽéŢ£åžęçŽĎæĽ’ĂæIJL’æŐŠåĹŮïijŇä¡ääŘŕäžěäijăéĂŠäÿĂäÿłåŘŕéĂL’çŽ

```
>>> for p in permutations(items, 2):
...     print(p)
...
('a', 'b')
('a', 'c')
('b', 'a')
('b', 'c')
('c', 'a')
('c', 'b')
>>>
```

ä¡£çŤĺ `itertools.combinations()` åŔŕå¿ŮåĹřè¿ŞåĚěéŻĘåŘĹäÿ■åĚČçť ăçŽĎæĽĂæIJĽçŽĎçżĽ

```
>>> from itertools import combinations
>>> for c in combinations(items, 3):
...     print(c)
...
('a', 'b', 'c')

>>> for c in combinations(items, 2):
...     print(c)
...
('a', 'b')
('a', 'c')
('b', 'c')

>>> for c in combinations(items, 1):
...     print(c)
...
('a',)
('b',)
('c',)
>>>
```

åŕźäžŐ `combinations()` æÍěèőšïijŇåĚČçť ăçŽĎéąžåžŔåůšçżŔäÿ■éĞ■èęĄäžĘãĂĆ äź§åřśæŸŕèŕťˇïijŇçżĎåŘĹ `('a', 'b')` èů§ `('b', 'a')` åĚűåőđæŸŕäÿĂæăůçŽĎ(æIJĂçżĹåŔłäijŽè¿ŞåĞžåĚűäÿ■äÿĂäÿł)ãĂĆ

åIJÍèőąçőŮçżĎåŘĹçŽĎæŮűåĂŹïijŇäÿĂæŮęåĚČçť ăèćńéĂĽˇåŔŰåřśäijŽäżŐåĂŹéĂĽˇäÿ■åĽˇŤéŹďˇæŐĽˇ èĂŇåĞ¡æŢř `itertools.combinations_with_replacement()` åĚĄèőÿåŘŇäÿĂäÿłåĚČçť ăèćńéĂĽˇæŃľåďˇŽæňąïijŇæŕŤåęĆïijŽ

```
>>> for c in combinations_with_replacement(items, 3):
...     print(c)
...
('a', 'a', 'a')
('a', 'a', 'b')
('a', 'a', 'c')
('a', 'b', 'b')
('a', 'b', 'c')
('a', 'c', 'c')
('b', 'b', 'b')
('b', 'b', 'c')
('b', 'c', 'c')
('c', 'c', 'c')
>>>
```

èőÍèőž

è£ŹäÿĂåřŔèŁĆæĹŚäżňåŘŚä¡ăåśŢçďˇžçŽĎäżĚäżĚæŸŕ `itertools` æÍąåİŮçŽĎäÿĂéČÍåĹĘåŁ§èČ¡ãĂĆ åř¡çőąä¡ăäź§åŔŕäžèèĞłåůśæĽˇŃåŁÍåőđçŐřæŐŠåĹŮçżĎåŘĹçőŮæşŢïijŇä

å¡ŞæĹŚäžňçćřåĹřçIJŃäÿŁåŐżæIJL'äžŻåď■æİĆçŽĎè£■äžčéŮőécŸæŮűïijŇæIJĂåě¡åŔŕäžěåĚĹåŐżçIJŃçIJŃi
åęĆæđIJè£ŹäÿłéŮőécŸå¿ĹæŹőéĄ■ïijŇéĆčäźĹå¿ĹæIJL'åŔŕèČ¡äijŽåIJĺéĞŇéİćæL'¿åĹřèğčåĘşæŰźæąĹïijĄ

6.10 4.10 åžŔåĹŮäÿŁçť'ćåijŢåĂijè£■äžč

éŮőécŸ

ä¡ăæČşåIJĺè£■äžčäÿĂäÿłåžŔåĹŮçŽĎåŘŇæŮűèů§èÿłæ■čåIJĺèćńåď'ĎçŘĘçŽĎåĚČçť'ăçť'ćåijŢãĂĆ

èğčåĘşæŰźæąĹ

åĘĚç¡őçŽĎ `enumerate()` åĞ¡æŢřåŔŕäžěå¿Ĺåě¡çŽĎèğčåĘşè£ŹäÿłéŮőécŸïijŽ

```
>>> my_list = ['a', 'b', 'c']
>>> for idx, val in enumerate(my_list):
...     print(idx, val)
...
0 a
1 b
2 c
```

äÿžäžĘæŇL'äijăçż§èąŇåŔůè¿ŞåĞž(èąŇåŔůäžŐ1åijĂåğŃ)ïijŇä¡ääŔŕäžěäijăéĂŠäÿĂäÿłåijĂåğŃåŔĆæŢř

```
>>> my_list = ['a', 'b', 'c']
>>> for idx, val in enumerate(my_list, 1):
...     print(idx, val)
...
1 a
2 b
3 c
```

è£Źçğ■æČĚåĘţåIJĺä¡ăéĄ■åŐĘæŰĞäžűæŮűæČşåIJĺéŤŹèŕŕæűĹæĄŕäÿ■ä¡£çŤĺèąŇåŔůåőŽä¡■æŮűåĂŹéĺ

```
def parse_data(filename):
    with open(filename, 'rt') as f:
        for lineno, line in enumerate(f, 1):
            fields = line.split()
            try:
                count = int(fields[1])
                ...
            except ValueError as e:
                print('Line {}: Parse error: {}'.format(lineno, e))
```

`enumerate()` åŕźäžŐèů§èÿłæ§ŘäžŽåĂijåIJĺåĹŮèąĺäÿ■åĞžçŐřçŽĎä¡■ç¡őæŸŕå¿ĹæIJL'çŤĺçŽĎãĂĆ
æL'ĂäžëïijŇåęĆæđIJä¡ăæČşåřĘäÿĂäÿłæŰĞäžűäÿ■åĞžçŐřçŽĎå■Ţèŕ■æŸåřĎåĹřåőČåĞžçŐřçŽĎèąŇåŔůäÿ
`enumerate()` æİěåőŇæĹŘïijŽ

```
word_summary = defaultdict(list)

with open('myfile.txt', 'r') as f:
    lines = f.readlines()

for idx, line in enumerate(lines):
    # Create a list of words in current line
    words = [w.strip().lower() for w in line.split()]
    for word in words:
        word_summary[word].append(idx)
```

åęĆædIJä¡ăåd'ĎçŘĘåőŇæŰĞäżűåŘŐæL'Şå■ř word_summary ïijŇäijŽåŔŚçŐřåőČæŸŕäÿĂäÿłå■ŮåĚÿ(åĞEçąőæİèèőšæŸŕäÿĂäÿł defaultdict)ïijŇ åŕźäžŐæŕŔäÿłå■Ţèŕ■æIJL'äÿĂäÿł key ïijŇæŕŔäÿł key åŕźåžŢçŽĎåĂijæŸŕäÿĂäÿłçŢśè£Źäÿłå■Ţèŕ■åĞžçŐřè£Ğäÿd'æňąïijŇéĆčäźĹè£ŹäÿłèąŇåŔůżĎæĹŘçŽĎåĹŮèąĺãĂĆ åęĆædIJæ§Ŕäÿłå■Ţèŕ■åIJĺäÿĂèąŇäÿ■åĞžçŐřè£Ğäÿd'æňąïijŇéĆčäźĹè£ŹäÿłèąŇåŔůäź§äijŽåĞžçŐřäÿd'æňąi åŘŇæŮűäź§åŔŕäżěä¡IJäÿžæŰĞæIJńçŽĎäÿĂäÿłçőĂå■Ţçż§èőąãĂĆ

èőĺèőž

å¡Şä¡ăæČşéćİåd'ŮåőŽäźĽäÿĂäÿłèőąæŢřåŔŸéĞŔçŽĎæŮűåĂŹïijŇä¡£çŤĺ enumerate() åĞ¡æŢřäijŽæŻt'åŁăçőĂå■ŢãĂĆä¡ăåŔŕèČ¡äijŽåČŔäÿŃéİćè£ŹæăůåĘŹäżčçăĄïijŽ

```
lineno = 1
for line in f:
    # Process line
    ...
    lineno += 1
```

ä¡ĘæŸŕåęĆædIJä¡£çŤĺ enumerate() åĞ¡æŢřæİěäžčæŻ£åřśæŸ¿å¿ŮæŻt'åŁääijŸéŻĚäžĘïijŽ

```
for lineno, line in enumerate(f):
    # Process line
    ...
```

enumerate() åĞ¡æŢřè£ŤåŻđçŽĎæŸŕäÿĂäÿł enumerate åŕźèśąåőđä¿ŃïijŇ åőČæŸŕäÿĂäÿłè£■äžčåŹĺïijŇè£ŤåŻđè£đçż■çŽĎåŇĚåŘńäÿĂäÿłèőąæŢřåŠŇäÿĂäÿłåĂijçŽĎåĚČçżĎïijŇ åĚČçżĎäÿ■çŽĎåĂijéĂŽè£ĞåIJĺäijăåĚěåžŔåĹŮäÿŁèřČçŤĺ next() è£ŤåŻđãĂĆ

è£ŸæIJL'äÿĂçĆźåŔŕèČ¡åźűäÿ■å¿ĹéĞ■èęĄïijŇä¡ĘæŸŕäź§åĂijå¿ŮæşĺæĎŔïijŇ æIJL'æŮűåĂŹå¡Şä¡ăåIJĺäÿĂäÿłåůšçżŔèğčåŐŇåŘŐçŽĎåĚČçżĎåžŔåĹŮäÿŁä¡£çŤĺ enumerate() åĞ¡æŢřæŮűå¿Ĺåőźæ ŸŞèřČåĚěéŹůéŸśãĂĆ ä¡ăå¿ŮåČŔäÿŃéİćæ■čçąőçŽĎæŰźåijŔè£ŹæăůåĘŹïijŽ

```
data = [ (1, 2), (3, 4), (5, 6), (7, 8) ]

# Correct!
for n, (x, y) in enumerate(data):
    ...
```

```
# Error!
for n, x, y in enumerate(data):
    ...
```

6.11 4.11 åŘŇæŮűè£■äžčåď'Žäÿłåž ŕåĹŮ

éŮőécŸ

ä¡ăæČşåŘŇæŮűè£■äžčåď'Žäÿłåž ŕåĹŮïijŇæŕŕæňąåĹĘåĹńäżŐäÿĂäÿłåž ŕåĹŮäÿ■åŔŰäÿĂäÿłåĚČçť'ăãĂ

èğčåĘşæŰźæąĹ

äÿžäžĘåŘŇæŮűè£■äžčåď'Žäÿłåž ŕåĹŮïijŇä¡£çŤÍ `zip()` åĞ¡æŢřãĂĆæŕŤåęĆïijŽ

```
>>> xpts = [1, 5, 4, 2, 10, 7]
>>> ypts = [101, 78, 37, 15, 62, 99]
>>> for x, y in zip(xpts, ypts):
...     print(x,y)
...
1 101
5 78
4 37
2 15
10 62
7 99
>>>
```

`zip(a, b)` äijŽçŤ§æĹŘäÿĂäÿłåŕŕè£ŤåŻđåĚČçżĎ `(x, y)` çŽĎè£■äžčåŹĺïijŇåĚűäÿ■xæİěèĞłaïijŇyæİěèĞłbãĂĆ äÿĂæŮęåĚűäÿ■æ§Řäÿłåž ŕåĹŮåĹřåžŢçżŞář¿ïijŇè£■äž
åŻăæ■ď'è£■äžčéŢ£åžęèů§åŔĆæŢřäÿ■æIJĂç§■åžŕåĹŮéŢ£åžęäÿĂèĞť'ãĂĆ

```
>>> a = [1, 2, 3]
>>> b = ['w', 'x', 'y', 'z']
>>> for i in zip(a,b):
...     print(i)
...
(1, 'w')
(2, 'x')
(3, 'y')
>>>
```

åęĆæđIJè£Źäÿłäÿ■æŸŕä¡ăæČşèęĄçŽĎæŢĹæđIJïijŇéĆčäźĹè£ŸåŔŕäžěä¡£çŤÍ `itertools.zip_longest()` åĞ¡æŢřæİěäžčæŻ£ãĂĆæŕŤåęĆïijŽ

```
>>> from itertools import zip_longest
>>> for i in zip_longest(a,b):
...     print(i)
```

```
...
(1, 'w')
(2, 'x')
(3, 'y')
(None, 'z')

>>> for i in zip_longest(a, b, fillvalue=0):
...     print(i)
...
(1, 'w')
(2, 'x')
(3, 'y')
(0, 'z')
>>>
```

èőÍèőž

å¡Şä¡äæČşæĹŘåŕźåď'ĎçŘĘæŢřæ■őçŽĎæŮűåĂŹ `zip()` åĞ¡æŢřæŸŕå¿ĹæIJL'çŤÍçŽĎãĂĆ æŕŤåęĆïijŇåĄĞèő¿ä¡ääď'ťåĹŮèąĺåŠŇäÿĂäÿłåĂijåĹŮèąĺïijŇåřśåČŔäÿŇéÍć

```
headers = ['name', 'shares', 'price']
values = ['ACME', 100, 490.1]
```

ä¡£çŤÍzip()åŔŕäžěèőľ'ä¡ääřĘåőČäžňæL'ŞåŇĚåźűçŤ§æĹŘäÿĂäÿłå■ŮåĚÿïijŽ

```
s = dict(zip(headers,values))
```

æĹŰèĂĚä¡äää§åŔŕäžěåČŔäÿŇéÍćè£Źæăůäžğç Ť§è¿ŞåĞžïijŽ

```
for name, val in zip(headers, values):
    print(name, '=', val)
```

èŹ¡çĎűäÿ■åÿÿèğĄïijŇä¡ĘæŸŕ `zip()` åŔŕäžěæŐěåŔŮåď'ŽäžŐäÿď'äÿłçŽĎåžŔåĹŮçŽĎåŔĆæŢřãĂĆ è£ŹæŮűåĂŹæL'ĂçŤ§æĹŘçŽĎçżŞæđIJåĚČçżĎäÿ■åĚČçţ'ääÿłæŢřèů§è¿ŞåĚěåžŔåĹŮäÿłæŢřäÿĂæăůãĂĆæŕŤ

```
>>> a = [1, 2, 3]
>>> b = [10, 11, 12]
>>> c = ['x','y','z']
>>> for i in zip(a, b, c):
...     print(i)
...
(1, 10, 'x')
(2, 11, 'y')
(3, 12, 'z')
>>>
```

æIJĂåŘŐåijžèřČäÿĂçĆźåřśæŸŕïijŇ `zip()` äijŽåĹŻåżžäÿĂäÿłè£■äžčåŹĺæÍěä¡IJäÿžçżŞæđIJè£ŤåŻđãĂĆ åęĆæđIJä¡ăéIJĂèęĄåřĘçżŞåŕźçŽĎåĂijå■ŸåĆĺåIJĺåĹŮèąĺäÿ■ïijŇèęĄä¡£çŤÍ `list()` åĞ¡æŢřãĂĆæŕŤåęĆïijŽ

```
>>> zip(a, b)
<zip object at 0x1007001b8>
>>> list(zip(a, b))
[(1, 10), (2, 11), (3, 12)]
>>>
```

6.12 4.12 äÿ■åŘŇéŻĘåŘĹäÿŁåĚČçťäçŽĎè£■äžč

éŮőécŸ

ä¡ăæČşåIJĺåď'ŽäÿłåŕźèśąæL'ğèąŇçŻÿåŘŇçŽĎæŞ■ä¡IJïijŇä¡ĘæŸŕè£ŹäžŻåŕźèśąåIJĺäÿ■åŘŇçŽĎåőźåŹĺä

èğčåĘşæŰźæąĹ

itertools.chain() æŰźæşŢåŔŕäžěçŤĺæİěçőĂåŇŰè£ŹäÿłäżżåŁąãĂĆ åőČæŐěåŘŮäÿĂäÿłåŔŕè£■äžčåŕźèśąåĹŮèąĺä¡IJäÿžè¿ŞåĚčïijŇåźűè£ŤåŻđäÿĂäÿłè£■äžčåŹĺïijŇæIJL'æŢĹçŽĎ äÿžäžĘæijŤçď'žæÿĚæěŽïijŇèĂČèŹŚäÿŃéİćè£Źäÿłä¿Ńå■ŘïijŽ

```
>>> from itertools import chain
>>> a = [1, 2, 3, 4]
>>> b = ['x', 'y', 'z']
>>> for x in chain(a, b):
... print(x)
...
1
2
3
4
x
y
z
>>>
```

ä¡£çŤĺ chain() çŽĎäÿĂäÿłåÿÿèğĄåIJžæŹŕæŸŕå¡Şä¡ăæČşåŕźäÿ■åŘŇçŽĎéŻĘåŘĹäÿ■æL'ĂæIJL'åĚČç

```
# Various working sets of items
active_items = set()
inactive_items = set()

# Iterate over all items
for item in chain(active_items, inactive_items):
    # Process item
```

è£Źçğ■èğčåĘşæŰźæąĹèęĄæŕŤåČŔäÿŃéİćè£Źæăůä¡£çŤĺäÿď'äÿłå■ŢçŃňçŽĎå¿łçŐŕæŻť'åŁääijŸéŻĚïijŇ

```
for item in active_items:
    # Process item
```

```
    ...

for item in inactive_items:
    # Process item
    ...
```

èőÍèőž

itertools.chain() æŐěåŔŮäÿĂäÿłæĹŰåď'ŽäÿłåŔřè£■äžčåŕźèśąæIJĂäÿžè¿ŞåĚěåŔĆæŢřãĂĆçĎűåŘŐåĹŻåžžäÿĂäÿłè£■äžčåŹĺïijÑä¿İæňąè£đçż■çŽĎè£ŤåŻđæŕŔäÿłåŔřè£■äžčåŕźèśąäÿ■çŽĎåĚČçt'ããĂĆè£ŹçğæŰźåijŔèęĄæŕŤåĚĹářĘåžŔåĹŮåŘĹåźűåĘ■è£■äžčèęĄéńŸæŢĹçŽĎåď'ŽãĂĆæŕŤåęĆïijŽ

```
# Inefficent
for x in a + b:
    ...

# Better
for x in chain(a, b):
    ...
```

çňňäÿĂçğ■æŰźæąĹäÿ■ïijŇ a + b æŞ■ä¡IJäijŽåĹŻåžžäÿĂäÿłåĚĺæŰřçŽĎåžŔåĹŮåźűèęĄæśĆaåŠŇbçŽchian() äÿ■äijŽæIJL'è£ŹäÿĂæ■čïijŇæL'Ăäžěåę ĆæđIJè¿ŞåĚěåžŔåĹŮéİđåÿÿåď'ğçŽĎæŮűåĂŹäijŽå¿ĹçIJÅåźűäÿŤå¡ŞåŔřè£■äžčåŕźèśąçśžåđŃäÿ■äÿĂæăůçŽĎæŮűåĂŹ chain() åŘŇæăůåŔřäžěå¿Ĺåě¡çŽĎåůěä¡IJãĂĆ

6.13 4.13 åĹŻåžžæŢřæ■őåď'ĎçŘĘçőąéĄŞ

éŮőécŸ

ä¡ăæČşäžěæŢřæ■őçőąéĄŞ(çśžäijijUnixçőąéĄŞ)çŽĎæŰźåijŔè£■äžčåď'ĎçŘĘæŢřæ■őãĂĆæŕŤåęĆïijŇä¡ăæIJL'äÿłåď'ğéĞŔçŽĎæŢřæ■őéIJĂèęĄåď'ĎçŘĘïijŇä¡ĘæŸŕäÿ■èČ¡åřĘåőČäžňäÿĂæňąæĂğæŤ¿

èğčåĘşæŰźæąĹ

çŤ§æĹŘåŹĺåĞ¡æŢřæŸŕäÿĂäÿłåőđçŐřçőąéĄŞæIJžåĹűçŽĎåě¡åŁđæşŢãĂĆäÿžäžĘæijŤçď'žïijŇåĄĞåőŽä¡ăèęĄåď'ĎçŘĘäÿĂäÿłéİđåÿÿåď'ğçŽĎæŮěå£ŮæŰĞäžűçŻőå¡ŢïijŽ

```
foo/
    access-log-012007.gz
    access-log-022007.gz
    access-log-032007.gz
    ...
    access-log-012008
bar/
    access-log-092007.bz2
```

```
    ...
    access-log-022008
```

åĄĞèő¿æŕŔäÿłæŮěå£ŮæŰĞäżűåŇĚåŘńè£ŹæăůçŽĎæŢřæ■őïijŽ

```
124.115.6.12 - - [10/Jul/2012:00:18:50 -0500] "GET /robots.txt ..."␣
↪200 71
210.212.209.67 - - [10/Jul/2012:00:18:51 -0500] "GET /ply/ ..." 200␣
↪11875
210.212.209.67 - - [10/Jul/2012:00:18:51 -0500] "GET /favicon.ico ..
↪." 404 369
61.135.216.105 - - [10/Jul/2012:00:20:04 -0500] "GET /blog/atom.xml␣
↪..." 304 -
...
```

äÿžäžĘåď ĎçŘĘè£ŹäžŻæŰĞäżűïijŇä¡åŔŕäżěåőŽäźĽäÿĂäÿłçŤšåď ŽäÿłæĽğèąŇçĽźåőŽäżżåŁąçŃňçńŇ

```
import os
import fnmatch
import gzip
import bz2
import re

def gen_find(filepat, top):
    '''
    Find all filenames in a directory tree that match a shell␣
↪wildcard pattern
    '''
    for path, dirlist, filelist in os.walk(top):
        for name in fnmatch.filter(filelist, filepat):
            yield os.path.join(path,name)

def gen_opener(filenames):
    '''
    Open a sequence of filenames one at a time producing a file␣
↪object.
    The file is closed immediately when proceeding to the next␣
↪iteration.
    '''
    for filename in filenames:
        if filename.endswith('.gz'):
            f = gzip.open(filename, 'rt')
        elif filename.endswith('.bz2'):
            f = bz2.open(filename, 'rt')
        else:
            f = open(filename, 'rt')
        yield f
        f.close()

def gen_concatenate(iterators):
    '''
```

```
    Chain a sequence of iterators together into a single sequence.
    '''
    for it in iterators:
        yield from it

def gen_grep(pattern, lines):
    '''
    Look for a regex pattern in a sequence of lines
    '''
    pat = re.compile(pattern)
    for line in lines:
        if pat.search(line):
            yield line
```

çŐřåIJÍä¡ăåŔŕäžěå¿Ĺåőźæ˙ŸŞçŽĎåřĘè£ŹäžŻåĞ¡æŢřè£đèţůæİěåĹŻåžžäÿĂäÿłåď˙ĎçŘĘçőąéĄŞãĂĆ
æŕŤåęĆïijÑäÿžäžĘæ§ěæL’¿åŇĚåŘńå■Ţèŕ■pythonçŽĎæL’ĂæIJL’æŮěå£ÛèąÑïijÑä¡ăåŔŕäžěè£ŹæăůåĄŽïijŽ

```
lognames = gen_find('access-log*', 'www')
files = gen_opener(lognames)
lines = gen_concatenate(files)
pylines = gen_grep('(?i)python', lines)
for line in pylines:
    print(line)
```

åęĆæđIJåřĘæİěçŽĎæŮűåĂŹä¡ăæČşæL’l’åśŢçőąéĄŞïijÑä¡ăçŤŽèĞşåŔŕäžěåIJÍçŤ§æĹŘåŹÍèąÍè¿¿åijŔäÿ■
æŕŤåęĆïijÑäÿÑéÍćè£ŹäÿłçL’ĹæIJňèőąçőŮåĞžäijăè¿ŞçŽĎå■ÛèŁĆæŢřåźűèőąçőŮåĚűæĂżåŠÑãĂĆ

```
lognames = gen_find('access-log*', 'www')
files = gen_opener(lognames)
lines = gen_concatenate(files)
pylines = gen_grep('(?i)python', lines)
bytecolumn = (line.rsplit(None,1)[1] for line in pylines)
bytes = (int(x) for x in bytecolumn if x != '-')
print('Total', sum(bytes))
```

èőÍèőž

äžěçőąéĄŞæŰźåijŔåď˙ĎçŘĘæŢřæ■őåŔŕäžěçŤÍæİěèğčåĘşåŘĎçśżåĚűäžŰéŮőéćŸïijÑåŇĚæŃňèğčæđŘïi

äÿžäžĘçŘĘèğčäÿŁè£řäžčçăĄïijÑéĞ■çĆźæŸŕèęĄæŸŐçŹ¡ `yield`
èŕ■åŘëä¡IJäÿžæŢřæ■őçŽĎçŤ§äžğèĂĚèĂŇ `for` å¿łçŐŕèŕ■åŘëä¡IJäÿžæŢřæ■őçŽĎæűĹèť´źèĂĚãĂĆ
å¡Şè£ŹäžŻçŤ§æĹŘåŹÍèćńè£đåIJÍäÿĂèţůåŘŐïijÑærŔäÿł `yield`
äijŽåřĘäÿĂäÿłå■ŢçŃňçŽĎæŢřæ■őåĚČçť´ăäijăéĂŠçżŹè£■äžčåď˙ĎçŘĘçőąéĄŞçŽĎäÿÑäÿĂéŸűæőţãĂĆ
åIJÍä¿Ńå■ŘæIJĂåŘŐéČÍåĹĘïijÑ `sum()` åĞ¡æŢřæŸŕæIJĂçżĹçŽĎçÍÑåžŔél’šåŁÍèĂĚïijÑærŔæąäžŐçŤ§æĹŘ

è£Źçğ■æŰźåijŔäÿĂäÿłéIđåÿÿåě¡çŽĎçL’źçĆźæŸŕærŔäÿłçŤ§æĹŘåŹÍåĞ¡æŢřå¿ĹåřŘåźűäÿŤéČ¡æŸŕçŃňç
å¿Ĺåď˙ŽæŮűåĂŹïijÑè£ŹäžŻåĞ¡æŢřåęĆæđIJærŕŤè¿ČéĂŽçŤÍçŽĎèŕÍåŔŕäžěåIJÍåĚűäžŰåIJžæŹŕéĞ■åď˙■ä¡£çŤÍ
åźűäÿŤæIJĂçżĹåřĘè£ŹäžŻçżĎäžűçżĎåŘÍèţůæİěçŽĎäžčçăĄçIJŃäÿŁåŐżéIđåÿÿçőĂå■ŢïijÑäź§å¿Ĺåőźæ˙ŸŞç

ä¡£çŤÍè£ŹçğæŰźåijŔçŽĎåĘĚå■ŸæŢĹçŐĞäź§äÿ■å¿Ůäÿ■æŔŘãĂĆäÿŁè£řäžčçăĄå■şä¿£æŸŕåIJĺäÿĂäÿ
äžŇåőđäÿŁïijŇçŤšäžŐä¡£çŤĺäžĘè£■äžčæŰźåijŔåď ĎçŘĘïijŇäžčçăĄè£ŘèąŇè£ĞçĺŇäÿ■åŔłéIJĂèęĄå¿ĹåřŔå

åIJĺèřČçŤĺ `gen_concatenate()` åĞ¡æŢřçŽĎæŮűåĂŹä¡ääŔŕèČ¡äijŽæIJL'äžŽäÿ■åď łæŸŐçŹ¡ãĂĆ
è£ŹäÿłåĞ¡æŢřçŽĎçŽőçŽĎæŸŕåřĘè¿ŞåĚěåžŔåĹŮæŃijæŐěæĹŘäÿĂäÿłå¿ĹéŢ£çŽĎèąŇåžŔåĹŮãĂĆ
`itertools.chain()` åĞ¡æŢřåŘŇæăůæIJL'çśżäijijçŽĎåŁ§èČ¡ïijŇä¡ĘæŸŕåőČéIJĂèęĄåřĘæL'ĂæIJL'åŔŕè
åIJĺäÿŁéİćè£Źäÿłä¿Ńå■Řäÿ■ïijŇä¡ääŔŕèČ¡äijŽåĘŹçśżäijijè£Źæăůç ŽĎèŕ■åŔě

```
lines = itertools.chain(*files)
```

ïijŇ è£ŹåřĘåŕijèĞť `gen_opener()` çŤ§æĹŘåŹĺèćńæŔŘåL'■åĚĺéČĺæűĹèť źæŐL'ãĂĆ ä¡ĘçŤšäžŐ `gen_opener()` çŤ§æĹŘåŹĺæŕŘæňąçŤ§æĹŘäÿĂäÿłæL'ŞåijÄè£ĞçŽĎæŰĞäžűïijŇ
ç■L'åĹřäÿŃäÿĂäÿłè£■äžčæ■ěéłď æŮűæŰĞäžűůåřšåĚşéŮ■äžĘïijŇåŽăæ■ď `chain()`
åIJĺè£ŹéĞŃäÿ■èČ¡è£Źæăůä¡£çŤĺãĂĆ äÿŁéİćçŽĎæŰźæąĹåŔŕäžěéĄ£åĚ■è£ŹçğæČĚåĘţãĂĆ

`gen_concatenate()` åĞ¡æŢřäÿ■åĞžçŐřè£Ğ `yield from` èŕ■åŔěïijŇåőČåřĘ `yield` æŞ■ä¡IJäžčçŘĘåĹřçĹűçŤ§æĹŘåŹĺäÿŁåŐžãĂĆ èŕ■åŔě `yield from it` çőĂå■ŢçŽĎè£ŤåŽđçŤ§æĹŘåŹĺ `it` æL'Ăäžğç Ť§çŽĎæL'ĂæIJL'åĂijãĂĆ
åĚşäžŐè£ŹäÿłæĹŚäžňåIJĺ4.14åřŔèŁĆäijŽæIJL'æŻť'è£ŽäÿĂæ■ěçŽĎæŘŔè£řãĂĆ

æIJĂåŘŐè£ŸæIJL'äÿĂçĆźéIJĂèęĄæşĺæĎŘçŽĎæŸŕïijŇçőąéĄŞæŰźåijŔåźűäÿ■æŸŕäÿĞèČ¡çŽĎãĂĆ
æIJL'æŮűåĂŹä¡ăæČşçńÅ■şåď ĎçŘĘæL'ĂæIJL'æŢřæ■őãĂĆ çĎűèĂŇïijŇå■şä¿£æŸŕè£Źçğ■æČĚåĘţïijŇä¡£ç

David Beazley åIJĺäžŰçŽĎ Generator Tricks for Systems Programmers
æŢŹçĺŃäÿ■åŕźäžŐè£Źçğ■æŁĂæIJŕæIJL'éİđåÿÿæůśåĚěçŽĎèőšèğčãĂĆåŔŕäžěåŘĆèĂČè£ŹäÿłæŢŹçĺŃèŐůåŔ

6.14 4.14 åśŢåijĂåţŇåěŮçŽĎåžŔåĹŮ

éŮőécŸ

ä¡ăæČşåřĘäÿĂäÿłåď ŽåśĆåţŇåěŮçŽĎåžŔåĹŮåśŢåijĂæĹŘäÿĂäÿłå■ŢåśĆåĹŮèąĺ

èğčåĘşæŰźæąĹ

åŔŕäžěåĘŹäÿĂäÿłåŇĚåŘń `yield from` èŕ■åŘěçŽĎéĂŠå¡ŠçŤ§æĹŘåŹĺæİěè¡żæİ¿èğčåĘşè£ŹäÿłéŮőéć

```
from collections import Iterable

def flatten(items, ignore_types=(str, bytes)):
    for x in items:
        if isinstance(x, Iterable) and not isinstance(x, ignore_
↪types):
            yield from flatten(x)
        else:
            yield x

items = [1, 2, [3, 4, [5, 6], 7], 8]
# Produces 1 2 3 4 5 6 7 8
for x in flatten(items):
    print(x)
```

åIJÍäÿŁéİćäžčçăĄäÿ■ïijŇ `isinstance(x, Iterable)` æčĂæ§ěæ§ŘäÿłåĚČçť ăæŸŕåŘęæŸŕåŘŕè£■äžčçŽĎãĂĆ åęĆæđIJæŸŕçŽĎèŕİïijŇ `yield from` åŕśäijŽè£ŤåŽđæĽĂæIJL'å■Řä¿ŇçÍŇçŽĎåĂijãĂĆæIJĂçżĹè£ŤåŽđçżŞæđIJåŕśæŸŕäÿĂäÿłæšąæIJL'åţŇå

éćİåď'ŰçŽĎåŔĆæŢř `ignore_types` åŠŇæčĂæţŃèŕ■åŘě `isinstance(x, ignore_types)` çŤÍæİěåřĘå■Ůçňęäÿšå ŠŇå■ŮèŁĆæŐŠéŹď'åIJÍåŘŕè£■äžčåŕźèśąåď'ŰïijŇéŸšæ■ćåřĘåőČäz è£Źæăůç ŽĎèŕİå■ŮçňęäÿšæŢřçżĎåŕśèČ¡æIJĂçźĹè£ŤåŽđæĹŚäžňæĽ'ĂæIJ§æIJŻçŽĎçżŞæđIJäžĘãĂĆæŕŤåęĆ

```
>>> items = ['Dave', 'Paula', ['Thomas', 'Lewis']]
>>> for x in flatten(items):
...     print(x)
...
Dave
Paula
Thomas
Lewis
>>>
```

èőÍèőž

èŕ■åŘě `yield from` åIJÍä¡ăæČşåIJÍçŤ§æĹŘåŹÍäÿ■èřČçŤÍåĚűäžŰçŤ§æĹŘåŹÍä¡IJäÿžå■Řä¿ŇçÍŇçŽĎa åęĆæđIJä¡ääÿ■ä¡£çŤÍåőČçŽĎèŕİïijŇéĆčäźĹåŕśå£Ěéąžå ĘŹéćİåď'ŰçŽĎ `for` å¿łçŐŕäžĘãĂĆæŕŤåęĆïijŽ

```
def flatten(items, ignore_types=(str, bytes)):
    for x in items:
        if isinstance(x, Iterable) and not isinstance(x, ignore_
↪types):
            for i in flatten(x):
                yield i
        else:
            yield x
```

åř¡çőąåŘłæŤźäžĘäÿĂçĆźçĆźïijŇä¡ĘæŸŕ `yield from` èŕ■åŘěçIJŃäÿŁåŐżæĎ§ègL'æŽť'åě¡ïijŇåźűäÿŤäź§ä¡£å¿ŮäžčçăĄæŽť'çőĂæť'Ąæÿ ĚçĹ¡ãĂĆ

äźŃåL'■æŘŘåĹřçŽĎåŕźäžŐå■Ůçňęäÿšå ŠŇå■ŮèŁĆçŽĎéćİåď'ŰæčĂæ§ěæŸŕäÿžäžĘéŸšæ■ćåřĘåőČäžňå åęĆæđIJè£ŸæIJL'åĚűäžŰä¡ääÿ■æČşåśŢåijĂçŽĎçśžåđŃïijŇä£őæŤźåŔĆæŢř `ignore_types` å■şåŔŕãĂĆ

æIJĂåŘŐèęĄæşĺæĎŘçŽĎäÿĂçĆźæŸŕïijŇ `yield from` åIJÍæűL'åŘŁåĹřå§žäžŐå■ŘçÍŇåŠŇçŤ§æĹŘåŹÍçŽĎåźűåŘŠçijŰçÍŃäÿ■æL'őæijŤçİĂæŽť'åŁáéĞ■èęĄçŽĎèğŠè åŔŕäžěåŔĆèĂČ12.12åřŘèŁĆæ§ěçIJŃåŘęåď'ŰäÿĂäÿłä¿Ńå■ŘãĂĆ

6.15 4.15 éąžåžŔè£■äžčåŘĹåźűåŘŐçŽĎæŐŠåžŔè£■äžčåŕźèśą

éŮőécŸ

ä¡ăæIJL'äÿĂçşžåĹŮæŐŠåžŔåžŔåĹŮïijŇæČşåřĘåőČäžňåŘĹåźűåŘŐå¿ŮåĹřäÿĂäÿłæŐŠåžŔåžŔåĹŮåźűå

èğčåĘşæŰźæąĹ

heapq.merge() åĞ¡æŢřåŔŕäžěåÿőä¡ăèğčåĘşè£ŹäÿłéŮőécŸãĂĆæŕŤåęĆïijŽ

```
>>> import heapq
>>> a = [1, 4, 7, 10]
>>> b = [2, 5, 6, 11]
>>> for c in heapq.merge(a, b):
...     print(c)
...
1
2
4
5
6
7
10
11
```

èőÍèőž

heapq.merge åŔŕè£■äžčçL'źæĂğæĎŔåŠşçİĂåőČäÿ■äijŽçńÑél'ňèřžåŔŰæL'ĂæIJL'åžŔåĹŮãĂĆè£ŹåřśæĎŔåŠşçİĂä¡ăåŔŕäžěåIJÍéİđåÿÿéŢ£çŽĎåžŔåĹŮäÿ■ä¡£çŤĺåőČïijŇèĂŇäÿ■äijŽæIJL'åď'łåď'ğçŽĎåijÄéæŕŤåęĆïijŇäÿÑéİćæŸŕäÿĂäÿłä¿Ńå■ŘæİěæijŤçď'žåęĆä¡ŢåŘĹåźűäÿď'äÿłæŐŠåžŔæŰĞäžűïijŽ

```
with open('sorted_file_1', 'rt') as file1, \
    open('sorted_file_2', 'rt') as file2, \
    open('merged_file', 'wt') as outf:

    for line in heapq.merge(file1, file2):
        outf.write(line)
```

æIJL'äÿĂçĆźèęĄåijžěřČçŽĎæŸŕ heapq.merge() éIJĂèęĄæL'ĂæIJL'è¿ŞåĚěåžŔåĹŮå£Ěéążæ ŸŕæŐŠçL'źåĹńçŽĎïijŇåőČåźűäÿ■äijŽécĎåĚĹèŕžåŘŰæL'ĂæIJL'æŢřæ■őåĹřåäĘæăĹäÿ■æĹŰèĂĚécĎåĚĹæŐŠåžŔïijåőČäžĚäżĚæŸŕæčĂæ§ěæL'ĂæIJL'åžŔåĹŮçŽĎåijĂäğŃéČĺåĹĘåźűè£ŤåŻđæIJĂårŔçŽĎéĆčäÿłïijŇè£ŹäÿłèŞČ

6.16 4.16 è£■äžčåŹĺäžčæŻ£whileæŮăéŹŘå¿łçŐŕ

éŮőécŸ

ä¡ăåIJĺäžčçăĄäÿ■ä¡£çŤĺ while å¿łçŐŕæİěè£■äžčåď'ĎçŘĘæŢřæ■őïijŇåŻääÿžåőČéIJĂèęĄèřČçŤĺæ§ŘäÿèČ¡äÿ■èČ¡çŤĺè£■äžčåŹĺæİěéĞ■åĘŹè£ŹäÿłåżłçŐŕåŚćïij§

èğčåĘşæŰźæąĹ

äÿĂäÿłåÿÿèğĄçŽĎIOæŞ■ä¡IJçÍŃåžŔåŔŕèČ¡äijŽæČşäÿŃéİćè£ŹæăůïijŽ

```
CHUNKSIZE = 8192

def reader(s):
    while True:
        data = s.recv(CHUNKSIZE)
        if data == b'':
            break
        process_data(data)
```

è£Źçğ■äžčçăĄéĂŽåÿÿåŔŕäžěä¡£çŤÍ `iter()` æİěäžčæŻ£ïijŇåęĆäÿŇæĽĂçď žïijŽ

```
def reader2(s):
    for chunk in iter(lambda: s.recv(CHUNKSIZE), b''):
        pass
        # process_data(data)
```

åęĆæđIJä¡ăæĂĂçŰŠåőČåĹŕåžŢèČ¡äÿ■èČ¡æ■čåÿÿåůěä¡IJïijŇåŔŕäžěèŕŢéłŇäÿŇäÿĂäÿłçőÅå■ŢçŽĎä¿Ňå

```
>>> import sys
>>> f = open('/etc/passwd')
>>> for chunk in iter(lambda: f.read(10), ''):
...     n = sys.stdout.write(chunk)
...
nobody:*:-2:-2:Unprivileged User:/var/empty:/usr/bin/false
root:*:0:0:System Administrator:/var/root:/bin/sh
daemon:*:1:1:System Services:/var/root:/usr/bin/false
_uucp:*:4:4:Unix to Unix Copy Protocol:/var/spool/uucp:/usr/sbin/
 ↪uucico
...
>>>
```

èőĺèőž

`iter` åĞ¡æŢřäÿĂäÿłéšIJäÿžäžžçş§ěçŽĎçĽźæĂğæŸŕåőČæŐěåŔŮäÿĂäÿłåŔŕéĂĽ'çŽĎ `callable` åŕźèśąåŠŇäÿĂäÿłæăĞèőř(çżŞář¿)åĂijä¡IJäÿžè¿ŞåĚěåŔĆæŢřãĂĆ å¡Şäžěè£Źçğ■æŰźåijŔä¡£çŤĺçŽĎæŮűåĂŹïijŇåőČäijŽåĹŻåžžäÿĂäÿłè£■äžčåŹĺïijŇ è£Źäÿłè£■äžčåŹĺäijŽäÿ■æŰ■èřČçŤÍ `callable` åŕźèśąçŻt'åĹřè£ŤåŻđåĂijåŠŇæăĞèőřåĂijçŻÿç■L'äÿžæ■ćãĂ

è£Źçğ■çL'źæőŁçŽĎæŰźæşŢåŕźäžŐäÿĂäžŻçL'źåőŽçŽĎäijŽèćńéĞ■åď'■èřČçŤĺçŽĎåĞ¡æŢřå¿ĹæIJL'æŢĺ äÿ¿ä¿ŃæİèèőšïijŇåęĆæđIJä¡ăæČşäžŐåěŮæŐěå■ŮæĹŰæŰĞäžűäÿ■äžěæŢřæ■őåİŮçŽĎæŰźåijŔèŕżåŔŰæŢřæ `read()` æĹŰ `recv()` ïijŇ åźűåIJĺåŘŐéİćçt'ğèů§äÿĂäÿłæŰĞäžűçżŞář¿æţŃèŕŢæİěåĘşåőŽæŸŕåŘęçżĹæ■ćãĂ `iter()` èřČçŤĺåršåŔŕäžěårĘäÿd'èĂĚçżŞåŘĹètůæİěäžĘãĂĆ åĚűäÿ■ `lambda` åĞ¡æŢřåŔĆæŢřæŸŕäÿžäžžĘåĹŻåžžäÿĂäÿłæŮăåŔĆçŽĎ `callable` åŕźèśąïijŇåźűäÿž `recv` æĹŰ `read()` æŰźæşŢæŘŘä¿ŻäžĘ `size` åŔĆæŢřãĂĆ

7 çňňäžŤçńäïijŽæŰĞäżűäÿŐlO

æĽĂæIJL’çÍŃåžŔéČ¡èęĄåď’ĎçŘĘè¿ŞåĚěåŠŇè¿ŞåĞžãĂĆ
è£ŹäÿĂçńäářĘæűţçŻŰåď’ĎçŘĘäÿ■åŘŇçśžåđŃçŽĎæŰĞäżűïijŇåŇĚæŃňæŰĞæIJňåŠŇäžŇè£ŻåĹűæŰĞäżűï
åŕźæŰĞäżűåŘ■åŠŇçŻőå¡ŢçŽĎæŞ■ä¡IJäź§äijŽæűĽ’åŔŁåĹřãĂĆ

Contents:

7.1 5.1 èŕżåĘŹæŰĞælJňæŢřæ■ő

éŮőécŸ

ä¡ăéIJĂèęĄèŕżåĘŹåŘĎçğ■äÿ■åŘŇçijŰçăĄçŽĎæŰĞæIJňæŢřæ■őïijŇærŤåęĆASCIIïijŇUTF-8æĹŰUTF-16çijŰçăĄç■L’ãĂĆ

èğčåĘşæŰźæąĹ

ä¡£çŤĺåÿęæIJL’ `rt` æĺąåijŔçŽĎ `open()` åĞ¡æŢřèŕżåŔŰæŰĞæIJňæŰĞäżűãĂĆåęĆäÿŇæL’Ăçď’žïijŽ

```
# Read the entire file as a single string
with open('somefile.txt', 'rt') as f:
    data = f.read()

# Iterate over the lines of the file
with open('somefile.txt', 'rt') as f:
    for line in f:
        # process line
        ...
```

çśżäijijçŽĎïijŇäÿžäžĘåĘŹåĚěäÿĂäÿłæŰĞæIJňæŰĞäżűïijŇä¡£çŤĺåÿęæIJL’ `wt` æĺąåijŔçŽĎ `open()` åĞ¡æŢřïijŇ åęĆædIJäźŇåL’■æŰĞäżűåĘĚåőźå■ŸåIJĺåĹŹæÿĚéŹď’åźűèęĘçŻŰæŐL’ãĂĆ

```
# Write chunks of text data
with open('somefile.txt', 'wt') as f:
    f.write(text1)
    f.write(text2)
    ...

# Redirected print statement
with open('somefile.txt', 'wt') as f:
    print(line1, file=f)
    print(line2, file=f)
    ...
```

åęĆædIJæŸŕåIJĺåůšå■ŸåIJĺæŰĞäżűäÿ■æůżåŁäåĘĚåőźïijŇä¡£çŤĺæĺąåijŔäÿž `at` çŽĎ `open()` åĞ¡æŢřãĂĆ

æŰĞäžűçŽĎèřžåĘŹæŞ■ä¡IJéżŸèőď'ä¡£çŤĺçşżçż§çijŰçăĄïijŇåŔřäžěéĂŽè£ĞèřČçŤĺ
sys.getdefaultencoding() æİěå¿ŮåĹřãĂĆ åIJĺåď'ğåď'ŽæŢřæIJžåŹĺäÿŁéİćéČ¡æŸŕutf-
8çijŰçăĄãĂĆåęĆæđIJä¡ăåůšçżŔç§ěéĄŞä¡ăèęĄèřžåĘŹçŽĎæŰĞæIJňæŸŕåĚűäžŰçijŰçăĄæŰźåijŔïijŇ
éĆčäźĹåŔřäžěéĂŽè£ĞäijăéĂŝäÿĂäÿłåŔřéĂL'çŽĎ encoding
åŔĆæŢřçżŹopen()åĞ¡æŢřãĂĆåęĆäÿŇæL'Ăçď'žïijŽ

```
with open('somefile.txt', 'rt', encoding='latin-1') as f:
    ...
```

PythonæŤŕæŇĄéİđåÿÿåď'ŽçŽĎæŰĞæIJňçijŰçăĄãĂĆåĞääÿłåÿÿèğĄçŽĎçijŰçăĄæŸŕascii,
latin-1, utf-8åŠŇutf-16ãĂĆ åIJĺwebåžŤçŤĺçÍŇåžŔäÿ■éĂŽåÿÿéČ¡ä¡£çŤĺçŽĎæŸŕUTF-8ãĂĆ
asciiåŕźåžŤäžŐU+0000åĹřU+007FèŇČåŻť åĘĚçŽĎ7ä¡■å■Ůçňęã ĂĆ latin-1æŸŕå■ŮèŁĆ0-
255åĹřU+0000èĞşU+00FFèŇČåŻť åĘĚUnicodeå■Ůçňęç ŽĎçŻť'æŐěæŸäåřĎãĂĆ
å¡Şèŕźå ŔŰäÿĂäÿłæIJłç§ěçijŰçăĄçŽĎæŰĞæIJňæŮűä¡£çŤĺlatin-
1çijŰçăĄæřÿè£IJäÿ■äijŽäžğçŤ§èğčçăĄéŤŹèŕŕãĂĆ ä¡£çŤĺlatin-
1çijŰçăĄèŕźåŔŰäÿĂäÿłæŰĞäžűçŽĎæŮűåĂŹäź§èőÿäÿ■èČ¡äžğçŤ§åőŇåĚĺæ■čçąőçŽĎæŰĞæIJňèğčçăĄæŢŕ
ä¡ĘæŸŕåőČäź§èČ¡äžŐäÿ■æŔŘåŔŰåĞžèűşåď'§åď'ŽçŽĎæIJL'çŤĺæŢřæ■őãĂĆåŘŇæŮűïijŇåęĆæđIJä¡ääźŇåŘ

èőĺèőž

èŕźåĘŹæŰĞæIJňæŰĞäžűäÿĂèĹňæİěèőšæŸŕæŕŤè¿ČçőĂå■ŢçŽĎãĂĆä¡ĘæŸŕäź§åĞäçĆźæŸŕéIJĂèęĄæş
éęŰåĚĹïijŇåIJĺä¿Ńå■ŘçÍŇåžŔäÿ■çŽĎwithèŕ■åŔěçżŹèćńä¡£çŤĺåĹřçŽĎæŰĞäžűåĹŻåžžäžĘäÿĂäÿłäÿŁäÿŇæ
ä¡Ę with æŐğåĹűåİŮçżŞæİ§æŮűïijŇæŰĞäžűäijŽèĞłåŁĺåĚşéŮ■ãĂĆä¡ääź§åŔŕäžěäÿ■ä¡£çŤĺ
with èŕ■åŔěïijŇä¡ĘæŸŕè£ŹæŮűåĂŹä¡ääřšå£Ěéąžèőřå¿ŮæL'ŃåŁĺåĚşéŮ■æŰĞäžűïijŽ

```
f = open('somefile.txt', 'rt')
data = f.read()
f.close()
```

åŔęåď'ŰäÿĂäÿłéŮőécŸæŸŕåĚşäžŐæ■ćèąŇçňęçŽĎèŕĘåĹńéŮőécŸïijŇåIJĺUnixåŠŇWindowsäÿ■æŸŕäÿ
\n åŠŇ \r\n)ãĂĆ éżŸèőď'æČĚåĘţäÿŇïijŇPythonäijŽäžěçż§äÿĂæĺąåijŔåď'ĎçŘĘæ■ćèąŇçňęãĂĆ
è£Źçğ■æĺąåijŔäÿŇïijŇåIJĺèŕźåŔŰæŰĞæIJňçŽĎæŮűåĂŹïijŇPythonåŔŕäžěèŕĘåĹńæL'ĂæIJL'çŽĎæŹőéĂŽæ
\n å■Ůçňęã ĂĆ çśžäijijçŽĎïijŇåIJĺè¿ŞåĞžæŮűäijŽářĘæ■ćèąŇçňę \n
è¡ňæ■ćäÿžçşżçż§éżŸèőď'çŽĎæ■ćèąŇçňęãĂĆ åęĆæđIJä¡ääÿ■åÿŇæIJŽè£Źçğ■éżŸèőď'çŽĎåď'ĎçŘĘæŰźåijŔï
open() åĞ¡æŢřäijăåĚěåŔĆæŢř newline='' ïijŇářšåČŔäÿŃéİćè£ŹæăůïijŽ

```
# Read with disabled newline translation
with open('somefile.txt', 'rt', newline='') as f:
    ...
```

äÿžäžĘèŕťæŸŐäÿď'èĂĚäźŃéŮť'çŽĎåůőåijĆïijŇäÿŃéİćæĹŠåIJĺUnixæIJžåŹĺäÿŁéİćèŕźåŔŰäÿĂäÿłWindo
hello world!\r\n ïijŽ

```
>>> # Newline translation enabled (the default)
>>> f = open('hello.txt', 'rt')
>>> f.read()
'hello world!\n'

>>> # Newline translation disabled
```

```
>>> g = open('hello.txt', 'rt', newline='')
>>> g.read()
'hello world!\r\n'
>>>
```

æIJĂåŘŐäÿĂäÿłéŮőéćŸåřśæŸŕæŰĞæIJňæŰĞäżűäÿ■åŔŕèČ¡åĞžçŐřçŽĎçijŰçăĄéŤŹèŕŕãĂĆ
ä¡Ęä¡ăèŕżåŔŰæĹŰèĂĚåĘŹåĚěäÿĂäÿłæŰĞæIJňæŰĞäżűæŮűïijŇä¡ăåŔŕèČ¡äijŽéĄĞåĹřäÿĂäÿłçijŰçăĄæĹŰè

```
>>> f = open('sample.txt', 'rt', encoding='ascii')
>>> f.read()
Traceback (most recent call last):
    File "<stdin>", line 1, in <module>
    File "/usr/local/lib/python3.3/encodings/ascii.py", line 26, in␣
 ↪decode
        return codecs.ascii_decode(input, self.errors)[0]
UnicodeDecodeError: 'ascii' codec can't decode byte 0xc3 in position
12: ordinal not in range(128)
>>>
```

åęĆæđIJåĞžçŐřè£ŹäÿłéŤŹèŕŕïijŇéĂŽåÿÿèąĺçd'žä¡ăèŕżåŔŰæŰĞæIJňæŮűæŇĞåőŽçŽĎçijŰçăĄäÿ■æ■čç
ä¡ăæIJĂåě¡äžŤçżĘéŸĚèŕżèŕť'æŸŐåźűçąőèőd'ä¡ăçŽĎæŰĞäżűçijŰçăĄæŸŕæ■čçąőçŽĎ(æŕŤåęĆä¡£çŤĺUTF-
8èĂŇäÿ■æŸŕLatin-1çijŰçăĄæĹŰåĚűäżŰ)ãĂĆ åęĆæđIJçijŰçăĄéŤŹèŕŕè£ŸæŸŕå■ŸåIJĺçŽĎèŕİïijŇä¡ăåŔŕäžěopen() åĞ¡æŢřäijăéĂŠäÿĂäÿłåŔŕéĂL'çŽĎ errors åŔĆæŢřæİěåď'ĎçŘĘè£ŹäžŻéŤŹèŕŕãĂĆ
äÿŃéIćæŸŕäÿĂäžŽåď'ĎçŘĘåÿÿèğĄéŤŹèŕŕçŽĎæŰźæşŢïijŽ

```
>>> # Replace bad chars with Unicode U+fffd replacement char
>>> f = open('sample.txt', 'rt', encoding='ascii', errors='replace')
>>> f.read()
'Spicy Jalape?o!'
>>> # Ignore bad chars entirely
>>> g = open('sample.txt', 'rt', encoding='ascii', errors='ignore')
>>> g.read()
'Spicy Jalapeo!'
>>>
```

åęĆæđIJä¡ăçżŔåÿÿä¡£çŤĺ errors åŔĆæŢřæİěåď'ĎçŘĘçijŰçăĄéŤŹèŕŕïijŇåŔŕèČ¡äijŽèőľä¡ăçŽĎçŢ§æt
åŕźäžŐæŰĞæIJňåď'ĎçŘĘçŽĎéęŰèęĄåŐ§åĹŹæŸŕçąőä£Ïä¡ăæĂżæŸŕä¡£çŤĺçŽĎæŸŕæ■čçąőçijŰçăĄãĂĆå¡Şa
8)ãĂĆ

7.2 5.2 æĽŞå■řè¿ŞåĞžèĞşæŰĞäżűäÿ■

éŮőécŸ

ä¡ăæČşåřĘ print() åĞ¡æŢřçŽĎè¿ŞåĞžéĞ■åőŽåŘŚåĹřäÿĂäÿłæŰĞäżűäÿ■åŐżãĂĆ

èğčåĘşæŰźæąĹ

åIJÍ `print()` åĞ¡æŢřäÿ■æŇĞåőŽ `file` åĚşéŤőå■ŮåŔĆæŢřïijŇåČŔäÿŃéİćè£ŹæăůïijŽ

```
with open('d:/work/test.txt', 'wt') as f:
    print('Hello World!', file=f)
```

èőÍèőž

åĚşäžŐè¿ŞåĞžéĞ■åőŽåŘŠåĹřæŰĞäżűäÿ■åřśè£ŹäžŻäžĘãĂĆä¡ĘæŸŕæIJL'äÿĂçĆźèęĄæşÍæĎŔçŽĎåřśæåęĆæđIJæŰĞäżűæŸŕäžŇè£ŻåĹűæÍąåijŔçŽĎèŕİïijŇæL'Şå■řåřśäijŽåĞžéŤŹãĂĆ

7.3 5.3 ä¡£çŤÍåĚűäżŰåĹĘéŽŤçňęæĹŰèąŇçżĹæ■ćçňęæL'Şå■ř

éŮőécŸ

ä¡ăæČşä¡£çŤÍ `print()` åĞ¡æŢřè¿ŞåĞžæŢřæ■őïijŇä¡ĘæŸŕæČşæŤźåŘŸéżŸèőd'çŽĎåĹĘéŽŤçňęæĹŰè

èğčåĘşæŰźæąĹ

åŘŕäżěä¡£çŤÍåIJÍ `print()` åĞ¡æŢřäÿ■ä¡£çŤÍ `sep` åŠŇ `end` åĚşéŤőå■ŮåŔĆæŢřïijŇäżěä¡ăæČşèęĄçŽĎæŰźåijŔè¿ŞåĞžãĂĆærŤåęĆïijŽ

```
>>> print('ACME', 50, 91.5)
ACME 50 91.5
>>> print('ACME', 50, 91.5, sep=',')
ACME,50,91.5
>>> print('ACME', 50, 91.5, sep=',', end='!!\n')
ACME,50,91.5!!
>>>
```

ä¡£çŤÍ `end` åŘĆæŢřäź§åŘŕäżěåIJÍè¿ŞåĞžäÿ■çęĄæ■ćæ■ćèąŇãĂĆærŤåęĆïijŽ

```
>>> for i in range(5):
...     print(i)
...
0
1
2
3
4
>>> for i in range(5):
...     print(i, end=' ')
...
0 1 2 3 4 >>>
```

èőÍèőž

å¡Şä¡ăæČşä¡£çŤÍéÍđçľžæăijåĹĘéŽŤçňęæÍěè¿ŞåĞžæŢřæ■őçŽĎæŮűåĂŹïijÑçżŹ `print()` åĞ¡æŢřäijăéĂŠäÿĂäÿł `sep` åŔĆæŢřæŸŕæIJĂçőÅå■ŢçŽĎæŰźæąĹãĂĆ æIJĽæŮűåĂŹä¡ăäijŽçIJÑåĹřäÿĂäžŽçÍÑåžŔåŚŸäijŽä¡£çŤÍ `str.join()` æÍěåőÑæĹŘåŘÑæăůçŽĎäžÑæČĚãĂĆærŤåęĆïijŽ

```
>>> print(','.join(('ACME','50','91.5')))
ACME,50,91.5
>>>
```

`str.join()` çŽĎéŮőécŸåIJÍäžŐåőČäżĚäżĚéĂĆçŤÍäžŐå■Ůçňęäÿšã ĂĆè£ŹæĎŔåŚşçİĂä¡ăéĂŽåÿÿéIJ

```
>>> row = ('ACME', 50, 91.5)
>>> print(','.join(row))
Traceback (most recent call last):
    File "<stdin>", line 1, in <module>
TypeError: sequence item 1: expected str instance, int found
>>> print(','.join(str(x) for x in row))
ACME,50,91.5
>>>
```

ä¡ăå¡ŞçĎűåŔŕäżěäÿ■çŤÍéĆčäźĹéžżçČęïijÑåŔłéIJĂèęĄåČŔäÿÑéÍćè£ŹæăůåĘŹïijŽ

```
>>> print(*row, sep=',')
ACME,50,91.5
>>>
```

7.4 5.4 èŕżåĘŹå■ŮèŁĆæŢřæ■ő

éŮőécŸ

ä¡ăæČşèŕżåĘŹäžÑè£ŽåĹűæŰĞäżűïijÑæŕŤåęĆåŻ¿çĽĞïijÑåčŕé§şæŰĞäżűç■Ľç■Ľ ãĂĆ

èğčåĘşæŰźæąĹ

ä¡£çŤÍæÍąåijŔäÿž `rb` æĹŰ `wb` çŽĎ `open()` åĞ¡æŢřæÍěèŕżåŔŰæĹŰåĘŹåĚěäžÑè£ŽåĹűæŢřæ■őãĂĆærŤ

```
# Read the entire file as a single byte string
with open('somefile.bin', 'rb') as f:
    data = f.read()

# Write binary data to a file
with open('somefile.bin', 'wb') as f:
    f.write(b'Hello World')
```

åIJÍèŕżåŔŰäžÑè£ŽåĹűæŢřæ■őæŮűïijÑéIJĂèęĄæÑĞæŸŐçŽĎæŸŕæĽĂæIJĽè£ŤåŻđçŽĎæŢřæ■őéČ¡æ çśżäijijçŽĎïijÑåIJÍåĘŹåĚěçŽĎæŮűåĂŹïijÑå£Ěéążä£ÍèŕĄåŔĆæŢřæŸŕäžěå■ŮèŁĆå¡ćåijŔåŕźåď ŰæŽť éIJšæŢ

èőÍèőž

åIJÍèŕžåŘŰäžÑè£ŻåĹűæŢřæ■őçŽĎæŮűåĂŹïijÑå■ŮèŁĆå■ŮçňęäÿšåŠÑæŰĞæIJňå■ŮçňęäÿšçŽĎèŕ■äźĽ
çĽźåĹńéIJĂèęĄæşÍæĎŔçŽĎæŸŕïijÑçť́ćåijŢåŠÑè£■äžčåŁÍä¡IJè£ŤåŽđçŽĎæŸŕå■ŮèŁĆçŽĎåĂijèĂÑäÿ■æŸ

```
>>> # Text string
>>> t = 'Hello World'
>>> t[0]
'H'
>>> for c in t:
...     print(c)
...
H
e
l
l
o
...
>>> # Byte string
>>> b = b'Hello World'
>>> b[0]
72
>>> for c in b:
...     print(c)
...
72
101
108
108
111
...
>>>
```

åęĆæđIJä¡ăæČşäżŐäžÑè£ŻåĹűæÍąåijŔçŽĎæŰĞäžűäÿ■èŕžåŘŰæĹŰåĘŹåĚěæŰĞæIJňæŢřæ■őïijÑå£Ěéą

```
with open('somefile.bin', 'rb') as f:
    data = f.read(16)
    text = data.decode('utf-8')

with open('somefile.bin', 'wb') as f:
    text = 'Hello World'
    f.write(text.encode('utf-8'))
```

äžÑè£ŻåĹűI/Oè£ŸæIJL'äÿĂäÿłéšIJäÿžäžžç§ěçŽĎçL'źæĂğåřśæŸŕæŢřçżĎåŠŇCçżŞæđĎä¡Şçśžåđ́ÑèČ¡çŽ

```
import array
nums = array.array('i', [1, 2, 3, 4])
with open('data.bin','wb') as f:
    f.write(nums)
```

è£ŹäÿłéĂĆçŤÍäžŐäżżä¡ŢåőđçŐřäžĘèćńçğřäźŃäÿžâĂİçijŞåĘšæŐěåŔčâĂİçŽĎåŕźèšąïijÑè£Źçğ■åŕźèšąäi

äžÑè£ŻåĹűæŢřæ■őçŽĎåĘźåĚěářśæŸŕè£Źçśżæş■ä¡IJäźÑäÿĂãĂĆ

å¿Ĺåď Žářźèśąè£ŸåĚĄèőÿéĂŽè£Ğä¡£çŤĺæŰĞäžűářźèśąçŽĎ `readinto()` æŰźæşŢçŻť æŐěèŕżåŔŰäžÑè£ŻåĹűæŢřæ■őåĹřåĚűåžŢåśĆçŽĎåĘĚå■Ÿäÿ■åŐżãĂĆæŕŤåęĆïijŽ

```
>>> import array
>>> a = array.array('i', [0, 0, 0, 0, 0, 0, 0, 0])
>>> with open('data.bin', 'rb') as f:
...     f.readinto(a)
...
16
>>> a
array('i', [1, 2, 3, 4, 0, 0, 0, 0])
>>>
```

ä¡ĘæŸŕä¡£çŤĺè£Źçğ■æŁĂæIJŕçŽĎæŮűåĂŹéIJĂèęĄæäijåď ŰåřŔå£ČïijÑåŻääÿžåőČéĂŽåÿÿåĚůæIJL'åź åŔŕäžěæ§ěçIJŃ5.9åřŔèŁĆäÿ■åŔęåď ŰäÿĂäÿłèŕżåŔŰäžÑè£ŻåĹűæŢřæ■őåĹřåŔŕä£őæŤźçijŞåĘšåŇžçŽĎä¿Ńå

7.5 5.5 æŰĞäžűäÿ■å■ŸåIJĺæL'■èČ¡åĘŹåĚě

éŮőécŸ

ä¡ăæČşåČŔäÿĂäÿłæŰĞäžűäÿ■åĘŹåĚěæŢřæ■őïijÑä¡ĘæŸŕåL'■æŔŘå£ĚéążæŸŕè£ŹäÿłæŰĞäžűåIJĺæŰĞ äźş§åřśæŸŕäÿ■åĚĄèöÿèęEçŻŰåůšå■ŸåIJĺçŽĎæŰĞäžűåĘĚåőźãĂĆ

èğčåĘşæŰźæąĹ

åŔŕäžěåIJĺ `open()` åĞ¡æŢřäÿ■ä¡£çŤĺ `x` æĺąåijŔæİěäžčæŻ£ `w` æĺąåijŔçŽĎæŰźæşŢæİěèğčåĘşè£ŹäÿłéŮőécŸãĂĆæŕŤåęĆïijŽ

```
>>> with open('somefile', 'wt') as f:
...     f.write('Hello\n')
...
>>> with open('somefile', 'xt') as f:
...     f.write('Hello\n')
...
Traceback (most recent call last):
File "<stdin>", line 1, in <module>
FileExistsError: [Errno 17] File exists: 'somefile'
>>>
```

åęĆæđIJæŰĞäžűæŸŕäžÑè£ŻåĹűçŽĎïijÑä¡£çŤĺ `xb` æİěäžčæŻ£ `xt`

èőÍèőž

è£ŹäÿĂåřŔèŁĆæijŤçď žäžĘåIJĺåĘŹæŰĞäžűæŮűéĂŽåÿÿäijŽéĄĞåĹřçŽĎäÿĂäÿłéŮőécŸçŽĎåőÑç¿Őèğ äÿĂäÿłæŻ£äžčæŰźæąĹæŸŕåĚĹæţÑèŕŢè£ŹäÿłæŰĞäžűæŸŕåŘęå■ŸåIJĺïijÑåČŔäÿÑéÍćè£Źæăůïijž

```
>>> import os
>>> if not os.path.exists('somefile'):
...     with open('somefile', 'wt') as f:
...         f.write('Hello\n')
... else:
...     print('File already exists!')
...
File already exists!
>>>
```

æŸ¿èĂŇæŸŞèğĄïijŇä¡£çŤĺxæŰĞäžűæĺąåijŕæŻťåŁăçőÅå■ŢãĂĆèęĄæşĺæĎŕçŽĎæŸŕxæĺąåijŕæŸŕäÿ
open() åĞ¡æŢřçL'źæIJL'çŽĎæL'ľåśŢãĂĆ åIJĺPythonçŽĎæŮğçL'ĹæIJňæĹŰèĂĚæŸŕPythonåőđçŐřçŽĎåžŢ

7.6 5.6 å■Ůçňęäÿšç ŽĎl/OæŞ■ä¡lJ

éŮőécŸ

ä¡ăæČşä¡£çŤĺæŞ■ä¡IJcśżæŰĞäžűåŕźèśąçŽĎçÍŃåžŕæİěæŞ■ä¡IJæŰĞæIJňæĹŰäžŇè£ŻåĹűå■Ůçňęäÿšã

èğčåĘşæŰźæąĹ

ä¡£çŤĺ io.StringIO() åŠŇ io.BytesIO() çśżæİěåĹŻåžžçśżæŰĞäžűåŕźèśąæŞ■ä¡IJå■ŮçňęäÿšæŢ

```
>>> s = io.StringIO()
>>> s.write('Hello World\n')
12
>>> print('This is a test', file=s)
15
>>> # Get all of the data written so far
>>> s.getvalue()
'Hello World\nThis is a test\n'
>>>

>>> # Wrap a file interface around an existing string
>>> s = io.StringIO('Hello\nWorld\n')
>>> s.read(4)
'Hell'
>>> s.read()
'o\nWorld\n'
>>>
```

io.StringIO åŔłèČ¡çŤĺäžŐæŰĞæIJñãĂĆåęĆæđIJä¡ăèęĄæŞ■ä¡IJäžŇè£ŻåĹűæŢřæ■őïijŇèęĄä¡£çŤĺ
io.BytesIO çśżæİěäžčæŻ£ãĂĆæŕŤåęĆïijŽ

```
>>> s = io.BytesIO()
>>> s.write(b'binary data')
>>> s.getvalue()
```

```
b'binary data'
>>>
```

èőÍèőž

å¡Şä¡äæČşæÍąæŃ§äÿĂäÿłæŹőéĂŽçŽĎæŰĞäžűçŽĎæŮűåĂŹ `StringIO` åŠŇ `BytesIO` çśżæŸŕå¿ĹæIJL'çŤÍçŽĎãĂĆ æŕŤåęĆïijŇåIJÍå■ŢåĚČæţŃèŕŢäÿ■ïijŇä¡ååŔŕäžěä¡£çŤÍ `StringIO` æİěåĹŽåžžäÿĂäÿłåŇĚåŘńæţŃèŕŢæŢřæ■őçŽĎçśżæŰĞäžűåŕźčśąïijŇè£ŹäÿłåŕźčśąåŔŕäžěèćńäijäçżŹæ§ŘäÿłåŔĆæŢřäÿžæŹőéĂŽæŰĞäžűåŕźčśąçŽĎåĞ¡æŢřãĂĆ

éIJĂèęĄæşĺæĎŘçŽĎæŸŕïijŇ `StringIO` åŠŇ `BytesIO` åőđä¿Ńåźűæšąæ IJL'æ■čçąőçŽĎæŢt'æŢřçśżåđŃçŽĎæŰĞäžűæŔŔè£řçňęãĂĆ åŻäæ■d'ïijŇåőČäžñäÿ■èČ¡åIJĺéĆčäžŻéIJĂèęĄä¡£çŤÍçIJ§åőđçŽĎçşżçż§çžğæŰĞäžűåęĆæŰĞäžűïijŇçőąéĄŞ

7.7 5.7 èŕżåĘŹåŐŃçijľæŰĞäžű

éŮőécŸ

ä¡äæČşèŕżåĘŹäÿĂäÿłgzipæĹŰbz2æäijåijŔçŽĎåŐŃçijľæŰĞäžűãĂĆ

èğčåĘşæŰźæąĹ

`gzip` åŠŇ `bz2` æÍąåİŮåŔŕäžěå¿Ĺåőźæ ŸŞçŽĎåd'ĎçŘĘè£ŹäžŻæŰĞäžűãĂĆ äÿd'äÿłæÍąåİŮéČ¡äÿž `open()` åĞ¡æŢřæŔŘä¿ŻäžĘåŔęåd'ŰçŽĎåőđçŐřæİèèğčåĘşè£ŹäÿłéŮőécŸãĂĆ æŕŤåęĆïijŇäÿžäžĘäžěæŰĞæIJňå¡ćåijŔèŕżåŔŰåŐŃçijľæŰĞäžűïijŇåŔŕäžěè£ŹæäůåĄŽïijŽ

```
# gzip compression
import gzip
with gzip.open('somefile.gz', 'rt') as f:
    text = f.read()

# bz2 compression
import bz2
with bz2.open('somefile.bz2', 'rt') as f:
    text = f.read()
```

çśżäijijçŽĎïijŇäÿžäžĘåĘŹåĚěåŐŃçijľæŢřæ■őïijŇåŔŕäžěè£ŹæäůåĄŽïijŽ

```
# gzip compression
import gzip
with gzip.open('somefile.gz', 'wt') as f:
    f.write(text)

# bz2 compression
import bz2
```

```
with bz2.open('somefile.bz2', 'wt') as f:
    f.write(text)
```

åęĆäÿŁïijŇæL’ĂæIJL’çŽDI/OæŞ■ä¡IJéČ¡ä¡£çŤĺæŰĞæIJňæĺąåijŔåźűæL’ğèąŇUnicodeçŽDçijŰçăĄ/èğčç
çśżäijijçŽDïijŇåęĆæđIJä¡ăæČşæŞ■ä¡IJäžŇè£ŻåĹűæŢřæ■őïijŇä¡£çŤĺ rb æĹŰèĂĚ wb
æŰĞäżűæĺąåijŔå■şåŔřãĂĆ

èőĺèőž

åd’ğéČĺåĹĘæČĚåĘţäÿŃèŕżåĘŹåŐŃçijl’æŢřæ■őéČ¡æŸŕå¿ĹçőĂå■ŢçŽDãĂĆä¡ĘæŸŕèęĄæşĺæĎŔçŽDæŸ
åęĆæđIJä¡ääÿ■æŇĞåőŽæĺąåijŔïijŇéĆčäźĹéżŸèőd’çŽDåřśæŸŕäžŇè£ŻåĹűæĺąåijŔïijŇåęĆæđIJè£ŹæŮűåĂŹç
gzip.open() åŠŇ bz2.open() æŐěåŔŮèů§åĘĚç¡őçŽĎ open()
åĞ¡æŢřäÿĂæăůçŽDåŔĆæŢřïijŇ åŇĚæŃň encodingïijŇerrorsïijŇnewline
ç■L’ç■L’ãĂĆ

å¡ŞåĘŹåĚěåŐŃçijl’æŢřæ■őæŮűïijŇåŔŕäżěä¡£çŤĺ compresslevel
è£ŹäÿłåŔŕéĂL’çŽDåĚşéŤőå■ŮåŔĆæŢřæİěæŇĞåőŽäÿĂäÿłåŐŃçijl’çžğåĹńãĂĆæŕŤåęĆïijŽ

```
with gzip.open('somefile.gz', 'wt', compresslevel=5) as f:
    f.write(text)
```

éżŸèőd’çŽDç■L’çžğæŸŕ9ïijŇäź§æŸŕæIJĂéńŸçŽDåŐŃçijl’ç■L’çžğãĂĆç■L’çžğèűŁä¡ŐæĂğèČ¡èűŁåě¡ïij

æIJĂåŘŐäÿĂçĆźïijŇ gzip.open() åŠŇ bz2.open()
è£ŸæIJL’äÿĂäÿłå¿ĹářŠèćńç§ěéĄŞçŽDçL’źæĂğïijŇ åőČäžňåŔŕäżěä¡IJçŤĺåIJĺäÿĂäÿłåůšå■ŸåIJĺåźűäżěäžŇè£

```
import gzip
f = open('somefile.gz', 'rb')
with gzip.open(f, 'rt') as g:
    text = g.read()
```

è£ŹæăůářšåĚĄèőÿ gzip åŠŇ bz2 æĺąåİŮåŔŕäżěåůěä¡IJåIJĺèőÿåd’ŽçźżæŰĞäżűářźèśąäÿŁïijŇæŕŤåęĆåě

7.8 5.8 åŻžåőŽåd’ğářŔèőřå¡ŢçŽDæŰĞäżűè£■äžc

éŮőécŸ

ä¡ăæČşåIJĺäÿĂäÿłåŻžåőŽéŢ£åžęèőřå¡ŢæĹŰèĂĚæŢřæ■őåİŮçŽDéŻĘåŘĹäÿŁè£■äžčïijŇèĂŇäÿ■æŸŕåIJ

èğčåĘşæŰźæąĹ

éĂŽè£ĞäÿŃéİćè£ŹäÿłářŔæŁĂåůğä¡£çŤĺ iter åŠŇ functools.partial()
åĞ¡æŢřïijŽ

```
from functools import partial

RECORD_SIZE = 32
```

```
with open('somefile.data', 'rb') as f:
    records = iter(partial(f.read, RECORD_SIZE), b'')
    for r in records:
        ...
```

è£Źäÿłä¿Ńå■Řäÿ■çŽĎ `records` åŕźèśąæŸŕäÿĂäÿłåŔŕè£■äžčåŕźèśąïijŇåőČäijŽäÿ■æŰ■çŽĎäžğçŢ§åŻž
èęĄæşĺæĎŔçŽĎæŸŕåęĆæđIJæĂżèőŕå¡Ţåď ğåřŔäÿ■æŸŕåİŮåď ğåřŔçŽĎæŢť æŢřåĂ■çŽĎèŕÏïijŇæIJĂåŘŐäÿĂ

èőÍèőž

`iter()` åĞ¡æŢřæIJL'äÿĂäÿłéšIJäÿžäžžç§ěçŽĎçL'źæĂğåřśæŸŕïijŇåęĆæđIJä¡äçżŹåőČäijåéĂŠäÿĂäÿłåI
è£Źäÿłè£■äžčåŹĺäijŽäÿĂçŻť'èřČçŢĺäijååĚěçŽĎåŔŕèřČçŢĺåŕźèśąçŻť'åĹřåőČè£ŢåŻđæăĞèőŕåÄijäÿžæ■ćïijŇè£

åIJĺä¿Ńå■Řäÿ■ïijŇ `functools.partial` çŢĺæİěåĹŻåžžäÿĂäÿłæŕŔæňąèćńèřČçŢĺæŮűäżŐæŰĞäžűä
æăĞèőŕåÄij `b''` åřśæŸŕå¡ŞåĹřè¿¿æŰĞäžűçżŞåř¿æŮűçŽĎè£ŢåŻđåÄijãĂĆ

æIJĂåŘŐåĘ■æŔŘäÿĂçĆźïijŇäÿŁéIćçŽĎä¿Ńå■Řäÿ■çŽĎæŰĞäžűæŮűäžěäžŇè£ŻåĹűæĺąåijŔæĽŞåijĂç
åęĆæđIJæŸŕèŕźåŔŰåŻžåőŽåď ğåřŔçŽĎèőŕå¡ŢïijŇè£ŹéĂŽåÿÿæŸŕæIJĂæŹőéĄ■çŽĎæČĚåĘţãĂĆ
èĂŇåŕźäžŐæŰĞæIJñæŰĞäžűïijŇäÿĂèąŇäÿĂèąŇçŽĎèŕźåŔŰ(éżŸèőď'çŽĎè£■äžčèąŇäÿž)æŻť'æŹőéĄ■çĆźã

7.9 5.9 èŕźåŔŰäžŇè£ŻåĹűæŢřæ■őåĹřåŔŕåŔŸçijŞåĘšåŇžäÿ■

éŮőécŸ

ä¡ăæČşçŻť'æŐěèŕźåŔŰäžŇè£ŻåĹűæŢřæ■őåĹřäÿĂäÿłåŔŕåŔŸçijŞåĘšåŇžäÿ■ïijŇèĂŇäÿ■éIJĂèęĄåĄŽäż
æĹŰèĂĚä¡ăæČşåŐ§åIJřä£őæŤźæŢřæ■őåźűårĘáőČåĘŹåŻđåĹřäÿĂäÿłæŰĞäžűäÿ■åŐżãĂĆ

èğčåĘşæŰźæąĹ

äÿžäžĘèŕźåŔŰæŢřæ■őåĹřäÿĂäÿłåŔŕåŔŸæŢřçżĎäÿ■ïijŇä¡£çŢĺæŰĞäžűåŕźèśąçŽĎ
`readinto()` æŰźæşŢãĂĆæŕŤåęĆïijŽ

```
import os.path

def read_into_buffer(filename):
    buf = bytearray(os.path.getsize(filename))
    with open(filename, 'rb') as f:
        f.readinto(buf)
    return buf
```

äÿŃéIćæŸŕäÿĂäÿłæijŤçd'žè£ŹäÿłåĞ¡æŢřä¡£çŢĺæŰźæşŢçŽĎä¿Ńå■ŘïijŽ

```
>>> # Write a sample file
>>> with open('sample.bin', 'wb') as f:
...     f.write(b'Hello World')
...
```

```
>>> buf = read_into_buffer('sample.bin')
>>> buf
bytearray(b'Hello World')
>>> buf[0:5] = b'Hallo'
>>> buf
bytearray(b'Hallo World')
>>> with open('newsample.bin', 'wb') as f:
...     f.write(buf)
...
11
>>>
```

èőÍèőž

æŰĞäżűåŕźèśąçŽĎ `readinto()` æŰźæşŢèČ¡èćńçŤÍæİěäÿžécĎåĚĹåĹĘéĚ■åĘĚå■ŸçŽĎæŢřçżĎåąńåĚ `array` æÍąåİŮæĹŰ `numpy` åžŞåĹŻåżžçŽĎæŢřçżĎãĂĆ åŠŇæŹőéĂŽ `read()` æŰźæşŢäÿ■åŘŇçŽĎæŸŕïijŇ `readinto()` åąńåĚĚåůšå■ŸåIJÍçŽĎçijŞåĘšåŇžèĂŇäÿ■æŸŕäÿžæŰřåŕźèśąéĞ åŽăæ■ď˙ïijŇä¡ăåŔŕäžěä¡£çŤÍåőČæİěéĄ£åĚ■åď˙ğéĞŔçŽĎåĘĚå■ŸåĹĘéĚ■æŞ■ä¡IJãĂĆ æŕŤåęĆïijŇåęĆæđIJä¡ăèŕžåŔŰäÿĂäÿłçŤśçŻÿåŘŇåď˙ğåřŔçŽĎèőřå¡ŢçżĎæĹŘçŽĎäžŇè£ŻåĹűæŰĞäżűæŮűïi

```
record_size = 32 # Size of each record (adjust value)

buf = bytearray(record_size)
with open('somefile', 'rb') as f:
    while True:
        n = f.readinto(buf)
        if n < record_size:
            break
        # Use the contents of buf
        ...
```

åŔęåď˙ŰæIJL˙äÿĂäÿłæIJL˙èűčçL˙źæĂğåřśæŸŕ `memoryview` ïijŇ åőČåŔŕäžěéĂŽè£ĞéŽűåď˙■åĹűçŽĎæŰźåijŔåŕźåůšå■ŸåIJÍçŽĎçijŞåĘšåŇžæL˙ğèąŇåĹĞçL˙ĞæŞ■ä¡IJïijŇçŤŽè

```
>>> buf
bytearray(b'Hello World')
>>> m1 = memoryview(buf)
>>> m2 = m1[-5:]
>>> m2
<memory at 0x100681390>
>>> m2[:] = b'WORLD'
>>> buf
bytearray(b'Hello WORLD')
>>>
```

ä¡£çŤÍ `f.readinto()` æŮűéIJĂèęĄæşÍæĎŔçŽĎæŸŕïijŇä¡ăå£ĚéążæčĂæ§ěåőČçŽĎè£ŤåŽđåĂijïijŇä

åęĆæđIJå■ŮèŁĆæŢřåŕŔäžŐçijŞåĘšåŇžåď˙ğåřŔïijŇèąÍæŸŐæŢřæ■őèćńæĹłæŰ■æĹŰèĂĚèćńçăť˙åİŔäžĘ

æIJĂåŘŐïijŇçŢŹå£ČèğĆåŕ§åĚűäžŰåĞ¡æŢřåžŞåŠŇæÍąåİŮäÿ■åŠŇ `into`

çŻÿåĚşçŽĎåĞ¡æŢř(æŕŤåęĆ `recv_into()` ïijŇ `pack_into()` ç■Ľ)ãĂĆ PythonçŽĎå¿Ĺåď˙ŽåĚűäžŰéČĺåĹĘåůšçżŔèČ¡æŤŕæŇĄçŻť˙æŐěçŽĎI/OæĹŰæŢřæ■ő讹£éŮőæŞ■ä¡IJïijŇè£Źä

åĚşäžŐèğčædŘäžŇè£ŽåĹűçżŞædĎåŠŇ `memoryviews` ä¡£çŤĺæŰźæşŢçŽĎæŻť˙énŸçžğä¿Ńå■ŘïijŇèŕůåŔĆèĂČ6.12åřŔèŁĆãĂĆ

7.10 5.10 åĘĚå■ŸæŸăåřĎçŽĎäžŇè£ŽåĹűæŰĞäžű

éŮőécŸ

ä¡ăæČşåĘĚå■ŸæŸăåřĎäÿĂäÿłäžŇè£ŽåĹűæŰĞäżűåĹřäÿĂäÿłåŔŕåŔŸå■ŮèŁĆæŢřçżĎäÿ■ïijŇçŽőçŽĎåĿ

èğčåĘşæŰźæąĹ

ä¡£çŤĺ `mmap` æĺąåİŮæİěåĘĚå■ŸæŸăåřĎæŰĞäżűãĂĆ äÿŃéİćæŸŕäÿĂäÿłåůěåĚůåĞ¡æŢřïijŇåŘŠä¡ăæijŤçď˙žäžĘąęĆä¡ŢæĽŞåijĂäÿĂäÿłæŰĞäżűåźűäžëäÿĂçğ■ä¿£æ

```
import os
import mmap

def memory_map(filename, access=mmap.ACCESS_WRITE):
    size = os.path.getsize(filename)
    fd = os.open(filename, os.O_RDWR)
    return mmap.mmap(fd, size, access=access)
```

äÿžäžĘä¡£çŤĺè£ŹäÿłåĞ¡æŢřïijŇä¡ăéIJĂèęĄæIJL'äÿĂäÿłåůšåĹŻåžžåźűäÿŤåĘĚåőźäÿ■äÿžçľžçŽĎæŰĞäż äÿŃéİćæŸŕäÿĂäÿłä¿Ńå■ŘïijŇæŢŹä¡ăæĂŐæăůåĹİåğŃåĹŻåžžäÿĂäÿłæŰĞäżűåźűåřĘåĚűåĘĚåőźæĽľ˙åĚĚåĹř

```
>>> size = 1000000
>>> with open('data', 'wb') as f:
...     f.seek(size-1)
...     f.write(b'\x00')
...
>>>
```

äÿŃéİćæŸŕäÿĂäÿłåĹľçŤĺ `memory_map()` åĞ¡æŢřçśżåĘĚå■ŸæŸăåřĎæŰĞäżűåĘĚåőźçŽĎä¿Ńå■ŘïijŽ

```
>>> m = memory_map('data')
>>> len(m)
1000000
>>> m[0:10]
b'\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00'
>>> m[0]
0
>>> # Reassign a slice
>>> m[0:11] = b'Hello World'
>>> m.close()
```

```
>>> # Verify that changes were made
>>> with open('data', 'rb') as f:
... print(f.read(11))
...
b'Hello World'
>>>
```

mmap() è£ŤåŻđçŽĎ mmap åŕźèśąåŘŇæăůäź§åŔŕäžěä¡IJäÿžäÿĂäÿłäÿŁäÿŃæŰĞçőąçŘĘåŹÍæÌěä¡£çŤĺïij
è£ŹæŮűůåĂŹåžŢåśÇçŽĎæŰĞäžűäijŽèćńèĞłåŁĺåĚşéŮ■ãĂĆærŤåęĆïijŽ

```
>>> with memory_map('data') as m:
...     print(len(m))
...     print(m[0:10])
...
1000000
b'Hello World'
>>> m.closed
True
>>>
```

éżŸèőd'æČĚåĘţäÿŃïijŇ memeory_map() åĞ¡æŢřæL'Şåij ĂçŽĎæŰĞäžűåŘŇæŮűæŤŕæŇĄèŕžåŠŇåĘŹ
äżżä¡ŢçŽĎä£őæŤźåĘĚåőźéČ¡äijŽåd'■åĹűåŻđåŐ§æÌěçŽĎæŰĞäžűäÿ■ãĂĆ
åęĆæđIJéIJĂèęĄåŔłèŕżçŽĎè£éŮőæÍąåijŔïijŇåŔŕäžěçżŹåŔĆæŢř access èţŃåĂijäÿž
mmap.ACCESS_READ ãĂĆærŤåęĆïijŽ

```
m = memory_map(filename, mmap.ACCESS_READ)
```

åęĆæđIJä¡ăæČşåIJÍæIJňåIJřä£őæŤźæŢřæ■őïijŇä¡ĘæŸŕåŔĹäÿ■æČşåřĘä£őæŤźåĘŹåŻđåĹřåŐ§ågŃæŰĞ
mmap.ACCESS_COPY ïijŽ

```
m = memory_map(filename, mmap.ACCESS_COPY)
```

èőÍèőž

äÿžäžĘéŽŔæIJžèő£éŮőæŰĞäžűçŽĎåĘĚåőźïijŇä¡£çŤÍ mmap
åřĘæŰĞäžűæŸăåřĎåĹřåĘĚå■ŸäÿæŸŕäÿĂäÿłéńŸæŢĹåŠŇäijŸéŻĘçŽĎæŰźæşŢãĂĆ
ä¿ŃåęĆïijŇä¡ăæŮăéIJĂæL'ŞåijĂäÿĂäÿłæŰĞäžűåźűæL'ğèąŇåď'ğéĞŔçŽĎ seek() ïijŇ
read() ïijŇ write() èřČçŤÍïijŇ åŔłéIJĂèęĄçőĂå■ŢçŽĎæŸăåřĎæŰĞäžűåźűä¡£çŤÍåĹĞçL'ĞæŞ■ä¡IJèő£é

äÿĂèĹñæÌěèőšïijŇ mmap() æL'ĂæŽť'éIJšçŽĎåĘĚå■ŸçIJŃäÿŁåŐżåřśæŸŕäÿĂäÿłäžŇè£ŻåĹűæŢřçżĎårź
ä¡ĘæŸŕïijŇä¡ăåŔŕäžěä¡£çŤÍäÿĂäÿłåĘĚå■ŸèğĘåŻ¿æÌèèğčæđŘåĚűäÿ■çŽĎæŢřæ■őãĂĆærŤåęĆïijŽ

```
>>> m = memory_map('data')
>>> # Memoryview of unsigned integers
>>> v = memoryview(m).cast('I')
>>> v[0] = 7
>>> m[0:4]
b'\x07\x00\x00\x00'
>>> m[0:4] = b'\x07\x01\x00\x00'
```

```
>>> v[0]
263
>>>
```

éIJÄèęĄåijžèřČçŽĎäÿĂçĆźæŸŕïijŇåĘĚå■ŸæŸăåřĎäÿĂäÿłæŰĞäżűåźűäÿ■äijŽåŕijèĞť'æŢť'äÿłæŰĞäżűë
äź§åřśæŸŕèŕť'ïijŇæŰĞäżűåźűæšąæIJL'èćńåď'■åĹűåĹřåĘĚå■ŸçijŞå■ŸæĹŰæŢřçżĎäÿ■ãĂĆçŻÿåŔ■ïijŇæŞ■ä¡
å¡Şä¡äèő£éŮőæŰĞäżűçŽĎäÿ■åŘŇåŇžå§§æŮűïijŇè£ŹäžŻåŇžå§§çŽĎåĘĚåőźæL'■æäźæ■őéIJÄèęĄèćńèŕžåŔ
èĂŇéĆčäžŻäżŐæšąèćńèő£éŮőåĹřçŽĎéČĺåĹĘè£ŸæŸŕçŢŹåIJÍçčĄçŻŸäÿŁãĂĆæL'ĂæIJL'è£ŹäžŻè£ĞçÍŃæŸ

åęĆæđIJåď'ŽäÿłpythonèğčéĞŁåŹĺåĘĚå■ŸæŸăåřĎåŘŇäÿĂäÿłæŰĞäżűïijŇå¿ŮåĹřçŽĎ
`mmap` åŕźèśąèČ¡åď'§èćńçŤĺæİěåIJÍèğčéĞŁåŹĺçŻť'æŐěäžď'æ■ćæŢřæ■őãĂĆ
äź§åřśæŸŕèŕť'ïijŇæL'ĂæIJL'èğčéĞŁåŹĺéČ¡èČ¡åŘŇæŮűèŕžåĘŹæŢřæ■őïijŇåźűäÿŤåĚűäÿ■äÿĂäÿłèğčéĞŁåŹĺa
å¿ĹæŸŐæŸ¿ïijŇè£ŹéĞŇéIJÄèęĄèĂČèŹŠåŘŇæ■ěçŽĎéŮőécŸãĂĆä¡ĘæŸŕè£Źçğ■æŰźæşŢæIJL'æŮűåĂŹåŔ

è£ŹäÿĂåřŔèŁĆäÿ■åĞ¡æŢřår¡éĞŔåĘŹå¿Ůå¿ĹéĂŽçŤĺïijŇåŘŇæŮűéĂĆçŤĺäžŐUnixåŠŇWindowsåźşåŔì
èęĄæşĺæĎŔçŽĎæŸŕä¡£çŤĺ `mmap()` åĞ¡æŢřæŮűäijŽåIJÍåžŢåśĆæIJL'äÿĂäžŻåźşåŘŕçŽĎåůőåijĆæĂğãĂĆ
åŘęåď'ŰïijŇè£ŸæIJL'äÿĂäžŻéĂL'éąźåŔŕäžěçŤĺæİěåĹŻåżžåŇ£åŘ■çŽĎåĘĚå■ŸæŸăåřĎåŇžå§§ãĂĆ
åęĆæđIJä¡ăåŕźè£ŹäÿłæĎ§åĚt'èűčïijŇçąőä£Ïä¡ăäžŤçżĘçăŤèŕžäžĘPythonæŰĞæąčäÿ■
è£ŹæŰźéIćçŽĎåĘĚåőź ãĂĆ

7.11 5.11 æŰĞäżűèůŕå¿ĎåŘ■çŽĎæŞ■ä¡IJ

éŮőécŸ

ä¡ăéIJÄèęĄä¡£çŤĺèůŕå¿ĎåŘ■æİěèŐůåŔŰæŰĞäżűåŘ■ïijŇçŻőå¡ŢåŘ■ïijŇçżİåŕźèůŕå¿Ďç■L'ç■L'ãĂĆ

èğčåĘşæŰźæąĹ

ä¡£çŤĺ `os.path` æĺąåİŮäÿ■çŽĎåĞ¡æŢřæİěæŞ■ä¡IJèůŕå¿ĎåŘ■ãĂĆ
äÿŇéIćæŸŕäÿĂäÿłäžď'äžŠåijŔä¿Ńå■ŘæİěæijŤçď'žäÿĂäžŻåĚşéŤőçŽĎçL'źæĂğïijŽ

```
>>> import os
>>> path = '/Users/beazley/Data/data.csv'

>>> # Get the last component of the path
>>> os.path.basename(path)
'data.csv'

>>> # Get the directory name
>>> os.path.dirname(path)
'/Users/beazley/Data'

>>> # Join path components together
>>> os.path.join('tmp', 'data', os.path.basename(path))
'tmp/data/data.csv'

>>> # Expand the user's home directory
>>> path = '~/Data/data.csv'
```

```
>>> os.path.expanduser(path)
'/Users/beazley/Data/data.csv'

>>> # Split the file extension
>>> os.path.splitext(path)
('~/Data/data', '.csv')
>>>
```

èőÍèőž

åŕźäžŐäżżä¡ŢçŽĎæŰĞäžűåŘ■çŽĎæŞ■ä¡IJïijŇä¡äéČ¡åžŤèŕěä¡£çŤÍ os.path æÍąåİŮïijŇèĂŇäÿ■æŸŕä¡£çŤÍæăĞåĞĘå■ŮçňęäÿšæŞ■ä¡IJæİěæđĎéĂäèĞłåůśçŽĎäżčçăĄãĂĆçL'źåĹńæŸŕäÿžäžĘåŔŕçğżæď■æĂğèĂČèŹŚçŽĎæŮűåĂŹæŻť'åžŤåęĆæ■ď'ïijŇ åŽääÿž os.path æÍąåİŮç§ěéĄŞUnixåŠŇWindowsçşżçż§äźŃéŮť'çŽĎåůőåijĆåźűäÿŤèČ¡åď'§åŔŕéİääIJřåď'ĎçŘĘçśżäijij Data/data.csv åŠŇ Data\data.csv è£ŹæăůçŽĎæŰĞäžűåŘ■ãĂĆ åĚűæňąïijŇä¡äçIJ§çŽĎäÿ■åžŤèŕěæţłèť'źæŮűéŮť'åŐżéĞ■åď'■éĂäè¡őå■ŘãĂĆéĂŽåÿÿæIJĂåě¡æŸŕçŻť'æŐëä¡£

èęĄæşÍæĎŔçŽĎæŸŕ os.path è£ŸæIJL'æŻť'åď'ŽçŽĎåŁ§èČ¡åIJÍè£ŹéĞŇåźűæšąæIJL'åĹŮäÿ¿åĞžæİěãåŔŕäżěæ§ěéŸĚåőŸæŰźæŰĞæąčæİèèŐůåŔŰæŻť'åď'ŽäÿŐæŰĞäžűæţŃèŕŢïijŇçňęåŘůéŞ¿æŐëç■L'çŽÿåĚşçŽ

7.12 5.12 æţŃèŕŢæŰĞäžűæŸŕåŘęå■ŸåIJÍ

éŮőécŸ

ä¡ăæČşæţŃèŕŢäÿĂäÿłæŰĞäžűæĹŰçŻőå¡ŢæŸŕåŘęå■ŸåIJÍãĂĆ

èğčåĘşæŰźæąĹ

ä¡£çŤÍ os.path æÍąåİŮæİěæţŃèŕŢäÿĂäÿłæŰĞäžűæĹŰçŻőå¡ŢæŸŕåŘęå■ŸåIJÍãĂĆæŕŤåęĆïijŽ

```
>>> import os
>>> os.path.exists('/etc/passwd')
True
>>> os.path.exists('/tmp/spam')
False
>>>
```

ä¡ăè£ŸèČ¡è£ŻäÿĂæ■ěæţŃèŕŢè£ŹäÿłæŰĞäžűæŮűäżĂäźĹçśżåđŃçŽĎãĂĆ åIJÍäÿŃéİćè£ŹäžŻæţŃèŕŢäÿ■ïijŇåęĆæđIJæţŃèŕŢçŽĎæŰĞäžűäÿ■å■ŸåIJÍçŽĎæŮűåĂŹïijŇçżŞæđIJéČ¡äijŽè

```
>>> # Is a regular file
>>> os.path.isfile('/etc/passwd')
True

>>> # Is a directory
>>> os.path.isdir('/etc/passwd')
```

```
False

>>> # Is a symbolic link
>>> os.path.islink('/usr/local/bin/python3')
True

>>> # Get the file linked to
>>> os.path.realpath('/usr/local/bin/python3')
'/usr/local/bin/python3.3'
>>>
```

åęĆæđIJä¡ăè£ŸæČşèŐůåŔŰåĚČæŢřæ■ő(æŕŤåęĆæŰĞäżűåď˘ğåřŔæĹŰèĂĚæŸŕä£őæŤźæŮěæIJ§)ïijŇäź
`os.path` æĺąåİŮæİěèğčåEşïijŽ

```
>>> os.path.getsize('/etc/passwd')
3669
>>> os.path.getmtime('/etc/passwd')
1272478234.0
>>> import time
>>> time.ctime(os.path.getmtime('/etc/passwd'))
'Wed Apr 28 13:10:34 2010'
>>>
```

èőÍèőž

ä¡£çŤÍ `os.path` æİěè£ŻèąŇæŰĞäżűæţŃèŕŢæŸŕå¿ĹçőĂå■ŢçŽĎãĂĆ
åIJĺåĘŹè£ŹäžŻèĎŽæIJňæŮűïijŇåŔŕèČ¡åŤŕäÿĂéIJĂèęĄæşĺæĎŔçŽĎåřśæŸŕä¡ăéIJĂèęĄèĂČèŹŚæŰĞäżűæİČ

```
>>> os.path.getsize('/Users/guido/Desktop/foo.txt')
Traceback (most recent call last):
    File "<stdin>", line 1, in <module>
    File "/usr/local/lib/python3.3/genericpath.py", line 49, in␣
 ↪getsize
        return os.stat(filename).st_size
PermissionError: [Errno 13] Permission denied: '/Users/guido/
 ↪Desktop/foo.txt'
>>>
```

7.13 5.13 èŐůåŔŰæŰĞäżűåď´žäÿ■çŽĎæŰĞäżűåĹŮèąĺ

éŮőécŸ

ä¡ăæČşèŐůåŔŰæŰĞäżűçşżçż§äÿ■æ§ŘäÿłçŻőå¡ŢäÿŃçŽĎæĽĂæIJĽæŰĞäżűåĹŮèąĺãĂĆ

èğčåĘşæŰźæąĹ

ä¡£çŤÍ `os.listdir()` åĞ¡æŢřæİěèŐůåŔŰæ§ŘäÿłçŻőå¡Ţäÿ■çŽĎæŰĞäžűåĹŮèąĺïijŽ

```
import os
names = os.listdir('somedir')
```

çžŞæđIJäijŽè£ŤåŻđçŻőå¡Ţäÿ■æĽĂæIJL'æŰĞäžűåĹŮèąĺïijŇåŇĚæŃňæĽĂæIJL'æŰĞäžűïijŇå■ŘçŻőå¡Ţ åęĆæđIJä¡ăéIJĂèęĄéĂŽè£Ğæ§Řçğ■æŰźåijŔè£Ğæžď'æŢřæ■őïijŇåŔŕäžěèĂČèŹŚçżŞåŘĹ `os.path` åžŞäÿ■çŽĎäÿĂäžŻåĞ¡æŢřæİěä¡£çŤĺåĹŮèąĺæŐĺåŕijãĂĆæŕŤåęĆïijŽ

```
import os.path

# Get all regular files
names = [name for name in os.listdir('somedir')
        if os.path.isfile(os.path.join('somedir', name))]

# Get all dirs
dirnames = [name for name in os.listdir('somedir')
        if os.path.isdir(os.path.join('somedir', name))]
```

å■Ůçňęäÿšç ŽĎ `startswith()` åŠŇ `endswith()` æŰźæşŢåŕźäžŐè£ĞæžďäÿĂäÿłçŻőå¡ŢçŽĎåĘĚåőźäź§æŸŕå¿ĹæIJL'çŤĺçŽĎãĂĆæŕŤåęĆïijŽ

```
pyfiles = [name for name in os.listdir('somedir')
           if name.endswith('.py')]
```

åŕźäžŐæŰĞäžűåŘ■çŽĎåŇźéĚ■ïijŇä¡ăåŔŕèČ¡äijŽèĂČèŹŚä¡£çŤÍ `glob` æĹŰ `fnmatch` æĺąåİŮãĂĆæŕŤåęĆïijŽ

```
import glob
pyfiles = glob.glob('somedir/*.py')

from fnmatch import fnmatch
pyfiles = [name for name in os.listdir('somedir')
           if fnmatch(name, '*.py')]
```

èŐĺèŐž

èŐůåŔŰçŻőå¡Ţäÿ■çŽĎåĹŮèąĺæŸŕå¿ĹåőźæŸ§çŽĎïijŇä¡ĘæŸŕåĚűè£ŤåŻđçżŞæđIJåŔłæŸŕçŻőå¡Ţäÿ■åĉ åęĆæđIJä¡ăè£ŸæČşèŐůåŔŰåĚűäžŰçŽĎåĚČä£ąæĄŕïijŇæŕŤåęĆæŰĞäžűåđ'ğåřŔïijŇä£őæŤźæŮűéŮť'ç■Ľ'ç■ä¡ăæĹŰèőÿè£ŸéIJĂèęĄä¡£çŤĺåĹř `os.path` æĺąåİŮäÿ■çŽĎåĞ¡æŢřæĹŰçİĂ `os.stat()` åĞ¡æŢřæİěæŤűéŻĘæŢřæ■őãĂĆæŕŤåęĆïijŽ

```
# Example of getting a directory listing

import os
import os.path
import glob
```

```
pyfiles = glob.glob('*.py')

# Get file sizes and modification dates
name_sz_date = [(name, os.path.getsize(name), os.path.
↪getmtime(name))
                for name in pyfiles]
for name, size, mtime in name_sz_date:
    print(name, size, mtime)

# Alternative: Get file metadata
file_metadata = [(name, os.stat(name)) for name in pyfiles]
for name, meta in file_metadata:
    print(name, meta.st_size, meta.st_mtime)
```

æIJÄåŘŐè£ŸæIJL'äÿĂçĆźèęĄæşÍæĎŔçŽĎåřśæŸřïijŇæIJL'æŮűåĂŹåIJÍåď'ĎçŘĘæŰĞäżűåŘ■çijŰçăĄéĂŽåÿÿæİěèőšïijŇåĞ¡æŢř `os.listdir()` è£ŤåŻđçŽĎåőđä¡ŞåĹŮèąÍäijŽæäźæ■őçşžçż§éżŸèöď'çŽĎæŰĞäą¡ĘæŸřæIJL'æŮűåĂŹäź§äijŽçćřåĹřäÿĂäžŽäÿ■èČ¡æ■čåÿÿèğčçăĄçŽĎæŰĞäžűåŘ■ãĂĆ åĚşäžŐæŰĞäżűåŘ■çŽĎåď'ĎçŘĘéŮőécŸïijŇåIJÍ5.14åŠŇ5.15åřŔèŁĆæIJL'æŻt'èŕęçżĘçŽĎèőšèğčãĂĆ

7.14 5.14 å£¡çŢěæŰĞäżűåŘ■çijŰçăĄ

éŮőécŸ

ä¡ăæČşä¡£çŤĺåŐ§ågŇæŰĞäżűåŘ■æL'ğèąŇæŰĞäžűçŽĎI/OæŞ■ä¡IJïijŇäź§åřśæŸŕèŕť'æŰĞäżűåŘ■åźűæš

èğčåĘşæŰźæąĹ

éżŸèöď'æČĚåĘţäÿŃïijŇæL'ĂæIJL'çŽĎæŰĞäżűåŘ■éČ¡äijŽæäźæ■ő `sys.getfilesystemencoding()` è£ŤåŻđçŽĎæŰĞæIJñçijŰçăĄæİěçijŰçăĄæĹŰèğčçăĄãĂĆæŕŤåęĆïijŽ

```
>>> sys.getfilesystemencoding()
'utf-8'
>>>
```

åęĆædIJåŽääÿžæ§Řçğ■åŐ§åŽää¡ăæČşå£¡çŢěè£Źçğ■çijŰçăĄïijŇåŔŕäżěä¡£çŤĺäÿĂäÿłåŐ§ågŃå■ŮèŁĆå

```
>>> # Wrte a file using a unicode filename
>>> with open('jalape\xf1o.txt', 'w') as f:
...     f.write('Spicy!')
...
6
>>> # Directory listing (decoded)
>>> import os
>>> os.listdir('.')
['jalapeÃśo.txt']
```

```
>>> # Directory listing (raw)
>>> os.listdir(b'.') # Note: byte string
[b'jalapen\xcc\x83o.txt']

>>> # Open file with raw filename
>>> with open(b'jalapen\xcc\x83o.txt') as f:
...     print(f.read())
...
Spicy!
>>>
```

æ■čåęĆä¡ăæĽĂèğĄïijŇåIJÍæIJĂåŘŐäÿd'äÿłæŞ■ä¡IJäÿ■ïijŇå¡Şä¡ăçżŹæŰĞäžűçŻÿåĚşåĞ¡æŢřåęĆ
`open()` åŠŇ `os.listdir()` äijăéĂŠå■ÙèŁĆå■ŮçňęäÿšæŮűïijŇæŰĞäžűåŘ■çŽĎåd'ĎçŘĘæŰźåijŔäijŽçĺ

èőÍèőž

éĂŽåÿÿæİěèőšïijŇä¡ăäÿ■éIJĂèęĄæŃĚå£ČæŰĞäžűåŘ■çŽĎçijŰçăĄåŠŇèğčçăĄïijŇæŹőéĂŽçŽĎæŰĞäž
ä¡ĘæŸŕïijŇæIJL'äžŻæŞ■ä¡IJçşżçż§åĚĄèőÿçŤÍæĹůéĂŽè£ĞåĄűçĎűæĹŰæĄűæĎŔæŰźåijŔåŐżåĹŻåżžåŘ■å■
è£ŹäžŻæŰĞäžűåŘ■åŔŕèČ¡äijŽçěđçğŸåIJŕäÿ■æŰ■éĆčäžŻéIJĂèęĄåd'ĎçŘĘåd'ğéĞŘæŰĞäžűçŽĎPythonçÍŃ

èŕżåŔŰçŻőå¡ŢåźűéĂŽè£ĞåŐ§ågŃæIJłèğčçăĄæŰźåijŔåd'ĎçŘĘæŰĞäžűåŘ■åŔŕäžěæIJL'æŢĹçŽĎéĄ£å
år¡çőąè£ŹæăůäijŽåÿęæİěäÿĂåőŽçŽĎçijŰçÍŃéŽ¿åžęãĂĆ

åĚşäžŐæL'Şå■řäÿ■åŔŕèğčçăĄçŽĎæŰĞäžűåŘ■ïijŇèŕůåŔĆèĂČ5.15åřŔèŁĆãĂĆ

7.15 5.15 æL'Şå■řäÿ■åŘĹæşŢçŽĎæŰĞäžűåŘ■

éŮőécŸ

ä¡ăçŽĎçÍŃåžŔèŐůåŔŰäžĘäÿĂäÿłçŻőå¡Ţäÿ■çŽĎæŰĞäžűåŘ■åĹŮèąĺïijŇä¡ĘæŸŕå¡ŞåőČèŕŢçİĂåŐżæL'Ş
åĞžçŐřäžĘ `UnicodeEncodeError` åijĆåÿÿåŠŇäÿĂæİąåěĞæĂłçŽĎæűĹæĄŕâĂŤâĂŤ
`surrogates not allowed` ãĂĆ

èğčåĘşæŰźæąĹ

å¡ŞæL'Şå■řæIJłç§ěçŽĎæŰĞäžűåŘ■æŮűïijŇä¡£çŤÍäÿŃéİćçŽĎæŰźæşŢåŔŕäžěéĄ£åĚ■è£ŹæăůçŽĎéŤŹè

```
def bad_filename(filename):
    return repr(filename)[1:-1]

try:
    print(filename)
except UnicodeEncodeError:
    print(bad_filename(filename))
```

èőÍèőž

è£ŹäÿĂåřŔèŁĆèőÍèőžçŽĎæŸŕåIJÍçijŰåEŹå£Ěéąžåď ĎçŘĘæŰĞäžűçşžçż§çŽĎçÍŃåžŔæŮűäÿĂäÿłäÿ■åd
éżŸèőď æČĚåĘţäÿŃïijŇPythonåĄĞåőŽæĽĂæIJL'æŰĞäžűåŘ■éČ¡åůšçżŔæăźæ■ő
`sys.getfilesystemencoding()` çŽĎåĂijçijŰçăĄè£ĞäžĘãĂĆ
ä¡ĘæŸŕïijŇæIJL'äÿĂäžŽæŰĞäžűçşžçż§åźűæšąæIJL'åijžåĹűèęĄæśĆè£ŹæăůåĄŽïijŇåŽăæ■ď åĚĄèőÿåĹŽåžž
è£ŹçğæČĚåĘţäÿ■åď łåÿÿèğĄïijŇä¡ĘæŸŕæĂżäijŽæIJL'äžŽçŤÍæĹůåĘŠéŹl'è£ŹæăůåĄŽæĹŰèĂĚæŸŕæŮăæĎ
åŔŕèČ¡æŸŕåIJÍäÿĂäÿłæIJL'çijžéŹůçŽĎäžčçăĄäÿ■çżŹ `open()`
åĞ¡æŢŕäijăéĂŠäžĘäÿĂäÿłäÿ■åŘĹèğĎèŇČçŽĎæŰĞäžűåŘ■)ãĂĆ

å¡ŞæĽğèąŇçśžäijij `os.listdir()` è£ŹæăůçŽĎåĞ¡æŢŕæŮűïijŇè£ŹäžŽäÿ■åŘĹèğĎèŇČçŽĎæŰĞäžűå
äÿĂæŰźéİćïijŇåőČäÿ■èČ¡äžĚäžĚåŔłæŸŕäÿćåijČè£ŹäžŽäÿ■åŘĹæăijçŽĎåŘ■å■ŮãĆèĂŇåŔęäÿĂæŰźéİćïij
Pythonåŕźè£ŹäÿłéŮőécŸçŽĎèğčåĘşæŰźæąĹæŸŕäžŐæŰĞäžűåŘ■äÿ■èŐůåŔŰæIJłèğčçăĄçŽĎå■ŮèŁĆåĂijæ
`\xhh` åźűåřĘåőČæŸăåřĎæĹŘUnicodeå■Ůçňę `\udchh` èąĺçď žçŽĎæĽĂèřŞçŽĎâĂİäžčçŘEçijŰçăĄâĂİãĂĆ
äÿŃéİćäÿĂäÿłä¿Ńå■ŘæijŤçď žäžĘå¡ŞäÿĂäÿłäÿ■åŘĹæăijçŽőå¡ŢåĹŮèąĺäÿ■åŘńæIJL'äÿĂäÿłæŰĞäžűåŘ■äÿžb
1èĂŇäÿ■æŸŕUTF-8çijŰçăĄ)æŮűçŽĎæăůå■Řïijž

```
>>> import os
>>> files = os.listdir('.')
>>> files
['spam.py', 'b\udce4d.txt', 'foo.txt']
>>>
```

åęĆæđIJä¡ăæIJL'äžčçăĄéIJĂèęĄæŞ■ä¡IJæŰĞäžűåŘ■æĹŰèĂĚåřĘæŰĞäžűåŘ■äijăéĂŠçžŹ
`open()` è£ŹæăůçŽĎåĞ¡æŢŕïijŇäÿĂåĹĞéČ¡èČ¡æ■čåÿÿåůëä¡IJãĂĆ
åŘłæIJL'å¡Şä¡ăæČşèęĄè¿ŞåĞžæŰĞäžűåŘ■æŮűæL'■äijŽçćřåĹřäžŹéžžçČę(æŕŤåęĆæL'Şå■řè¿ŞåĞžåĹřåśŔåź
çL'źåĹńçŽĎïijŇå¡Şä¡ăæČşæL'Şå■řäÿŁéİćçŽĎæŰĞäžűåŘ■åĹŮèąĺæŮűïijŇä¡ăçŽĎçÍŃåžŔårśäijŽåť l'æžČïijž

```
>>> for name in files:
...     print(name)
...
spam.py
Traceback (most recent call last):
    File "<stdin>", line 2, in <module>
UnicodeEncodeError: 'utf-8' codec can't encode character '\udce4' in
position 1: surrogates not allowed
>>>
```

çÍŃåžŔåť l'æžČçŽĎåŐ§åŻăářśæŸŕå■Ůçňę `\udce4` æŸŕäÿĂäÿłéİđæşŢçŽĎUni-
codeå■Ůçňęã ĂĆ åőČåĚűåőđæŸŕäÿĂäÿłèćńçğřäÿžäžčçŘĘå■Ůçňęåŕźç ŽĎåŔŇå■Ůçňęçż ĎåŘĹçŽĎåŘŐå■ŁéČ
çŤśäžŐçijžåřŚäžĘåĽ■å■ŁéČĺåĹĘïijŇåŽăæ■ď åőČæŸŕäÿłéİđæşŢçŽĎUnicodeãĂĆ
æĽĂäžěïijŇåŤŕäÿĂèČ¡æĹŘåŁ§è¿ŞåĞžçŽĎæŰźæşŢåřśæŸŕå¡ŞéĄĞåĹřäÿ■åŘĹæşŢæŰĞäžűåŘ■æŮűéĞĞåŔU
æŕŤåęĆåŔŕäžěåřĘäÿŁè£ŕäžčçăĄä£őæŤźåęĆäÿŃïijž

```
>>> for name in files:
... try:
...     print(name)
... except UnicodeEncodeError:
...     print(bad_filename(name))
...
```

```
spam.py
b\udce4d.txt
foo.txt
>>>
```

åIJÍ bad_filename() åĞ¡æŢřäÿ■æĂŐæäůåď Ďç¡őåŔŰåĘşäžŐä¡äèĞłåůśãĂĆ åŔęåď ŰäÿĂäÿłéĂL'æŃľåřśæŸŕéĂŽè£Ğæ§Řçğ■æŰźåijŔéĞ■æŰřçijŰçăĄïijŇçď'žä¿ŃåęĆäÿŃïijŽ

```
def bad_filename(filename):
    temp = filename.encode(sys.getfilesystemencoding(), errors=
↪'surrogateescape')
    return temp.decode('latin-1')
```

èŕŚèĂĚæşÍ:

```
surrogateescape:
è£Źçğ■æŸŕPythonåIJÍçżÍåd'ğéČĺåĹĘéÍćåŘŚOSçŽĎAPIäÿ■æL'Ăä¡£çŤÍçŽĎéŤŹèŕŕåd'ĎçŘĘåŹĺïi
åőČèČ¡äżěäÿĂçğ■äijŸéŽĚçŽĎæŰźåijŔåd'ĎçŘĘçŤśæŞ■ä¡IJçşżçżŞæŔŘä¿ŽçŽĎæŢřæ■őçŽĎçijŰçăĄé
åIJÍèğčçăĄåĞžéŤŹæŮűäijŽåřĘåĞžéŤŹå■ÙèŁĆå■ŸåĆĺåĹřäÿĂäÿłå¿ĹåřŚèćńä¡£çŤÍåĹřçŽĎUnicode
åIJÍçijŰçăĄæŮűåřĘéĆčäžżéŽŘèŮŔåĂijåŔĹè£ŸåŐ§åŻđåŐ§åĚĹèğčçăĄåd'śèt'ěçŽĎå■ÙèŁĆåžŘåĹŮ
åőČäÿ■äżĚåŕźäžŐOS␣
↪APIéİđåÿÿæIJL'çŤÍïijÑäź§èČ¡å¿ĹåőźæŸŞçŽĎåd'ĎçŘĘåĚűäżŰæČĚåĘţäÿŃçŽĎçijŰçăĄéŤŹèŕŕã
```

ä¡£çŤÍè£ŹäÿłçĽĹæIJňäžğçŤ§çŽĎè¿ŞåĞžåęĆäÿŃïijŽ

```
>>> for name in files:
...     try:
...         print(name)
...     except UnicodeEncodeError:
...         print(bad_filename(name))
...
spam.py
bÃd'd.txt
foo.txt
>>>
```

è£ŹäÿĂåřŔèŁĆäÿżécŸåŔŕèČ¡äijŽèćńåď ğéČĺåĹĘèŕżèĂĚæL'Ăå£¡çŢěãĂĆä¡ĘæŸŕåęĆæđIJä¡ääIJÍçijŰåĘ
åřśå£Ěéążå¿ŮèĂČèŹŚåĹřè£ŹäÿłãĂĆåŘęåĹŹä¡ääŔŕèČ¡äijŽåIJÍæ§Řäÿłåŝ́ÍæIJńèćńåŔńåĹřåŁđåĚňåőđ'åŐżèřČ

7.16 5.16 åćđåŁăæĹŰæŤźåŔŸåůšæL'ŞåijĂæŰĞäžűçŽĎçijŰçăĄ

éŮőécŸ

ä¡ăæČşåIJÍäÿ■åĚşéŮ■äÿĂäÿłåůšæL'ŞåijĂçŽĎæŰĞäžűåL'■æŔŘäÿŃåćđåŁăæĹŰæŤźåŔŸåőČçŽĎUnico

èğčåĘşæŰźæąĹ

åęĆædIJä¡ăæČşçżŹäÿĂäÿłäžëäžŇè£ŻåĹűæĺąåijŔæL'ŞåijĂçŽĎæŰĞäžűæůżåŁăUnicodeçijŰçăĄ/èğčçăĄ
åŔŕäžëä¡£çŤĺ `io.TextIOWrapper()` åŕźèśąåŇĚèčĚåőČãĂĆæŕŤåęĆïijŽ

```
import urllib.request
import io

u = urllib.request.urlopen('http://www.python.org')
f = io.TextIOWrapper(u, encoding='utf-8')
text = f.read()
```

åęĆædIJä¡ăæČşä£őæŤźäÿĂäÿłåůšçżŔæL'ŞåijĂçŽĎæŰĞæIJňæĺąåijŔçŽĎæŰĞäžűçŽĎçijŰçăĄæŰźåijŔ
`detach()` æŰźæşŢçğżéŹď'æŐL'åůšå■ŸåIJĺçŽĎæŰĞæIJňçijŰçăĄåśĆïijŇ
åźűä¡£çŤĺæŰřçŽĎçijŰçăĄæŰźåijŔäžčæŽ£ãĂĆäÿŇéİćæŸŕäÿĂäÿłåIJĺ `sys.stdout`
äÿŁä£őæŤźçijŰçăĄæŰźåijŔçŽĎä¿Ńå■ŘïijŽ

```
>>> import sys
>>> sys.stdout.encoding
'UTF-8'
>>> sys.stdout = io.TextIOWrapper(sys.stdout.detach(), encoding=
↪'latin-1')
>>> sys.stdout.encoding
'latin-1'
>>>
```

è£Źæăůå˛ŽåŔŕèČ¡äijŽäÿ■æŰ■ä¡ăçŽĎçżĹçńŕïijŇè£ŹéĞŇäžĚäžĚæŸŕäÿžäžĘæijŢçď'žèĂŇåůšãĂĆ

èőĺèőž

I/Oçşżçž§çŤśäÿĂçşżåĹŮçŽĎåśĆæňąædĎåżžèĂŇæĹŘãĂĆä¡ăåŔŕäžëèŕŢçİÄè£ŘèąŇäÿŃéİćè£ŹäÿłæŞ■ä

```
>>> f = open('sample.txt','w')
>>> f
<_io.TextIOWrapper name='sample.txt' mode='w' encoding='UTF-8'>
>>> f.buffer
<_io.BufferedWriter name='sample.txt'>
>>> f.buffer.raw
<_io.FileIO name='sample.txt' mode='wb'>
>>>
```

åIJĺè£Źäÿłä¿Ńå■Řäÿ■ïijŇ`io.TextIOWrapper` æŸŕäÿĂäÿłçijŰçăĄåŠŇèğčçăĄU-
nicodeçŽĎæŰĞæIJňåď'ĎçŘĘåśĆïijŇ `io.BufferedWriter`
æŸŕäÿĂäÿłåď'ĎçŘĘäžŇè£ŻåĹűæŢŕæ■őçŽĎåÿęçijŞåĘšçŽĎI/OåśĆïijŇ `io.FileIO`
æŸŕäÿĂäÿłèąĺçď'žæŞ■ä¡IJçşżçž§åžŢåśĆæŰĞäžűæŔŘè£rçňęçŽĎåŐ§ågŃæŰĞäžűãĂĆ
åćđåŁăæĹŰæŤźåŔŸæŰĞæIJňçijŰçăĄäijŽæűL'åŔŁåćđåŁăæĹŰæŤźåŔŸæIJĂäÿŁéİćçŽĎ
`io.TextIOWrapper` åśĆãĂĆ

äÿĂèĹňæİèèőšïijŇåČŔäÿŁéİćä¿Ńå■Řè£ŹæăůéĂŽè£Ğèŏ£éŮőåśđæĂğåĂijæİěçŻť'æŐěæŞ■ä¡IJäÿ■åŘŇç
ä¿ŃåęĆïijŇåęĆædIJä¡ăèŕŢçİÄä¡£çŤĺäÿŃéİćè£ŹæăůçŽĎæŁĂæIJŕæŤźåŔŸçijŰçăĄçIJŃçIJŃäijŽåŔŠçŢ§äžĂä

```
>>> f
<_io.TextIOWrapper name='sample.txt' mode='w' encoding='UTF-8'>
>>> f = io.TextIOWrapper(f.buffer, encoding='latin-1')
>>> f
<_io.TextIOWrapper name='sample.txt' encoding='latin-1'>
>>> f.write('Hello')
Traceback (most recent call last):
    File "<stdin>", line 1, in <module>
ValueError: I/O operation on closed file.
>>>
```

çżŞædIJåĞžéŤŹäžĘïijŇåŻääÿžfçŽĎåŐ§ågŃåĂijåůšçżŔèćńçăť åİŔäžĘåźűåĚşéŮ■äžĘåžŢåśĆçŽĎæŰĞäz

detach() æŰźæşŢäijŽæŰ■åijĂæŰĞäżűçŽĎæIJĂéąűåśĆåźűè£ŤåŻđçňňäžŇåśĆïijŇäźŃåŘŐæIJĂéąűå

```
>>> f = open('sample.txt', 'w')
>>> f
<_io.TextIOWrapper name='sample.txt' mode='w' encoding='UTF-8'>
>>> b = f.detach()
>>> b
<_io.BufferedWriter name='sample.txt'>
>>> f.write('hello')
Traceback (most recent call last):
    File "<stdin>", line 1, in <module>
ValueError: underlying buffer has been detached
>>>
```

äÿĂæŮęæŰ■åijĂæIJĂéąűåśĆåŘŐïijŇä¡ăářśåŔŕäžěçżŹè£ŤåŻđçżŞædIJæůżåŁääÿĂäÿłæŰřçŽĎæIJĂéąűå

```
>>> f = io.TextIOWrapper(b, encoding='latin-1')
>>> f
<_io.TextIOWrapper name='sample.txt' encoding='latin-1'>
>>>
```

ář¡çőąåůšçżŔåŘŚä¡ăæijŤçd'žäžĘæŤźåŔŸçijŰçăĄçŽĎæŰźæşŢïijŇ
ä¡ĘæŸŕä¡ăè£ŸåŔŕäžěåĹ'çŤĺè£Źçğ■æŁĂæIJŕæİěæŤźåŔŸæŰĞäžűèąŇåd'ĎçŘĘãĂąéŤŹèŕŕæIJžåĹűäžěåŘŁæ

```
>>> sys.stdout = io.TextIOWrapper(sys.stdout.detach(), encoding=
↪'ascii',
...                                errors='xmlcharrefreplace')
>>> print('Jalape\u00f1o')
Jalape&#241;o
>>>
```

æşÍæĎŔäÿŃæIJĂåŘŐè¿ŞåĞžäÿ■çŽĎéİđASCIIå■Ůçňę Ãś æŸŕåęĆä¡Ţèćń ñ åŘŰäžčçŽĎãĂĆ

7.17 5.17 åřĘå■ÙèŁĆåĘŹåĚěæŰĞæIJňæŰĞäžű

éŮőécŸ

ä¡ăæČşåIJÍæŰĞæIJňæÍąåijŔæL'Şåij ĂçŽĎæŰĞäžűäÿ■åĘŹåĚěåŐ§ågŃçŽĎå■ÙèŁĆæŢřæ■őãĂĆ

èğčåĘşæŰźæąĹ

åřĘå■ÙèŁĆæŢřæ■őçŻť'æŐěåĘŹåĚěæŰĞäžűçŽĎçijŞåĘšåŇžå■şåŔřïijŇä¿ŃåęĆïijŽ

```
>>> import sys
>>> sys.stdout.write(b'Hello\n')
Traceback (most recent call last):
    File "<stdin>", line 1, in <module>
TypeError: must be str, not bytes
>>> sys.stdout.buffer.write(b'Hello\n')
Hello
5
>>>
```

çśżäijijçŽĎïijŇèČ¡åď'§éĂŽè£ĞèŕżåŔŰæŰĞæIJňæŰĞäžűçŽĎ `buffer` åśđæĂğæÌěèŕżåŔŰäžŇè£ŻåĹűæŢřæ■őãĂĆ

èőÍèőž

I/Oçşżçż§äžěåśĆçžğçżŞæđĎçŽĎå¡ćåijŔæđĎåżžèĂŇæĹŘãĂĆ
æŰĞæIJňæŰĞäžűæŸŕéĂŽè£ĞåIJÍäÿĂäÿłæŃěæIJL'çijŞåĘšçŽĎäžŇè£ŻåĹűæÍąåijŔæŰĞäžűäÿŁåćđåŁääÿĂäÿ
`buffer` åśđæĂğæŇĞåŘŠåŕźåžŤçŽĎåžŢåśĆæŰĞäžűãĂĆåęĆæđIJä¡ăçŻť'æŐèèő£éŮőåőĆçŽĎèŕÌåřšäijŽçżŢè

æIJňåřŔèŁĆä¿Ńå■ŘåśŢçd'žçŽĎ `sys.stdout` åŔŕèČ¡çIJŃètůæÌěæIJL'çĆźçL'źæőŁãĂĆ
éżŸèőd'æČĚåĘţäÿŃïijŇsys.stdout æĂżæŸŕäžěæŰĞæIJňæÍąåijŔæL'Şåij ĂçŽĎãĂĆ
ä¡ĘæŸŕåęĆæđIJä¡ååIJÍåĘŹäÿĂäÿłéIJĂèęĄæL'Şå■řäžŇè£ŻåĹűæŢřæ■őåĹřæăĞåĞĘè¿ŞåĞžçŽĎèĎŽæIJňçŽĎ

7.18 5.18 åřĘæŰĞäžűæŔŔè£řçňęåŇĚèčĚæĹŘæŰĞäžűåŕźèśą

éŮőécŸ

ä¡ăæIJL'äÿĂäÿłåŕźåžŤäžŐæŞ■ä¡IJçşżçż§äÿŁäÿĂäÿłåůšæL'Şåij ĂçŽĎI/OéĂŽéĄŞ(æŕŤåęĆæŰĞäžűãĂĄç
ä¡ăæČşåřĘåőČåŇĚèčĚæĹŘäÿĂäÿłæŽť'énŸåśĆçŽĎPythonæŰĞäžűåŕźèśąãĂĆ

èğčåĘşæŰźæąĹ

äÿĂäÿłæŰĞäžűæŔŔè£řçňęåŠŇäÿĂäÿłæL'Şåij ĂçŽĎæŹőéĂŽæŰĞäžűæŸŕäÿ■äÿĂæăůçŽĎãĂĆ
æŰĞäžűæŔŔè£řçňęäžĚäžĚæŸŕäÿĂäÿłçŤśæŞ■ä¡IJçşżçż§æŇĞåőŽçŽĎæŢť'æŢřïijŇçŤÍæÌěæŇĞäžčæ§Řäÿłçş
åęĆæđIJä¡ăçćřåůğæIJL'è£ŻäźĹäÿĂäÿłæŰĞäžűæŔŔè£řçňęïijŇä¡ăåŔŕäžěéĂŽè£Ğä¡£çŤÍ

open() åĞ¡æŢřæİěářĘåĚűåŇĚèčĚäÿžäÿĂäÿłPythonçŽĎæŰĞäžűářźèśąąĂĆ
ä¡ăäžĚäžĚåŔłéIJĂèęĄä¡£çŤĺè£ŹäÿłæŢťæŢřåĂijçŽĎæŰĞäžűæŔŔè£řçňęä¡IJäÿžçňňäÿĂäÿłåŔĆæŢřæİěäžčæ

```
# Open a low-level file descriptor
import os
fd = os.open('somefile.txt', os.O_WRONLY | os.O_CREAT)

# Turn into a proper file
f = open(fd, 'wt')
f.write('hello world\n')
f.close()
```

å¡ŞéńŸåśĆçŽĎæŰĞäžűářźèśąèćńåĚşéŮ■æĹŰèĂĚçăť åİŔçŽĎæŮűåĂŹïijŇåžŢåśĆçŽĎæŰĞäžűæŔŔè£ì
åęĆæđIJè£Źäÿłåźűäÿ■æŸŕä¡ăæČşèęĄçŽĎçżŞæđIJïijŇä¡ăåŔŕäžěçżŹ open()
åĞ¡æŢřäijăéĂŠäÿĂäÿłåŔŕéĂĽçŽĎ colsefd=False ãĂĆæŕŤåęĆïijŽ

```
# Create a file object, but don't close underlying fd when done
f = open(fd, 'wt', closefd=False)
...
```

èőĺèőž

åIJÍUnixçşżçż§äÿ■ïijŇè£Źçğ■åŇĚèčĚæŰĞäžűæŔŔè£řçňęçŽĎæŁĂæIJŕåŔŕäžěå¿ĹæŰźä¿£çŽĎåřĘäÿĂä
åęĆçőąéĄŞãĂĄåěŮæŐěå■Ůç■Ľ˜ãĂĆäÿ¿ä¿ŃæİěèőšïijŇäÿŃéİćæŸŕäÿĂäÿłæŞ■ä¡IJçőąéĄŞçŽĎä¿Ńå■ŘïijŽ

```
from socket import socket, AF_INET, SOCK_STREAM

def echo_client(client_sock, addr):
    print('Got connection from', addr)

    # Make text-mode file wrappers for socket reading/writing
    client_in = open(client_sock.fileno(), 'rt', encoding='latin-1',
                     closefd=False)

    client_out = open(client_sock.fileno(), 'wt', encoding='latin-1
↪',
                      closefd=False)

    # Echo lines back to the client using file I/O
    for line in client_in:
        client_out.write(line)
        client_out.flush()

    client_sock.close()

def echo_server(address):
    sock = socket(AF_INET, SOCK_STREAM)
    sock.bind(address)
    sock.listen(1)
    while True:
```

```
        client, addr = sock.accept()
        echo_client(client, addr)
```

éIJÄèęĄéĞ■çĆźåijžèřČçŽĎäÿĂçĆźæŸŕïijŇäÿŁéİćçŽĎä¿Ńå■ŘäżĚäżĚæŸŕäÿžäžĘæijŢçď žåĘĚç¡őçŽĎ
`open()` åĞ¡æŢřçŽĎäÿĂäÿłçĽźæĂğïijŇåźűäÿŤäź§åŔłéĂĆçŤĺäžŐå§žäžŐUnixçŽĎçşżçż§ãĂĆ
åęĆæđIJä¡ăæČşářĘäÿĂäÿłçśżæŰĞäżűæŐěåŔčä¡IJçŤĺåIJĺäÿĂäÿłåěŮæŐěå■Ůåźűåÿ̃ÑæIJŻä¡ăçŽĎäżčçăĄåŔŕä
`makefile()` æŰźæşŢãĂĆ ä¡ĘæŸŕåęĆæđIJäÿ■èĂČèŹŚåŔŕçğżæď■æĂğçŽĎèŕÍïijÑéĆčäÿŁéİćçŽĎèğčåĘşæ
`makefile()` æĂğèČ¡æŻť åě¡äÿĂçĆźãĂĆ

ä¡ăäź§åŔŕäżěä¡£çŤĺè£ŹçğæŁĂæIJŕæİěæđĎéĂääÿĂäÿłåĹńåŘ■ïijŇåĚĄèőÿäżěäÿ■åŘÑäžŐçñňäÿĂæňąą
ä¿ŇåęĆïijŇäÿÑéİćæijŢçď žåęĆä¡ŢåĹŻåżžäÿĂäÿłæŰĞäżűåŕźèśąïijŇåőČåĚĄèőÿä¡ăè¿ŞåĞžäžÑè£ŻåĹűæŢřæ

```
import sys
# Create a binary-mode file for stdout
bstdout = open(sys.stdout.fileno(), 'wb', closefd=False)
bstdout.write(b'Hello World\n')
bstdout.flush()
```

ař¡çőąåŔŕäżěařĘäÿĂäÿłåůšå■ŸåIJĺçŽĎæŰĞäżűæŔŔè£rçňęåÑĚècĚæĹŘäÿĂäÿłæ■čåÿÿçŽĎæŰĞäżűåŕźè
ä¡ĘæŸŕèęĄæşÍæĎŔçŽĎæŸŕåźűäÿ■æŸŕæĽĂæIJĽçŽĎæŰĞäżűæÍąåijŔéČ¡ècńæŤŕæŇĄïijŇåźűäÿŤæ§ŘäžŻçş
(çĽźåĹńæŸŕæűĽåŔŁåĹřéŤŹèŕŕåď ĎçŘĘãĂĄæŰĞäżűçżŞař¿æİąäžűç■Ľç■Ľç ŽĎæŮűåĂŹ)ãĂĆ
åIJĺäÿ■åŘÑçŽĎæŞ■ä¡IJçşżçż§äÿŁè£Źçğ■èąÑäÿžäź§æŸŕäÿ■äÿĂæăůïijÑçĽźåĹńçŽĎïijÑäÿŁéİćçŽĎä¿Ńå■Ře
æĹŠèŕťäžĘè£ŹäźĹåď ŽïijÑæĎŔæĂİåŕśæŸŕèőľä¡ăåĚĚåĹĘæţÑèŕŢèĞłåůśçŽĎåőđçŐŕäžčçăĄïijÑçąőä£İåőČè

7.19 5.19 åĹŻåżžäÿťæŮűæŰĞäżűåŠÑæŰĞäżűåď ź

éŮőécŸ

ä¡ăéIJĂèęĄåIJĺçĺÑåžŔæĽğèąÑæŮűåĹŻåżžäÿĂäÿłäÿťæŮűæŰĞäżűæĹŰçŽő å¡ŢïijÑåźűåÿÑæIJŻä¡£çŤĺå

èğčåĘşæŰźæąĹ

`tempfile` æĺąåİŮäÿ■æIJĽå¿Ĺåď ŽçŽĎåĞ¡æŢřåŔŕäžěåőÑæĹŘè£ŹäżżåŁąãĂĆ
äÿžäžĘåĹŻåżžäÿĂäÿłåÑ£åŘ■çŽĎäÿťæŮűæŰĞäżűïijÑåŔŕäžěä¡£çŤĺ `tempfile.TemporaryFile` ïijŽ

```
from tempfile import TemporaryFile

with TemporaryFile('w+t') as f:
    # Read/write to the file
    f.write('Hello World\n')
    f.write('Testing\n')

    # Seek back to beginning and read the data
    f.seek(0)
    data = f.read()
```

```
# Temporary file is destroyed
```

æĹŰèĂĚïijŇåęĆæđIJä¡ăåŰIJæňćïijŇä¡ăè£ŸåŔŕäžěåČŔè£Źæăůä¡£çŤĺäÿťæŮűæŰĞäžűïijŽ

```
f = TemporaryFile('w+t')
# Use the temporary file
...
f.close()
# File is destroyed
```

TemporaryFile() çŽĎçňňäÿĂäÿłåŔĆæŢřæŸŕæŰĞäžűæĺąåijŔïijŇéĂŽåÿÿæİěèőšæŰĞæIJňæĺąåijŔä w+t ïijŇäžŇè£ŻåĹűæĺąåijŔä¡£çŤĺ w+b ãĂĆ è£ŹäÿłæĺąåijŔåŘŇæŮűæŤŕæŇĄèŕžåŠŇåĘŹæŞ■ä¡IJïijŇåIJĺè£Ź TemporaryFile() åŔęåď Úè£ŸæŤŕæŇĄèů§åĘĚç¡őçŽĎ open() åĞ¡æŢřäÿĂæăůçŽĎåŔĆæŢřãĂĆæŕŤåęĆïijŽ

```
with TemporaryFile('w+t', encoding='utf-8', errors='ignore') as f:
    ...
```

åIJĺåď ğåď ŽæŢřUnixçşżçż§äÿŁïijŇéĂŽè£Ğ TemporaryFile() åĹŻåžžçŽĎæŰĞäžűéČ¡æŸŕåŇ£åŘ■çŽĎïijŇçŤŽèĞşè£đçŻőå¡ŢéČ¡æšąæIJL'ãĂĆ åęĆæđIJä¡ăæČşæL'Şçăť è£ŹäÿłéŹŘåĹűïijŇåŔŕäžěä¡£çŤĺ NamedTemporaryFile() æİěäžčæŽ£ãĂĆæŕŤåęĆïijŽ

```
from tempfile import NamedTemporaryFile

with NamedTemporaryFile('w+t') as f:
    print('filename is:', f.name)
    ...

# File automatically destroyed
```

è£ŹéĞŇïijŇèćńæL'ŞåijĂæŰĞäžűçŽĎ f.name åšđæĂğåŇĚåŔńäžĘèŕěäÿťæŮűæŰĞäžűçŽĎæŰĞäžűåŘ å¡Şä¡ăéIJĂèęĄåřĘæŰĞäžűåŘ■äijăéĂŠçżŹåĚűäžŰäžčçĂąæİěæL'ŞåijĂè£ŹäÿłæŰĞäžűçŽĎæŰűåĂŹïijŇè£Źäÿ åŠŇ TemporaryFile() äÿĂæăůïijŇçżŞæđIJæŰĞäžűåĚşéŮ■æŮűäijŽèćńèĞłåŁĺåĹăéŹď'æŐL'ãĂĆ åęĆæđIJä¡ääÿ■æČşè£ŹäźĹåĄŽïijŇåŔŕäžěäijăéĂŠäÿĂäÿłåĚşéŤőå■ŮåŔĆæŢř delete=False å■şåŔŕãĂĆæŕŤåęĆïijŽ

```
with NamedTemporaryFile('w+t', delete=False) as f:
    print('filename is:', f.name)
    ...
```

äÿžäžĘåĹŻåžžäÿĂäÿłäÿť æŮűçŽőå¡ŢïijŇåŔŕäžěä¡£çŤĺ tempfile.TemporaryDirectory() ãĂĆæŕŤåęĆïijŽ

```
from tempfile import TemporaryDirectory

with TemporaryDirectory() as dirname:
    print('dirname is:', dirname)
    # Use the directory
```

```
    ...
# Directory and all contents destroyed
```

èőĺèőž

TemporaryFile() ãĂĄNamedTemporaryFile() åŠŇ TemporaryDirectory() åĞ¡æŢř åžŤèŕěæŸŕåď ĎçŘĘäÿť æŮűæŰĞäžűçŻőå¡ŢçŽĎæIJĂçőĂå■ŢçŽĎæŰź åIJĺäÿĂäÿłæŻťä¡ŐçŽĎçžğåĹńïijŇä¡ăåŔŕäżěä¡£çŤÍ mkstemp() åŠŇ mkdtemp() æÌěåĹŻåžžäÿť æŮűæŰĞäžűåŠŇçŻőå¡ŢãĂĆæŕŤåęĆïijŽ

```
>>> import tempfile
>>> tempfile.mkstemp()
(3, '/var/folders/7W/7WZl5sfZEF0pljrEB1UMWE+++TI/-Tmp-/tmp7fefhv')
>>> tempfile.mkdtemp()
'/var/folders/7W/7WZl5sfZEF0pljrEB1UMWE+++TI/-Tmp-/tmp5wvcv6'
>>>
```

ä¡ĘæŸŕïijŇè£ŹäžŻåĞ¡æŢřåźűäÿ■äijŽåĄŽè£ŻäÿĂæ■ěçŽĎçőąçŘĘäžĘãĂĆ ä¿ŃåęĆïijŇåĞ¡æŢř mkstemp() äżĚäżĚářśè£ŤåŻđäÿĂäÿłåŐ§ågŃçŽĎOSæŰĞäžűæŔŔè£řçňęïijŇä¡ăéIJĂèę åŘŇæăůä¡ãè£ŸéIJĂèęĄèĞłåůśæÿĚçŘĘè£ŹäžŻæŰĞäžűãĂĆ

éĂŽåÿÿæÌěèőšïijŇäÿť æŮűæŰĞäžűåIJÍçşżçż§éźŸèőď çŽĎä¡■ç¡őèćńåĹŻåžžïijŇæŕŤåęĆ /var/tmp æĹŰçśżäijijçŽĎåIJřæŰźãĂĆ äÿžäžĘèŐůåŔŰçIJ§åőđçŽĎä¡■ç¡őïijŇåŔŕäżěä¡£çŤÍ tempfile.gettempdir() åĞ¡æŢřãĂĆæŕŤåęĆïijŽ

```
>>> tempfile.gettempdir()
'/var/folders/7W/7WZl5sfZEF0pljrEB1UMWE+++TI/-Tmp-'
>>>
```

æĽĂæIJL'åŠŇäÿť æŮűæŰĞäžűçŻÿåĚşçŽĎåĞ¡æŢřéČ¡åĚĄèőÿä¡ăéĂŽè£Ğä¡£çŤĺåĚşéŤőå■ŮåŔĆæŢř prefix ãĂĄsuffix åŠŇ dir æÌěèĞłåőŽäźĽçŽőå¡ŢäžěåŔŁåŚ¡åŘ■èğĎåĹŹãĂĆæŕŤåęĆïijŽ

```
>>> f = NamedTemporaryFile(prefix='mytemp', suffix='.txt', dir='/tmp
↪')
>>> f.name
'/tmp/mytemp8ee899.txt'
>>>
```

æIJĂåŘŐè£ŸæIJL'äÿĂçĆźïijŇår¡åŔŕèČ¡äžěæIJĂåőĽåĚÍçŽĎæŰźåijŔä¡£çŤÍ tempfile æÍąåİŮæÌěåĹŻåžžäÿť æŮűæŰĞäžűãĂĆ åŇĚæŃňäžĚçżŹå¡ŞåĽ■çŤÍæĹůæŐĹæİČèő£éŮőäžěåŔŁåIJÍæŰĞäžűèęĄæşÍæĎŔçŽĎæŸŕäÿ■åŘŇçŽĎåźşåŘřåŔŕèČ¡äijŽäÿ■äÿĂæăůãĂĆåŽăæ■ď ä¡ăæIJĂåě¡éŸĚèŕż åőŸæŰźæŰĞæąč æÌěäžĘèğčæŽť åď ŽçŽĎçżĘèŁĆãĂĆ

7.20 5.20 äÿŐäÿšèąŇçńŕåŔčçŽĎæŢřæ■őéĂŽä£ą

éŮőécŸ

ä¡ăæČşéĂŽè£ĞäÿšèąŇçńŕåŔčèŕżåĘŹæŢřæ■őïijŇåĚÿåđŃåIJžæŹŕåřśæŸŕåŠŇäÿĂäžŻçąňäžűëő¿åd'ĞæL'Ş

èğčåĘşæŰźæąĹ

åř¡çőąä¡ăåŔŕäžěéĂŽè£Ğä¡£çŤÍPythonåĘĚç¡őçŽĎI/OæÍąåİŮæİěåőŇæĹŘè£ŹäÿłäżżåŁąïijŇä¡ĘåŕźäžŐäÿš
pySerialåŇĚ ãĂĆ è£ŹäÿłåŇĚçŽĎä¡£çŤÍéİđåÿÿçőĂå■ŢïijŇåĚĹåőL'èčĚpySerialïijŇä¡£çŤÍçśżäijijäÿŃéİćè£Źæ

```
import serial
ser = serial.Serial('/dev/tty.usbmodem641', # Device name varies
                    baudrate=9600,
                    bytesize=8,
                    parity='N',
                    stopbits=1)
```

èő¿åd'ĞåŘ■åŕźäžŐäÿ■åŘŇçŽĎèő¿åd'ĞåŠŇæŞ■ä¡IJçşżçż§æŸŕäÿ■äÿĂæăůçŽĎãĂĆ
æŕŤåęĆïijŇåIJÍWindowsçşżçż§äÿŁïijŇä¡ăåŔŕäžěä¡£çŤÍ0, 1ç■L'èąÍçd'žçŽĎäÿĂäÿłèő¿åd'ĞæİěæL'ŞåijĂéĂŽä
äÿĂæŮęçńŕåŔčæL'ŞåijĂïijŇéĆčåŕśåŔŕäžěä¡£çŤÍ `read()` ïijŇ`readline()` åŠŇ `write()`
åĞ¡æŢřèŕżåĘŹæŢřæ■őäžĘãĂĆä¿ŃåęĆïijŽ

```
ser.write(b'G1 X50 Y50\r\n')
resp = ser.readline()
```

åd'ğåd'ŽæŢřæČĚåĘţäÿŃïijŇçőĂå■ŢçŽĎäÿšåŔčéĂŽä£ąäžŐæ■d'åŔŸå¿Ůå■ĄåĹĘçőĂå■ŢãĂĆ

èőÍèőž

ař¡çőąèąÍéİćäÿŁçIJŃèţůæİěå¿ĹçőĂå■ŢïijŇåĚűåőđäÿšåŔčéĂŽä£ąæIJL'æŮűåĂŹäź§æŸŕæŇžéžżçČęçŽĎ
æŐÍè■Řä¡ää¡£çŤÍçňňäÿL'æŰźåŇĚåęĆ `pySerial` çŽĎäÿĂäÿłåŐ§åŽăæŸŕåőČæŔŘä¿ŻäžĘåŕźénŸçžğçL'źæĂ
(æŕŤåęĆèűĚæŮűïijŇæŐğåĹűæţĄïijŇçijŞåĘšåŇžåĹůæŰřïijŇæŔąæL'Ńå■Řèőőç■L'ç■L')ãĂĆäÿ¿äÿłä¿Ńå■Řïij
`RTS-CTS` æŔąæL'Ńå■Řèőőïij Ň ä¡ăåŔłéIJĂèęĄçżŹ `Serial()` äijăéĂŠäÿĂäÿł
`rtscts=True` çŽĎåŔĆæŢřå■şåŔŕãĂĆ åĚűåőŸæŰźæŰĞæąčéİđåÿÿåőŇåŰĎïijŇåŽăæ■d'æĹŠåIJÍè£ŹéĞŇa

æŮűåĹżèőřä¡ŔæL'ĂæIJL'æűL'åŔŁåĹřäÿšåŔčçŽĎI/OéČ¡æŸŕäžŇè£ŻåĹűæÍąåijŔçŽĎãĂĆåŽăæ■d'ïijŇçą
(æĹŰæIJL'æŮűåĂŹæL'ğèąŇæŰĞæIJńçŽĎçijŰçăĄ/èğčçăĄæŞ■ä¡IJ)ãĂĆ
åŔęåd'Űå¡Şä¡ăéIJĂèęĄåĹŻåžżäžŇè£ŻåĹűçijŰçăĄçŽĎæŇĞäžd'æĹŰæŢřæ■őåŇĚçŽĎæŮűåĂŹïijŇ`struct`
æÍąåİŮäź§æŸŕéİđåÿÿæIJL'çŤÍçŽĎãĂĆ

7.21 5.21 åžŔåĹŮåŇŰPythonářźèšą

éŮőécŸ

ä¡ăéIJĂèęĄåřĘäÿĂäÿłPythonářźèšąåžŔåĹŮåŇŰäÿžäÿĂäÿłå■ŮèŁĆæţĄïijŇäžěä¿£åřĘåőČä£Íå■ŸåĹřäÿĂ

èğčåĘşæŰźæąĹ

åŕźäžŐåžŔåĹŮåŇŰæIJĂæŹőéĄ■çŽĎåĄŽæşŢåřśæŸŕä¡£çŤÍ pickle æĺąåİŮãĂĆäÿžäžĘåřĘäÿĂäÿłåŕźèśąä£Ìå■ŸåĹřäÿĂäÿłæŰĞäžűäÿ■ïijŇåŔŕäžěè£ŹæăůåĄŽïijŽ

```
import pickle

data = ... # Some Python object
f = open('somefile', 'wb')
pickle.dump(data, f)
```

äÿžäžĘåřĘäÿĂäÿłåŕźèśąè¡ňåĆĺäÿžäÿĂäÿłå■ŮçňęäÿšïijŇåŔŕäžěä¡£çŤÍ pickle.dumps() ïijŽ

```
s = pickle.dumps(data)
```

äÿžäžĘäžŐå■ŮèŁĆæţĄäÿ■æĄćåd'■äÿĂäÿłåŕźèśąïijŇä¡£çŤÍ picle.load() æĹŰ pickle.loads() åĞ¡æŢřãĂĆæŕŤåęĆïijŽ

```
# Restore from a file
f = open('somefile', 'rb')
data = pickle.load(f)

# Restore from a string
data = pickle.loads(s)
```

èŐĺèŏž

åŕźäžŐåd'ğåd'ŽæŢřåžŤçŤÍçÍŃåžŔæİěèőšïijŇdump() åŠŇ load() åĞ¡æŢřçŽĎä¡£çŤÍåřśæŸŕä¡ăæIJL'æŢĹä¡£çŤÍ pickle æĺąåİŮæL'ĂéIJĂçŽĎåĚÍéČÍäžĘãĂĆ åőČåŔŕéĂĆçŤÍäžŐçżİåd'ğéČÍåĹĘPythonæŢřæ■őçśżåđŃåŠŇçŤÍæĹůèĞłåőŽäźL'çśżçŽĎåŕźèśąåőđä¿ŃãĂĆ åęĆæđIJä¡ăçćřåĹřæ§Řäÿłåžşåŕźäžěèől'ä¡ăåIJÍæŢřæ■őåžŞäÿ■ä£Ìå■Ÿ/æĄćåd'■PythonåŕźèśąæĹŰèĂĚæŸŕéĂŽ éČčäźĹå¿ĹæIJL'åŔŕèČ¡è£ŹäÿłåžŞçŽĎåžŢåśĆåŕśä¡£çŤÍäžĘ pickle æĺąåİŮãĂĆ

pickle æŸŕäÿĂçğ■PythonçL'źæIJL'çŽĎèĞłæŔŔè£řçŽĎæŢřæ■őçijŰçăĄãĂĆ éĂŽè£ĞèĞłæŔŔè£řïijŇèćńåžŔåĹŮåŇŰåŘŐçŽĎæŢřæ■őåŇĚåŘńæŕŔäÿłåŕźèśąåijĂåğŃåŠŇçżŞæİ§äžěåŔŁåČ åŽăæ■d'ïijŇä¡ăæŮăéIJĂæŃĚå£Čåŕźèśąèőřå¡ŢçŽĎåőŽäźL'ïijŇåőČæĂžæŸŕèČ¡åůëä¡IJãĂĆ äÿ¿äÿłä¿Ńå■ŘïijŇåęĆæđIJèęĄåd'ĎçŘĘåd'ŽäÿłåŕźèśąïijŇä¡ăåŔŕäžěè£ŹæăůåĄŽïijŽ

```
>>> import pickle
>>> f = open('somedata', 'wb')
>>> pickle.dump([1, 2, 3, 4], f)
>>> pickle.dump('hello', f)
>>> pickle.dump({'Apple', 'Pear', 'Banana'}, f)
>>> f.close()
>>> f = open('somedata', 'rb')
>>> pickle.load(f)
[1, 2, 3, 4]
>>> pickle.load(f)
```

```
'hello'
>>> pickle.load(f)
{'Apple', 'Pear', 'Banana'}
>>>
```

ä¡äè£ŸèČ¡åžŔåĹŮåŇŰåĞ¡æŢřïijŇçśžïijŇè£ŸæIJL’æŐěåŔčïijŇä¡ĘæŸŕçżŞæđIJæŢřæ■őäżĚäżĚåřĘåőČä

```
>>> import math
>>> import pickle.
>>> pickle.dumps(math.cos)
b'\x80\x03cmath\ncos\nq\x00.'
>>>
```

å¡ŞæŢřæ■őåŔ■åžŔåĹŮåŇŰåŻđæİěçŽĎæŮűåĂŹïijŇäijŽåĚĹåĄĞåőŽæL’ĂæIJL’çŽĎæžŘæŢřæ■őæŮűåĘ
æĺąåİŮãĂĄçśżåŠŇåĞ¡æŢřäijŽèĞłåŁĺæŇL’éIJĂåŕijåĚèè£ŻæİěãĂĆåŕźäžŐPythonæŢřæ■õèćńäÿ■åŘŇæIJžåŹĺã
æŢřæ■őçŽĎä£Ía■ŸåŔŕèČ¡äijŽæIJL’éŮőécŸïijŇåŻääÿžæL’ĂæIJL’çŽĎæIJžåŹĺéČ¡å£Ěéążèő£éŮőåŘŇäÿĂäÿł

æşÍ

```
å■ČäÿĞäÿ■èęĄåŕźäÿ■ä£ąäżżçŽĎæŢřæ■őä¡£çŤÍpickle.load()ãĂĆ
pickleåIJÍåŁãè¡¡æŮűæIJL’äÿĂäÿłåL’ŕä¡IJçŤÍåřśæŸŕåőČäijžèĞłåŁĺåŁãè¡¡çŻÿåžŤæĺąåİŮåź
ä¡ĘæŸŕæ§ŘäÿłåİŔäžžåęĆæđIJç§ěéĄ§pickleçŽĎåůěä¡IJåŐ§çŘĘïijŇ
äżŰåřśåŔŕäżěåĹżåžžäÿĂäÿłæĄűæĎŔçŽĎæŢřæ■őåŕijèĞt’PythonæL’ğèąŇéŽŘæĎŔæŇĞåőŽçŽĎçşżçż
åŻăæ■d’ïijŇäÿĂåőŽèęĄä£İèŕĄpickleåŔłåIJÍçŻÿäžŠäźŃéŮt’åŔŕäżěèőd’èŕĄåŕźæŰźçŽĎèğčæđŘ
```

æIJL’äžŽçśżåđŃçŽĎåŕźèśąæŸŕäÿ■èČ¡èćńåžŔåĹŮåŇŰçŽĎãĂĆè£ŹäžŻéĂŽåÿÿæŸŕéĆčäžŻä¿İèţŰåđ’Ůé
æŕŤåęĆæL’ŞåijĂçŽĎæŰĞäżűïijŇç¡ŚçżIJè£đæŐěïijŇçž£çÍŃïijŇè£ŽçÍŃïijŇæăĹåÿğç■L’ç■L’ãĂĆ
çŤÍæĹůèĞłåőŽäźL’çśżåŔŕäżěéĂŽè£ĞæŔŘä¿Ż __getstate__()
åŠŇ __setstate__() æŰźæşŢæİěçżŢè£Ğè£ŹäžŻéŹŘåĹűãĂĆ
åęĆæđIJåőŽäźL’äžĘè£ŹäÿđäÿłæŰźæşŢïijŇpickle.dump()
åřśäijŽèřČçŤÍ __getstate__() èŐůåŔŰåžŔåĹŮåŇŰçŽĎåŕźèśąãĂĆ
çśżäijijçŽĎïijŇ__setstate__() åIJÍåŔ■åžŔåĹŮåŇŰæŮűèćńèřČçŤÍãĂĆäÿžäžĘæijŢçđ’žè£Źäÿłåůěä¡IJåĆ
äÿŃéİćæŸŕäÿĂäÿłåIJÍåĘĚéČÍåőŽäźL’äžĘäÿĂäÿłçž£çÍŃä¡Ęäż■çĎůåŔŕäżěåžŔåĹŮåŇŰåŠŇåŔ■åžŔåĹŮåŇŰç

```
# countdown.py
import time
import threading

class Countdown:
    def __init__(self, n):
        self.n = n
        self.thr = threading.Thread(target=self.run)
        self.thr.daemon = True
        self.thr.start()

    def run(self):
        while self.n > 0:
            print('T-minus', self.n)
            self.n -= 1
            time.sleep(5)
```

```
    def __getstate__(self):
        return self.n

    def __setstate__(self, n):
        self.__init__(n)
```

èŕŢçİĂè£ŘèąŉäÿŉéİćçŽĎåžŔåĹŮåŇŰèŕŢéłŇäżčçăĄïijŽ

```
>>> import countdown
>>> c = countdown.Countdown(30)
>>> T-minus 30
T-minus 29
T-minus 28
...

>>> # After a few moments
>>> f = open('cstate.p', 'wb')
>>> import pickle
>>> pickle.dump(c, f)
>>> f.close()
```

çĎűåŘŐéĂĂåĞžPythonèğčæđŘåŹĺåźűéĞ■åŘŕåŘŐåĘ■èŕŢéłŇäÿŉïijŽ

```
>>> f = open('cstate.p', 'rb')
>>> pickle.load(f)
countdown.Countdown object at 0x10069e2d0>
T-minus 19
T-minus 18
...
```

ä¡ăåŔŕäžěçIJŃåĹřçž£çĺŃåŔĹåěĞè£źèĹňçŽĎéĞ■çŤ§äžĘïijŇäżŐä¡ăçňňäÿĂæňąåžŔåĹŮåŇŰåőČçŽĎåIJ

pickle åŕźäžŐåď ğåđŃçŽĎæŢřæ■őçżŞæđĎæŕŤåęĆä¡£çŤĺ array æĹŰ numpy æĺąåİŮåĹŻåžžçŽĎäžŇè£ŻåĹűæŢřçżĎæŢĹçŐĞåźűäÿ■æŸŕäÿĂäÿłéńŸæŢĹçŽĎçijŰçăĄæŰźåijŔãĂĆ åęĆæđIJä¡ăéIJĂèęĄçğżåŁĺåď ğéĞŔçŽĎæŢřçżĎæŢřæ■őïijŇä¡ăæIJĂåě¡æŸŕåĚĹåIJĺäÿĂäÿłæŰĞäžűäÿ■årĘåĚ (éIJĂèęĄçňňäÿL'æŰźåžŞçŽĎæŤŕæŇĄ)ãĂĆ

çŤśäžŐ pickle æŸŕPythonçL'źæIJL'çŽĎåźűäÿŤéŹĎçİĂåIJĺæžŘçăĄäÿŁïijŇæL'ĂæIJL'åęĆæđIJéIJĂèę ä¿ŃåęĆïijŇåęĆæđIJæžŘçăĄåŘŸåŁĺäžĘïijŇä¡ăæL'ĂæIJL'çŽĎå■ŸåĆĺæŢřæ■őåŔŕèČ¡äijŽèćńçăt'åİŔåźűäÿŤåŘ åİęçŹ¡æİèèőšïijŇårźäžŐåIJĺæŢřæ■őåžŞåŠŇå■Ÿæąćæ ŰĞäżűäÿ■å■ŸåĆĺæŢřæ■őæŮűïijŇä¡ăæIJĂåě¡ä¡£çŤĺæŽ è£ŹäžŽçijŰçăĄæăijåijŔæŽt'æăĞåĞĘïijŇåŔŕäžěèćńäÿ■åŘŇçŽĎèŕ■èĺĂæŤŕæŇĄïijŇåźűäÿŤäź§èČ¡å¿Ĺåě¡çŽĎ

æIJĂåŘŐäÿĂçĆźèęĄæşĺæĎŔçŽĎæŸŕ pickle æIJL'åď ğéĞŔçŽĎéĚ■ç¡őéĂL'éąźåŠŇäÿĂäžŽæčŸæL'Ń åŕźäžŐæIJĂåÿÿèğĄçŽĎä¡£çŤĺåIJžæŹŕïijŇä¡ääÿ■éIJĂèęĄåŐżæŃĚå£Čè£ŹäÿłïijŇä¡ĘæŸŕåęĆæđIJä¡ăèęĄåIJĺ æIJĂåě¡åŐżæ§ěéŸĚäÿĂäÿŃ åőŸæŰźæŰĞæąč ãĂĆ

8 çňňåĚ■çńäïijŽæŢřæ■őçijŰçăĄåŠŇåď'ĎçŘĘ

è£ŹäÿĂçńääÿžèęĄèőÍèőžä¡£çŤÍPythonåď'ĎçŘĘåŘĎçğ■äÿ■åŘŇæŰźåijŔçijŰçăĄçŽĎæŢřæ■őïijŇæŕŤåę
åŠŇæŢřæ■őçżŞæđĎéĆčäÿĂçńääÿ■åŘŇçŽĎæŸŕïijŇè£Źçńääÿ■äijŽèőÍèőžçĽźæőŁçŽĎçőŮæşŢéŮőécŸïijŇè

Contents:

8.1 6.1 èŕżåĘŹCSVæŢřæ■ő

éŮőécŸ

ä¡ăæČşèŕżåĘŹäÿĂääÿłCSVæăijåijŔçŽĎæŰĞäžűãĂĆ

èğčåĘşæŰźæąĹ

åŕźäžŐåď'ğåď'ŽæŢřçŽĎCSVæăijåijŔçŽĎæŢřæ■őèŕżåĘŹéŮőécŸïijŇéČ¡åŔŕäžěä¡£çŤÍ
csv åžŞãĂĆ ä¿ŃåęĆïijŽåĄĞèő¿ä¡ääIJÍäÿĂäÿłåŘ■åŔństocks.csvæŰĞäžűäÿ■æIJĽäÿĂäžŻèĆąçĕÍåÿĆåIJžæŢ

```
Symbol,Price,Date,Time,Change,Volume
"AA",39.48,"6/11/2007","9:36am",-0.18,181800
"AIG",71.38,"6/11/2007","9:36am",-0.15,195500
"AXP",62.58,"6/11/2007","9:36am",-0.46,935000
"BA",98.31,"6/11/2007","9:36am",+0.12,104800
"C",53.08,"6/11/2007","9:36am",-0.25,360900
"CAT",78.29,"6/11/2007","9:36am",-0.23,225400
```

äÿŃéIćåŘŚä¡ääśŢçď'žåęĆä¡ŢårĘè£ŹäžŻæŢřæ■őèŕżåŔŰäÿžäÿĂäÿłåĚČçżĎçŽĎåžŔåĹŮïijŽ

```
import csv
with open('stocks.csv') as f:
    f_csv = csv.reader(f)
    headers = next(f_csv)
    for row in f_csv:
        # Process row
        ...
```

åIJÍäÿŁéIćçŽĎäžčçăĄäÿ■ïijŇ row äijŽæŸŕäÿĂäÿłåĹŮèąÍãĂĆåŻäæ■d'ïijŇäÿžäžĘèő£éŮőæ§Ŕäÿłå■Ůæč
row[0] èő£éŮőSymbolïijŇ row[4] èő£éŮőChangeãĂĆ

çŤśäžŐè£Źçğ■äÿŃæăĞèő£éŮőéĂŽåÿÿäijŽåijŢètůæůůæůĘïijŇä¡ääŔŕäžěèĂČèŹŚä¡£çŤÍłåŚ¡åŘ■åĚČçżĎâ

```
from collections import namedtuple
with open('stock.csv') as f:
    f_csv = csv.reader(f)
    headings = next(f_csv)
    Row = namedtuple('Row', headings)
    for r in f_csv:
        row = Row(*r)
```

```
        # Process row
        ...
```

åőČåĚĄèőÿä¡ää¡£çŤĺåĹŮåŘ■åęĆ `row.Symbol` åŠŇ `row.Change` äžčæŽ£äÿŃæäĞèő£éŮõãĂĆ éIJĂèęĄæşĺæĎŔçŽĎæŸŕè£ŹäÿłåŔłæIJL’åIJĺåĹŮåŘ■æŸŕåŘĹæşŢçŽĎPythonæä¡ăåŔŕèČ¡éIJĂèęĄä£őæŤźäÿŃåŐ§ågŃçŽĎåĹŮåŘ■(åęĆåřĘéİđæäĞèŕĘçňęå■Ůçňęæ Ž£æ■ćæĹŘäÿŃåĹŠçž£äźåŔęåd’ŰäÿĂäÿłéĂL’æŃl’åřśæŸŕåřĘæŢřæ■őèŕźåŔŰåĹřäÿĂäÿłå■ŮåĚÿåžŔåĹŮäÿ■åŐżãĂĆåŔŕäžěè£ŹæäÿłçL’ĹæIJñäÿ■ïijŇä¡ăåŔŕäžěä¡£çŤĺåĹŮåŘ■åŐżèő£éŮőæŕŔäÿĂèąŃçŽĎæŢřæ■őäžĘãĂĆæŕŤåęĆæĹŰèĂĚ `row['Change']`

äÿžäžĘåĘŹåĚěCSVæŢřæ■őïijŇä¡ääż■çĎűåŔŕäžěä¡£çŤĺcsvæĺąåİŮïijŇäÿ■è£ĞèŹæŮűåĂŹåĚĹåĹŻåžžäÿ `writer` åŕźèśąãĂĆä¿ŃåęĆ:

```
headers = ['Symbol','Price','Date','Time','Change','Volume']
rows = [('AA', 39.48, '6/11/2007', '9:36am', -0.18, 181800),
          ('AIG', 71.38, '6/11/2007', '9:36am', -0.15, 195500),
          ('AXP', 62.58, '6/11/2007', '9:36am', -0.46, 935000),
        ]

with open('stocks.csv','w') as f:
    f_csv = csv.writer(f)
    f_csv.writerow(headers)
    f_csv.writerows(rows)
```

åęĆæđIJä¡äæIJL’äÿĂäÿłå■ŮåĚÿåžŔåĹŮçŽĎæŢřæ■őïijŇåŔŕäžěåČŔè£ŹæăůåĄŽïijŽ

```
headers = ['Symbol', 'Price', 'Date', 'Time', 'Change', 'Volume']
rows = [{'Symbol':'AA', 'Price':39.48, 'Date':'6/11/2007',
         'Time':'9:36am', 'Change':-0.18, 'Volume':181800},
         {'Symbol':'AIG', 'Price': 71.38, 'Date':'6/11/2007',
         'Time':'9:36am', 'Change':-0.15, 'Volume': 195500},
         {'Symbol':'AXP', 'Price': 62.58, 'Date':'6/11/2007',
         'Time':'9:36am', 'Change':-0.46, 'Volume': 935000},
         ]

with open('stocks.csv','w') as f:
    f_csv = csv.DictWriter(f, headers)
    f_csv.writeheader()
    f_csv.writerows(rows)
```

èőÍèőž

ä¡ăåžŤèřěæĂžæŸřäijŸåĚĹéĂĽ'æŃľcsvæĺąåİŮåĹĘåĽ'šæĹŰèğčæđŘCSVæŢřæ■őãĂĆä¿ŃåęĆïijŇä¡ăåŘŕ

```
with open('stocks.csv') as f:
for line in f:
    row = line.split(',')
    # process row
    ...
```

ä¡£çŤĺè£Źçğ■æŰźåijŘçŽĎäÿĂäÿłçijžçĆźåřśæŸřä¡ăäž■çĎűéIJĂèęĄåŐžåď ĎçŘĘäÿĂäžŻæčŸæĽ'ŃçŽĎç
ærŤåęĆïijŇåęĆæđIJæ§ŘäžŻå■ŮæőţåĂijèćńåijŢåŘůåŇĚåŻť'ïijŇä¡ăäÿ■å¿Ůäÿ■åŐžéŹď'è£ŹäžŻåijŢåŘůãĂĆ
åŘęåď ŰïijŇåęĆæđIJäÿĂäÿłèćńåijŢåŘůåŇĚåŻť çŽĎå■ŮæőţçćřåůğåŘńæIJL'äÿĂäÿłéĂŮåŘůïijŇéĆčäźĹçĺŃåž

éżŸèőď'æČĚåĘţäÿŃïijŇcsv åžŞåŘŕèřĘåĹńMicrosoft Ex-
celæL'Ăä¡£çŤĺçŽĎCSVçijŰçăĄèğĎåĹŹãĂĆ è£ŹæĹŰèőÿäź§æŸřæIJĂåÿÿèğĄçŽĎå¡ćåijŘïijŇåźűäÿŤäź§äijŽ
çĎűèĂŇïijŇåęĆæđIJä¡ăæ§ěçIJŃcsvçŽĎæŰĞæąčïijŇåřśäijŽåŘŚçŐřæIJL'å¿Ĺåď'Žçğ■æŰźæŞţåřĘåőČåžŢçŤĺ
ä¿ŃåęĆïijŇåęĆæđIJä¡ăæČşèŕžåŘŰäžětabåĹĘåL'šçŽĎæŢřæ■őïijŇåŘŕäžěè£ŹæăůåĄŽïijŽ

```
# Example of reading tab-separated values
with open('stock.tsv') as f:
    f_tsv = csv.reader(f, delimiter='\t')
    for row in f_tsv:
        # Process row
        ...
```

åęĆæđIJä¡ăæ■čåIJĺèŕžåŘŰCSVæŢřæ■őåźűåřĘåőČäžňè¡ňæ■ćäÿžåŚ¡åŘ■åĚČçżĎïijŇéIJĂèęĄæşĺæĎŘåŕź
ä¿ŃåęĆïijŇäÿĂäÿłCSVæäijåijŘæŰĞäžűæIJL'äÿĂäÿłåŇĚåŘńéİđæşŢæăĞèŕĘçňęçŽĎåĹŮåď't'èąŇïijŇçśžäijijä

```
StreetÂăAddress,Num-Premises,Latitude,Longitude 5412ÂăNÂăCLARK,10,
↪41.980262,-87.668452
```

è£ŹæăůæIJĂçżĹäijŽåŕijèĞt'åIJĺåĹŻåžžäÿĂäÿłåŚ¡åŘ■åĚČçżĎæŮűäžğçŤ§äÿĂäÿł
ValueError åijĆåÿÿèĂŇåď śèt'ěãĂĆ äÿžäžEèğčåEşè£ŹéŮőécŸïijŇä¡ăåŘŕèČ¡äÿ■å¿Ůäÿ■åĚĹåŐžä£őæ■čå
ä¿ŃåęĆïijŇåŘŕäžěåČŘäÿŃéİćè£ŹæăůåIJĺéİđæşŢæăĞèŕĘçňęäÿŁä¡£çŤĺäÿĂäÿłæ■čåĹŹèąĺè¿¿åijŘæŻ£æ■ćïijŽ

```
import re
with open('stock.csv') as f:
    f_csv = csv.reader(f)
    headers = [ re.sub('[^a-zA-Z_]', '_', h) for h in next(f_csv) ]
    Row = namedtuple('Row', headers)
    for r in f_csv:
        row = Row(*r)
        # Process row
        ...
```

è£ŸæIJL'éĞ■èęĄçŽĎäÿĂçĆźéIJĂèęĄåijžèřČçŽĎæŸřïijŇcsväžğçŤ§çŽĎæŢřæ■őéČ¡æŸřå■Ůçňęäÿšçśżå
åęĆæđIJä¡ăéIJĂèęĄåĄŽè£ŹæăůçŽĎçśžåđŃè¡ňæ■ćïijŇä¡ăå£Ěéążè Ğłåůśæ L'ŃåŁĺåŐžåőđçŐřãĂĆ
äÿŃéİćæŸřäÿĂäÿłåIJĺCSVæŢřæ■őäÿŁæL'ğèąŇåĚűäžŮçśžåđŃè¡ňæ■ćçŽĎä¿Ńå■ŘïijŽ

```
col_types = [str, float, str, str, float, int]
with open('stocks.csv') as f:
    f_csv = csv.reader(f)
    headers = next(f_csv)
    for row in f_csv:
        # Apply conversions to the row items
        row = tuple(convert(value) for convert, value in zip(col_
↪types, row))
        ...
```

åŘęåď ŰïijŇäÿŃéÍćæŸŕäÿĂäÿłè¡ňæ■ćå■ŮåĚÿäÿ■çL’źåőŽå■Ůæőţç ŽĎä¿Ńå■ŘïijŽ

```
print('Reading as dicts with type conversion')
field_types = [ ('Price', float),
                ('Change', float),
                ('Volume', int) ]

with open('stocks.csv') as f:
    for row in csv.DictReader(f):
        row.update((key, conversion(row[key]))
                   for key, conversion in field_types)
        print(row)
```

éĂŽåÿÿæÌěëőšïijŇä¡ăåŘŕèČ¡åźűäÿ■æČşè£ĞåďŽåŐżèĂČèŹŚè£ŹäžŽè¡ňæ■ćéŮőécŸãĂĆ
åIJĺåőđéŹĚæČĚåĘţäÿ■ïijŇCSVæŰĞäżűéČ¡æĹŰåď ŽæĹŰåřŚæIJL’äžŽçijžåď śçŽĎæŢřæ■őïijŇèćńçăt’åİŘçŽĎ
åŽäæ■ď ïijŇéŹď éÍđä¡ăçŽĎæŢřæ■őçąőåőđæIJL’ä£ÍéŽIJæŸŕåĞEçąőæŮäèŕŕçŽĎïijŇåŘęåĹŹä¡åå£Ěéążè ĂČèŹ

æIJĂåŘŐïijŇåęĆæđIJä¡ăèŕżåŘŰCSVæŢřæ■őçŽĎçŻőçŽĎæŸŕåĄŽæŢřæ■őåĹĘæđŘåŠŇçż§èőąçŽĎèŕÍïij
ä¡ăåŘŕèČ¡éIJĂèęĄçIJŃäÿĂçIJŃ `Pandas` åŇĚãĂĆPandas
åŇĚåŘńäžĘäÿĂäÿłéÍđåÿÿæŰźä¿£çŽĎåĞ¡æŢřåŘń `pandas.read_csv()`
ïijŇ åőČåŘŕäżěåŁäè¡¡CSVæŢřæ■őåĹřäÿĂäÿł `DataFrame` åŕźèśąäÿ■åŐżãĂĆ
çĎűåŘŐåĹl’çŤÍè£Źäÿłåŕźèśąä¡ăåřśåŘŕäżěçŤ§æĹŘåŘĎçğ■å¡ćåijŘçŽĎçż§èőąãĂĄè£Ğæżď æŢřæ■őäžěåŘŁæI
åIJÍ6.13åřŘèŁĆäÿ■äijŽæIJL’è£ŹæăůäÿĂäÿłä¿Ńå■ŘãĂĆ

8.2 6.2 èŕżåĘŹJSONæŢřæ■ő

éŮőécŸ

ä¡ăæČşèŕżåĘŹJSON(JavaScript Object Notation)çijŰçăĄæäijåijŘçŽĎæŢřæ■őãĂĆ

èğčåĘşæŰźæąĹ

`json` æĺąåİŮæŘŘä¿ŻäžĘäÿĂçğ■å¿ĹçőĂå■ŢçŽĎæŰźåijŘæİěçijŰçăĄåŠŇèğčçăĄJSONæŢřæ■őãĂĆ
åĚűäÿ■äÿď äÿłäÿżèęĄçŽĎåĞ¡æŢřæŸŕ `json.dumps()` åŠŇ `json.loads()`
ïijŇ èęĄæŕŤåĚűäżŰåžŘåĹŮåŇŰåĞ¡æŢřåžŞåęĆpickleçŽĎæŐěåŘčářŠå¿Ůåď ŽãĂĆ
äÿŃéÍćæijŤçď žåęĆä¡ŢářĘäÿĂäÿłPythonæŢřæ■őçżŞædĎè¡ňæ■ćäÿžJSONïijŽ

```
import json

data = {
    'name' : 'ACME',
    'shares' : 100,
    'price' : 542.23
}

json_str = json.dumps(data)
```

äÿŃéÍćæijŤçď'žåęĆä¡ŢåřĘäÿĂäÿłJSONçijŰçăĄçŽĎå■Ůçňęäÿšè¡ňæ■ćåŻđäÿĂäÿłPythonæŢřæ■őçżŞæđÌ

```
data = json.loads(json_str)
```

åęĆæđIJä¡ăèęĄåď'ĎçŘĘçŽĎæŸŕæŰĞäžűèĂŇäÿ■æŸŕå■ŮçňęäÿšïijŇä¡ăåŔŕäžěä¡£çŤÍ `json.dump()` åŠŇ `json.load()` æÍěçijŰçăĄåŠŇèğčçăĄJSONæŢřæ■őãĆĆä¿ŃåęĆïijŽ

```
# Writing JSON data
with open('data.json', 'w') as f:
    json.dump(data, f)

# Reading data back
with open('data.json', 'r') as f:
    data = json.load(f)
```

èőÍèőž

JSONçijŰçăĄæŤŕæŇĄçŽĎå§žæIJňæŢřæ■őçśžåđŃäÿž `None` ïijŇ `bool` ïijŇ `int` ïijŇ `float` åŠŇ `str` ïijŇ äžěåŔŁåŇĚåŘńè£ŹäžŻçśžåđŃæŢřæ■őçŽĎlistsïijŇtuplesåŠŇdictionariesãĆĆ åŕźäžŐdictionariesïijŇkeyséIJĂèęĄæŸŕå■ŮçňęäÿšçśžåđŃ(å■ŮåĚÿäÿ■äżžä¡ŢéÍđå■ŮçňęäÿšçśžåđŃçŽĎkeyåI äÿžäžĘéĄţå¿ŁJSONèğĎèŇČïijŇä¡ăåžŤèŕěåŔŁçijŰçăĄPythonçŽĎlistsåŠŇdictionariesãĆĆ èĂŇäÿŤïijŇåIJÍwebåžŤçŤÍçÍŇåžŔäÿ■iijŇéąűåśĆåŕźèśąèćńçijŰçăĄäÿžäÿĂäÿłå■ŮåĚÿæŸŕäÿĂäÿłæăĞåĞĘåA

JSONçijŰçăĄçŽĎæăijåijŔåŕźäžŐPythonèŕ■æşŢèĂŇåůšåĞääźŐæŸŕåőŇåĚÍäÿĂæăůçŽĎïijŇéŹď'äžĘäÿĂ æŕŤåęĆïijŇTrueäijŽèćńæŸăåřĎäÿžtrueïijŇFalseèćńæŸăåřĎäÿž-falseïijŇèĂŇNoneäijŽèćńæŸăåřĎäÿžnullãĆĆ äÿŃéÍćæŸŕäÿĂäÿłä¿Ńå■ŘïijŇæijŤçď'žäžĘçijŰçăĄåŘŐçŽĎå■

```
>>> json.dumps(False)
'false'
>>> d = {'a': True,
...      'b': 'Hello',
...      'c': None}
>>> json.dumps(d)
'{"b": "Hello", "c": null, "a": true}'
>>>
```

åęĆæđIJä¡ăèŕŢçİÅåŐżæčÄæ§ěJSONèğčçăĄåŘŐçŽĎæŢřæ■őijŇä¡ăéĂŽåÿÿå¿ŁéŽ¿éĂŽè£ĞçőÅå■ŢçŽĹ çL'źåĹńæŸŕå¡ŞæŢřæ■őçŽĎåţŇåěŮçżŞæđĎåśĆæňąå¿Ĺæůśæĺ ŮèĂĚåŇĚåŘńåď'ğéĞŘçŽĎå■ŮæőţæŮűãĆĆ äÿžäžĘèğčåĘşè£ŹäÿłéŮőécŸïijŇåŔŕäžěèĂČèŹŚä¡£çŤÍpprintæÍąåİŮçŽĎ

pprint() åĞ¡æŢřæİěäžčæŻ£æŹőéĂŽçŽĎ print() åĞ¡æŢřãĂĆ
åőČäijŽæŇL'çĚğkeyçŽĎå■Ůæí■éąžåžŔåźűäžěäÿĂçğ■æŻť'åŁăç¿ŐèğĆçŽĎæŰźåijŔè¿ŞåĞžãĂĆ
äÿŃéÍćæŸŕäÿĂäÿłæijŤçď'žåęĆä¡ŢæijĆäžőçŽĎæL'Şå■řè¿ŞåĞžTwitteräÿŁæŘIJçť'ćçżŞædIJçŽĎä¿Ńå■ŘïijŽ

```
>>> from urllib.request import urlopen
>>> import json
>>> u = urlopen('http://search.twitter.com/search.json?q=python&
 ↪rpp=5')
>>> resp = json.loads(u.read().decode('utf-8'))
>>> from pprint import pprint
>>> pprint(resp)
{'completed_in': 0.074,
'max_id': 264043230692245504,
'max_id_str': '264043230692245504',
'next_page': '?page=2&max_id=264043230692245504&q=python&rpp=5',
'page': 1,
'query': 'python',
'refresh_url': '?since_id=264043230692245504&q=python',
'results': [{'created_at': 'Thu, 01 Nov 2012 16:36:26 +0000',
             'from_user': ...
             },
             {'created_at': 'Thu, 01 Nov 2012 16:36:14 +0000',
             'from_user': ...
             },
             {'created_at': 'Thu, 01 Nov 2012 16:36:13 +0000',
             'from_user': ...
             },
             {'created_at': 'Thu, 01 Nov 2012 16:36:07 +0000',
             'from_user': ...
             }
             {'created_at': 'Thu, 01 Nov 2012 16:36:04 +0000',
             'from_user': ...
             }],
'results_per_page': 5,
'since_id': 0,
'since_id_str': '0'}
>>>
```

äÿĂèĹñæİěèőšïijŇJSONèğčçăĄäijŽæăźæ■őæŔŘä¿ŻçŽĎæŢřæ■őåĹŻåžždictsæĹŰlistsãĂĆ
åęĆæđIJä¡ăæČşèęĄåĹŻåžžåĚűäžŰçśžåđŇçŽĎåŕźèśąïijŇåŔŕäžěçżŹ json.
loads() äijăéĂŠobject_pairs_hookæĹŰobject_hookåŔĆæŢřãĂĆ
ä¿ŃåęĆïijŇäÿŃéÍćæŸŕæijŤçď'žåęĆä¡Ţèğčçă ĄJSONæŢřæ■őåźűåIJĺäÿĂäÿłOrderedDictäÿ■ä£ÍçŢŹåĚűéąžåžŘ

```
>>> s = '{"name": "ACME", "shares": 50, "price": 490.1}'
>>> from collections import OrderedDict
>>> data = json.loads(s, object_pairs_hook=OrderedDict)
>>> data
OrderedDict([('name', 'ACME'), ('shares', 50), ('price', 490.1)])
>>>
```

äÿŃéÍćæŸŕåęĆä¡ŢåřĘäÿĂäÿłJSONå■ŮåĚÿè¡ñæ■ćäÿžäÿĂäÿłPythonåŕźèśąä¿Ńå■ŘïijŽ

```
>>> class JSONObject:
...     def __init__(self, d):
...         self.__dict__ = d
...
>>>
>>> data = json.loads(s, object_hook=JSONObject)
>>> data.name
'ACME'
>>> data.shares
50
>>> data.price
490.1
>>>
```

æIJĂåŘŐäÿĂäÿłä¿Ńå■Řäÿ■ïijŇJSONèğčçăĄåŘŐçŽĎå■ŮåĚÿä¡IJäÿžäÿĂäÿłå■Ţäÿłå
__init__() ãĂĆ çĎűåŘŐïijŇä¡ăåřśåŔŕäżěéŽŔå£ČæĽĂæňšçŽĎä¡£çŤĺåőČäžĘïijŇæŕŤåęĆä¡IJäÿžäÿĂäÿłå

åIJÍçijŰçăĄJSONçŽĎæŮűåĂŹïijŇè£ŸæIJĽäÿĂäžŻéĂĽéąźå¿ĹæIJĽçŤĺãĂĆ
åęĆædIJä¡ăæČşèŐůå¿ŮæijĆäžőçŽĎæăijåijŔåŇŰå■ŮçňęäÿšåŘŐè¿ŞåĞžïijŇåŔŕäżěä¡£çŤĺ
json.dumps() çŽĎindentåŔĆæŢřãĂĆ åőČäijŽä¡£å¿Ůè¿ŞåĞžåŠŇpprint()åĞ¡æŢřæŢĹædIJçśżäijijãĂĆæŕŤ

```
>>> print(json.dumps(data))
{"price": 542.23, "name": "ACME", "shares": 100}
>>> print(json.dumps(data, indent=4))
{
    "price": 542.23,
    "name": "ACME",
    "shares": 100
}
>>>
```

åŕźèśąåőđä¿ŃéĂŽåÿÿåźűäÿ■æŸŕJSONåŔŕåžŔåĹŮåŇŰçŽĎãĂĆä¿ŃåęĆïijŽ

```
>>> class Point:
...     def __init__(self, x, y):
...         self.x = x
...         self.y = y
...
>>> p = Point(2, 3)
>>> json.dumps(p)
Traceback (most recent call last):
    File "<stdin>", line 1, in <module>
    File "/usr/local/lib/python3.3/json/__init__.py", line 226, in␣
↪dumps
        return _default_encoder.encode(obj)
    File "/usr/local/lib/python3.3/json/encoder.py", line 187, in␣
↪encode
        chunks = self.iterencode(o, _one_shot=True)
    File "/usr/local/lib/python3.3/json/encoder.py", line 245, in␣
↪iterencode
        return _iterencode(o, 0)
```

```
    File "/usr/local/lib/python3.3/json/encoder.py", line 169, in␣
↪default
        raise TypeError(repr(o) + " is not JSON serializable")
TypeError: <__main__.Point object at 0x1006f2650> is not JSON␣
↪serializable
>>>
```

åęĆædIJä¡ăæČşåžŘåĹŮåŇŰářźèśąåőđä¿ŃïijŇä¡ăåŘŕäžěæŔŘä¿ŻäÿĂäÿłåĞ¡æŢřïijŇåőČçŽĎè¿ŞåĚěæŸŕ

```
def serialize_instance(obj):
    d = { '__classname__' : type(obj).__name__ }
    d.update(vars(obj))
    return d
```

åęĆædIJä¡ăæČşåŔ■è£ĞæİěèŐůåŔŰè£Źäÿłåőđä¿ŃïijŇåŘŕäžěè£ŹæăůåĄŽïijŽ

```
# Dictionary mapping names to known classes
classes = {
    'Point' : Point
}

def unserialize_object(d):
    clsname = d.pop('__classname__', None)
    if clsname:
        cls = classes[clsname]
        obj = cls.__new__(cls) # Make instance without calling __
↪init__
        for key, value in d.items():
            setattr(obj, key, value)
        return obj
    else:
        return d
```

äÿŃéİćæŸŕåęĆä¡Ţä¡£çŤĺè£ŹäžŻåĞ¡æŢřçŽĎä¿Ńå■ŘïijŽ

```
>>> p = Point(2,3)
>>> s = json.dumps(p, default=serialize_instance)
>>> s
'{"__classname__": "Point", "y": 3, "x": 2}'
>>> a = json.loads(s, object_hook=unserialize_object)
>>> a
<__main__.Point object at 0x1017577d0>
>>> a.x
2
>>> a.y
3
>>>
```

`json` æĺąåİŮè£ŸæIJL'å¿Ĺåd'ŽåĚűäžŰéĂL'éąźæİěæŐğåĹűæŻt'ä¡ŐçžğåĹńçŽĎæŢřå■ŮãĂĄçL'źæőŁåĂi
åŘŕäžěåŘĆèĂČåőŸæŰźæŰĞæąčèŐůåŘŰæŻt'åd'ŽçżĘèŁĆãĂĆ

8.3 6.3 èğčæđŘçőĂå■ŢçŽĎXMLæŢřæ■ő

éŮőécŸ

ä¡ăæČşäżŐäÿĂäÿłçőĂå■ŢçŽĎXMLæŰĞæąčäÿ■æŔŘåŔŰæŢřæ■őãĂĆ

èğčåĘşæŰźæąĹ

åŘŕäžěä¡£çŤÍ xml.etree.ElementTree æÍąåİŮäżŐçőĂå■ŢçŽĎXMLæŰĞæąčäÿ■æŔŘåŔŰæŢřæ■őãĂĆ äÿžäžĘæijŤçd'žïijŇåĄĞèő¿ä¡ăæČşèğčæđŘPlanet PythonäÿŁçŽĎRSSæžŘãĂĆäÿŃéİćæŸŕçŻÿåžŤçŽĎäžčçăĄïijŽ

```
from urllib.request import urlopen
from xml.etree.ElementTree import parse

# Download the RSS feed and parse it
u = urlopen('http://planet.python.org/rss20.xml')
doc = parse(u)

# Extract and output tags of interest
for item in doc.iterfind('channel/item'):
    title = item.findtext('title')
    date = item.findtext('pubDate')
    link = item.findtext('link')

    print(title)
    print(date)
    print(link)
    print()
```

è£ŘèąŇäÿŁéİćçŽĎäžčçăĄïijŇè¿ŞåĞžçżŞæđIJçśżäijijè£ŹæăůïijŽ

```
Steve Holden: Python for Data Analysis
Mon, 19 Nov 2012 02:13:51 +0000
http://holdenweb.blogspot.com/2012/11/python-for-data-analysis.html

Vasudev Ram: The Python Data model (for v2 and v3)
Sun, 18 Nov 2012 22:06:47 +0000
http://jugad2.blogspot.com/2012/11/the-python-data-model.html

Python Diary: Been playing around with Object Databases
Sun, 18 Nov 2012 20:40:29 +0000
http://www.pythondiary.com/blog/Nov.18,2012/been-...-object-
 ↪databases.html

Vasudev Ram: Wakari, Scientific Python in the cloud
Sun, 18 Nov 2012 20:19:41 +0000
http://jugad2.blogspot.com/2012/11/wakari-scientific-python-in-
 ↪cloud.html
```

```
Jesse Jiryu Davis: Toro: synchronization primitives for Tornado␣
↪coroutines
Sun, 18 Nov 2012 20:17:49 +0000
http://feedproxy.google.com/~r/EmptysquarePython/~3/_DOZT2Kd0hQ/
```

å¿ÍæŸ¿çĎűïijŇåęĆæđIJä¡ăæČşåĄŽè£ŻäÿĂæ■ěçŽĎåď ĎçŘĘïijŇä¡ăéIJĂèęĄæŻ£æ■ć `print()` èí■åŔěæİěåőŇæÍŘåĚűäžŰæIJL'èűčçŽĎäžŇãĂĆ

èőÍèőž

åIJÍå¿Íåď ŽåžŤçŤÍçÍŃåžŔäÿ■åď ĎçŘĘXMLçijŰçăĄæăijåijŔçŽĎæŢřæ■őæŸŕå¿Íåÿÿè§ĄçŽĎãĂĆäÿ■äžĚåŻääÿžXMLåIJÍInternetäÿŁéİćåůšçżŔèćńäź£æşŽåžŤçŤÍäžŐæŢřæ■őäžď æ■ćïijŇåŘŇæŮűåőČäź§æŸŕäÿĂçğ■å■ŸåĆÍåžŤçŤÍçÍŃåžŔæŢřæ■őçŽĎåÿÿçŤÍæăijåijŔ(æŕŤåęĆå■Ůåď ĎçŘĘïijŇé§şäæŐěäÿŃæİěçŽĎèőÍèőžäijŽåĚÍåĄĞåőŽèŕżèĂĚåůšçżŔåŕźXMLå§žçąĂæŕŤè¿ČçĘ§æĆL'äžĘãĂĆ

åIJÍå¿Íåď ŽæČĚåĘţäÿŃïijŇå¡Şä¡£çŤÍXMLæİěäžĚäżĚå■ŸåĆÍæŢřæ■őçŽĎæŮűåĂŹïijŇåŕźåžŤçŽĎæŰĞä¿ŃåęĆïijŇäÿŁéİćä¿Ńå■Řäÿ■çŽĎRSSèőćéŸĚæžŘçśżäijijäžŐäÿŃéİćçŽĎæăijåijŔïijŽ

```
<?xml version="1.0"?>
<rss version="2.0" xmlns:dc="http://purl.org/dc/elements/1.1/">
    <channel>
        <title>Planet Python</title>
        <link>http://planet.python.org/</link>
        <language>en</language>
        <description>Planet Python - http://planet.python.org/</
↪description>
        <item>
            <title>Steve Holden: Python for Data Analysis</title>
            <guid>http://holdenweb.blogspot.com/...-data-analysis.
↪html</guid>
            <link>http://holdenweb.blogspot.com/...-data-analysis.
↪html</link>
            <description>...</description>
            <pubDate>Mon, 19 Nov 2012 02:13:51 +0000</pubDate>
        </item>
        <item>
            <title>Vasudev Ram: The Python Data model (for v2 and␣
↪v3)</title>
            <guid>http://jugad2.blogspot.com/...-data-model.html</
↪guid>
            <link>http://jugad2.blogspot.com/...-data-model.html</
↪link>
            <description>...</description>
            <pubDate>Sun, 18 Nov 2012 22:06:47 +0000</pubDate>
        </item>
        <item>
            <title>Python Diary: Been playing around with Object␣
↪Databases</title>
```

```
            <guid>http://www.pythondiary.com/...-object-databases.
↪html</guid>
            <link>http://www.pythondiary.com/...-object-databases.
↪html</link>
            <description>...</description>
            <pubDate>Sun, 18 Nov 2012 20:40:29 +0000</pubDate>
        </item>
        ...
    </channel>
</rss>
```

xml.etree.ElementTree.parse() åĞ¡æŢřèğčæđŘæŢť'äÿłXMLæŰĞæąčåźűåřĘåĚűè¡ňæ■ćæĹŘçĎűåŘŐïijŇä¡ăåřśèČ¡ä¡£çŤÍ find() ãĂĄiterfind() åŠŇ findtext() ç■L'æŰźæşŢæÌěæŘIJçť'ćçL'źåőŽçŽĎXMLåĚČçť'ääžĘãĂĆè£ŹäžŽåĞ¡æŢřçŽĎåŘĆæŢřåřśæŸŕæ§Řäÿłæ ŇĞåőŽçŽĎæăĞç■¿åŘ■ïijŇä¿ŃåęĆ channel/item æĹŰ title ãĂĆ

æŕŘæňąæŇĞåőŽæ§Řäÿłæ ăĞç■¿æŮűïijŇä¡ăéIJĂèęĄéĄ■åŐĘæŢť'äÿłæŰĞæąčçżŞæđĎãĂĆæŕŘæňąæŘIJåŘŇæăůïijŇæŕŘæňąæŞ■ä¡IJæĽĂæŇĞåőŽçŽĎæăĞç■¿åŘ■äź§æŸŕèţůåğŃåĚČçť'ăçŽĎçŽÿåŕźèůŕå¿ĎãĂĆä¿ŃåęĆïijŇæĽ'ğèąŇ doc.iterfind('channel/item') æÌěæŘIJçť'ćæĽĂæIJĽåIJÍ channel åĚČçť'ääÿŃéÌćçŽĎ item åĚČçť'äãĂĆ doc äżčèąÍæŰĞæąčçŽĎæIJĂéąűåśĆ(äź§åřśæŸŕçňňäÿĂçžğçŽĎ rss åĚČçť'ă)ãĂĆçĎűåŘŐæŐěäÿŃæÌěçŽĎèřČçŤÍ item.findtext() äijŽäžŐåůšæĽ¿åĹřçŽĎ item åĚČçť'ää¡■ç¡őåijĂåğŃæŘIJçť'ćãĂĆ

ElementTree æÍąåÌŮäÿ■çŽĎæŕŘäÿłåĚČçť'ăæIJĽäÿĂäžŽéĞ■èęĄçŽĎåśđæĂğåŠŇæŰźæşŢïijŇåIJÍèğčtag åśđæĂğåŃĚåŘńäžĘąĂğç■¿çŽĎåŘ■å■ŮïijŇtext åśđæĂğåŃĚåŘńäžĘąĘĚéČÍçŽĎæŰĞæIJñïijŇèĂŇget() æŰźæşŢèČ¡èŐůåŘŰåśđæĂğåĂijãĂĆä¿ŃåęĆïijŽ

```
>>> doc
<xml.etree.ElementTree.ElementTree object at 0x101339510>
>>> e = doc.find('channel/title')
>>> e
<Element 'title' at 0x10135b310>
>>> e.tag
'title'
>>> e.text
'Planet Python'
>>> e.get('some_attribute')
>>>
```

æIJĽäÿĂçĆźèęĄåijžèřČçŽĎæŸŕ xml.etree.ElementTree åźűäÿ■æŸŕXML-LèğčæđŘçŽĎåŤŕäÿĂæŰźæşŢãĂĆ åŕźäžŐæŻť'énŸçžğçŽĎåžŤçŤÍçÍŃåžŘïijŇä¡äéIJĂèęĄèĂČèŹŚä¡£çŤÍ lxml ãĂĆ åőČä¡£çŤÍäžĘąŠŇElementTreeåŘŇæăůçŽĎçijŰçÍŃæŐěåŘčïijŇåŻăæ■ď'äÿŁéÌćçŽĎä¿Ńå■ŘåŘŇää¡ääŔłéIJĂèęĄåřĘąĹŽåijĂåğŃçŽĎimportèŕ■åŘěæ■ćæĹŘ from lxml.etree import parse åřśèąŇäžĘãĂĆ lxml åőŇåĚÍéĄţå¿ŁXMLæăĞåĞĘïijŇåźűäÿŤéĂ§åžęäź§éÌđåÿÿå£ńïijŇåŘŇæŮűè£Ÿa

8.4 6.4 åćđéĞŔåijŔèğčædŘåď'ğåđŃXMLæŰĞäžű

éŮőécŸ

ä¡äæČşä¡£çŤĺår¡åŔŕèČ¡ářŚçŽĎåĘĚå■ŸäżŐäÿĂäÿłèűĚåď'ğçŽĎXMLæŰĞæąčäÿ■æŔŘåŔŰæŢřæ■őãĂĆ

èğčåĘşæŰźæąĹ

äżżä¡ŢæŮűåĂŹåŔłèęĄä¡äéĄĞåĹřåćđéĞŔåijŔçŽĎæŢřæ■őåď'ĎçŘĘæŮűïijŇçňňäÿĂæŮűéŮť'åřśåžŤèŕěa
äÿŃéİćæŸŕäÿĂäÿłå¿ĹçőĂå■ŢçŽĎåĞ¡æŢřïijŇåŔłä¡£çŤĺå¿ĹářŚçŽĎåĘĚå■ŸářśèČ¡åćđéĞŔåijŔçŽĎåď'ĎçŘĘä

```
from xml.etree.ElementTree import iterparse

def parse_and_remove(filename, path):
    path_parts = path.split('/')
    doc = iterparse(filename, ('start', 'end'))
    # Skip the root element
    next(doc)

    tag_stack = []
    elem_stack = []
    for event, elem in doc:
        if event == 'start':
            tag_stack.append(elem.tag)
            elem_stack.append(elem)
        elif event == 'end':
            if tag_stack == path_parts:
                yield elem
                elem_stack[-2].remove(elem)
            try:
                tag_stack.pop()
                elem_stack.pop()
            except IndexError:
                pass
```

äÿžäžĘæţŃèŕŢè£ŹäÿłåĞ¡æŢřïijŇä¡äéIJĂèęĄåĚĹæIJL'äÿĂäÿłåď'ğåđŃçŽĎXMLæŰĞäžűãĂĆ
éĂŽåÿÿä¡ääŔŕäžěåIJÍæŤ£åžIJç¡ŚçńŹæĹŰåĚňåĚśæŢřæ■őç¡ŚçńŹäÿŁæL'¿åĹřè£Źæăůç˘ĎæŰĞäžűãĂĆ
ä¿ŃåęĆïijŇä¡ääŔŕäžěäÿŃè¡¡XMLæäijåijŔçŽĎèŁİåŁääŞěå§ŐåÿĆéĄŞèůŕåİŚæť'ijæŢřæ■őåžŞãĂĆ
åIJĺåĘŹè£ŹæIJñäźęçŽĎæŮűåĂŹïijŇäÿŃè¡¡æŰĞäžűåůšçżŔåŇĚåŘńèűĚè£Ğ100,000èąŇæŢřæ■őïijŇçijŰçăĄ

```
<response>
    <row>
        <row ...>
            <creation_date>2012-11-18T00:00:00</creation_date>
            <status>Completed</status>
            <completion_date>2012-11-18T00:00:00</completion_date>
            <service_request_number>12-01906549</service_request_
↪number>
            <type_of_service_request>Pot Hole in Street</type_of_
↪service_request>
```

```
            <current_activity>Final Outcome</current_activity>
            <most_recent_action>CDOT Street Cut ... Outcome</most_
↪recent_action>
            <street_address>4714 S TALMAN AVE</street_address>
            <zip>60632</zip>
            <x_coordinate>1159494.68618856</x_coordinate>
            <y_coordinate>1873313.83503384</y_coordinate>
            <ward>14</ward>
            <police_district>9</police_district>
            <community_area>58</community_area>
            <latitude>41.808090232127896</latitude>
            <longitude>-87.69053684711305</longitude>
            <location latitude="41.808090232127896"
            longitude="-87.69053684711305" />
        </row>
        <row ...>
            <creation_date>2012-11-18T00:00:00</creation_date>
            <status>Completed</status>
            <completion_date>2012-11-18T00:00:00</completion_date>
            <service_request_number>12-01906695</service_request_
↪number>
            <type_of_service_request>Pot Hole in Street</type_of_
↪service_request>
            <current_activity>Final Outcome</current_activity>
            <most_recent_action>CDOT Street Cut ... Outcome</most_
↪recent_action>
            <street_address>3510 W NORTH AVE</street_address>
            <zip>60647</zip>
            <x_coordinate>1152732.14127696</x_coordinate>
            <y_coordinate>1910409.38979075</y_coordinate>
            <ward>26</ward>
            <police_district>14</police_district>
            <community_area>23</community_area>
            <latitude>41.91002084292946</latitude>
            <longitude>-87.71435952353961</longitude>
            <location latitude="41.91002084292946"
            longitude="-87.71435952353961" />
        </row>
    </row>
</response>
```

åĄĞèő¿ä¡ăæČşåĘźäÿĂäÿłèĎŽæIJňæİěæŇL’çĔğåİŚæt’ijæŁěåŚŁæŢřéĞŔæŐŠåĹŮéĆőçijŰůŔůçăĄãĆä

```
from xml.etree.ElementTree import parse
from collections import Counter

potholes_by_zip = Counter()

doc = parse('potholes.xml')
for pothole in doc.iterfind('row/row'):
```

```
    potholes_by_zip[pothole.findtext('zip')] += 1
for zipcode, num in potholes_by_zip.most_common():
    print(zipcode, num)
```

è£Źäÿłè ĎŽæIJňåŤŕäÿĂçŽĎéŮőécŸæŸŕåőČäijŽåĚĹåřĘæŢťäÿłXMLæŰĞäžűåŁäè¡¡åĹřåĘĚå■Ÿäÿ■çĎűå IJĺæĹŠçŽĎæIJžåŹĺäÿŁïijŇäÿžäžĘè£ŘèąŇè£ŹäÿłçĺŇåžŔéIJĂèęĄçŤĺåĹř450MBåůęåŔşçŽĎåĘĚå■Ÿçľ žéŮťă åęĆædIJä¡£çŤĺåęĆäÿŇäžčçăĄïijŇçĺŇåžŔåŔłéIJĂèęĄä£őæŤźäÿĂçĆźçĆźïijŽ

```
from collections import Counter

potholes_by_zip = Counter()

data = parse_and_remove('potholes.xml', 'row/row')
for pothole in data:
    potholes_by_zip[pothole.findtext('zip')] += 1
for zipcode, num in potholes_by_zip.most_common():
    print(zipcode, num)
```

çżŞædIJæŸŕïijŽè£ŹäÿłçL'ĹæIJňçŽĎäžčçăĄè£ŘèąŇæŮűåŔłéIJĂèęĄ7MBçŽĎåĘĚå■Ÿ–åď ğåď ğèŁĆçžę

èőĺèőž

è£ŹäÿĂèŁĆçŽĎæŁĂæIJŕäijŽä¿ÌèţŰ `ElementTree` æĺąåİŮäÿ■çŽĎäÿď'äÿłæăÿå£ČåŁ§èČ¡ãĂĆ çňňäÿĂïijŇ`iterparse()` æŰźæşŢåĚĄèőÿåŕźXMLæŰĞæąčè£ŻèąŇåćđéĞŔæŞ■ä¡IJãĂĆ ä¡£çŤĺæŮűïijŇä¡äéIJĂèęĄæŔŘä¿ŻæŰĞäžűåŘ■åŠŇäÿĂäÿłåŇĚåŘńäÿŃéİćäÿĂçğ■æĹŮåď'Žçğ■çśžåđŇçŽĎä `start` , `end`, `start-ns` åŠŇ `end-ns` ãĂĆ çŤś `iterparse()` åĹŻåžžçŽĎè£■äžčåŹĺäijŽäžğçŤ§å¡ćåęĆ `(event, elem)` çŽĎåĚČçżĎïijŇ åĚűäÿ■ `event` æŸŕäÿŁè£ŕäžŃäžűåĹŮèąĺäÿ■çŽĎæ§ŘäÿĂäÿłïijŇèĂŇ `elem` æŸŕçŻÿåžŤçŽĎXM-LåĚČçť'äãĂĆä¿ŃåęĆïijŽ

```
>>> data = iterparse('potholes.xml',('start','end'))
>>> next(data)
('start', <Element 'response' at 0x100771d60>)
>>> next(data)
('start', <Element 'row' at 0x100771e68>)
>>> next(data)
('start', <Element 'row' at 0x100771fc8>)
>>> next(data)
('start', <Element 'creation_date' at 0x100771f18>)
>>> next(data)
('end', <Element 'creation_date' at 0x100771f18>)
>>> next(data)
('start', <Element 'status' at 0x1006a7f18>)
>>> next(data)
('end', <Element 'status' at 0x1006a7f18>)
>>>
```

`start` äžŃäžűåIJĺæ§ŘäÿłåĚČçť'äçňňäÿĂæňąèćńåĹŻåžžåźűäÿŤè£ŸæšąæIJL'èćńæŔŠåĚěåĚűäžŰæŢřæ■ èĂŇ `end` äžŃäžűåIJĺæ§ŘäÿłåĚČçť'ăåůšçżŔåőŇæĹŘæŮűèćńåĹŻåžžãĂĆ

åř¡çőąæšąæIJL'åIJÍä¿Ńå■Řäÿ■æijŤçď žïijŃ `start-ns` åŠŃ `end-ns` äžŃäžűèćńçŤÍæÍěåď'ĎçŘĘXMLæŰĞæąčåŚ¡åŘ■çl'žéÚť'çŽĎåčřæŸŐãĂĆ

è£ŹæIJńèŁCä¿Ńå■Řäÿ■ïijŃ `start` åŠŃ `end` äžŃäžűèćńçŤÍæÍěçőąçŘĘåĚČçt'ääŠŃæäĞç■¿æäĹãĂĆ æäĹäžčèąÍäžĘæŰĞæąčèćńèğčæđŘæŮűçŽĎåśĆæňąçżŞæđĎïijŃ è£ŸèćńçŤÍæÍěåĹď'æŰ■æ§Řäÿ łåĚČçt'äæŸŕåŘęåŃźéĚ■äijäçżŹåĞ¡æŢř `parse_and_remove()` çŽĎèůŕå¿ĎãĂĆ åęĆæđIJåŃźéĚ■ïijŃåřšåĹl'çŤÍ `yield` èŕ■åŘěåŘŚèřČçŤÍèĂĚè£ŤåŻđè£ŹäÿłåĚČçt'ããĂĆ

åIJÍ `yield` äźŃåŘŐçŽĎäÿŃéÍćè£Źäÿłèŕ■åŘěæL'■æŸŕä¡£å¿ŮçÍŃåžŘå■ăçŤÍæđĄåřŚåĘĚå■ŸçŽĎElemen

```
elem_stack[-2].remove(elem)
```

è£Źäÿłèŕ■åŘěä¡£å¿ŮäźŃåL'■çŤś `yield` äžğçŤ§çŽĎåĚČçt'ääžŐåőČçŽĎçĹűèŁĆçĆźäÿ■åĹäéŹď'æŐL'ãA åĄĞèő¿åůšçżŔæšąæIJL'åĚűåőČçŽĎåIJřæŰźåijŢçŤÍè£ŹäÿłåĚČçt'ääžĘïijŃéĆčäźLè£ŹäÿłåĚČçt'ääřšèćńéŤĂæ

åŕźèŁĆçĆźçŽĎè£■äžčåijŔèğčæđŘåŠŃåĹäéŹď'çŽĎæIJĂçżĹæŢĹæđIJåřśæŸŕäÿĂäÿłåIJÍæŰĞæąčäÿŁéńŸ æŰĞæąčæăŚçżŞæđĎäžŐåğŃèĞłçżĹæšąèćńåőŇæŢt'çŽĎåĹŻåžžè£ĞãĂĆář¡çőąåęĆæ■d'ïijŃè£ŸæŸŕèČ¡éĂŽè

è£Źçğ■æŰźæąĹçŽĎäÿżèęĄçijžéŹůåřśæŸŕåőČçŽĎè£ŘèąŇæĂğèČ¡äžĘãĂĆ æĹŚèĞłåůšæţŃèŕŢçŽĎçżŞæđIJæŸŕŕïijŃèŕżåŘŰæŢt'äÿłæŰĞæąčåĹřåĘĚå■Ÿäÿ■çŽĎçL'ĹæIJńçŽĎè£ŘèąŇéĂ§ ä¡ĘæŸŕåőČå■t'ä¡£çŤÍäžĘèúĚè£ĞåŘŐèĂĚ60åĂ■çŽĎåĘĚå■ŸãĂĆ åŽăæ■d'ïijŃåęĆæđIJä¡ăæŻt'åĘşå£ČåĘĚå■Ÿä¡£çŤÍéĞŘçŽĎèŕĬïijŃéĆčäźĹåćđéĞŘåijŘçŽĎçL'ĹæIJńåőŃèČIJ

8.5 6.5 åřĘå■ŮåĚÿè¡ňæ■ćäÿžXML

éŮőécŸ

ä¡ăæČşä¡£çŤÍäÿĂäÿłPythonå■ŮåĚÿå■ŸåĆÍæŢřæ■őïijŃåźűåřĘåőČè¡ňæ■ćæĹŘXMLæăijåijŘãĂĆ

èğčåĘşæŰźæąĹ

åř¡çőą `xml.etree.ElementTree` åžŞéĂŽåÿÿçŤÍæÍěåĄŽèğčæđŘåůëä¡IJïijŃåĚűåőđåőČäź§åŔŕäžëåÍ ä¿ŃåęĆïijŃèĂČèŹŚåęĆäÿŃè£ŹäÿłåĞ¡æŢřïijŽ

```
from xml.etree.ElementTree import Element

def dict_to_xml(tag, d):
'''
Turn a simple dict of key/value pairs into XML
'''
elem = Element(tag)
for key, val in d.items():
    child = Element(key)
    child.text = str(val)
    elem.append(child)
return elem
```

äÿŃéÍćæŸŕäÿĂäÿłä¡£çŤÍä¿Ńå■ŘïijŽ

```
>>> s = { 'name': 'GOOG', 'shares': 100, 'price':490.1 }
>>> e = dict_to_xml('stock', s)
>>> e
<Element 'stock' at 0x1004b64c8>
>>>
```

è¡ňæ■ćçżŞæđIJæŸŕäÿĂäÿł `Element` åőđä¿ŃãĂĆåŕźäžŐI/OæŞ■ä¡IJïijŇä¡£çŤÍ `xml.etree.ElementTree` äÿ■çŽĎ `tostring()` åĞ¡æŢřå¿ĹåőźæŸŞåřśèČ¡ářĘåőČè¡ňæ■ćæĹŘäÿĂäÿłå■ŮèŁ

```
>>> from xml.etree.ElementTree import tostring
>>> tostring(e)
b'<stock><price>490.1</price><shares>100</shares><name>GOOG</name></
↪stock>'
>>>
```

åęĆæđIJä¡ăæČşçżŹæ§ŘäÿłåĚČçť'ăæůżåŁåášđæĂğåĂijïijŇåŔŕäžěä¡£çŤÍ `set()` æŰźæşŢïijŽ

```
>>> e.set('_id','1234')
>>> tostring(e)
b'<stock _id="1234"><price>490.1</price><shares>100</shares><name>
↪GOOG</name>
</stock>'
>>>
```

åęĆæđIJä¡ăè£ŸæČşä£ÍæŇĄåĚČçť'ăçŽĎéąžåžŔïijŇåŔŕäžěèĂČèŹŚæđĎéĂääÿĂäÿł `OrderedDict` æÍěäžčæŻ£äÿĂäÿłæŹőéĂŽçŽĎå■ŮåĚÿãĂĆèŕůåŔĆèĂČ1.7åřŔèŁĆãĂĆ

èőÍèőž

å¡ŞåĹŻåžžXMLçŽĎæŮűåĂŹïijŇä¡ăèćńéŹŘåĹűåŔłèČ¡æđĎéĂää■ŮçňęäÿšçśžåđŃçŽĎåĂijãĂĆä¿ŃåęĆï

```
def dict_to_xml_str(tag, d):
    '''
    Turn a simple dict of key/value pairs into XML
    '''
    parts = ['<{}>'.format(tag)]
    for key, val in d.items():
        parts.append('<{0}>{1}</{0}>'.format(key,val))
    parts.append('</{}>'.format(tag))
    return ''.join(parts)
```

éŮőécŸæŸŕåęĆæđIJä¡ăæL'ŃåŁÍçŽĎåŐżæđĎéĂăçŽĎæŮűåĂŹåŔŕèČ¡äijŽçćřåĹřäÿĂäžŽéžżçČęãĂĆä¿Ń

```
>>> d = { 'name' : '<spam>' }

>>> # String creation
>>> dict_to_xml_str('item',d)
'<item><name><spam></name></item>'
```

```
>>> # Proper XML creation
>>> e = dict_to_xml('item',d)
>>> tostring(e)
b'<item><name>&lt;spam&gt;</name></item>'
>>>
```

æşÍæĎŔåĹřçÍŃåžŔçŽĎåŘŐéİćéĆčäÿłä¿Ńå■Řäÿ■ïijŇå■Ůçňę âĂŸ<âĂŹ åŠŇ âĂŸ>âĂŹ èćńæŻ£æ■ćæĹŘäžĘ `<` åŠŇ `>`

äÿŃéİćäżĚä¿ŻåŔĆèĂČïijŇåęĆæđIJä¡ăéIJĂèęĄæĽ'ŃåŁĺåŐżè¡ňæ■ćè£ŹäžŻå■Ůçňę̈ïijŇ åŘŕäžěä¡£çŤÍ `xml.sax.saxutils` äÿ■çŽĎ `escape()` åŠŇ `unescape()` åĞ¡æŢřãĂĆä¿ŃåęĆïijŽ

```
>>> from xml.sax.saxutils import escape, unescape
>>> escape('<spam>')
'&lt;spam&gt;'
>>> unescape(_)
'<spam>'
>>>
```

éŹđ'äžĘèČ¡åĹŻåžžæ■čçąőçŽĎè¿ŞåĞžåđ'Űïij Ňè£ŸæIJL'åŔęåđ'ŰäÿĂäÿłåŐ§åŻăæŐÍè■Řä¡ääĹŻåžž `Element` åőđä¿ŃèĂŇäÿ■æŸŕå■Ůçňę̈äÿšïijŇ éĆčářśæŸŕä¡£çŤÍå■Ůçňę̈äÿšçżĎåŘĹæđĎéĂäÿĂäÿłæŻt'åđ'ğç èĂŇ `Element` åőđä¿ŃåŔŕäžěäÿ■çŤÍèĂČèŹŠèğčæđŘXMLæŰĞæIJňçŽĎæČĚåĘţäÿŃéĂŽè£Ğåđ'Žçğ■æŰźäi äź§ářśæŸŕèŕt'ïijŇä¡ääŔŕäžěåIJÍäÿĂäÿłéńŸçžğæŢřæ■őçżŞæđĎäÿŁåőŇæĹŘä¡ăæĽ'ĂæIJL'çŽĎæŞ■ä¡IJïijŇåźű

8.6 6.6 èğčæđŘåŠŇä£őæŤźXML

éŮőécŸ

ä¡ăæČşèŕžåŘŰäÿĂäÿłXMLæŰĞæąčïijŇåŕźåőČæIJĂäÿĂäžŻä£őæŤźïijŇçĎűåŘŐåřĘçżŞæđIJåĘŹåŻđXM

èğčåĘşæŰźæąĹ

ä¡£çŤÍ `xml.etree.ElementTree` æÍąåİŮåŔŕäžěå¿ĹåőźæŸŞçŽĎåđ'ĎçŘĘè£ŹäžŻäżżåŁąãĂĆ çňňäÿĂæ■ěæŸŕäžěéĂŽåÿÿçŽĎæŰźåijŔæİèèğčæđŘè£ŹäÿłæŰĞæąčãĂĆä¿ŃåęĆïijŇåĄĞèő¿ä¡ăæIJL'äÿĂäÿłå `pred.xml` çŽĎæŰĞæąčïijŇçśżäijijäÿŃéİćè£Źæăůïij Ž

```
<?xml version="1.0"?>
<stop>
    <id>14791</id>
    <nm>Clark &amp; Balmoral</nm>
    <sri>
        <rt>22</rt>
        <d>North Bound</d>
        <dd>North Bound</dd>
    </sri>
    <cr>22</cr>
```

```
    <pre>
        <pt>5 MIN</pt>
        <fd>Howard</fd>
        <v>1378</v>
        <rn>22</rn>
    </pre>
    <pre>
        <pt>15 MIN</pt>
        <fd>Howard</fd>
        <v>1867</v>
        <rn>22</rn>
    </pre>
</stop>
```

äÿŃéÌćæŸŕäÿĂäÿłåĹľçŤÍ ElementTree æÌěèŕžåŔŰè£ŹäÿłæŰĞæąčåźűåŕźåőČåĄŽäÿĂäžŽä£őæŤźçŽ

```
>>> from xml.etree.ElementTree import parse, Element
>>> doc = parse('pred.xml')
>>> root = doc.getroot()
>>> root
<Element 'stop' at 0x100770cb0>

>>> # Remove a few elements
>>> root.remove(root.find('sri'))
>>> root.remove(root.find('cr'))
>>> # Insert a new element after <nm>...</nm>
>>> root.getchildren().index(root.find('nm'))
1
>>> e = Element('spam')
>>> e.text = 'This is a test'
>>> root.insert(2, e)

>>> # Write back to a file
>>> doc.write('newpred.xml', xml_declaration=True)
>>>
```

åď ĎçŘEçżŞæđIJæŸŕäÿĂäÿłåČŔäÿŃéÌćè£ŹæăůæŰřçŽĎXMLæŰĞäžűïijŽ

```
<?xml version='1.0' encoding='us-ascii'?>
<stop>
    <id>14791</id>
    <nm>Clark &amp;amp; Balmoral</nm>
    <spam>This is a test</spam>
    <pre>
        <pt>5 MIN</pt>
        <fd>Howard</fd>
        <v>1378</v>
        <rn>22</rn>
    </pre>
    <pre>
        <pt>15 MIN</pt>
```

```
        <fd>Howard</fd>
        <v>1867</v>
        <rn>22</rn>
    </pre>
</stop>
```

èőÍèőž

ä£őæŤźäÿĂäÿłXMLæŰĞæąčçžŞæđĎæŸŕå¿Ĺåőźæŷ§çŽĎïijŇä¡ĘæŸŕä¡ăå£Ěéążç L'ćèőřçŽĎæŸŕæL'ĂæI
åřĘåőČä¡IJäÿžäÿĂäÿłåĹŮèąÍæİěåď'ĎçŘĘãĂĆä¿ŃåęĆïijŇåęĆæđIJä¡ăåĹăéŹď'æ§Řäÿłå ĚČçt'ăïijŇéĂŽè£ĞěřČ
`remove()` æŰźæşŢäżŐåőČçŽĎçŻť'æŐěçĹűèŁĆçĆźäÿ■åĹăéŹď'ãĂĆ
åęĆæđIJä¡ăæŔŠåĚěæĹŰåćđåŁăæŰřçŽĎåĚČçt'ăïijŇä¡ăåŘŇæăůä¡£çŤĺçĹűèŁĆçĆźåĚČçt'ăçŽĎ
`insert()` åŠŇ `append()` æŰźæşŢãĂĆ è£ŸèČ¡åŕźåĚČçt'ăä¡£çŤĺçt'ćåijŢåŠŇåĹĞçL'ĞæŞ■ä¡IJïijŇæŕŤåęĆ
`element[i]` æĹŰ `element[i:j]`

åęĆæđIJä¡ăéIJĂèęĄåĹŻåżžæŰřçŽĎåĚČçt'ăïijŇåŔŕäżěä¡£çŤĺæIJňèŁĆæŰźæąĹäÿ■æijŤçd'žçŽĎ
`Element` çśżãĂĆæĹŠäżňåIJĺ6.5åřŔèŁĆåůšçżŔèŕęçżĘèőĺèőžè£ĞäžĘãĂĆ

8.7 6.7 åĹľçŤĺåŚ¡åŘ■çľžéŮť'èğčæđŘXMLæŰĞæąč

éŮőécŸ

ä¡ăæČşèğčæđŘæ§ŘäÿłXMLæŰĞæąčïijŇæŰĞæąčäÿ■ä¡£çŤĺäžĘXMLåŚ¡åŘ■çľžéŮť'ãĂĆ

èğčåĘşæŰźæąĹ

èĂČèŹŚäÿŃéIćè£Źäÿłä¡£çŤĺäžĘåŚ¡åŘ■çľžéŮť'çŽĎæŰĞæąčïijŽ

```
<?xml version="1.0" encoding="utf-8"?>
<top>
    <author>David Beazley</author>
    <content>
        <html xmlns="http://www.w3.org/1999/xhtml">
            <head>
                <title>Hello World</title>
            </head>
            <body>
                <h1>Hello World!</h1>
            </body>
        </html>
    </content>
</top>
```

åęĆæđIJä¡ăèğčæđŘè£ŹäÿłæŰĞæąčåźűæL'ğèąŇæŹőéĂŽçŽĎæ§ěèŕćïijŇä¡ăäijŽåŔŚçŐřè£Źäÿłåźűäÿ■æŸ

```
>>> # Some queries that work
>>> doc.findtext('author')
'David Beazley'
>>> doc.find('content')
<Element 'content' at 0x100776ec0>
>>> # A query involving a namespace (doesn't work)
>>> doc.find('content/html')
>>> # Works if fully qualified
>>> doc.find('content/{http://www.w3.org/1999/xhtml}html')
<Element '{http://www.w3.org/1999/xhtml}html' at 0x1007767e0>
>>> # Doesn't work
>>> doc.findtext('content/{http://www.w3.org/1999/xhtml}html/head/
↪title')
>>> # Fully qualified
>>> doc.findtext('content/{http://www.w3.org/1999/xhtml}html/'
... '{http://www.w3.org/1999/xhtml}head/{http://www.w3.org/1999/
↪xhtml}title')
'Hello World'
>>>
```

ä¡äåŔŕäżěéĂŽè£ĞåřĘåŚ¡åŘ■çľ'žéŮť'åď'ĎçŘĘéĂżè¿ŚåŇĚèčĚäÿžäÿĂäÿłåůěåĚůçśżæİěçőĂåŇŰè£Źäÿłè£

```
class XMLNamespaces:
    def __init__(self, **kwargs):
        self.namespaces = {}
        for name, uri in kwargs.items():
            self.register(name, uri)
    def register(self, name, uri):
        self.namespaces[name] = '{'+uri+'}'
    def __call__(self, path):
        return path.format_map(self.namespaces)
```

éĂŽè£ĞäÿŃéİćçŽĎæŰźåijŔä¡£çŤÍè£Źäÿłçśżïij Ž

```
>>> ns = XMLNamespaces(html='http://www.w3.org/1999/xhtml')
>>> doc.find(ns('content/{html}html'))
<Element '{http://www.w3.org/1999/xhtml}html' at 0x1007767e0>
>>> doc.findtext(ns('content/{html}html/{html}head/{html}title'))
'Hello World'
>>>
```

èőÍèőž

èğčæđŘåŘńæIJĽåŚ¡åŘ■çľ'žéŮť'çŽĎXMLæŰĞæąčäijŽæŕŤè¿ČçźĄçŘŘãĂĆ äÿŁéİćçŽĎ XMLNamespaces äżĚäżĚæŸŕåĚĄèőÿä¡ää¡£çŤÍçijľ'çŢěåŘ■äżčæŻ£åőŇæŢť'çŽĎURIåřĘåĚűåŘŸå¿Ůçĺ■å¿őç

å¿Łäÿ■åźÿçŽĎæŸŕïijŇåIJĺåŞžæIJňçŽĎ ElementTree èğčæđŘäÿ■æšąæIJĽäżżä¡ŢéĂŤå¿ĎèŐůåŔŰåŚ¡åŘ■çľ'žéŮť'çŽĎä£ąæĄŕãĂĆ ä¡ĘæŸŕïijŇåęĆæđIJä¡ää¡£çŤÍ iterparse() åĞ¡æŢřçŽĎèŕİåřśåŔŕäżěèŐůåŔŰæŻť'åď'ŽåĚşäžŐåŚ¡åŘ■çľ'žé

```
>>> from xml.etree.ElementTree import iterparse
>>> for evt, elem in iterparse('ns2.xml', ('end', 'start-ns', 'end-
 ↪ns')):
... print(evt, elem)
...
end <Element 'author' at 0x10110de10>
start-ns ('', 'http://www.w3.org/1999/xhtml')
end <Element '{http://www.w3.org/1999/xhtml}title' at 0x1011131b0>
end <Element '{http://www.w3.org/1999/xhtml}head' at 0x1011130a8>
end <Element '{http://www.w3.org/1999/xhtml}h1' at 0x101113310>
end <Element '{http://www.w3.org/1999/xhtml}body' at 0x101113260>
end <Element '{http://www.w3.org/1999/xhtml}html' at 0x10110df70>
end-ns None
end <Element 'content' at 0x10110de68>
end <Element 'top' at 0x10110dd60>
>>> elem # This is the topmost element
<Element 'top' at 0x10110dd60>
>>>
```

æIJĂåŘŐäÿĂçĆźïijŇåęĆæđIJä¡ãèęĄåď'ĎçŘEçŽĎXMLæŰĞæIJňéŹď'äžEèęĄä¡£çŤĺåĹřåĚűäžŰéńŸçžğ
åžžèőőä¡ãæIJĂåě¡æŸŕä¡£çŤÍ lxml åĞ¡æŢřåžŞæİěäžčæŻ£ ElementTree ãĂĆ
ä¿ŇåęĆïijŇlxml åŕźåĹľçŤÍDTDéłŇèŕĄæŰĞæąčãĂĄæŻť'åě¡çŽĎXPathæŤŕæŇĄåŠŇäÿĂäžŻåĚűäžŰéńŸçžğ
è£ŹäÿĂåřŔèŁĆåĚűåőđåŔłæŸŕæŢŹä¡ãåęĆä¡Ţèőľ'XMLèğčæđŘçĺ■å¿őçőĂå■ŢäÿĂçĆźãĂĆ

8.8 6.8 äÿŐåĚşçşżåđŃæŢřæ■őåžŞçŽĎäžď'äžŠ

éŮőécŸ

ä¡ăæČşåIJĺåĚşçşżåđŃæŢřæ■őåžŞäÿ■æ§ěèŕćãĂĄåćđåŁăæĹŰåĹăéŹď'èőřå¡ŢãĂĆ

èğčåĘşæŰźæąĹ

Pythonäÿ■èąĺçď'žåď'ŽèąŇæŢřæ■őçŽĎæăĞåĞĘæŰźåijŔæŸŕäÿĂäÿłçŤśåĚČçżĎæđĎæĹŘçŽĎåžŔåĹŮãĂ

```
stocks = [
    ('GOOG', 100, 490.1),
    ('AAPL', 50, 545.75),
    ('FB', 150, 7.45),
    ('HPQ', 75, 33.2),
]
```

ä¿Iæ■őPEP249ïijŇéĂŽè£Ğè£Źçğ■å¡ćåijŔæŔŘä¿ŻæŢřæ■őïijŇ
åŔŕäžěå¿ĹåőźæŸ§çŽĎä¡£çŤÍPythonæăĞåĞĘæŢřæ■őåžŞAPIåŠŇåĚşçşżåđŃæŢřæ■őåžŞè£ŻèąŇäžď'äžŠãĂĆ
æĽĂæIJĽæŢřæ■őåžŞäÿŁçŽĎæŞ■ä¡IJéČ¡éĂŽè£ĞSQLæ§ěèŕćèŕ■åŘěæİěåőŇæĹŘãĂĆæŕŔäÿĂèąŇè¿ŞåĚěè¿Ş

äÿžäžĘæijŤçď'žèŕť'æŸŐïijŇä¡ääŔŕäžěä¡£çŤÍPythonæăĞåĞĘåžŞäÿ■çŽĎ sqlite3
æĺąåİŮãĂĆ åęĆæđIJä¡ää¡£çŤÍçŽĎæŸŕäÿĂäÿłäÿ■åŘŇçŽĎæŢřæ■őåžŞ(æŕŤåęĆMySqlãĂĄPostgresqlæĹŰèĂ

è£Ÿå¿Ůåő L’èčĚçŻÿåžŤçŽĎçňňäÿL’æŰźæÍąåİŮæİěæŔŘä¿ŻæŤŕæŇĄãĂĆ
äÿ■è£ĞçŻÿåžŤçŽĎçijŰçÍŃæŐěåŔčåĞääźŐéČ¡æŸŕäÿĂæăůçŽĎïijŇéŹď’äžĘäÿĂçĆźçĆźçżĘå¿őåůőåĹńåď’Ůã

çňňäÿĂæ■ěæŸŕè£đæŐěåĹřæŢřæ■őåžŞãĂĆéĂŽåÿÿä¡äèęĄæL’ğèąŇ `connect()`
åĞ¡æŢřïijŇ çżŹåőČæŔŘä¿ŻäÿĂäžŻæŢřæ■őåžŞåŘ■ãĂĄäÿżæIJžãĂĄçŤÍæĹůåŘ■ãĂĄåŕĘçăĄåŠŇåĚűäżŰå£Ě

```
>>> import sqlite3
>>> db = sqlite3.connect('database.db')
>>>
```

äÿžäžĘåď’ĎçŘĘæŢřæ■őïijŇäÿŃäÿĂæ■ěä¡äéIJĂèęĄåĹŻåżžäÿĂäÿłæÿÿæăĞãĂĆ
äÿĂæŮęä¡äæIJL’äžĘæÿÿæăĞïijŇéĆčäźĹä¡ăåřšåŔŕäžěæL’ğèąŇSQLæ§ěèŕćèŕ■åŘěäžĘãĂĆæŕŤåęĆïijŽ

```
>>> c = db.cursor()
>>> c.execute('create table portfolio (symbol text, shares integer,␣
 ↪price real)')
<sqlite3.Cursor object at 0x10067a730>
>>> db.commit()
>>>
```

äÿžäžĘåŘŚæŢřæ■őåžŞèąĺäÿ■æŘŠåĚěåď’Žæİąèőŕå¡ŢïijŇä¡£çŤĺçśżäijijäÿŃéİćè£ŹæăůçŽĎèŕ■åŘěïijŽ

```
>>> c.executemany('insert into portfolio values (?,?,?)', stocks)
<sqlite3.Cursor object at 0x10067a730>
>>> db.commit()
>>>
```

äÿžäžĘæL’ğèąŇæ§Řäÿłæ§ěèŕćïijŇä¡£çŤĺåČŘäÿŃéİćè£ŹæăůçŽĎèŕ■åŘěïijŽ

```
>>> for row in db.execute('select * from portfolio'):
...     print(row)
...
('GOOG', 100, 490.1)
('AAPL', 50, 545.75)
('FB', 150, 7.45)
('HPQ', 75, 33.2)
>>>
```

åęĆæđIJä¡ăæČşæŐěåŔŮçŤĺæĹůè¿ŞåĚëä¡IJäÿžåŔĆæŢřæİěæL’ğèąŇæ§ěèŕćæŞ■ä¡IJïijŇå£Ěéążçąőä£Ía¡ăä

```
>>> min_price = 100
>>> for row in db.execute('select * from portfolio where price >= ?
 ↪',
                          (min_price,)):
...     print(row)
...
('GOOG', 100, 490.1)
('AAPL', 50, 545.75)
>>>
```

èőÍèőž

åIJÍæŕŤè¿Čä¡ŐçŽĎçžğåĹńäÿŁåŠŇæŢřæ■őåžŞäžď äžŠæŸŕéÍđåÿÿçőĂå■ŢçŽĎãĂĆ
ä¡ăåŘłéIJĂæŘŘä¿ŻSQLèŕ■åŘěåźűèřČçŤÍçŽÿåžŤçŽĎæĺąåÍŮåřśåŘŕäžěæŽť æŰřæĹŰæŘŘåŘŰæŢřæ■őäžĘãĂ
èŹ¡èŕť åęĆæ■ď ïijŇè£ŸæŸŕæIJL äÿĂäžŻæŕŤè¿ČæčŸæĽŃçŽĎçżĘèŁĆéŮőécŸéIJĂèęĄä¡ăéĂŘäÿłåĹŮåĞžåĆ

äÿĂäÿłéŽ¿çĆźæŸŕæŢřæ■őåžŞäÿ■çŽĎæŢřæ■őåŠŇPythonçśžåđŃçŽť æŐěçŽĎæŸăåřĎãĂĆ
åŕźäžŐæŮěæIJ§çśžåđŃïijŇéĂŽåÿÿåŘŕäžěä¡£çŤÍ `datetime` æĺąåÍŮäÿ■çŽĎ `datetime`
åőđä¿ŃïijŇ æĹŰèĂĚåŘŕèČ¡æŸŕ `time` æĺąåÍŮäÿ■çŽĎçşżçž§æŮűéŮť æĹşãĂĆ
åŕźäžŐæŢřå■ŮçśžåđŃïijŇçĽźåĹńæŸŕä¡£çŤÍåĹřåŕŘæŢřçŽĎéĞŚèđ■æŢřæ■őïijŇåŘŕäžěçŤÍ
`decimal` æĺąåÍŮäÿ■çŽĎ `Decimal` åőđä¿ŃæÍěèąĺçď žãĂĆ
äÿ■åźÿçŽĎæŸŕïijŇåŕźäžŐäÿ■åŘŇçŽĎæŢřæ■őåžŞèĂŇèÍĂåĚůä¡ŞæŸăåřĎèğĎåĹŹæŸŕäÿ■äÿĂæăůçŽĎïijŇä¡

åŘęåď ŰäÿĂäÿłæŻť åŁăåď ■æİĆçŽĎéŮőécŸåřśæŸŕSQLèŕ■åŘěå■ŮçňęäÿšçŽĎæđĎéĂããĂĆ
ä¡ăå■ČäÿĞäÿ■èęĄä¡£çŤÍPythonå■ŮçňęäÿšæăijåijŔåŇŰæŞ■ä¡IJçňę(åęĆ%)æĹŰèĂĚ
`.format()` æŰźæşŢæİěåĹŻåżžè£ŹæăůçŽĎå■Ůçňęäÿšã ĂĆ
åęĆæđIJäijăéĂŠçżŹè£ŹäžŻæăijåijŔåŇŰæŞ■ä¡IJçňęçŽĎåĂijæİěèĞłäžŐçŤÍæĹůçŽĎè¿ŞåĚěïijŇéĆčäźĹä¡äçŽ
http://xkcd.com/327)ãĂĆ æ§ěèŕćèŕ■åŘěäÿ■çŽĎéĂŽéĚ■çňę ?
æŇĞçď žåŘŐåŘŕæŢřæ■őåžŞä¡£çŤÍåőČèĞłåůśçŽĎå■ŮçňęäÿšæŻ£æ■ćæIJžåĹűïijŇè£ŹæăůæŻť åŁäçŽĎåőL åł

äÿ■åźÿçŽĎæŸŕïijŇäÿ■åŘŇçŽĎæŢřæ■őåžŞåŘŐåŘřåŕźäžŐéĂŽéĚ■çňęçŽĎä¡£çŤÍæŸŕäÿ■äÿĂæăůçŽĎãĂ
`?` æĹŰ `%s` ïijŇ è£ŸæIJL åĚűäžŰäÿĂäžŻä¡£çŤÍäžĘäÿ■åŘŇçŽĎçňęåŘůïijŇærŤåęĆ:0æĹŰ:1æİěæŇĞçď žåŘĆ
åŘŇæăůçŽĎïijŇä¡ăè£ŸæŸŕå¿ŮåŐżåŘĆèĂČä¡ăä¡£çŤÍçŽĎæŢřæ■őåžŞæĺąåÍŮçŻÿåžŢçŽĎæŰĞæąčãĂĆ
äÿĂäÿłæŢřæ■őåžŞæĺąåÍŮçŽĎ `paramstyle` åšđæĂğåŇĚåŘńäžĘåŘĆæŢřåijŢçŤÍéčŐæäijçŽĎä£ąæĄŕãĂĆ

åŕźäžŐçőĂå■ŢçŽĎæŢřæ■őåžŞæŢřæ■őçŽĎèŕżåĘŹéŮőécŸïijŇä¡£çŤÍæŢřæ■őåžŞAPIéĂŽåÿÿéÍđåÿÿçőĂ
åęĆæđIJä¡äèęĄåď ĎçŘĘæŻť åŁăåď ■æİĆçŽĎéŮőécŸïijŇåżżèőőä¡ăä¡£çŤÍæŻť åŁăénŸçžğçŽĎæŐěåŘčïijŇæí
çśžäijij `SQLAlchemy` è£ŹæăůçŽĎåžŞåĚĄèőÿä¡ăä¡£çŤÍPythonçśžæÍěèąÍçď žäÿĂäÿłæŢřæ■őåžŞèąĺïijŇ
åźűäÿŤèČ¡åIJÍéŽŘèŮŔåžŢåśĆSQLçŽĎæČĚåĘţäÿŇåődçŐřåŘĎçğ■æŢřæ■őåžŞçŽĎæŞ■ä¡IJãĂĆ

8.9 6.9 çijŰçăĄåŠŇèğčçăĄå■ĄåĚ■è£ŻåĹűæŢř

éŮőécŸ

ä¡ăæČşåřĘäÿĂäÿłå■ĄåĚ■è£ŻåĹűå■ŮçňęäÿšèğčçăĄæĹŘäÿĂäÿłå■ŮèŁĆå■ŮçňęäÿšæĹŰèĂĚåřĘäÿĂäÿłå

èğčåĘşæŰźæąĹ

åęĆæđIJä¡ăåŘłæŸŕçőĂå■ŢçŽĎèğčçăĄæĹŰçijŰçăĄäÿĂäÿłå■ĄåĚ■è£ŻåĹűçŽĎåŐ§ågŃå■ŮçňęäÿšïijŇå
æĺąåÍŮãĂĆä¿ŃåęĆïijŽ

```
>>> # Initial byte string
>>> s = b'hello'
>>> # Encode as hex
>>> import binascii
>>> h = binascii.b2a_hex(s)
>>> h
b'68656c6c6f'
```

```
>>> # Decode back to bytes
>>> binascii.a2b_hex(h)
b'hello'
>>>
```

çśżäijijçŽĎåŁ§èČ¡åŘŇæăůåŔŕäżěåIJĺ `base64` æĺąåİŮäÿ■æĽ¿åĹřãĂĆä¿ŃåęĆïijŽ

```
>>> import base64
>>> h = base64.b16encode(s)
>>> h
b'68656C6C6F'
>>> base64.b16decode(h)
b'hello'
>>>
```

èőĺèőž

åď ğéČĺåĹĘæČĚåĘţäÿŃïijŇéĂŽè£Ğä¡£çŤĺäÿŁè£řçŽĎåĞ¡æŢřæİěè¡ňæ■ćå■ĄåĚ■è£ŻåĹűæŸŕå¿ĹçőĂå■Ţäÿ
Łéİćäÿďçğ■æŁĂæIJŕçŽĎäÿżèęĄäÿ■åŘŇåIJĺäžŐåď ğářŔåĘŹçŽĎåď ĎçŘĘãĂĆ
åĞ¡æŢř `base64.b16decode()` åŠŇ `base64.b16encode()`
åŔłèČ¡æŞ■ä¡IJåď ğåĘŹå¡ćåijŔçŽĎå■ĄåĚ■è£ŻåĹűå■Ůæŕ■ïijŇ èĂŇ `binascii`
æĺąåİŮäÿ■çŽĎåĞ¡æŢřåď ğářŔåĘŹéČ¡èČ¡åď ĎçŘĘãĂĆ

è£ŸæIJL'äÿĂçĆźéIJĂèęĄæşĺæĎŔçŽĎæŸŕçijÚçăĄåĞ¡æŢřæL'Ăäžğç Ť§çŽĎè¿ŞåĞžæĂżæŸŕäÿĂäÿłå■Ů
åęĆæđIJæČşåijžåĹűäžěUnicodeå¡ćåijŔè¿ŞåĞžïijŇä¡ăéIJĂèęĄåćđåŁääÿĂäÿłéćİåď ŰçŽĎçŢŇéİćæ■ěéłď ãĂĆ

```
>>> h = base64.b16encode(s)
>>> print(h)
b'68656C6C6F'
>>> print(h.decode('ascii'))
68656C6C6F
>>>
```

åIJĺèğčçăĄå■ĄåĚ■è£ŻåĹűæŢřæŮűïijŇåĞ¡æŢř `b16decode()`
åŠŇ `a2b_hex()` åŔŕäžěæŐěåŔŮå■ŮèŁĆæĹŰunicodeå■Ůçňęäÿšã ĂĆ
ä¡ĘæŸŕïijŇunicodeå■Ůçňęäÿšå£ĚéążäžĚäžĚåŔłåŇĚåŘńASCIIçijŰçăĄçŽĎå■ĄåĚ■è£ŻåĹűæŢřãĂĆ

8.10 6.10 çijŰçăĄèğčçăĄBase64æŢřæ■ő

éŮőécŸ

ä¡ăéIJĂèęĄä¡£çŤĺBase64æăijåijŔèğčçăĄæĹŰçijŰçăĄäžŇè£ŻåĹűæŢřæ■őãĂĆ

èğčåĘşæŰźæąĹ

base64 æĺąåİŮäÿ■æIJL'äÿd'äÿłåĞ¡æŢř b64encode() and b64decode() åŔŕäžěåÿőä¡ăèğčåĘşè£ŹäÿłéŮőécŸãĂĆä¿ŃåęĆ;

```
>>> # Some byte data
>>> s = b'hello'
>>> import base64

>>> # Encode as Base64
>>> a = base64.b64encode(s)
>>> a
b'aGVsbG8='

>>> # Decode from Base64
>>> base64.b64decode(a)
b'hello'
>>>
```

èőÍèőž

Base64çijŰçăĄäžĚäžĚçŤÍäžŐéÍćåŘŚå■ŮèŁĆçŽĎæŢřæ■őærŤåęĆå■ŮèŁĆå■ŮçňęäÿšåŠŇå■ŮèŁĆæŢřçż
æ■d'åd'ŰïijŇçijŰçăĄåd'ĎçŘĘçŽĎè¿ŞåĞžçżŞæđIJæĂżæŸŕäÿĂäÿłå■ŮèŁĆå■Ůçňęäÿšã ĂĆ
åęĆæđIJä¡ăæČşæůůåŘĹä¡£çŤÍBase64çijŰçăĄçŽĎæŢřæ■őåŠŇUnicodeæŰĞæIJñïijÑä¡ăå£ĚéążæůżåŁääÿĂä

```
>>> a = base64.b64encode(s).decode('ascii')
>>> a
'aGVsbG8='
>>>
```

å¡Şèğčçă ĄBase64çŽĎæŮűåĂŹïijŇå■ŮèŁĆå■Ůçňęäÿšå ŠŇUnicodeæŰĞæIJñéČ¡åŔŕäžěä¡IJäÿžåŔĆæŢřă
ä¡ĘæŸŕïijŇUnicodeå■Ůçňęäÿšå ŘłèČ¡åŇĚåŘńASCIIå■Ůçňęã ĂĆ

8.11 6.11 èŕžåĘŹäžŇè£ŻåĹűæŢřçżĎæŢřæ■ő

éŮőécŸ

ä¡ăæČşèŕžåĘŹäÿĂäÿłäžŇè£ŻåĹűæŢřçżĎçŽĎçżŞæđĎåŇŰæŢřæ■őåĹřPythonåĚČçżĎäÿ■ãĂĆ

èğčåĘşæŰźæąĹ

åŔŕäžěä¡£çŤÍ struct æĺąåİŮåd'ĎçŘĘäžŇè£ŻåĹűæŢřæ■õã ĂĆ
äÿŃéÍćæŸŕäÿĂæőţçd'žä¿ŃäżčçăĄåřĘäÿĂäÿłPythonåĚČçżĎåĹŮèąĺåĘŹåĚěäÿĂäÿłäžŇè£ŻåĹűæŰĞäżűïijÑå
struct åřĘæŕŘäÿłåĚČçżĎçijŰçăĄäÿžäÿĂäÿłçżŞæđĎä¡ŞãĂĆ

```
from struct import Struct
def write_records(records, format, f):
    '''
    Write a sequence of tuples to a binary file of structures.
    '''
    record_struct = Struct(format)
    for r in records:
        f.write(record_struct.pack(*r))

# Example
if __name__ == '__main__':
    records = [ (1, 2.3, 4.5),
                (6, 7.8, 9.0),
                (12, 13.4, 56.7) ]
    with open('data.b', 'wb') as f:
        write_records(records, '<idd', f)
```

æIJL'å¿Ĺåd'Žçğ■æŰźæşŢæİěèŕžåŔŰè£ŹäýłæŰĞäžűåźűè£ŤåŻđäÿĂäýłåĚČçżĎåĹŮèąĺãĂĆ
éęŰåĚĹïijŇåęĆæđIJä¡ăæĽŞçőŮäžěåİŮçŽĎå¡ćåijŔåćđéĞŔèŕžåŔŰæŰĞäžűïijŇä¡ăåŔŕäžěè£ŹæăůåĄŽïijŽ

```
from struct import Struct

def read_records(format, f):
    record_struct = Struct(format)
    chunks = iter(lambda: f.read(record_struct.size), b'')
    return (record_struct.unpack(chunk) for chunk in chunks)

# Example
if __name__ == '__main__':
    with open('data.b','rb') as f:
        for rec in read_records('<idd', f):
            # Process rec
            ...
```

åęĆæđIJä¡ăæČşåřĘæŢťäýłæŰĞäžűäÿĂæňąæĂğèŕžåŔŰåĹřäÿĂäýłå■ŮèŁĆå■Ůçňęäÿšäÿ■ïijŇçĎűåŘŐåĽ

```
from struct import Struct

def unpack_records(format, data):
    record_struct = Struct(format)
    return (record_struct.unpack_from(data, offset)
            for offset in range(0, len(data), record_struct.size))

# Example
if __name__ == '__main__':
    with open('data.b', 'rb') as f:
        data = f.read()
    for rec in unpack_records('<idd', data):
        # Process rec
        ...
```

äÿd'çğ■æČĚåĘţäÿŃçŽĎçżŞæđIJéČ¡æŸŕäÿĂäÿłåŔŕè£ŤåŻđçŤĺæİěåĹŻåżžèŕěæŰĞäžűçŽĎåŐ§ågŃåĚČçž

èőÍèőž

åŕźäžŐéIJĂèęĄçijŰçăĄåŠŇèğčçăĄäžŇè£ŻåĹűæŢřæ■őçŽĎçÍŃåžŔèĂŇèÍĂïijŇéĂŽåÿÿäijŽä¡£çŤÍ `struct` æÍąåİŮãĂĆ äÿžäžĘåčřæŸŐäÿĂäÿłæŰřçŽĎçżŞæđĎä¡Şïij ŇåŔłéIJĂèęĄåČŔè£ŹæăůåĹŻåżžäÿĂäÿł `Struct` åőđä¿Ńå■şåŔŕïijŽ

```
# Little endian 32-bit integer, two double precision floats
record_struct = Struct('<idd')
```

çżŞæđĎä¡ŞéĂŽåÿÿäijŽä¡£çŤÍäÿĂäžŻçżŞæđĎçăĄåĂiji, d, fç■L' [åŔĆèĂČ PythonæŰĞæąč]ãĂĆ è£ŹäžŻäžčçăĄåĹĘåĹńäžčèąÍæ§ŘäÿłçL'źåőŽçŽĎäžŇè£ŻåĹűæŢřæ■őçśżåđŃåęĆ32ä¡■a çňňäÿĂäÿłå■Ůçňę < æŇĞåőŽäžEå■ŮèŁĆéąžåžŔãĂĆåIJÍè£ŹäÿłäżŃå■Řäÿ■ïijŇåőČèąÍçđ'žâĂÍä¡Őä¡■åIJÍåL'■ æŻť'æŤźè£Źäÿłå■Ůçňęäÿž > èąÍçđ'žéńŸä¡■åIJÍåL'■ïijŇæĹŰèĂĚæŸŕ ! èąÍçđ'žç¡ŚçżIJå■ŮèŁĆéąžåžŔãĂĆ

äžğçŤ§çŽĎ `Struct` åőđä¿ŃæIJL'å¿Ĺåđ'Žåśđæ ĂğåŠŇæŰźæşŢçŤÍæÍěæŞ■ä¡IJçŻÿåžŤçśżåđŃçŽĎçżŞæđ `size` åśđæĂğåŇĚåŘńäžEçżŞæđĎçŽĎå■ŮèŁĆæŢřïijŇè£ŹåIJÍI/OæŞ■ä¡IJæŰűéİđåÿÿæIJL'çŤÍãĂĆ `pack()` åŠŇ `unpack()` æŰźæşŢèćńçŤÍæÍěæL'ŞåŇĚåŠŇèğčåŇĚæŢřæ■õãĂĆæŕŤåęĆïijŽ

```
>>> from struct import Struct
>>> record_struct = Struct('<idd')
>>> record_struct.size
20
>>> record_struct.pack(1, 2.0, 3.0)
b
 ↪'\x01\x00\x00\x00\x00\x00\x00\x00\x00\x00@\x00\x00\x00\x00\x00\x00\x08@
 ↪'
>>> record_struct.unpack(_)
(1, 2.0, 3.0)
>>>
```

æIJL'æŮűåĂŹä¡àè£ŸäijŽçIJŃåĹř `pack()` åŠŇ `unpack()` æŞ■ä¡IJäžěæÍąåİŮçžğåĹńåĞ¡æŢřèćńěřČçŤÍïijŇçśžäijijäÿŃéİćè£ŹæăůïijŽ

```
>>> import struct
>>> struct.pack('<idd', 1, 2.0, 3.0)
b
 ↪'\x01\x00\x00\x00\x00\x00\x00\x00\x00\x00@\x00\x00\x00\x00\x00\x00\x08@
 ↪'
>>> struct.unpack('<idd', _)
(1, 2.0, 3.0)
>>>
```

è£ŹæăůåŔŕäžěåůěä¡IJïijŇä¡ĘæŸŕæĎ§èğL'æšąæIJL'åőđä¿ŃæŰźæşŢéĆčäźĹäijŸéŻĚïijŇçL'źåĹńæŸŕåIJÍà éĂŽè£ĞåĹŻåžžäÿĂäÿł `Struct` åőđä¿ŃïijŇæäijåijŔäžčçăĄåŔłäijŽæŇĞåőŽäÿĂæňąåźűäÿŤæL'ĂæIJL'çŽĎæ è£ŹæăůäÿĂæİěäžčçăĄçżť'æŁď'åŕśåŔŸå¿ŮæŻť'åŁăçőĂå■ŢäžĘ(åŽääÿžä¡ääŔłéIJĂèęĄæŤźåŔŸäÿĂåď'ĎäžčçăĄ

èŕžåŔŰäžŇè£ŻåĹűçžŞæđĎçŽĎäžčçăĄèęĄçŤÍåĹřäÿĂäžŻéİđåÿÿæIJL'èűčèĂŇäijŸç¿ŐçŽĎçijŰçÍŃæŁĂ

åIJÍåĞ¡æŢřãĂĂread_recordsäÿ■ïijÑiter()èćńçŢÍæİěåĹŻåżžäÿĂäÿłè£ŤåŻđåŻžåőŽåď ğåřŔæŢřæ■őå
è£ŹäÿłèŁ■äžčåŹÍäijŽäÿ■æŰ■çŽĎěřČçŢÍäÿĂäÿłçŢÍæĹůæŔŘä¿ŻçŽĎåŔŕèřČçŢÍåŕźèśą(æŕŤåęĆ
lambda: f.read(record_struct.size))ïijÑ çŻť åĹřåőČè£ŤåŻđäÿĂäÿłçL'źæőŁçŽĎåĂij(åęĆbâ

```
>>> f = open('data.b', 'rb')
>>> chunks = iter(lambda: f.read(20), b'')
>>> chunks
<callable_iterator object at 0x10069e6d0>
>>> for chk in chunks:
... print(chk)
...
b'\x01\x00\x00\x00ffffff\x02@\x00\x00\x00\x00\x00\x00\x12@'
b'\x06\x00\x00\x00333333\x1f@\x00\x00\x00\x00\x00\x00"@'
b'\x0c\x00\x00\x00\xcd\xcc\xcc\xcc\xcc\xcc*@\x9a\x99\x99\x99\x99YL@'
>>>
```

åęĆä¡ăæL'ĂèğĄïijÑåĹŻåżžäÿĂäÿłåŔŕè£■äžčåŕźèśąçŽĎäÿĂäÿłåŐ§åŻăæŸŕåőČèČ¡åĚĄèőÿä¡£çŤÍäÿĂäÿ
åęĆæđIJä¡ăäÿ■ä¡£çŤÍè£ŹçğæŁĂæIJŕïijÑéĆčäźĹäžčçăĄåŔŕèČ¡äijŽåČŔäÿÑéİćè£ŹæăůïijŽ

```
def read_records(format, f):
    record_struct = Struct(format)
    while True:
        chk = f.read(record_struct.size)
        if chk == b'':
            break
        yield record_struct.unpack(chk)
```

åIJÍåĞ¡æŢř unpack_records() äÿ■ä¡£çŤÍäžĘåŔęåď ŰäÿĂçğ■æŰźæşŢ
unpack_from() ãĂĆunpack_from() åŕźäžŐäżŐäÿĂäÿłåď ğåđÑäžŇè£ŻåĹűæŢřçžĎäÿ■æŔŘåŔŰäžŇè
åŻăäÿžåőČäÿ■äijŽäžğçŢ§äżżä¡ŢçŽĎäÿť æŮűåŕźèśąæĹŰèĂĚè£ŻèąŇåĘĚå■Ÿåď ■åĹűæŞ■ä¡IJãĂĆ
ä¡ăåŘłéIJĂèęĄçżŹåőČäÿĂäÿłå■ŮèŁĆå■Ůçňęäÿš(æĹŰæŢřçžĎ)åŠŇäÿĂäÿłå■ŮèŁĆåĄŔçğżéĞŕïijÑåőČäijŽ

åęĆæđIJä¡ăä¡£çŤÍ unpack() æİěäžčæŻ£ unpack_from() ïijÑ
ä¡ăéIJĂèęĄä£őæŤźäżčçăĄæİěæđĎéĂăåď ğéĞŔçŽĎåřŔçŽĎåĹĞçL'Ğäžěåŕŀè£ŻèąŇåĄŔçğżéĞŔçŽĎèőąçőŮ

```
def unpack_records(format, data):
    record_struct = Struct(format)
    return (record_struct.unpack(data[offset:offset + record_struct.
↪size])
            for offset in range(0, len(data), record_struct.size))
```

è£Źçğ■æŰźæąĹéŹď'äžĘäżčçăĄçIJŃäÿŁåŐżå¿Ĺåď ■æİĆåď ŰïijÑè£Ÿå¿ŮåĄŽå¿Ĺåď ŽéćÍåď ŰçŽĎåůěä¡Ł
åď ■åĹűæŢřæ■őäžěåŔŁædĎéĂăåřŔçŽĎåĹĞçL'ĞåŕźèśąãĆ åęĆæđIJä¡ăåĞĘåď ĞäżŐèŕżåŔŰåĹŕçŽĎäÿĂäÿłå
äijŽèąĺçŐřçŽĎæŻť åĞžèL'šãĂĆ

åIJÍèğčåŇĚçŽĎæŮűåĂŹïijÑcollections æĺąåİŮäÿ■çŽĎåŚ¡åŘ■åĚČçżĎåŕźèśąæĹŰèőÿæŸŕä¡ăæČşè
åőČåŔŕäžěèől'ä¡ăçżŹè£ŤåŻđåĚČçżĎèő¿ç¡őåśđæĂğåŘ■çğřãĆä¿ŃåęĆïijŽ

```
from collections import namedtuple

Record = namedtuple('Record', ['kind','x','y'])
```

```
with open('data.p', 'rb') as f:
    records = (Record(*r) for r in read_records('<idd', f))

for r in records:
    print(r.kind, r.x, r.y)
```

åęĆædIJä¡ăçŽĎçÍŃåžŔéIJĂèęĄåď'ĎçŘĘåď'ğéĞŔçŽĎäžŇè£ŻåĹűæŢřæ■őïijŇä¡ăæIJĂåě¡ä¡£çŤÍ
numpy æÍąåİŮãĂĆ ä¿ŃåęĆïijŇä¡ăåŔŕäžěårĘäÿĂäÿłäžŇè£ŻåĹűæŢřæ■õèŕżåŔŰåĹřäÿĂäÿłçżŞædĎåŇŰæŢřçż

```
>>> import numpy as np
>>> f = open('data.b', 'rb')
>>> records = np.fromfile(f, dtype='<i,<d,<d')
>>> records
array([(1, 2.3, 4.5), (6, 7.8, 9.0), (12, 13.4, 56.7)],
dtype=[('f0', '<i4'), ('f1', '<f8'), ('f2', '<f8')])
>>> records[0]
(1, 2.3, 4.5)
>>> records[1]
(6, 7.8, 9.0)
>>>
```

æIJĂåŘŐæŔŘäÿĂçĆźïijŇåęĆædIJä¡ăéIJĂèęĄäżŐåůšç§ěçŽĎæŰĞäżűæăijåijŔ(åęĆåŻ¿çL'ĞæăijåijŕïijŇ
åĚĹæčĂæ§ěçIJŃçIJŃPythonæŸŕäÿ■æŸŕåůšçżŔæŔŘä¿ŻäžEçŐŕå■ŸçŽĎæĺąåİŮãĂĆåŻăäÿžäÿ■åĹřäÿĞäÿ■å¿

8.12 6.12 èŕżåŔŰåţŇåěŮåŠŇåŔŕåŔŸéŢ£äžŇè£ŻåĹűæŢřæ■ő

éŮőécŸ

ä¡ăéIJĂèęĄèŕżåŔŰåŇĚåŘńåţŇåěŮæĹŰèĂĚåŔŕåŔŸéŢ£èőŕå¡ŢéŻĘåŘĹçŽĎåď'■æİĆäžŇè£ŻåĹűæăijåijŔ

èğčåĘşæŰźæąĹ

struct æÍąåİŮåŔŕèćńçŤÍæİěçijŰçăĄ/èğčçăĄåĞääźŐæL'ĂæIJL'çśżåđŃçŽĎäžŇè£ŻåĹűçŽĎæŢřæ■őçż
æİěèąÍçď'žäÿĂäÿłçżĎæĹŘäÿĂçşżåĹŮåď'Žè¿źå¡ćçŽĎçĆźçŽĎéŻĘåŘĹïijŽ

```
polys = [
    [ (1.0, 2.5), (3.5, 4.0), (2.5, 1.5) ],
    [ (7.0, 1.2), (5.1, 3.0), (0.5, 7.5), (0.8, 9.0) ],
    [ (3.4, 6.3), (1.2, 0.5), (4.6, 9.2) ],
]
```

çŐřåIJÍåĄĞèő¿è£ŹäÿłæŢřæ■õèćńçijŰçăĄåĹřäÿĂäÿłäżěäÿŃåĹŮåď't'éČĺåijĂåğŃçŽĎäžŇè£ŻåĹűæŰĞäż

```
+------+--------+-----------------------------------+
|Byte  | Type   |  Description                      |
+======+========+===================================+
|0     | int    |  æŰĞäżűäżčçăĄïijĹ0x1234ïijŇåřŔçńŕïijL'          |
```

```
+------+--------+-----------------------------------+
|4     | double |  x çŽĎæIJĂåřŕåĂijïijĺåřŕçńŕïijL’                |
+------+--------+-----------------------------------+
|12    | double |  y çŽĎæIJĂåřŕåĂijïijĺåřŕçńŕïijL’                |
+------+--------+-----------------------------------+
|20    | double |  x çŽĎæIJĂåd’ğåĂijïijĺåřŕçńŕïijL’                 |
+------+--------+-----------------------------------+
|28    | double |  y çŽĎæIJĂåd’ğåĂijïijĺåřŕçńŕïijL’                 |
+------+--------+-----------------------------------+
|36    | int    |  äÿL’èğŠå¡ćæŢřéĞŕïijĺåřŕçńŕïijL’                |
+------+--------+-----------------------------------+
```

çt’ğèů§çİĂåd’t’éČĺæŸŕäÿĂçşżåĹŮçŽĎåd’Žè¿źå¡ćèőřå¡ŢïijŇçijŰçăĄæăijåijŔåęĆäÿŃïijŽ

```
+------+--------+-----------------------------------------+
|Byte  | Type   |  Description                            |
+======+========+=========================================+
|0     | int    |  èőřå¡ŢéŢ£åžęïijĺNå■ŮèŁĆïijL’                 ⌟
 ↪  |
+------+--------+-----------------------------------------+
|4-N   | Points |  (X,Y) åİŘæăĞïijŇäżěætőçĆźæŢřèąÍçd’ž          ⌟
 ↪   |
+------+--------+-----------------------------------------+
```

äÿžäžĘåĘŹè£ŹæăůçŽĎæŰĞäżűïijŇä¡ääŔŕäžěä¡£çŤĺåęĆäÿŃçŽĎPythonäžčçăĄïijŽ

```
import struct
import itertools

def write_polys(filename, polys):
    # Determine bounding box
    flattened = list(itertools.chain(*polys))
    min_x = min(x for x, y in flattened)
    max_x = max(x for x, y in flattened)
    min_y = min(y for x, y in flattened)
    max_y = max(y for x, y in flattened)
    with open(filename, 'wb') as f:
        f.write(struct.pack('<iddddi', 0x1234,
                            min_x, min_y,
                            max_x, max_y,
                            len(polys)))
        for poly in polys:
            size = len(poly) * struct.calcsize('<dd')
            f.write(struct.pack('<i', size + 4))
            for pt in poly:
                f.write(struct.pack('<dd', *pt))
```

åřĘæŢřæ■őèŕžåŔŮåŻđæİěçŽĎæŮűåĂŹïijŇåŔŕäžěåĹľçŤĺåĞ¡æŢř `struct.unpack()` ïijŇäžčçăĄå¿ĹçŻÿäijijïijŇå§žæIJňářśæŸŕäÿŁéİćåĘŹæŞ■ä¡IJçŽĎéĂĘåžŔãĂĆåęĆäÿŃïijŽ

```
def read_polys(filename):
    with open(filename, 'rb') as f:
        # Read the header
        header = f.read(40)
        file_code, min_x, min_y, max_x, max_y, num_polys = \
            struct.unpack('<iddddi', header)
        polys = []
        for n in range(num_polys):
            pbytes, = struct.unpack('<i', f.read(4))
            poly = []
            for m in range(pbytes // 16):
                pt = struct.unpack('<dd', f.read(16))
                poly.append(pt)
            polys.append(poly)
    return polys
```

åř¡çőąè£Źäÿłäžčçă Ąå Ŕŕäžěåůěä¡IJïijŇä¡EæŸŕéĞŇéİćæůůæİĆäžEå¿Ĺåď Žèŕžå ŔŰãĂĄèğčå ŇĚæŢřæ■őçž
éĆčæIJłåĚ■äź§åď łçźĄæİĆäžEçĆźãĂĆåŻäæ■ď å¿ĹæŸ¿çĎűåžŤèřěæIJL’åŘęäÿĂçğ■èğčåEşæŰźæşŢåŔŕäžěçő

åIJÍæIJňářŔèŁĆæŐěäÿŃæİěçŽĎéČĺåĹĘïijŇæĹŚäijŽéĂŘæ■ěæijŤçď žäÿĂäÿłæŻť åŁääijŸçğĂçŽĎèğčæd
çŻőæăĞæŸŕåŔŕäžěçżŹçÍŃåžŔåŚŸæŔŘä¿ŻäÿĂäÿłéńŸçžğçŽĎæŰĞäžűæăijåijŔåŇŰæŰźæşŢïijŇåźűçőĂåŇŰ
æIJňářŔèŁĆæŐěäÿŃæİěçŽĎéČĺåĹĘäžčçăĄåžŤèřěæŸŕæŢť æIJňäźęäÿ■æIJĂåď■æİĆæIJĂénŸçžğçŽĎä¿Ńå■İ
äÿĂåőŽèęĄäżŤçżEçŽĎéŸĚèŕżæĹŚäžňçŽĎèőÍèőžéČĺåĹĘïijŇåŔęåď Űäź§èęĄåŔĆèĂČäÿŃåĚűäžŰçńäèŁĆåĘ

éęŰåĚĹïijŇå¡Şèŕżå ŔŰå■ŮèŁĆæŢřæ■őçŽĎæŮűåĂŹïijŇéĂŽåÿÿåIJÍæŰĞäžűåijĂågŃéČĺåĹĘäijŽåŇĚåŘ
åř¡çőąstructæÍąåİŮåŔŕäžěèğčåŇĚè£ŹäžŻæŢřæ■őåĹřäÿĂäÿłåĚČçżĎäÿ■åŐžïijŇåŔęåď ŰäÿĂçğ■èąÍçď žè£ŹçğĄ
åřšåČŔäÿŃéİćè£ŹæăůïijŽ

```
import struct

class StructField:
    '''
    Descriptor representing a simple structure field
    '''
    def __init__(self, format, offset):
        self.format = format
        self.offset = offset
    def __get__(self, instance, cls):
        if instance is None:
            return self
        else:
            r = struct.unpack_from(self.format, instance._buffer,␣
↪self.offset)
            return r[0] if len(r) == 1 else r

class Structure:
    def __init__(self, bytedata):
        self._buffer = memoryview(bytedata)
```

è£ŹéĞŇæĹŚäžňä¡£çŤÍäžĘäÿĂäÿłæŔŘè£řåŹÍæİěèąÍçď žærŔäÿłçżŞædĎå■ŮæőţïijŇærŔäÿłæŔŘè£řåŹÍåŇ
å■ŸåĆÍåIJÍåĘĚéČÍçŽĎåĘĚå■ŸçijŞåĘšäÿ■ãĂĆåIJÍ `__get__()` æŰźæşŢäÿ■ïijŇstruct.

unpack_from() åĞ¡æŢřèćńçŤĺæİěäżŐçijŞåĘšäÿ■èğčåŇĚäÿĂäÿłåĂijïijŇçIJĄåŐżäžĘéćİåď ŰçŽĎåĹĘçL’Č

Structure çśżåřśæŸŕäÿĂäÿłå§žçąĂçśżïijŇæŐěåŔŮå■ŮèŁĆæŢřæ■őåźűå■ŸåĆĺåIJĺåĘĚéČĺçŽĎåĘĚå■ StructField æŔŔè£řåŹĺä¡£çŤĺãĂĆ è£ŹéĞŇä¡£çŤĺäžĘ memoryview() ïijŇæĹŚäżñäijŽåIJĺåŘŐéİćèřęçżĘèőšèğčåőČæŸŕçŤĺæİěåźšåŸŻçŽĎãĂĆ

ä¡£çŤĺè£ŹäÿłäżčçăĄïijŇä¡ăçŐřåIJĺåřśèČ¡åőŽäźĽäÿĂäÿłénŸåśĆæňąçŽĎçżŞæđĎåŕźèśąæİěèąĺçd’žäÿŁéİ

```
class PolyHeader(Structure):
    file_code = StructField('<i', 0)
    min_x = StructField('<d', 4)
    min_y = StructField('<d', 12)
    max_x = StructField('<d', 20)
    max_y = StructField('<d', 28)
    num_polys = StructField('<i', 36)
```

äÿŃéİćçŽĎä¿Ńå■ŘåĹl’çŤĺè£ŹäÿłçśżæİěèŕżåŔŰäźŃåĽ’■æĹŚäżňåĘŹåĚěçŽĎåď Žè¿źå¡ćæŢřæ■őçŽĎåď t’

```
>>> f = open('polys.bin', 'rb')
>>> phead = PolyHeader(f.read(40))
>>> phead.file_code == 0x1234
True
>>> phead.min_x
0.5
>>> phead.min_y
0.5
>>> phead.max_x
7.0
>>> phead.max_y
9.2
>>> phead.num_polys
3
>>>
```

è£Źäÿłå¿ĹæIJL’èűčïijŇäÿ■è£Ğè£ŹçğæŰźåijŔè£ŸæŸŕæIJL’äÿĂäžŽçČęäžžçŽĎåIJřæŰźãĂĆéęŰåĚĹïijŇ ä¡ĘæŸŕè£ŹäÿłäżčçăĄè£ŸæŸŕæIJL’çĆźèĞČèĆ£ïijŇè£ŸéIJĂèęĄä¡£çŤĺèĂĚæŇĞåőŽå¿Ĺåď ŽåžŢåśĆçŽĎçżĘ StructFieldïijŇæŇĞåőŽåĄŔçğźéĞŔç■L’)ãĂĆ åŔęåď ŰïijŇè£ŤåŻđçŽĎçżŞæđIJçśżåŘŇæăůçąőåőđäÿĂä

äżżä¡ŢæŮűåĂŹåŔłèęĄä¡ăéĄĞåĹřäžĘåČŔè£ŹæăůåĘŮä¡ŹçŽĎçśżåőŽäźĽïijŇä¡ăåžŤèŕěèĂČèŹŚäÿŃä¡£ç åĚČçśżæIJL’äÿĂäÿłçL’źæĂğåŕśæŸŕåőČèČ¡åď §ècńçŤĺæİěåąńåĚĚèõÿåď Žä¡ŐåśĆçŽĎåőđçŐřçżĘèŁĆïijŇäžŐ äÿŃéİćæĹŚæİěäÿ¿äÿłä¿Ńå■ŘïijŇä¡£çŤĺåĚČçśżçĺ■å¿őæŤźéĂääÿŃæĹŚäžńçŽĎ Structure çśżïijŽ

```
class StructureMeta(type):
    '''
    Metaclass that automatically creates StructField descriptors
    '''
    def __init__(self, clsname, bases, clsdict):
        fields = getattr(self, '_fields_', [])
        byte_order = ''
        offset = 0
        for format, fieldname in fields:
```

```
            if format.startswith(('<','>','!','@')):
                byte_order = format[0]
                format = format[1:]
            format = byte_order + format
            setattr(self, fieldname, StructField(format, offset))
            offset += struct.calcsize(format)
        setattr(self, 'struct_size', offset)

class Structure(metaclass=StructureMeta):
    def __init__(self, bytedata):
        self._buffer = bytedata

    @classmethod
    def from_file(cls, f):
        return cls(f.read(cls.struct_size))
```

ä¡£çŤĺæŰřçŽĎ `Structure` çśžïijŇä¡ååŔŕäžěåČŔäÿŃéİćè£ŹæăůåőŽäźL’äÿĂäÿłçżŞæđĎïijŽ

```
class PolyHeader(Structure):
    _fields_ = [
        ('<i', 'file_code'),
        ('d', 'min_x'),
        ('d', 'min_y'),
        ('d', 'max_x'),
        ('d', 'max_y'),
        ('i', 'num_polys')
    ]
```

æ■čåęĆä¡ăæL’ĂèğĄïijŇè£ŹæăůåĘŹåřśçőĂå■Ţåd’ŽäžĘãĂĆæĹŚäžňæůżåŁăçŽĎçśżæŰźæşŢ `from_file()` èőľ’æĹŚäžňåIJĺäÿ■éIJĂèęĄç§ěéĄŞäžżä¡ŢæŢřæ■őçŽĎåd’ğářŔåŠŇçżŞæđĎçŽĎæČĚåĘţäÿŃă

```
>>> f = open('polys.bin', 'rb')
>>> phead = PolyHeader.from_file(f)
>>> phead.file_code == 0x1234
True
>>> phead.min_x
0.5
>>> phead.min_y
0.5
>>> phead.max_x
7.0
>>> phead.max_y
9.2
>>> phead.num_polys
3
>>>
```

äÿĂæŮęä¡ăâijĂâğŃä¡£çŤĺäžĘåĚČçśżïijŇä¡ăâřśåŔŕäžěèőľ’åőČåŔŸå¿ŮæŻt’åŁăæŹžèČ¡ãĂĆä¿ŃåęĆïijŇåäÿŃéİćæŸŕåŕźåL’■éİćåĚČçśżçŽĎäÿĂäÿłåřŔçŽĎæŤźè£ŻïijŇæŔŘä¿ŻäžĘäÿĂäÿłæŰřçŽĎè¿ĚåŁl’æŔŔè£řåŹĺa

```
class NestedStruct:
    '''
    Descriptor representing a nested structure
    '''
    def __init__(self, name, struct_type, offset):
        self.name = name
        self.struct_type = struct_type
        self.offset = offset

    def __get__(self, instance, cls):
        if instance is None:
            return self
        else:
            data = instance._buffer[self.offset:
                                    self.offset+self.struct_type.struct_
↪size]
            result = self.struct_type(data)
            # Save resulting structure back on instance to avoid
            # further recomputation of this step
            setattr(instance, self.name, result)
            return result

class StructureMeta(type):
    '''
    Metaclass that automatically creates StructField descriptors
    '''
    def __init__(self, clsname, bases, clsdict):
        fields = getattr(self, '_fields_', [])
        byte_order = ''
        offset = 0
        for format, fieldname in fields:
            if isinstance(format, StructureMeta):
                setattr(self, fieldname,
                        NestedStruct(fieldname, format, offset))
                offset += format.struct_size
            else:
                if format.startswith(('<','>','!','@')):
                    byte_order = format[0]
                    format = format[1:]
                format = byte_order + format
                setattr(self, fieldname, StructField(format,␣
↪offset))
                offset += struct.calcsize(format)
        setattr(self, 'struct_size', offset)
```

åIJÍè£ŹæőţäžčçăĄäÿ■ïijŇNestedStruct æŔŔè£řåŹÍèćńçŤÍæÌěåŔäåŁäåŔęåd'ŰäÿĂäÿłåőŽäźL'åIJÍæ§
åőČéĂŽè£ĞåřĘåŐ§åğŃåĘĚå■ŸçijŞåĘšè£Žèą ŇåĽĞçL'ĞæŞ■ä¡IJåŘŐåőđä¿ŃåŇŰçżŹåőŽçŽĎçżŞæđĎçśžåđŇ
æL'Ăäžěè£Źçğ■åĽĞçL'ĞæŞ■ä¡IJäÿ■äijŽåijŢåŔŚäżżä¡ŢçŽĎéćÌåd'ŰçŽĎåĘĚå■Ÿåd'■åĹűãĂĆçŻÿåŔ■ïijŇåőČ
åŔęåd'ŰïijŇäÿžäžĘéŸšæ■ćéĞ■åd'■åőđä¿ŃåŇŰïijŇéĂŽè£Ğä¡£çŤĺåŠŇ8.10åřŔèŁĆåŘŇæăůçŽĎæŁĂæIJřïijŇ

ä¡£çŤÍè£ŹäÿłæŰřçŽĎä£őæ■čçL'ĹïijŇä¡ăářšåŔřäžěåČŔäÿŃéÍćè£ŹæăůçijŰåĘŹïijŽ

```
class Point(Structure):
    _fields_ = [
        ('<d', 'x'),
        ('d', 'y')
    ]

class PolyHeader(Structure):
    _fields_ = [
        ('<i', 'file_code'),
        (Point, 'min'), # nested struct
        (Point, 'max'), # nested struct
        ('i', 'num_polys')
    ]
```

äžd'äžžæČŁèőűçŽĎæŸŕřijŇåőČäź§èČ¡æŇL'çĚğéćĎæIJ§çŽĎæ■čåÿÿåůëä¡IJïijŇæĹŚäžňåőđéŹĚæŞ■ä¡IJ

```
>>> f = open('polys.bin', 'rb')
>>> phead = PolyHeader.from_file(f)
>>> phead.file_code == 0x1234
True
>>> phead.min # Nested structure
<__main__.Point object at 0x1006a48d0>
>>> phead.min.x
0.5
>>> phead.min.y
0.5
>>> phead.max.x
7.0
>>> phead.max.y
9.2
>>> phead.num_polys
3
>>>
```

åĹřçŽőåL'■äÿžæ■ćïijŇäÿĂäÿłåď'ĎçŘĘåőŽéŢ£èőřå¡ŢçŽĎæąĘæđűåůšçżŔåĘŹåě¡äžĘãĂĆä¡ĘæŸŕåęĆæđI
æŕŤåęĆïijŇåď'Žè¿źå¡ćæŰĞäžűåŇĚåŘńåŔŸéŢ£çŽĎéČĺåĹĘãĂĆ

äÿĂçğ■æŰźæąĹæŸŕåĘŹäÿĂäÿłçśżæİěèąÍçď'žå■ŮèŁĆæŢřæ■őïijŇåŘŇæŮűåĘŹäÿĂäÿłåůëåĚůåĞ¡æŢřæ

```
class SizedRecord:
    def __init__(self, bytedata):
        self._buffer = memoryview(bytedata)

    @classmethod
    def from_file(cls, f, size_fmt, includes_size=True):
        sz_nbytes = struct.calcsize(size_fmt)
        sz_bytes = f.read(sz_nbytes)
        sz, = struct.unpack(size_fmt, sz_bytes)
        buf = f.read(sz - includes_size * sz_nbytes)
        return cls(buf)
```

```
    def iter_as(self, code):
        if isinstance(code, str):
            s = struct.Struct(code)
            for off in range(0, len(self._buffer), s.size):
                yield s.unpack_from(self._buffer, off)
        elif isinstance(code, StructureMeta):
            size = code.struct_size
            for off in range(0, len(self._buffer), size):
                data = self._buffer[off:off+size]
                yield code(data)
```

çśżæŰźæşŢ `SizedRecord.from_file()` æŸŕäÿĂäÿłåůěåĚůïijŇçŤĺæĺěäżŐäÿĂäÿłæŰĞäžűäÿ■èŕżå
è£Źäź§æŸŕå¿Ĺåď˙ŽæŰĞäžűæäijåijŔåÿÿçŤĺçŽĎæŰźåijŔãĂĆä¡IJäÿžè¿ŞåĚěïijŇåőČæŐěåŔŮäÿĂäÿłåŇĚåŘńå
åŔŕéĂĽçŽĎ `includes_size` åŔĆæŢřæŇĞåőŽäžĘå■ŮèŁĆæŢřæŸŕåŘęåŇĚåŘńåď˙ťéČĺåď˙ğářŔãĂĆ
äÿŇéĺćæŸŕäÿĂäÿłä¿Ńå■ŘæŢŹä¡äæĂŐæăůä¡£çŤĺäżŐåď˙Žè¿źå¡ćæŰĞäžűäÿ■èŕżåŔŰå■ŢçŇńçŽĎåď˙Žè¿źå¡ća

```
>>> f = open('polys.bin', 'rb')
>>> phead = PolyHeader.from_file(f)
>>> phead.num_polys
3
>>> polydata = [ SizedRecord.from_file(f, '<i')
...              for n in range(phead.num_polys) ]
>>> polydata
[<__main__.SizedRecord object at 0x1006a4d50>,
<__main__.SizedRecord object at 0x1006a4f50>,
<__main__.SizedRecord object at 0x10070da90>]
>>>
```

åŔŕäżěçIJŃåĞžïijŇ`SizedRecord`åőđä¿ŃçŽĎåĘĚåőźè£ŸæšąæIJL’èćńèğčæđŘåĞžæĺěãĂĆ
åŔŕäżěä¡£çŤĺ `iter_as()` æŰźæşŢæĺěè¿¿åĹřçŻőçŽĎïijŇè£ŹäÿłæŰźæşŢæŐěåŔŮäÿĂäÿłçżŞæđĎæăijåijŔål
`Structure` çśżä¡IJäÿžè¿ŞåĚěãĂĆ è£ŹæăůåŘåŔŕäżěå¿ĹçĄţæť˙žçŽĎåŐżèğčæđŘæŢřæ■őïijŇä¿ŃåęĆïijŽ

```
>>> for n, poly in enumerate(polydata):
...     print('Polygon', n)
...     for p in poly.iter_as('<dd'):
...         print(p)
...
Polygon 0
(1.0, 2.5)
(3.5, 4.0)
(2.5, 1.5)
Polygon 1
(7.0, 1.2)
(5.1, 3.0)
(0.5, 7.5)
(0.8, 9.0)
Polygon 2
(3.4, 6.3)
(1.2, 0.5)
(4.6, 9.2)
```

```
>>>

>>> for n, poly in enumerate(polydata):
...     print('Polygon', n)
...     for p in poly.iter_as(Point):
...         print(p.x, p.y)
...
Polygon 0
1.0 2.5
3.5 4.0
2.5 1.5
Polygon 1
7.0 1.2
5.1 3.0
0.5 7.5
0.8 9.0
Polygon 2
3.4 6.3
1.2 0.5
4.6 9.2
>>>
```

åřĘæL’ĂæIJL’è£ŹäžŻçżŞåŘĹèţůæİěïijŇäÿŃéİćæŸŕäÿĂäÿł `read_polys()` åĞ¡æŢřçŽĎåŔęåď’ŰäÿĂäÿłä£őæ■čçL’Ĺïij Ž

```
class Point(Structure):
    _fields_ = [
        ('<d', 'x'),
        ('d', 'y')
    ]

class PolyHeader(Structure):
    _fields_ = [
        ('<i', 'file_code'),
        (Point, 'min'),
        (Point, 'max'),
        ('i', 'num_polys')
    ]

def read_polys(filename):
    polys = []
    with open(filename, 'rb') as f:
        phead = PolyHeader.from_file(f)
        for n in range(phead.num_polys):
            rec = SizedRecord.from_file(f, '<i')
            poly = [ (p.x, p.y) for p in rec.iter_as(Point) ]
            polys.append(poly)
    return polys
```

èőÍèőž

è£ŹäÿĂèŁĆåŘŚä¡ăáśŢçd’žäžĘèőÿåd’ŽéńŸçžğçŽĎçijŰçÍŃæŁĂæIJŕïijŇåŇĚæŃňæŔŔè£řåŹÍïijŇåżűè£§ë
çĎűèĂŇïijŇåőČäžňéČ¡äÿžäžĘåŘŇäÿĂäÿłçĽźåőŽçŽĎçŽőæăĞæIJ■åŁąãĂĆ

äÿŁéÍćçŽĎåőđçŐřçŽĎäÿĂäÿłäÿżèęĄçĽźå¿ĄæŸŕåőČæŸŕå§žäžŐæĞŠèğčåŇĚçŽĎæĂİæČşãĂĆå¡ŞäÿĂä
`Structure` åőđä¿ŃèćńåĹŻåžžæŮűïijŇ `__init__()` äžĚäžĚåŔłæŸŕåĹŻåžžäÿĂäÿłå■ŮèŁĆæŢřæ■őçŽĎå
çĽźåĹńçŽĎïijŇè£ŹæŰűåĂŹåźűæšąæIJL’äżżä¡ŢçŽĎèğčåŇĚæĹŰèĂĚåĚűäžŰäÿŐçżŞæđĎçŻÿåĚşçŽĎæŞ■ä¡
è£ŹæăůåĄŽçŽĎäÿĂäÿłåŁÍæIJżæŸŕä¡ăåŔŕèČ¡äžĚäžĚåŔłåŕźäÿĂäÿłå■ŮèŁĆèőřå¡ŢçŽĎæ§ŘäÿĂářŔéČÍåĹĘæ

äÿžäžĘåőđçŐřæĞŠèğčåŇĚåŠŇæL’ŞåŇĚïijŇéIJĂèęĄä¡£çŤÍ
`StructField` æŔŔè£řåŹÍçśżãĂĆ çŤÍæĹůåIJÍ `_fields_`
äÿ■åĹŮåĞžæİęçŽĎæŕŔäÿłåśđæĂğéČ¡äijŽèćńè¡ňåŇŰæĹŘäÿĂäÿł `StructField`
æŔŔè£řåŹÍïijŇ åőČářĘçŻÿåĚşçżŞæđĎæăijåijŔçăĄåŠŇåĄŘçğżåĂijä£Ía■ŸåĹřå■ŸåĆÍçijŞå■Ÿäÿ■ãĆåĚČçś
`StructureMeta` åIJÍåď’ŽäÿłçżŞæđĎçśżèćńåőŽäźĽ’æŮűèĞłåŁÍåĹŻåžžäžĘè£ŹäžŽæŔŔè£řåŹÍãĂĆ
æĹŚäžňä¡£çŤÍåĚČçśżçŽĎäÿĂäÿłäÿżèęĄåŐ§åŽăæŸŕåőČä¡£å¿ŮçŤÍæĹůéİđåÿÿæŰźä¿£çŽĎéĂŽè£ĞäÿĂäÿłér

`StructureMeta` çŽĎäÿĂäÿłå¿Ĺå¿őåęŹçŽĎåIJřæŰźářśæŸŕåőČäijŽåŽžåőŽå■ŮèŁĆæŢřæ■őéąžäžŔãĂ
äź§ářśæŸŕèŕť’ïijŇåęĆæđIJäžżæĎŔçŽĎåśđæĂğæŇĞåőŽäžĘäÿĂäÿłå■ŮèŁĆéąžäžŔ(<èąÍçd’žä¡Őä¡■äijŸåĚĹ
æĹŰèĂĚ >èąÍçd’žéńŸä¡■äijŸåĚĹ)ïijŇ éĆčåŘŐéİćæL’ĂæIJL’å■Ůæőţç ŽĎéąžäžŔéČ¡äžèè£ŹäÿłéąžäžŔäÿžåĞE
æŕŤåęĆïijŇä¡ăåŔŕèČ¡æIJL’äÿĂäžŽæŕŤè¿Čåď’■æİĆçŽĎçżŞæđĎïijŇářśåČŔäÿŇéİćè£ŹæăůïijŽ

```
class ShapeFile(Structure):
    _fields_ = [ ('>i', 'file_code'), # Big endian
         ('20s', 'unused'),
         ('i', 'file_length'),
         ('<i', 'version'), # Little endian
         ('i', 'shape_type'),
         ('d', 'min_x'),
         ('d', 'min_y'),
         ('d', 'max_x'),
         ('d', 'max_y'),
         ('d', 'min_z'),
         ('d', 'max_z'),
         ('d', 'min_m'),
         ('d', 'max_m') ]
```

äźŃåL’■æĹŚäžňæŔŘåĹřè£ĞïijŇmemoryview() çŽĎä¡£çŤÍåŔŕäžěåÿőåŁl’æĹŚäžňéĄ£åĚ■åĘĚå■ŸçŽĎ
å¡ŞçżŞæđĎå■ŸåIJÍåţŇåěŮçŽĎæŮűåĂŹïijŇmemoryviews åŔŕäžěåŔäåŁäåŘŇäÿĂäĘĚå■ŸåŇžå§§äÿŁåőŽä
è£ŹäÿłçL’źæĂğæŕŤè¿Čå¿őåęŹïijŇä¡ĘæŸŕåőČåĚşæşÍçŽĎæŸŕåĘĚå■ŸègĘåŻ¿äÿŐæŹőéĂŽå■ŮèŁĆæŢřçżĎçŽ
åęĆæđIJä¡ååIJÍäÿĂäÿłå■ŮèŁĆå■ŮçňęäÿšæĹŰå■ŮèŁĆæŢřçżĎäÿŁæL’ğèąŇåĹĞçL’ĞæŞ■ä¡IJïijŇä¡äéĂŽåÿÿä
èĂŇåĘĚå■ŸègĘåŻ¿åĹĞçL’Ğäÿ■æŸŕè£ŹæăůçŽĎïijŇåőČäžĚäžĚæŸŕåIJÍåůšå■ŸåIJÍçŽĎåĘĚå■ŸäÿŁéİćåŔäă

è£ŸæIJL’å¿Ĺåď’ŽçŻÿåĚşçŽĎçńäèŁĆåŔŕäžěåÿőåŁl’æĹŚäžňæL’l’åśŢè£ŹéĞŇèőÍèőžçŽĎæŰźæąĹãĂĆ
åŔĆèĂČ8.13åřŔèŁĆä¡£çŤÍæŔŔè£řåŹÍædĎåžžäÿĂäÿłçśżåđŃçşżçż§ãĂĆ
8.10åřŔèŁĆæIJL’æŻť’åď’ŽåĚşäžŐåžűè£§èőąçőŮåśđæĂğåĂijçŽĎèőÍèőžïijŇåźűäÿŤèů§NestedStructæŔŔè£řå
9.19åřŔèŁĆæIJL’äÿĂäÿłä¡£çŤÍåĚČçśżæİěåĹİåğŃåŇŰçśżæĹŘåŚŸçŽĎä¿Ńå■ŘïijŇåŠŇ
`StructureMeta` çśźéİđåÿÿçŻÿäijijãĂĆ PythonçŽĎ `ctypes`
æžŘçăĄåŘŇæăůäź§å¿ĹæIJL’èűčïijŇåőČæŔŔä¿ŻäžĘåŕźåőŽäźĽ’æŢřæ■őçżŞæđĎãĂĄæŢřæ■őçżŞæđĎåţŇåěŮ

8.13 6.13 æŢřæ■őçŽĎçťŕåŁääÿŐçż§èőąæŞ■ä¡IJ

éŮőécŸ

ä¡äéIJĂèęĄåď ĎçŘĘäÿĂäÿłå¿Ĺåď ğçŽĎæŢřæ■őéŻĘåźűéIJĂèęĄèőąçőŮæŢřæ■őæĂżåŠŇæĹŰåĚűäżŰçż

èğčåĘşæŰźæąĹ

åŕźäžŐäżżä¡Ţæű L’åŘŁåĹřçż§èőąãĂĄæŮűéŮť’åžŔåĹŮäżěåŘŁåĚűäżŰçŻÿåĚşæŁĂæIJŕçŽĎæŢřæ■őåĹĘ
PandasåžŞ ãĂĆ

äÿžäžĘèőľä¡ăåĚĹä¡ŞéłŇäÿŃïijŇäÿŃéİćæŸŕäÿĂäÿłä¡£çŤÍPandasæİěåĹĘædŘèŁİåŁăåŞěå§ŐåÿĆçŽĎ
èĂĄéijăåŠŇåŢőé¡£çśżåŁÍçĽľ’æŢřæ■őåžŞ çŽĎä¿Ńå■ŘãĂĆ åIJĺæĹŠåĘŹè£ŹçŕĞæŰĞçńăçŽĎæŮűåĂŹïijŇè£Ź

```
>>> import pandas

>>> # Read a CSV file, skipping last line
>>> rats = pandas.read_csv('rats.csv', skip_footer=1)
>>> rats
<class 'pandas.core.frame.DataFrame'>
Int64Index: 74055 entries, 0 to 74054
Data columns:
Creation Date 74055 non-null values
Status 74055 non-null values
Completion Date 72154 non-null values
Service Request Number 74055 non-null values
Type of Service Request 74055 non-null values
Number of Premises Baited 65804 non-null values
Number of Premises with Garbage 65600 non-null values
Number of Premises with Rats 65752 non-null values
Current Activity 66041 non-null values
Most Recent Action 66023 non-null values
Street Address 74055 non-null values
ZIP Code 73584 non-null values
X Coordinate 74043 non-null values
Y Coordinate 74043 non-null values
Ward 74044 non-null values
Police District 74044 non-null values
Community Area 74044 non-null values
Latitude 74043 non-null values
Longitude 74043 non-null values
Location 74043 non-null values
dtypes: float64(11), object(9)

>>> # Investigate range of values for a certain field
>>> rats['Current Activity'].unique()
array([nan, Dispatch Crew, Request Sanitation Inspector],␣
 ↪dtype=object)
>>> # Filter the data
```

```
>>> crew_dispatched = rats[rats['Current Activity'] == 'Dispatch␣
↪Crew']
>>> len(crew_dispatched)
65676
>>>

>>> # Find 10 most rat-infested ZIP codes in Chicago
>>> crew_dispatched['ZIP Code'].value_counts()[:10]
60647 3837
60618 3530
60614 3284
60629 3251
60636 2801
60657 2465
60641 2238
60609 2206
60651 2152
60632 2071
>>>

>>> # Group by completion date
>>> dates = crew_dispatched.groupby('Completion Date')
<pandas.core.groupby.DataFrameGroupBy object at 0x10d0a2a10>
>>> len(dates)
472
>>>

>>> # Determine counts on each day
>>> date_counts = dates.size()
>>> date_counts[0:10]
Completion Date
01/03/2011 4
01/03/2012 125
01/04/2011 54
01/04/2012 38
01/05/2011 78
01/05/2012 100
01/06/2011 100
01/06/2012 58
01/07/2011 1
01/09/2012 12
>>>

>>> # Sort the counts
>>> date_counts.sort()
>>> date_counts[-10:]
Completion Date
10/12/2012 313
10/21/2011 314
09/20/2011 316
```

```
10/26/2011 319
02/22/2011 325
10/26/2012 333
03/17/2011 336
10/13/2011 378
10/14/2011 391
10/07/2011 457
>>>
```

åŮŕïijŇçIJŃæăůå■Ř2011åźť10æIJĹ7æŮěåŕźèĂĄéijääžňæİěèŕť'æŸŕäÿłå¿Ĺå£ŹçćŇçŽĎæŮěå■ŘåŢŁïijĄ

èőĺèőž

PandasæŸŕäÿĂäÿłæŃěæIJL'å¿Ĺåď'ŽçL'źæĂğçŽĎåď'ğåđŃåĞ¡æŢřåžŞïijŇæĹŚåIJĺè£ŹéĞŇäÿ■åŔŕèČ¡äżŇ
ä¡ĘæŸŕåŔłèęĄä¡ăéIJĂèęĄåŐżåĹĘæđŘåď'ğåđŃæŢřæ■őéŽĘåŘĹãĂĄåŕźæŢřæ■őåĹEçżĎãĂĄèőąçŐŮåŘĎçğ■

9 çňňäÿČçńäïijŽåĞ¡æŢř

ä¡£çŤĺ def èŕ■åŘěåőŽäźL'åĞ¡æŢřæŸŕæL'ĂæIJL'çĺŃåžŔçŽĎå§žçąĂãĂĆ
æIJňçńäçŽĎçŻőæăĞæŸŕèőšèğčäÿĂäžŽæŻť'åŁăéńŸçžğåŠŇäÿ■åÿÿèğĄçŽĎåĞ¡æŢřåőŽäźL'äÿŐä¡£çŤĺæĺąåijŔ
æűL'åŘŁåĹřçŽĎåĘĚåőźåŇĚæŃňéżŸèőď'åŔĆæŢřãĂĄäżżæĎŔæŢřéĞŘåŘĆæŢřãĂĄåijžåĹűåĚşéŤőå■ŮåŘĆ
åŘęåď'ŰïijŇäÿĂäžŽéńŸçžğçŽĎæŐğåĹűæţĄåŠŇåĹľçŤĺåŻđèřČåĞ¡æŢřäijăéĂŠæŢřæ■őçŽĎæŁĂæIJŕåIJĺè£Ź

Contents:

9.1 7.1 åŔŕæŐěåŘŮäżżæĎŔæŢřéĞŘåŘĆæŢřçŽĎåĞ¡æŢř

éŮőécŸ

ä¡ăæČşæđĎéĂääÿĂäÿłåŔŕæŐěåŘŮäżżæĎŔæŢřéĞŘåŘĆæŢřçŽĎåĞ¡æŢřãĂĆ

èğčåĘşæŰźæąĹ

äÿžäžĘèČ¡èőľäÿĂäÿłåĞ¡æŢřæŐěåŘŮäżżæĎŔæŢřéĞŘçŽĎä¡■ç¡őåŘĆæŢřijŇåŔŕäżěä¡£çŤĺäÿĂäÿł*åŘĆ

```
def avg(first, *rest):
    return (first + sum(rest)) / (1 + len(rest))

# Sample use
avg(1, 2) # 1.5
avg(1, 2, 3, 4) # 2.5
```

åIJĺè£Źäÿłä¿Ńå■Řäÿ■ïijÑrestæŸŕçŤśæL'ĂæIJL'åĚűäżŰä¡■ç¡őåŘĆæŢřçżĎæĹŘçŽĎåĚČçżĎãĂĆçĎűåŘ

äÿžäžĘæŐěåŘŮäżżæĎŔæŢřéĞŘçŽĎåĚşéŤőå■ŮåŘĆæŢřijŇä¡£çŤĺäÿĂäÿłäžě**åijĂåď't'çŽĎåŘĆæŢřã

```
import html

def make_element(name, value, **attrs):
    keyvals = [' %s="%s"' % item for item in attrs.items()]
    attr_str = ''.join(keyvals)
    element = '<{name}{attrs}>{value}</{name}>'.format(
                name=name,
                attrs=attr_str,
                value=html.escape(value))
    return element

# Example
# Creates '<item size="large" quantity="6">Albatross</item>'
make_element('item', 'Albatross', size='large', quantity=6)

# Creates '<p>&lt;spam&gt;</p>'
make_element('p', '<spam>')
```

åIJÍè£ŹéĞŇïijŇattrsæŸŕäÿĂäÿłåŇĚåŘńæĽĂæIJĽèćńäijååĚěè£ŻæİěçŽĎåĚşéŤőå■ŮåŔĆæŢřçŽĎå■ŮåĚ

åęĆæđIJä¡ăè£ŸåÿŇæIJŻæ§ŘäÿłåĞ¡æŢřèČ¡åŘŇæŮűæŐěåŔŮäżżæĎŔæŢřéĞŔçŽĎä¡■ç¡őåŔĆæŢřåŠŇål

```
def anyargs(*args, **kwargs):
    print(args) # A tuple
    print(kwargs) # A dict
```

ä¡£çŤÍè£ŹäÿłåĞ¡æŢřæŮűïijŇæĽĂæIJĽä¡■ç¡őåŔĆæŢřäijŽèćńæŤ¿åĹřargsåĚČçżĎäÿ■ïijŇæĽĂæIJĽåĚş

èőÍèőž

äÿĂäÿł*åŔĆæŢřåŔłèČ¡åĞžçŐřåIJÍåĞ¡æŢřåőŽäźĽäÿ■æIJĂåŘŐäÿĂäÿłä¡■ç¡őåŔĆæŢřåŘŐéİćïijŇèĂŇ
**åŔĆæŢřåŔłèČ¡åĞžçŐřåIJÍæIJĂåŘŐäÿĂäÿłåŔĆæŢřãĂĆ æIJĽäÿĂçĆźèęĄæşÍæĎŔçŽĎæŸŕïijŇåIJÍ*åŔĆæ

```
def a(x, *args, y):
    pass

def b(x, *args, y, **kwargs):
    pass
```

è£Źçğ■åŔĆæŢřåřśæŸŕæĹŚäžňæĽĂèŕť'çŽĎåijžåĹűåĚşéŤőå■ŮåŔĆæŢřïijŇåIJÍåŘŐéİć7.2åřŔèŁĆè£Ÿäij

9.2 7.2 åŘłæŐěåŔŮåĚşéŤőå■ŮåŔĆæŢřçŽĎåĞ¡æŢř

éŮőécŸ

ä¡ăåÿŇæIJŻåĞ¡æŢřçŽĎæ§ŘäžŻåŔĆæŢřåijžåĹűä¡£çŤĺåĚşéŤőå■ŮåŔĆæŢřäijåéĂŠ

èğčåĘşæŰźæąĹ

åřĘåijžåĹűåĚşéŤőå■ŮåŔĆæŢřæŤ¿åĹřæ§Řäÿł*åŔĆæŢřæĹŰèĂĚå■Ţäÿł*åŘŐéİćåřśèČ¡è¿¿åĹřè£Źçğ■æ

```
def recv(maxsize, *, block):
    'Receives a message'
    pass

recv(1024, True) # TypeError
recv(1024, block=True) # Ok
```

åĹľçŤĺè£Źçğ■æŁĂæIJřïijŇæĹŚäžňè£ŸèČ¡åIJÍæŐěåŘŮäżżæĎŔåď˙Žäÿłä¡■ç¡őåŔĆæŢřçŽĎåĞ¡æŢřäÿ■æ

```
def mininum(*values, clip=None):
    m = min(values)
    if clip is not None:
        m = clip if clip > m else m
    return m

minimum(1, 5, 2, -5, 10) # Returns -5
minimum(1, 5, 2, -5, 10, clip=0) # Returns 0
```

èŐÍèŐž

å¿Ĺåď˙ŽæČĚåĘţäÿŃïijŇä¡£çŤĺåijžåĹűåĚşéŤőå■ŮåŔĆæŢřäijŽæŕŤä¡£çŤĺä¡■ç¡őåŔĆæŢřèąÍæĎŔæŻť˙åŁă
ä¿ŇåęĆïijŇèĂČèŹŚäÿŇåęĆäÿŇäÿĂäÿłåĞ¡æŢřèřČçŤĺïijŽ

```
msg = recv(1024, False)
```

åęĆæđIJèřČçŤĺèĂĚårźrecvåĞ¡æŢřåźűäÿ■æŸŕå¿ĹçĘ§æĆL˙ïijŇéĆčäžŰèĆŕåőŽäÿ■æŸŐçŹ¡éĆčäÿłFalseå
ä¡ĘæŸŕïijŇåęĆæđIJäžčçăĄåŘŸæĹŘäÿŃéİćè£Źæăůå■ŘçŽĎèŕİåřśæÿĚæěŽåď˙ŽäžĘïijŽ

```
msg = recv(1024, block=False)
```

åŘęåď˙ŰïijŇä¡£çŤĺåijžåĹűåĚşéŤőå■ŮåŔĆæŢřäź§äijŽæŕŤä¡£çŤĺ**kwargsåŔĆæŢřæŻť˙åě¡ïijŇåŻääÿžåIJ

```
>>> help(recv)
Help on function recv in module __main__:
recv(maxsize, *, block)
    Receives a message
```

åijžåĹűåĚşéŤőå■ŮåŔĆæŢřåIJĺäÿĂäžŽæŻť˙énŸçžğåIJžåŘĹåŘŇæăůäź§å¿ĹæIJL˙çŤĺãĆ
ä¿ŇåęĆïijŇåőČäžňåŔŕäžěèćńçŤĺæİěåIJĺä¡£çŤĺ*argsåŠŇ**kwargsåŔĆæŢřä¡IJäÿžè¿ŞåĚěçŽĎåĞ¡æŢřäÿ■æŘŠ

9.3 7.3 çżŹåĞ¡æŢřåŔĆæŢřåćđåŁääĚČä£qæĄŕ

éŮőécŸ

ä¡ääĘŹåě¡äžĘäÿĂäÿłåĞ¡æŢřijŇçĎűåŘŐæČşäÿžè£ŹäÿłåĞ¡æŢřçŽĎåŔĆæŢřåćđåŁääÿĂäžŻécİåď˙ŰçŽĎ

èğčåĘşæŰźæąĹ

ä¡£çŤĺåĞ¡æŢřåŔĆæŢřæşĺèğčæŸŕäÿĂäÿłå¿Ĺåě¡çŽĎåŁđæşŢïijŇåőČèČ¡æŔŘçď˙žçĺŃåžŔåŚŸåžŤèŕěæĂŐ
ä¿ŃåęĆïijŇäÿŃéİćæIJL˙äÿĂäÿłècńæşĺèğčäžĘçŽĎåĞ¡æŢřijŽ

```
def add(x:int, y:int) -> int:
    return x + y
```

pythonèğčéĞŁåŹĺäÿ■äijŽåŕźè£ŹäžŻæşĺèğčæůżåŁääżżä¡ŢçŽĎèŕ■äźL˙ãĂĆåőČäžñäÿ■äijŽècńçśżåđŃæčĂ
çĎűèĂŇïijŇåŕźäžŐéĆčäžŻéŸĚèŕżæžŘçăĄçŽĎäžżæİèèőšåřšå¿ĹæIJL˙åÿőåŁľ˙åŢęãĂĆçňñäÿL˙æŰźåůěåĚůåŠŇ

```
>>> help(add)
Help on function add in module __main__:
add(x: int, y: int) -> int
>>>
```

åř¡çőąä¡ääŔŕäžëä¡£çŤĺäżżæĎŘçśżåđŃçŽĎåŕźèśąçżŹåĞ¡æŢřæůżåŁääşĺèğč(ä¿ŃåęĆæŢřå■ŮïijŇå■Ůçňęä

èőĺèőž

åĞ¡æŢřæşĺèğčåŔłå■ŸåĆĺåIJĺåĞ¡æŢřçŽĎ `__annotations__`
åšđæĂğäÿ■ãĂĆä¿ŃåęĆïijŽ

```
>>> add.__annotations__
{'y': <class 'int'>, 'return': <class 'int'>, 'x': <class 'int'>}
```

åř¡çőąæşĺèğčçŽĎä¡£çŤĺæŰźæşŢåŔŕèČ¡æIJL˙å¿Ĺåď˙Žçğ■ïijŇä¡ĘæŸŕåőČäžñçŽĎäÿżèęĄçŤĺéĂŤè£ŸæŸŕ
åŻääÿžpythonåźűæšąæIJL˙çśżåđŃåčřæŸŐïijŇéĂŽåÿÿæİèèőšäžĚäžĚéĂŽè£ĞéŸĚèŕżæžŘçăĄå¿ĹéŽ¿ç§ěéĄŞå
è£ŹæŮűåĂŹä¡£çŤĺæşĺèğčåřśèČ¡çżŹçĺŃåžŔåŚŸæŻť˙åď˙ŽçŽĎæŔŘçď˙žïijŇèőľ˙äžŰäžñåŔŕäžëæ■čçąőçŽĎä¡£ç

åŔĆèĂČ9.20åřŘèŁĆçŽĎäÿĂäÿłæŻť˙åŁäéńŸçžğçŽĎä¿Ńå■ŘïijŇæijŤçď˙žäžĘåęĆä¡ŢåĹľçŤĺæşĺèğčæİèåć

9.4 7.4 è£ŤåŻđåď˙ŽäÿłåĂijçŽĎåĞ¡æŢř

éŮőécŸ

ä¡ääÿŇæIJŻæđĎéĂääÿĂäÿłåŔŕäžëè£ŤåŻđåď˙ŽäÿłåĂijçŽĎåĞ¡æŢř

èğčåĘşæŰźæąĹ

äÿžäžĘèČ¡è£ŤåŻđåd'ŽäÿłåĂijïijŇåĞ¡æŢřçŻt'æŐěreturnäÿĂäÿłåĚČçżĎářśèąŇäžĘãĂĆä¿ŃåęĆïijŽ

```
>>> def myfun():
... return 1, 2, 3
...
>>> a, b, c = myfun()
>>> a
1
>>> b
2
>>> c
3
```

èőÍèőž

åř¡çőąmyfun()çIJŃäÿŁåŐżè£ŤåŻđäžĘåd'ŽäÿłåĂijïijŇåőđéŹĚäÿŁæŸŕåĚĹåĹŻåżžäžĘäÿĂäÿłåĚČçżĎçĎu
è£Źäÿłèí■æşŢçIJŃäÿŁåŐżæŕŤè¿ČåěĞæĂłïijŇåőđéŹĚäÿŁæĹŚäžňä¡£çŤĺçŽĎæŸŕéĂŮåŔůæİěçŤ§æĹŘäÿĂäÿ

```
>>> a = (1, 2) # With parentheses
>>> a
(1, 2)
>>> b = 1, 2 # Without parentheses
>>> b
(1, 2)
>>>
```

å¡ŞæĹŚäžňèřČçŤĺè£ŤåŻđäÿĂäÿłåĚČçżĎçŽĎåĞ¡æŢřçŽĎæŮűåĂŹ
ïijŇéĂŽåÿÿæĹŚäžňäijŽåřĘçżŞæđIJèţŃåĂijçżŹåd'ŽäÿłåŔŸéĞŔïijŇåřśåČŔäÿŁéİćçŽĎéĆčæăůãĂĆ
åĚűåőđè£ŹåřśæŸŕ1.1åřŔèŁĆäÿ■æĹŚäžňæĽĂèŕt'çŽĎåĚČçżĎèğčåŇĚãĂĆè£ŤåŻđçżŞæđIJäź§åŔŕäžěèţŃåĂij
è£ŹæŮűåĂŹè£ŹäÿłåŔŸéĞŔåĂijåřśæŸŕåĞ¡æŢřè£ŤåŻđçŽĎéĆčäÿłåĚČçżĎæIJňèžńäžĘïijŽ

```
>>> x = myfun()
>>> x
(1, 2, 3)
>>>
```

9.5 7.5 åőŽäźĽælJĽéżŸèőd'åŔĆæŢřçŽĎåĞ¡æŢř

éŮőécŸ

ä¡ăæČşåőŽäźĽäÿĂäÿłåĞ¡æŢřæĹŰèĂĚæŰźæşŢïijŇåőČçŽĎäÿĂäÿłæĹŰåd'ŽäÿłåŔĆæŢřæŸŕåŔŕéĂĽ'çŽ

èğčåĘşæŰźæąĹ

åőŽäźĽäÿĂäÿłæIJL’åŔŕéĂĽ’åŔĆæŢřçŽĎåĞ¡æŢřæŸŕéİđåÿÿçőĂå■ŢçŽĎïijÑçŻt’æŐěåIJÍåĞ¡æŢřåőŽäźĽ

```
def spam(a, b=42):
    print(a, b)

spam(1) # Ok. a=1, b=42
spam(1, 2) # Ok. a=1, b=2
```

åęĆæđIJéžŸèőd’åŔĆæŢřæŸŕäÿĂäÿłåŔŕä£őæŤźçŽĎåőźåŹĺæŕŤåęĆäÿĂäÿłåĹŮèąĺãĂĄéŻĘåŘĹæĹŰèĂĚ

```
# Using a list as a default value
def spam(a, b=None):
    if b is None:
        b = []
    ...
```

åęĆæđIJä¡ăåźűäÿ■æČşæŔŘä¿ŻäÿĂäÿłéžŸèőd’åĂijïijÑèĂŇæŸŕæČşäżĚäżĚæţŃèŕŢäÿŃæ§ŘäÿłéžŸèőd’å

```
_no_value = object()

def spam(a, b=_no_value):
    if b is _no_value:
        print('No b value supplied')
    ...
```

æĹŚäžňæţŃèŕŢäÿŃè£ŹäÿłåĞ¡æŢřijŽ

```
>>> spam(1)
No b value supplied
>>> spam(1, 2) # b = 2
>>> spam(1, None) # b = None
>>>
```

äżŤçżĘèğĆåŕ§åŔŕäžěåŘŚçŐřåĹřäijăéĂŠäÿĂäÿłNoneåĂijåŠŇäÿ■äijăåĂijäÿd’çğ■æČĚåĘţæŸŕæIJL’åůőå

èőÍèőž

åőŽäźĽåÿęéžŸèőd’åĂijåŔĆæŢřçŽĎåĞ¡æŢřæŸŕå¿ĹçőĂå■ŢçŽĎïijÑä¡EçżÍäÿ■äżĚäżĚåŔłæŸŕè£ŹäÿłïijÑ

éęŰåĚĹïijÑéžŸèőd’åŔĆæŢřçŽĎåĂijäżĚäżĚåIJÍåĞ¡æŢřåőŽäźĽçŽĎæŮűåĂŹètŃåĂijäÿĂæňąãĂĆèŕŢçİ

```
>>> x = 42
>>> def spam(a, b=x):
...     print(a, b)
...
>>> spam(1)
1 42
>>> x = 23 # Has no effect
```

```
>>> spam(1)
1 42
>>>
```

æşÍæĎŔåĹřå¡ŞæĹŚäžňæŤźåŔŸxçŽĎåĂijçŽĎæŮűåĂŹåŕźéżŸèőď åŔĆæŢřåĂijåźűæšąæIJL’å¡śåŞ■ïijÑè

åĚűæňąïijÑéżŸèőď åŔĆæŢřçŽĎåĂijåžŤèŕěæŸŕäÿ■åŔŕåŔŸçŽĎåŕźèśąïijÑæŕŤåęĆNoneãĂĄTrueãĂĄFal
çL’źåĹńçŽĎïijÑå■ČäÿĞäÿ■èęĄåČŔäÿŃéİćè£ŹæăůåĘŹäžčçăĄïijŽ

```
def spam(a, b=[]): # NO!
    ...
```

åęĆæđIJä¡ăè£ŹäźĹåĄŽäžĘïijÑå¡ŞéżŸèőď åĂijåIJÍåĚűäżŮåIJřæŰźèćńä£őæŤźåŘŐä¡ăářĘäijŽéĄĞåĹřåŘ

```
>>> def spam(a, b=[]):
...     print(b)
...     return b
...
>>> x = spam(1)
>>> x
[]
>>> x.append(99)
>>> x.append('Yow!')
>>> x
[99, 'Yow!']
>>> spam(1) # Modified list gets returned!
[99, 'Yow!']
>>>
```

è£Źçğ■çżŞæđIJåžŤèŕěäÿ■æŸŕä¡ăæČşèęĄçŽĎãĂĆäÿžäžĘéĄ£åĚ■è£Źçğ■æČĚåĘţçŽĎåŔŞçŤ§ïijÑæIJĂå
çĎůåŘŐåIJÍåĞ¡æŢřéĞŃéİćæčĂæ§ěåőČïijÑåL’■éİćçŽĎä¿Ńå■ŘåřśæŸŕè£Źæăůå ĄŽçŽĎãĂĆ

åIJÍæţŃèŕŢNoneåĂijæŮűä¡£çŤÍ is æŞ■ä¡IJçňęæŸŕå¿ĹéĞ■èęĄçŽĎïijÑäź§æŸŕè£Źçğ■æŰźæąĹçŽĎåĚş
æIJL’æŮűåĂŹåď ğåőűäijŽçŁŕäÿŃäÿŃéİćè£ŹæăůçŽĎéŤŹèŕŕïijŽ

```
def spam(a, b=None):
    if not b: # NO! Use 'b is None' instead
        b = []
    ...
```

è£ŹäźĹåĘŹçŽĎéŮőécŸåIJÍäžŐår¡çőąNoneåĂijçąőåőđæŸŕècńå¡ŞæĹŘFalseïijÑ
ä¡ĘæŸŕè£ŸæIJL’åĚűäżŰçŽĎåŕźèśą(æŕŤåęĆéŢ£åžęäÿž0çŽĎå■Ůçňęäÿšă ĂĄåĹÙèąÍãĂĄåĚČçżĎãĂĄå■ŮåĚÿ
åŽăæ■d’ïijÑäÿŁéİćçŽĎäžčçăĄäijŽèŕŕåřĘäÿĂäžŻåĚűäżŰè¿ŞåĚěäź§å¡ŞæĹŘæŸŕæšąæIJL’è¿ŞåĚěãĆæŕŤåęĆ

```
>>> spam(1) # OK
>>> x = []
>>> spam(1, x) # Silent error. x value overwritten by default
>>> spam(1, 0) # Silent error. 0 ignored
>>> spam(1, '') # Silent error. '' ignored
>>>
```

æIJÄåŘŐäÿĂäÿłéŮőécŸærŤè¿Čå¿őåęŹïijŇéĆčářśæŸŕäÿĂäÿłåĞ¡æŢřéIJÄèęĄæţŃèŕŢæ§ŘäÿłåŔŕéĂĽ'åŔ
è£ŹæŮűåĂŹéIJÄèęĄåřŔå£ČçŽĎæŸŕä¡ääÿ■èČ¡çŤĺæ§ŘäÿłéżŸèőď'åĂijærŤåęĆNoneãĂĄ
0æĹŰèĂĚFalseåĂijæĭěæţŃèŕŢçŤĺæĹůæŔŘä¿ŻçŽĎåĂij(åŽääÿžè£ŹäžŽåĂijéČ¡æŸŕåŘĹæşŢçŽĎåĂijïijŇæŸ
åŽäæ■d'ïijŇä¡äéIJÄèęĄåĚűäžŰçŽĎèğčåEşæŰźæąĹäžĘãĂĆ

äÿžäžĘèğčåEşè£ŹäÿłéŮőécŸïijŇä¡ääŔŕäżěåĹŽåžžäÿĂäÿłçŃňäÿĂæŮääžŇçŽĎçğĄæIJL'åŕźèśąåőđä¿Ńïij
åIJĺåĞ¡æŢřéĞŇéİćïijŇä¡ääŔŕäżěéĂŽè£ĞæčÄæ§ěèćńäijäéĂŠåŔĆæŢřåĂijèů§è£Źäÿłåőđä¿ŃæŸŕåĘäÿĂæăůa
è£ŹéĞŇçŽĎæĂİèůŕæŸŕçŤĺæĹůäÿ■åŔŕèČ¡åŐżäijäéĂŠè£Źäÿŀ_no_valueåőđä¿Ńä¡IJäÿžè¿ŞåĚěãĂĆ
åŽäæ■d'ïijŇè£ŹéĞŇéĂŽè£ĞæčÄæ§ěè£ŹäÿłåĂijåŕśèČ¡çąőåőŽæ§ŘäÿłåŔĆæŢřæŸŕåĘèćńäijäéĂŠè£ŽæİěäžE

è£ŹéĞŇåŕź `object()` çŽĎä¡£çŤĺçIJŃäÿŁåŐżæIJL'çĆźäÿ■åd'łåÿÿèğĄãĂĆ`object`
æŸŕpythonäÿ■æL'ÄæIJL'çśżçŽĎå§žçśżãĂĆ ä¡ääŔŕäżěåĹŽåžž `object`
çśżçŽĎåőđä¿ŃïijŇä¡ĘæŸŕè£ŹäžŽåőđä¿ŃæšąäžÄäźĹåőđéŹĚçŤĺåd'ĎïijŇåŽääÿžåőČåźűæšąæIJL'äżżä¡ŢæIJL'
äź§æšąæIJL'äżżä¡Ţåőđä¿ŃæŢ斮(åŽääÿžåőČæšąæIJL'äżżä¡ŢçŽĎåőđä¿Ńå■ŮåĚÿïijŇä¡äçŤŽèĞşéČ¡äÿ■èČ¡è
ä¡ääŤŕäÿĂèČ¡åĄŽçŽĎåŕśæŸŕæţŃèŕŢåŘŃäÿĂæĂğãĂĆè£ŹäÿłåĹŽåě¡çňęåŔĹæĹŚçŽĎèęĄæśĆïijŇåŽääÿžæĹ

9.6 7.6 åőŽäźĽåŇ£åŘ■æĹŰåĘĚèĄŤåĞ¡æŢř

éŮőécŸ

ä¡äæČşäÿž `sort()` æŞ■ä¡IJåĹŽåžžäÿĂäÿłå¿Łç§■çŽĎåŽđèŘČåĞ¡æŢřïijŇä¡ĘåŔĹäÿ■æČşçŤĺ
`def` åŐżåĘŹäÿĂäÿłå■ŢèąŇåĞ¡æŢřïijŃ èĂŇæŸŕåÿŇæIJŽéĂŽè£Ğæ§Řäÿłå£ńæ■ůæŰźåijŔäžěåĘĚèĄŤæŰźåi

èğčåEşæŰźæąĹ

å¡ŞäÿĂäžŽåĞ¡æŢřå¿ŁçőĂå■ŢïijŇäżĔäžĔåŔłæŸŕèőąçőŮäÿĂäÿłèąĺè¿¿åijŔçŽĎåĂijçŽĎæŮűåĂŹïijŇåřś

```
>>> add = lambda x, y: x + y
>>> add(2,3)
5
>>> add('hello', 'world')
'helloworld'
>>>
```

è£ŹéĞŇä¡£çŤĺçŽĎlambdaèąĺè¿¿åijŔèů§äÿŇéİćçŽĎæŢĹæđIJæŸŕäÿĂæăůçŽĎïijŽ

```
>>> def add(x, y):
...     return x + y
...
>>> add(2,3)
5
>>>
```

lambdaèąĺè¿¿åijŔåĚÿåđŇçŽĎä¡£çŤĺåIJžæŹŕæŸŕæŐŠåžŔæĹŰæŢřæ■őreduceç■L'ïijŽ

```
>>> names = ['David Beazley', 'Brian Jones',
...          'Raymond Hettinger', 'Ned Batchelder']
>>> sorted(names, key=lambda name: name.split()[-1].lower())
```

```
['Ned Batchelder', 'David Beazley', 'Raymond Hettinger', 'Brian␣
↪Jones']
>>>
```

èőÍèőž

åř¡çőąlambdaèąÍè¿¿åijŔåĚĄèőÿä¡ăåőŽäźL’çőĂå■ŢåĞ¡æŢřïijŇä¡ĘæŸŕåőČçŽĎä¡£çŤÍæŸŕæIJL’éŹŘåĹűç
ä¡ăåŔłèČ¡æŇĞåőŽå■Ţäÿłèąĺè¿¿åijŔïijŇåőČçŽĎåĂijåřśæŸŕæIJĂåŘŐçŽĎè£ŤåŽđåĂijãĂĆäź§åřśæŸŕèŕť äÿ■è
åŇĚæŃňåď’Žäÿłèŕ■åŔěãĂĄæİąäžűèąÍè¿¿åijŔãĂĄè£■äžčäžěåŔŁåijĆåÿÿåď’ĎçŘĘç■L’ç■L’ãĂĆ

ä¡ăåŔŕäžěäÿ■ä¡£çŤÍlambdaèąÍè¿¿åijŔåřśèČ¡çijŰåĘŹåď’ğéČÍåĹĘpythonäžčçăĄãĂĆ
ä¡ĘæŸŕïijŇå¡ŞæIJL’äžžçijŰåĘŹåď’ğéĞŔèőąçőÙèąÍè¿¿åijŔåĂijçŽĎç§■åřŔåĞ¡æŢřæĹŰèĂĚéIJĂèęĄçŤÍæĹůa
ä¡ăåřśäijŽçIJŃåĹřlambdaèąÍè¿¿åijŔçŽĎèžńå¡śäžĘãĂĆ

9.7 7.7 åŇ£åŘ■åĞ¡æŢřæ■ŢèŐůåŔŸéĞŔåĂij

éŮőécŸ

ä¡ăçŤÍlambdaåőŽäźL’äžĘäÿĂäÿłåŇ£åŘ■åĞ¡æŢřïijŇåźűæČşåIJÍåőŽäźL’æŮűæ■ŢèŐůåĹřæ§ŘäžŽåŔŸéĞ

èğčåĘşæŰźæąĹ

åĚÍçIJŃäÿŃäÿŃéİćäžčçăĄçŽĎæŢĹæđIJïijŽ

```
>>> x = 10
>>> a = lambda y: x + y
>>> x = 20
>>> b = lambda y: x + y
>>>
```

çŐřåIJÍæĹŚéŮőä¡ăïijŇa(10)åŠŇb(10)è£ŤåŽđçŽĎçżŞæđIJæŸŕäžĂäźĹïij§åęĆæđIJä¡ăèőď’äÿžçżŞæđIJæŸ

```
>>> a(10)
30
>>> b(10)
30
>>>
```

è£ŹåĚűäÿ■çŽĎåěěåęŹåIJÍäžŐlambdaèąÍè¿¿åijŔäÿ■çŽĎxæŸŕäÿĂäÿłèĞłçŤśåŔŸéĞŔïijŇ
åIJÍè£ŘèąŇæŮűçżŚåőŽåĂijïijŇèĂŇäÿ■æŸŕåőŽäźL’æŮűářçżŚåőŽïijŇè£ŹèůšåĞ¡æŢřçŽĎéżŸèőď’åĂijåŔĆæ
åŽăæ■d’ïijŇåIJÍèřĆçŤÍè£ŹäÿłlambdaèąÍè¿¿åijŔçŽĎæŮűåĂŹïijŇxçŽĎåĂijæŸŕæL’ğèąŇæŮűçŽĎåĂijãĂĆä¿Ň

```
>>> x = 15
>>> a(10)
25
>>> x = 3
```

```
>>> a(10)
13
>>>
```

åęĆædIJä¡ăæČşèőľæ§Řäÿłå Ň£åŘ■åĞ¡æŢřåIJĺåőŽäźĽæŮűåřśæ■ŢèŐůåĹřåĂijïijŇåŕřäžěářĘéĆčäÿłåŔĆ

```
>>> x = 10
>>> a = lambda y, x=x: x + y
>>> x = 20
>>> b = lambda y, x=x: x + y
>>> a(10)
20
>>> b(10)
30
>>>
```

èőĺèőž

åIJĺè£ŹéĞŇåĹŮåĞžæİěçŽĎéŮőécŸæŸŕæŰřæĽŃå¿Ĺåőźæ ŸŞçŁŕçŽĎéŤŹèŕŕïijŇæIJĽäžŻæŰřæĽŃåŔŕè
ærŤåęĆïijŇéĂŽè£ĞåIJĺäÿĂäÿłå¿łçŐŕæĹŰåĹŮèąĺæŐĺåŕijäÿ■åĹŻåżžäÿĂäÿłlambdaèąĺè¿¿åijŔåĹŮèąĺïijŇåźűa

```
>>> funcs = [lambda x: x+n for n in range(5)]
>>> for f in funcs:
... print(f(0))
...
4
4
4
4
4
>>>
```

ä¡ĘæŸŕåőđéŹĚæŢĹædIJæŸŕè£ŘèąŇæŸŕnçŽĎåĂijäÿžè£■äżčçŽĎæIJĂåŘŐäÿĂäÿłåĂijãĂĆçŐřåIJĺæĹŚă

```
>>> funcs = [lambda x, n=n: x+n for n in range(5)]
>>> for f in funcs:
... print(f(0))
...
0
1
2
3
4
>>>
```

éĂŽè£Ğä¡£çŤĺåĞ¡æŢřéżŸèőď åĂijåŔĆæŢřå¡ćåijŔïijŇlambdaåĞ¡æŢřåIJĺåőŽäźĽæŮűåřśèČ¡çżŚåőŽåĹřå

9.8 7.8 åĞŔåřŚåŔŕèřČçŤĺåŕźèśąçŽĎåŔĆæŢřäÿłæŢř

éŮőéćŸ

ä¡ăæIJL'äÿĂäÿłèćńåĚűäżŰpythonäżčçăĄä¡£çŤĺçŽĎcallableåŕźèśąïijŇåŔŕèČ¡æŸŕäÿĂäÿłåŻđèřČåĞ¡æŢřä¡ĘæŸŕåőČçŽĎåŔĆæŢřåd'łåď'ŽäžĘïijŇåŕijèĞt'èřČçŤĺæŮűåĞžéŤŹãĂĆ

èğčåĘşæŰźæąĹ

åęĆæđIJéIJĂèęĄåĞŔåřŚæ§ŘäÿłåĞ¡æŢřçŽĎåŔĆæŢřäÿłæŢřïijŇä¡ăåŔŕäżěä¡£çŤĺ `functools.partial()` ãĂĆ `partial()` åĞ¡æŢřåĚĄèőÿä¡ăçżŹäÿĂäÿłæĹŰåd'ŽäÿłåŔĆæŢřèő¿ç¡őåŻžäÿžäžĘæijŤçd'žæÿĚæěŽïijŇåĄĞèő¿ä¡ăæIJL'äÿŃéİćè£ŹæăůçŽĎåĞ¡æŢřïijŽ

```
def spam(a, b, c, d):
    print(a, b, c, d)
```

çŐřåIJĺæĹŚäżňä¡£çŤĺ `partial()` åĞ¡æŢřæİěåŻžåőŽæ§ŘäžŻåŔĆæŢřåĂijïijŽ

```
>>> from functools import partial
>>> s1 = partial(spam, 1) # a = 1
>>> s1(2, 3, 4)
1 2 3 4
>>> s1(4, 5, 6)
1 4 5 6
>>> s2 = partial(spam, d=42) # d = 42
>>> s2(1, 2, 3)
1 2 3 42
>>> s2(4, 5, 5)
4 5 5 42
>>> s3 = partial(spam, 1, 2, d=42) # a = 1, b = 2, d = 42
>>> s3(3)
1 2 3 42
>>> s3(4)
1 2 4 42
>>> s3(5)
1 2 5 42
>>>
```

åŔŕäżěçIJŃåĞž `partial()` åŻžåőŽæ§ŘäžŻåŔĆæŢřåźűè£ŤåŻđäÿĂäÿłæŰřçŽĎcallableåŕźèśąãĂĆè£Źã çĎűåŘŐèů§äźŃåĽ■åůšçżŔèţŃåĂijè£ĞçŽĎåŔĆæŢřåŘĹåźűèţůæİěïijŇæIJĂåŘŐåřĘæĽĂæIJL'åŔĆæŢřäijäéĂ

èőĺèőž

æIJňèŁĆèęĄèğčåĘşçŽĎéŮőéćŸæŸŕèőľ'åŐ§æIJňäÿ■åĚijåőźçŽĎäżčçăĄåŔŕäżěäÿĂèţůåůěä¡IJãĂĆäÿŃéİ

çňňäÿĂäÿłä¿Ńå■ŘæŸŕïijŇåĄĞèő¿ä¡ăæIJL'äÿĂäÿłçĆźçŽĎåĹŮèąĺæİěèąĺçd'ž(x,y)åİŘæăĞåĚĈçżĎãĂĆ ä¡ăåŔŕäżěä¡£çŤĺäÿŃéİćçŽĎåĞ¡æŢřæİěèőąçőŮäÿd'çĆźäźŃéŮt'çŽĎèůİçężïijŽ

```
points = [ (1, 2), (3, 4), (5, 6), (7, 8) ]

import math
def distance(p1, p2):
    x1, y1 = p1
    x2, y2 = p2
    return math.hypot(x2 - x1, y2 - y1)
```

çŐřåIJÍåĄĞèő¿ä¡ăæČşäžěæ§Řäył̨çĆźäÿžå§žçĆźïijŇæăźæ■őçĆźåŠŇå§žçĆźäźŃéŮťçŽĎèůİçężæİěæŐŠå åĹŮèąÍçŽĎ `sort()` æŰźæşŢæŐěåŔŮäÿĂäÿłåĚşéŤőå■ŮåŔĆæŢřæİěèĞłåőŽäźĽæŐŠåžŔéĂżè¿ŚïijŇ ä¡ĘæŸŕåőČåŔłèČ¡æŐěåŔŮäÿĂäÿłå■ŢäÿłåŔĆæŢřçŽĎåĞ¡æŢř(distance()å¿ĹæŸŐæŸ¿æŸŕäÿ■çňęåŘĹæİąäżűçŐřåIJÍæĹŚäżňåŔŕäžěéĂŽè£Ğä¡£çŤÍ `partial()` æİěèğčåĘşè£ŹäÿłéŮőécŸïijŽ

```
>>> pt = (4, 3)
>>> points.sort(key=partial(distance,pt))
>>> points
[(3, 4), (1, 2), (5, 6), (7, 8)]
>>>
```

æŻť'è£ŻäÿĂæ■ěïijŇ`partial()` éĂŽåÿÿèćńçŤÍæİěå¿őèřČåĚűäžŮåžŞåĞ¡æŢřæĽĂä¡£çŤÍçŽĎåŻđèřČå ä¿ŃåęĆïijŇäÿŃéİćæŸŕäÿĂæőţäžčçăĄïijŇä¡£çŤÍ `multiprocessing` æİěåijĆæ■čèőąçőŮäÿĂäÿłçżŞæđIJåĂijïijŇ çĎűåŘŐè£ŹäÿłåĂijèćńäijåéĂŠçżŹäÿĂäÿłæŐěåŘŮäÿĂäÿłresultåŹ

```
def output_result(result, log=None):
    if log is not None:
        log.debug('Got: %r', result)

# A sample function
def add(x, y):
    return x + y

if __name__ == '__main__':
    import logging
    from multiprocessing import Pool
    from functools import partial

    logging.basicConfig(level=logging.DEBUG)
    log = logging.getLogger('test')

    p = Pool()
    p.apply_async(add, (3, 4), callback=partial(output_result,␣
 ↪log=log))
    p.close()
    p.join()
```

å¡ŞçżŹ `apply_async()` æŔŘä¿ŻåŻđèřČåĞ¡æŢřæŮűïijŇéĂŽè£Ğä¡£çŤÍ `partial()` äijåéĂŠéćİåď'ŰçŽĎ `logging` åŔĆæŢřãĂĆ èĂŇ `multiprocessing` åŕźè£ŹäžŻäÿĂæŮăæĽĂç§ěâĂŤâĂŤåőČäżĚäżĚåŘłæŸŕä¡£çŤÍå■ŢäÿłåĂijæİěèřČçŤÍåŻđèřČåĞ¡æŢřãĂĆ

ä¡IJäÿžäÿĂäÿłçśžäijijçŽĎä¿Ńå■ŘïijŇèĂČèŹŚäÿŃçijŰåĘŹç¡ŚçżIJæIJ■åŁąåŹÍçŽĎéŮőécŸïijŇ`sockets` æÍąåİŮèőĺ'åőČåŘŸå¿Ůå¿Ĺåőźæ ŸŞãĂĆ äÿŃéİćæŸŕäÿłçőĂå■ŢçŽĎechoæIJ■åŁąåŹÍïijŽ

```
from socketserver import StreamRequestHandler, TCPServer

class EchoHandler(StreamRequestHandler):
    def handle(self):
        for line in self.rfile:
            self.wfile.write(b'GOT:' + line)

serv = TCPServer(('', 15000), EchoHandler)
serv.serve_forever()
```

äÿ■è£ĞïijŇåĄĞèő¿ä¡ăæČşçżŹEchoHandlerâćđåŁääÿĂäÿłåŔŕäžěæŐěåŔŮåĚűäžŰéĚ■ç¡őéĂL’éąźçŽĎ `__init__` æŰźæşŢãĂĆæŕŤåęĆïijŽ

```
class EchoHandler(StreamRequestHandler):
    # ack is added keyword-only argument. *args, **kwargs are
    # any normal parameters supplied (which are passed on)
    def __init__(self, *args, ack, **kwargs):
        self.ack = ack
        super().__init__(*args, **kwargs)

    def handle(self):
        for line in self.rfile:
            self.wfile.write(self.ack + line)
```

è£ŹäźĹä£őæŤźåŘŐïijŇæĹŚäžňåřšäÿ■éIJĂèęĄæŸ¿åijŔåIJřåIJÍTCPServerçśžäÿ■æůžåŁääL’■çijĂäžĘãĂĆä¡ĘæŸŕä¡ăåĘ■æňąè£ŘèąŇçÍŃåžŔåŘŐäijŽæŁěçśžäijijäÿŃéİćçŽĎéŤŹèŕŕïijŽ

```
Exception happened during processing of request from ('127.0.0.1',␣
↪59834)
Traceback (most recent call last):
...
TypeError: __init__() missing 1 required keyword-only argument: 'ack
↪'
```

åĹİçIJŃèţůæİěåě¡åČŔå¿ĹéŽ¿ä£őæ■čè£ŹäÿłéŤŹèŕŕïijŇéŹď äžĘä£őæŤź `socketserver` æĺąåİŮæžŘäžčçăĄæĹŰèĂĚä¡£çŤĺæ§ŘäžŽåěĞæĂłçŽĎæŰźæşŢäźŃåď ŰãĂĆä¡ĘæŸŕïijŇåęĆæđIJä¡£çŤĺ `partial()` åŕśèČ¡å¿Ĺè¡żæİ¿çŽĎèğčåĘşâĂŤâĂŤçžŹåőČäijăéĂŠ `ack` åŔĆæŢřçŽĎåÄijæİěåĹİåğŃåŇŰå■şåŔŕïijŇåęĆäÿŃïijŽ

```
from functools import partial
serv = TCPServer(('', 15000), partial(EchoHandler, ack=b'RECEIVED:
↪'))
serv.serve_forever()
```

åIJĺè£Źäÿłä¿Ńå■Řäÿ■ïijŇ`__init__()` æŰźæşŢäÿ■çŽĎack-åŔĆæŢřåčřæŸŐæŰźåijŔçIJŃäÿŁåŐżå¿ĹæIJL’èűčïijŇåĚűåőđåŕśæŸŕåčřæŸŐackäÿžäÿÄäÿłåijžåĹűåĚşéŤőå■Ůå ĚşäžŐåijžåĹűåĚşéŤőå■ŮåŔĆæŢřéŰőécŸæĹŚäžňåIJĺ7.2åŕŔèŁĆæĹŚäžňåůšçžŔèőĺèőžè£ĞäžĘïijŇèŕźèĂĚåŔ

å¿Ĺåď ŽæŰűåĂŹ `partial()` èČ¡åőđçŐřçŽĎæŢĹæđIJïijŇlambdaèąĺè¿¿åijŔäź§èČ¡åőđçŐřãĂĆæŕŤåęĆ

```
points.sort(key=lambda p: distance(pt, p))
p.apply_async(add, (3, 4), callback=lambda result: output_
↪result(result,log))
serv = TCPServer(('', 15000),
        lambda *args, **kwargs: EchoHandler(*args, ack=b'RECEIVED:',
↪ **kwargs))
```

è£ŹæăůåĘŹäź§èČ¡åőđçŐřåŘŇæăůçŽĎæŢĹæđIJïijŇäÿ■è£ĞçŻÿæŕŤèĂŇåůšäijŽæŸ¿å¿ŮæŕŤè¿ČèĞČèĆ
è£ŹæŮűůĂŹä¡£çŤĺ `partial()` åŔŕäžěæŽť'åŁăçŽť'èğĆçŽĎèąĺè¿¿ä¡ăçŽĎæĎŔåŻ¿(çżŹæ§ŘäžŽåŔĆæŢřécĎ

9.9 7.9 åřĘå■ŢæŰźæşŢçŽĎçśżè¡ňæ■ćäÿžåĞ¡æŢř

éŮőécŸ

ä¡ăæIJL'äÿĂäÿłéŹđ' `__init__()` æŰźæşŢåđ'ŰåŔłåőŽäźL'äžĘäÿĂäÿłæŰźæşŢçŽĎçśżãĂĆäÿžäžĘçőĂ

èğčåĘşæŰźæąĹ

åđ'ğåđ'ŽæŢřæČĚåĘţäÿŃïijŇåŔŕäžěä¡£çŤĺéŮ■åŇĚæİěårĘå■ŢäÿłæŰźæşŢçŽĎçśżè¡ňæ■ćæĹŘåĞ¡æŢřãĂ
äÿ¿äÿłä¿Ńå■ŘïijŇäÿŃéİćçđ'žä¿Ńäÿ■çŽĎçśżåĚĄèőÿä¡£çŤĺèĂĚæăźæ■őæ§Řäÿłæĺąæİ£æŰźæąĹæİěèŐůåŔŰå

```
from urllib.request import urlopen

class UrlTemplate:
    def __init__(self, template):
        self.template = template

    def open(self, **kwargs):
        return urlopen(self.template.format_map(kwargs))

# Example use. Download stock data from yahoo
yahoo = UrlTemplate('http://finance.yahoo.com/d/quotes.csv?s={names}
↪&f={fields}')
for line in yahoo.open(names='IBM,AAPL,FB', fields='sl1c1v'):
    print(line.decode('utf-8'))
```

è£ŹäÿłçśżåŕäžěèćńäÿĂäÿłæŽť'çőĂå■ŢçŽĎåĞ¡æŢřæİěäžčæŽ£ïijŽ

```
def urltemplate(template):
    def opener(**kwargs):
        return urlopen(template.format_map(kwargs))
    return opener

# Example use
yahoo = urltemplate('http://finance.yahoo.com/d/quotes.csv?s={names}
↪&f={fields}')
for line in yahoo(names='IBM,AAPL,FB', fields='sl1c1v'):
    print(line.decode('utf-8'))
```

èőÍèőž

åď ğéČÍåĹĘæČĚåĘţäÿŃïijÑä¡ăæŃěæIJL’äÿĂäÿłå■ŢæŰźæşŢçśżçŽĎåŐ§åŻăæŸŕéIJĂèęĄå■ŸåĆÍæ§ŘäžæŕŤåęĆïijÑåőŽäźL’UrlTemplateçśżçŽĎåŤŕäÿĂçŻőçŽĎåřśæŸŕåĚĹåIJÍæ§Řäÿłå IJřæŰźå■ŸåĆÍæÍąæİ£åĂijïijÑ

ä¡£çŤÍäÿĂäÿłåĘĚéČÍåĞ¡æŢřæĹŰèĂĚéŮ■åŇĚçŽĎæŰźæąĹéĂŽåÿÿäijŽæŻť äijŸéŻĚäÿĂäžŽãĂĆçőĂå■ åŘłäÿ■è£ĞåIJÍåĞ¡æŢřåĘĚéČÍåÿęäÿŁäžĘäÿĂäÿłéćİåď ŰçŽĎåŔŸéĞŘçŐŕåćČãĂĆéŮ■åŇĚåĚşéŤőçL’źçĆźåřśåŻăæ■d’ïijÑåIJÍæĹŚäžňçŽĎè ğčåĘşæŰźæąĹäÿ■ïijÑopener() åĞ¡æŢřèőřä¡ŔäžĘ template åŔĆæŢřçŽĎåĂijïijÑåźűåIJÍæŐěäÿŃæİěçŽĎèřĆçŤÍäÿ■ä¡£çŤÍåőĆãĂĆ

äżżä¡ŢæŮűåĂŹåŘłèęĄä¡ăçćřåĹřéIJĂèęĄçżŹæ§ŘäÿłåĞ¡æŢřåćđåŁăéćİåď ŰçŽĎçŁűæĂĄä£ąæĄŕçŽĎéŮçŻÿæŕŤåřĘä¡ăçŽĎåĞ¡æŢřè¡ñæ■ćæĹŘäÿĂäÿłçśżèĂŃèÍĂïijŃéŮ■åŇĚéĂŽåÿÿæŸŕäÿĂçğ■æŽť åŁăçőĂæť ĄåŠ

9.10 7.10 åÿęécİåď ŰçŁűæĂĄä£ąæĄŕçŽĎåŻđèřČåĞ¡æŢř

éŮőécŸ

ä¡ăçŽĎäżčçăĄäÿ■éIJĂèęĄä¿İèţŰåĹřåŽđèřČåĞ¡æŢřçŽĎä¡£çŤÍ(æŕŤåęĆäžŃäżűåď ĎçŘĘåŹÍãĂĄç■L’å¿Ě åźűäÿŤä¡ăè£ŸéIJĂèęĄèőľ åŽđèřČåĞ¡æŢřæŇěæIJL’écİåď ŰçŽĎçŁűæĂĄåĂijïijÑäžëä¿£åIJÍåőČçŽĎåĘĚéČÍä

èğčåĘşæŰźæąĹ

è£ŹäÿĂářŔèŁĆäÿżèęĄèőÍèőžçŽĎæŸŕéĆčäžŽåĞžçŐřåIJÍå¿Ĺåď ŽåĞ¡æŢřåžŞåŠŇæąĘæđűäÿ■çŽĎåŽđèřČ äÿžäžĘæijŤçď žäÿŐæţŃèŕŢïijÑæĹŚäżňåĚĹåőŽäźL’åęĆäÿŇäÿĂäÿłéIJĂèęĄèřČçŤÍåŽđèřČåĞ¡æŢřçŽĎåĞ¡æŢ

```
def apply_async(func, args, *, callback):
    # Compute the result
    result = func(*args)

    # Invoke the callback with the result
    callback(result)
```

åőđéŹĚäÿŁïijÑè£Źæőţäžčçă ĄåŔŕäžěåĄŽäżżä¡ŢæŻť éńŸçžğçŽĎåď ĎçŘĘïijÑåŇĚæŃńçž£çÍŃãĂĄè£Żçİ æĹŚäžňäżĚäżĚåŘłéIJĂèęĄåĚşæşĺåŽđèřČåĞ¡æŢřçŽĎèřČçŤÍãĂĆäÿŃéİćæŸŕäÿĂäÿłæijŤçď žæĂŐæăůä¡£çŤÍä

```
>>> def print_result(result):
...     print('Got:', result)
...
>>> def add(x, y):
...     return x + y
...
>>> apply_async(add, (2, 3), callback=print_result)
Got: 5
>>> apply_async(add, ('hello', 'world'), callback=print_result)
Got: helloworld
>>>
```

æşÍæĎŔåĹř `print_result()` åĞ¡æŢřäžĔäžĔåŔłæŐěåŔŮäÿĂäÿłåŔĆæŢř `result` ãĂĆäÿ■èČ¡åĘ■äijååĚěåĚűäžŰä£qæĄŕãĂĆ èĂŇå¡Şä¡ăæČşèőľ åŻđèřČåĞ¡æŢřèő£éŮőåĚűäžŰåŔŸéĞŔæĹŰè

äÿžäžĘèőľåŻđèřČåĞ¡æŢřèő£éŮőåď ŰéČĺä£qæĄřïijŇäÿĂçğ■æŰźæşŢæŸŕä¡£çŤĺäÿĂäÿłçżŚåőŽæŰźæşŢ æŕŤåęĆïijŇäÿŇéÍćè£ŹäÿłçśžäijŽä£Ía■ŸäÿĂäÿłåĘĚéČĺåžŔåĹŮåŔůïijŇæŕŔæňqæŐěæŤűåĹřäÿĂäÿł `result` çŽĎæŮűåĂŹåžŔåĹŮåŔůåŁă1ïijŽ

```
class ResultHandler:

    def __init__(self):
        self.sequence = 0

    def handler(self, result):
        self.sequence += 1
        print('[{}] Got: {}'.format(self.sequence, result))
```

ä¡£çŤĺè£ŹäÿłçśžçŽĎæŮűåĂŹïijŇä¡ăåĚĹåĹŻåžžäÿĂäÿłçśžçŽĎåőđä¿ŇïijŇçĎűåŘŐçŤĺåőČçŽĎ `handler()` çżŚåőŽæŰźæşŢæÍěåĄŽäÿžåŻđèřČåĞ¡æŢřijŽ

```
>>> r = ResultHandler()
>>> apply_async(add, (2, 3), callback=r.handler)
[1] Got: 5
>>> apply_async(add, ('hello', 'world'), callback=r.handler)
[2] Got: helloworld
>>>
```

çñňäžŇçğ■æŰźåijŔïijŇä¡IJäÿžçśžçŽĎæŻ£äžčïijŇåŕŕäžěä¡£çŤĺäÿĂäÿłéŮ■åŇĚæ■ŢèŐůçŁűæĂĄåĂijïijŇ

```
def make_handler():
    sequence = 0
    def handler(result):
        nonlocal sequence
        sequence += 1
        print('[{}] Got: {}'.format(sequence, result))
    return handler
```

äÿŇéÍćæŸŕä¡£çŤĺéŮ■åŇĚæŰźåijŔçŽĎäÿĂäÿłä¿Ńå■ŘïijŽ

```
>>> handler = make_handler()
>>> apply_async(add, (2, 3), callback=handler)
[1] Got: 5
>>> apply_async(add, ('hello', 'world'), callback=handler)
[2] Got: helloworld
>>>
```

è£ŸæIJL'åŔęåď ŰäÿĂäÿłæŻť'éńŸçžğçŽĎæŰźæşŢïijŇåŕŕäžěä¡£çŤĺå■ŔçÍŃæÍěåőŇæĹŘåŘŇæăůçŽĎäžŇ

```
def make_handler():
    sequence = 0
    while True:
```

```
        result = yield
        sequence += 1
        print('[{}] Got: {}'.format(sequence, result))
```

åŕźäžŐå■ŔçÍŃïijÑä¡ăéIJĂèęĄä¡£çŤÍåőČçŽĎ send() æŰźæşŢä¡IJäÿžåŻđèřČåĞ¡æŢřïijÑåęĆäÿŃæĽĂç

```
>>> handler = make_handler()
>>> next(handler) # Advance to the yield
>>> apply_async(add, (2, 3), callback=handler.send)
[1] Got: 5
>>> apply_async(add, ('hello', 'world'), callback=handler.send)
[2] Got: helloworld
>>>
```

èőÍèőž

å§žäžŐåŻđèřČåĞ¡æŢřçŽĎè¡ŕäžűéĂŽåÿÿéČ¡æIJL'åŔŕèČ¡åŔŸå¿ŮéIđåÿÿåd'■æİĆãĂĆäÿĂéČÍåĹEåŐ§åŻ
åŻăæ■d'ïijÑèŕůæśĆæL'ğèąÑåŠÑåd'ĎçŘEçżŞæđIJäźŃéŮt'çŽĎæL'ğèąÑçŐŕáćČåőđéŹĚäÿŁåůšçżŔäÿćåd'śäžE
éĆčä¡ăåŕšå£ĚéążåŐżèğčåEşåęĆä¡Ţä£Ìå■ŸåŠÑæĄćåd'■çŻÿåĚşçŽĎçŁűæĂĄä£ąæĄŕäžEąãĂĆ

èĞşåřŚæIJL'äÿd'çğ■äÿżèęĄæŰźåijŔæÌěæ■ŢèŐůåŠÑä£Ìå■ŸçŁűæĂĄä£ąæĄŕïijÑä¡ăåŔŕäžěåIJÍäÿĂäÿłåŕ
äÿd'çğ■æŰźåijŔçŻÿæŕŤïijÑéŮ■åÑĚæĹŰèőÿæŸŕæŻt'åŁăè¡żéĞŔçžğåŠÑèĞłçĎűäÿĂçĆźïijÑåŻääÿžåőČäżñå
åőČäżñè£ŸèČ¡èĞłåŁÍæ■ŢèŐůæL'ĂæIJL'èćńä¡£çŤÍåĹřçŽĎåŔŸéĞŔãĂĆåŻăæ■d'ïijÑä¡ăæŮăéIJĂåŐżæÑĚå£(

åęĆædIJä¡£çŤÍéŮ■åÑĚïijÑä¡ăéIJĂèęĄæşÍæĎŔåŕźéĆčäžŻåŔŕä£őæŤźåŔŸéĞŔçŽĎæŞ■ä¡IJãĂĆåIJÍäÿŁé
nonlocal åčřæŸŐèŕ■åŔěçŤÍæÌěæÑĞçd'žæŐěäÿŃæÌěçŽĎåŔŸéĞŔäijŽåIJÍåŻđèřČåĞ¡æŢřäÿ■èćńä£őæŤźãA

èĂÑä¡£çŤÍäÿĂäÿłå■ŔçÍŃæÌěä¡IJäÿžäÿĂäÿłåŻđèřČåĞ¡æŢřåřśæŻt'æIJL'èűčäžĘïijÑåőČèů§éŮ■åÑĚæŰźa
æ§Řçğ■æĎŔäźL'äÿŁæÌěèőšïijÑåőČæŸ¿å¿ŮæŻt'åŁăçőĂæt'ĄïijÑåŽääÿžæĂżåĚśåřśäÿĂäÿłåĞ¡æŢřèĂÑåůšãĂ
åźűäÿŤïijÑä¡ăåŔŕäžěå¿ĹèĞłçŤśçŽĎä£őæŤźåŔŸéĞŔèĂÑæŮăéIJĂåŐżä¡£çŤÍ nonlocal
åčřæŸŐãĂĆ è£Źçğ■æŰźåijŔåŤŕäÿĂçijżçĆźåřśæŸŕçŻÿåŕźäžŐåĚűäžŰPythonæŁĂæIJŕèĂÑèÍĂæĹŰèőÿæŕŤè¿
åŔęåd'Ůè£ŸæIJL'äÿĂäžŻæŕŤè¿ČéŽ¿æĞĆçŽĎéČĺåĹĘïijÑæŕŤåęĆä¡£çŤÍäźŃåL'■éIJĂèęĄèŕČçŤÍ
next() ïijÑåőđéŹĚä¡£çŤÍæŮűè£Źäÿłæ■ěéłd'å¿Ĺåőźæ ŸŞècńå£Ÿèőřã ĂĆ
år¡çőąåęĆæ■d'ïijÑå■ŔçÍŃè£ŸæIJL'åĚűäžŰçŤÍåd'ĎïijÑæŕŤåęĆä¡IJäÿžäÿĂäÿłåĘĚèĄŤåŻđèřČåĞ¡æŢřçŽĎåőŻ

åęĆædIJä¡ăäżĚäżĚåŔłéIJĂèęĄçżŹåŻđèřČåĞ¡æŢřäijäéĂŠécÍåd'ŰçŽĎåĂijçŽĎèŕÍïijÑè£ŸæIJL'äÿĂçğ■ä
partial() çŽĎæŰźåijŔäźš§å¿ĹæIJL'çŤÍãĂĆ åIJÍæšąæIJL'ä¡£çŤÍ partial()
çŽĎæŮűåĂŹïijÑä¡ăåŔŕèČ¡çżŔåÿÿçIJŃåĹřäÿŃéÍćè£Źçğ■ä¡£çŤÍlambdaèąÍè¿¿åijŔçŽĎåd'■æİĆäžčçăĄïijŽ

```
>>> apply_async(add, (2, 3), callback=lambda r: handler(r, seq))
[1] Got: 5
>>>
```

åŔŕäžěåŔĆèĂČ7.8åřŔèŁĆçŽĎåĞääÿłçd'žä¿ŃïijÑæŢŹä¡ăåęĆä¡Ţä¡£çŤÍ partial()
æÌěæŻt'æŤźåŔĆæŢřç■¿åŘ■æÌěçőĂåŇŰäÿŁè£ŕäžčçăĄãĂĆ

9.11 7.11 åĘĚèĄŤåŻđèřČåĞ¡æŢř

éŮőécŸ

å¡Şä¡ăçijŰåĘŹä¡£çŤĺåŻđèřČåĞ¡æŢřçŽĎäžčçăĄçŽĎæŮűåĂŹïijŇæŃĚå£Čå¿Ĺåď˙ŽářŕåĞ¡æŢřçŽĎæĽ'ľ'ä¡ăåÿŇæIJŻæĽ¿åĹřæ§ŘäÿłæŰźæşŢæĺěőľ'äžčçăĄçIJŃäÿŁåŐżæŻť˙åČŕæŸŕäÿĂäÿłæŹőéĂŽçŽĎæĽ'ğèąŇåžĚ

èğčåĘşæŰźæąĹ

éĂŽè£Ğä¡£çŤĺçŤ§æĹŘåŹĺåŠŇå■ŕçĺŃåŕŕäžěä¡£å¿ŮåŻđèřČåĞ¡æŢřåĘĚèĄŤåIJĺæ§ŘäÿłåĞ¡æŢřäÿ■ãĂĆäÿžäžĘæijŤçd'žèŕť˙æŸŐïijŇåĄĞèő¿ä¡ăæIJL'åęĆäÿŃæĽ'Ăçd'žçŽĎäÿĂäÿłæĽ'ğèąŇæ§Řçğ■èőąçőŮäżżåŁąçĎű

```
def apply_async(func, args, *, callback):
    # Compute the result
    result = func(*args)

    # Invoke the callback with the result
    callback(result)
```

æŐěäÿŃæĺěèőľ'æĹŚäžňçIJŃäÿĂäÿŃäÿŃéĺćçŽĎäžčçăĄïijŇåőČåŇĚåŘŕäžĘäÿĂäÿł Async çśżåŠŇäÿĂäÿł inlined_async èčĚéěřåŹĺïijŽ

```
from queue import Queue
from functools import wraps

class Async:
    def __init__(self, func, args):
        self.func = func
        self.args = args

def inlined_async(func):
    @wraps(func)
    def wrapper(*args):
        f = func(*args)
        result_queue = Queue()
        result_queue.put(None)
        while True:
            result = result_queue.get()
            try:
                a = f.send(result)
                apply_async(a.func, a.args, callback=result_queue.
↪put)
            except StopIteration:
                break
    return wrapper
```

è£Źäÿd'äÿłäžčçăĄçL'Ğæőţå ĚĄèőÿä¡ăä¡£çŤĺ yield èŕ■åŘěåĘĚèĄŤåŻđèřČæ■ěéłd'ãĂĆæŕŤåęĆïijŽ

```
def add(x, y):
    return x + y

@inlined_async
def test():
    r = yield Async(add, (2, 3))
    print(r)
    r = yield Async(add, ('hello', 'world'))
    print(r)
    for n in range(10):
        r = yield Async(add, (n, n))
        print(r)
    print('Goodbye')
```

åęĆædIJä¡ăèřČçŤÍ `test()` ïijŇä¡ăäijŽå¿ŮåĹřçśżäijijåęĆäÿŃçŽĎè¿ŞåĞžïijŽ

```
5
helloworld
0
2
4
6
8
10
12
14
16
18
Goodbye
```

ä¡ăäijŽåŔŚçŐřïijŇéŹď äžĘéĆčäÿłçL’źåĹńçŽĎèčĚéěřåŹĺåŠŇ `yield` èŕ■åŔěåď ŰïijŇåĚűäžŰåIJřæŰźåźűæšąæIJL’åĞžçŐřäżżä¡ŢçŽĎåŻđèřČåĞ¡æŢř(åĚűåőđæŸŕåIJĺåŘŐåŔřåőŽäź

èőÍèőž

æIJňářŔèŁĆäijŽåőđåőđåIJĺåIJÍçŽĎæţŃèřŢä¡ăåĚşäžŐåŻđèřČåĞ¡æŢřãĂĄçŤ§æĹŘåŹĺåŠŇæŐğåĹűæţĄç

éęŰåĚĹïijŇåIJÍéIJÄèęĄä¡£çŤĺåĹřåŻđèřČçŽĎäžčçãĄäÿ■ïijŇåĚşéŤőçĆźåIJÍäžŐå¡ŞåL’■èőąçőŮåůëä¡IJäi
å¡Şèőąçő Ůé Ğ■åŘræŮűïijŇåŻđèřČåĞ¡æŢřèćńèřČçŤÍæIěçžğçż■åď ĎçŘĘçżŞæđIJãĂĆ`apply_async()`
åĞ¡æŢřæijŤçď žäžĘæL’ğèąŇåŻđèřČçŽĎåőđéŹĚéĂżè¿Śïij Ň år¡çőąåőđéŹĚæČĚåĘţäÿ■åőČåŘŕèČ¡äijŽæŻť’åŁă

èőąçőŮçŽĎæŽĆåĄIJäÿŐéĞ■åŘræĂIèůŕèů§çŤ§æĹŘåŹĺåĞ¡æŢřçŽĎæL’ğèąŇæĺąåđŃäÿ■èřŃèĂŇåŘĹãĂ
åĚůä¡ŞæIěèőšïijŇ`yield` æŞ■ä¡IJäijŽä¡£äÿĂäÿłçŤ§æĹŘåŹĺåĞ¡æŢřäžğçŤ§äÿĂäÿłåĂijåźűæŽĆåĄIJãĂĆ
æŐěäÿŃæIěèřČçŤĺçŤ§æĹŘåŹĺçŽĎ `__next__()` æĹŰ `send()`
æŰźæşŢåŔĹäijŽèőľ’åőČäžŐæŽĆåĄIJåď ĎçżğçżæL’ğèąŇãĂĆ

æăźæ■őè£ŹäÿłæĂIèůŕïijŇè£ŹäÿĂåřŔèŁĆçŽĎæăÿå£Čåřšå IJÍ `inline_async()`
èčĚéěřåŹĺåĞ¡æŢřäÿ■äžĘãĂĆ åĚşéŤőçĆźåřšæŸŕïijŇèčĚéěřåŹĺäijŽéĂŘæ■ěéĄ■åŐEçŤ§æĹŘåŹĺåĞ¡æŢřçŽĎæ
`yield` èŕ■åŔěijŇæŕŘäÿĂæňąäÿĂäÿłãĂĆ äÿžäžĘè£ŹæăůåĄŽïijŇåĹŽåijĂåğŃçŽĎæŮűåĂŹåĹŻåžžäžĘäÿĂä
`result` éŸ§åĹŮåźűåŘŠéĞŇéIćæŤ¿åĚěäÿĂäÿł `None` åĂijãĂĆ

çĎűåŘŐåijĂåğŃäÿĂäÿłå¿łçŐŕæŞ■ä¡IJïijŇäżŐéŸ§åĹŮäÿ■åŔŰåĞžçżŞæđIJåĂijåźűåŔŚéĂĄçżŹçŢ§æĹŘåŹĺï
`yield` èŕ■åŔěïijŇ åIJĺè£ŹéĞŇäÿĂäÿł `Async` çŽĎåőđä¿Ńèćńæ Őěå ŘŮåĹřãĂĆçĎűåŘŐå¿łçŐŕåijĂåğŃæčĂæ
`apply_async()` ãĂĆ çĎűèĂŇïijŇè£ŹäÿłèőąçőŮæIJL'äÿłæIJĂèŕąåijĆéČĺåĹĘæŸŕåőČåźűæšąæIJL'ä¡£çŢĺäÿ
`put()` æŰźæşŢæİěåŻđèřČãĂĆ

è£ŹæŮűůåĂŹïijŇæŸŕæŮűůåĂŹèŕęçżĘèğčéĞŁäÿŃåĹřåžŢåŔŚçŢ§äžĘäżĂäźĹäžĘãĂĆäÿżå¿łçŐŕçńŃå■şè£
`get()` æŞ■ä¡IJãĂĆ åęĆæđIJæŢřæ■őå■ŸåIJĺïijŇåőČäÿĂåőŽæŸŕ `put()`
åŻđèřČå■ŸæŢ¿çŽĎçżŞæđIJãĂĆåęĆæđIJæšąæIJL'æŢřæ■őïijŇéĆčäźĹåĚĹæŽĆåĄIJæŞ■ä¡IJåźűç■L'å¿ĚçżŞæ
è£ŹäÿłåĚůä¡ŞæĂŐæăůåőđçŐŕæŸŕçŢś `apply_async()` åĞ¡æŢřæİěåĘşåőŽçŽĎãĂĆ
åęĆæđIJä¡ääÿ■çŻÿä£ąäijŽæIJL'è£ŹäźĹçěđåěĞçŽĎäžŃæČĚïijŇä¡ääŕäžěä¡£çŢĺ
`multiprocessing` åžŞæİèèŕŢäÿĂäÿŃïijŇ åIJĺå■ŢçŃňçŽĎè£ŻçĺŃäÿ■æL'ğèąŇåijĆæ■ěèőąçőŮæŞ■ä¡IJïijŃ

```
if __name__ == '__main__':
    import multiprocessing
    pool = multiprocessing.Pool()
    apply_async = pool.apply_async

    # Run the test function
    test()
```

åőđéŹĚäÿŁä¡ääijŽåŔŚçŐřè£ŹäÿłçIJ§çŽĎåřśæŸŕè£ŹæăůçŽĎïijŇä¡ĘæŸŕèęĄèğčéĞŁæÿĚæěŽåĚůä¡ŞçŽĺ

åřĘåd'■æİĆçŽĎæŐğåĹűæţĄéŽŘèŮŔåĹřçŢ§æĹŘåŹĺåĞ¡æŢřèČŇåŘŐçŽĎä¿Ńå■ŘåIJĺæăĞåĞĘåžŞåŠŇç
æŕŤåęĆïijŇåIJĺ `contextlib` äÿ■çŽĎ `@contextmanager`
èčĚéěřåŹĺä¡£çŢĺäžĘäÿĂäÿłäżd'äžžèť źèğčçŽĎæŁĂåůğïijŇ éĂŽè£ĞäÿĂäÿł `yield`
èŕ■åŔěåřĘè£ŻåĚěåŠŇçężåijĂäÿŁäÿŃæŰĞçőąçŘĘåŹĺçšŸåŘĹåIJĺäÿĂèţůãĂĆ
åŘęåd'ŰéİđåÿÿæţĄèąŇçŽĎ `Twisted` åŇĚäÿ■äź§åŇĚåŘńäžĘéİđåÿÿçśżäijijçŽĎåĘĚèĄŤåŻđèřČãĂĆ

9.12 7.12 èő£éŮőéŮ■åŇĚäÿ■åőŽäźĽçŽĎåŔŸéĞŔ

éŮőécŸ

ä¡ăæČşèęĄæĽl'åśŢåĞ¡æŢřäÿ■çŽĎæ§Řäÿłé Ů■åŇĚïijŇåĚĄèőÿåőČèČ¡èő£éŮőåŠŇä£őæŤźåĞ¡æŢřçŽĎå

èğčåĘşæŰźæąĹ

éĂŽåÿÿæİěèőšïijŇéŮ■åŇĚçŽĎåĘĚéČĺåŔŸéĞŔåŕźäžŐåd'ŰçŢŇæİěèőšæŸŕåőŇåĚĺéŽŘèŮŔçŽĎãĂĆ
ä¡ĘæŸŕïijŇä¡ăåŔŕäžěéĂŽè£ĞçijŰåĘŹèő£éŮőåĞ¡æŢřåźűåřĘåĚűä¡IJäÿžåĞ¡æŢřåśđæĂğçżŚåőŽåĹřéŮ■åŇĚäÿ

```
def sample():
    n = 0
    # Closure function
    def func():
        print('n=', n)

    # Accessor methods for n
    def get_n():
        return n
```

```
    def set_n(value):
        nonlocal n
        n = value

    # Attach as function attributes
    func.get_n = get_n
    func.set_n = set_n
    return func
```

äÿŃéÌćæŸŕä¡£çŤÍçŽĎä¿Ńå■Ř:

```
>>> f = sample()
>>> f()
n= 0
>>> f.set_n(10)
>>> f()
n= 10
>>> f.get_n()
10
>>>
```

èőÍèőž

äÿžäžĘèŕť æŸŐæÿĚæěŽåőČåęĆä¡Ţåůëä¡IJçŽĎïijŇæIJL’äÿd’çĆźéIJĂèęĄèğčéĞŁäÿĂäÿŃãĂĆéęŰåĚĹïij
åčřæŸŐåŘŕäżěèőľ æĹŚäžňçijŰåĘŹåĞ¡æŢřæİěä£őæŤźåĘĚéČĺåŔŸéĞŘçŽĎåĂijãĂĆ
åĚűæňąïijŇåĞ¡æŢřåšđæĂğåĚĄèőÿæĹŚäžňçŤĺäÿĂçğ■å¿ĹçőĂå■ŢçŽĎæŰźåijŔåřĘèő£éŮőæŰźæşŢçżŚåőŽåĹ

è£ŸåŘŕäžěè£ŻäÿĂæ■ěçŽĎæĽľåśŢïijŇèőľéŮ■åŇĚæĺąæŃ§çśżçŽĎåőđä¿ŃãĂĆä¡ăèęĄåĄŽçŽĎäżĚäżĚa

```
import sys
class ClosureInstance:
    def __init__(self, locals=None):
        if locals is None:
            locals = sys._getframe(1).f_locals

        # Update instance dictionary with callables
        self.__dict__.update((key,value) for key, value in locals.
↪items()
                             if callable(value) )
    # Redirect special methods
    def __len__(self):
        return self.__dict__['__len__']()

# Example use
def Stack():
    items = []
    def push(item):
        items.append(item)
```

```
    def pop():
        return items.pop()

    def __len__():
        return len(items)

    return ClosureInstance()
```

äÿŃéÌćæŸŕäÿĂäÿłäžd'äžŠåijŔäijŽèŕÌæÌěæijŤçd'žåőČæŸŕåęĆä¡Ţåůëä¡IJçŽĎïijŽ

```
>>> s = Stack()
>>> s
<__main__.ClosureInstance object at 0x10069ed10>
>>> s.push(10)
>>> s.push(20)
>>> s.push('Hello')
>>> len(s)
3
>>> s.pop()
'Hello'
>>> s.pop()
20
>>> s.pop()
10
>>>
```

æIJL'èűčçŽĎæŸŕïijŇè£ŹäÿłäžčçăĄè£ŘèąŇèţůæÌěäijŽæŕŤäÿĂäÿłæŹőéĂŽçŽĎçśżåőŽäźL'èęĄå£ńå¿Ĺåd'

```
class Stack2:
    def __init__(self):
        self.items = []

    def push(self, item):
        self.items.append(item)

    def pop(self):
        return self.items.pop()

    def __len__(self):
        return len(self.items)
```

åęĆædIJè£ŹæăůåĄŽïijŇä¡ääijŽå¿ŮåĹřçśżäijijåęĆäÿŃçŽĎçżŞædIJïijŽ

```
>>> from timeit import timeit
>>> # Test involving closures
>>> s = Stack()
>>> timeit('s.push(1);s.pop()', 'from __main__ import s')
0.9874754269840196
>>> # Test involving a class
>>> s = Stack2()
```

```
>>> timeit('s.push(1);s.pop()', 'from __main__ import s')
1.0707052160287276
>>>
```

çżŞæđIJæŸ¿çd'žïijŇéŮ■åŇĚçŽĎæŰźæąĹè£ŘèąŇètůæİěèęĄå£ńåd'ğæęĆ8%ïijŇåd'ğéČĺåĹĘåŐ§åŻăæŸ
éŮ■åŇĚæŻt'å£ńæŸŕåŻääÿžäÿ■äijŽæűL'åŔŁåĹřéćİåd'ŰçŽĎselfåŔŸéĞŔãĂĆ

Raymond Hettingerårźäž0è£ŹäÿłéŮőécŸèő¿èőąåĞžäžĘæŻt'åŁäéŽ¿äžěçŘĘèğčçŽĎæŤźè£ŻæŰźæąĹãĂ
èĂŇäÿŤåőČåŔłæŸŕçIJ§åőđçšżçŽĎäÿĂäÿłåěĞæĂłçŽĎæŻ£æ■ćèĂŇåůšïijŇä¿ŃåęĆïijŇçšżçŽĎäÿżèęĄçĹ'źæ
åźűäÿŤä¡ăèęĄåĄŽäÿĂäžŻåĚűäžŰçŽĎåůěä¡IJæĽ'■èČ¡èőľäÿĂäžŻçĽ'źæőŁæŰźæşŢçŤ§æŢĹ(æŕŤåęĆäÿŁéİć
`ClosureInstance` äÿ■éĞ■åĘŹè£ĞçŽĎ `__len__()` åőđçŐřãĂĆ)

æIJĂåŘŐïijŇä¡ăåŔŕèČ¡è£ŸäijŽèőľåĚűäžŰéŸĚèŕżä¡ääžčçăĄçŽĎäžžæĎ§åĹřçŰŚæČŚïijŇäÿžäžĂäźĹåőČ
(å¡ŞçĎűïijŇäżŰäžňäź§æČşç§ěéĄŞäÿžäżĂäźĹåőČè£ŘèąŇètůæİěäijŽæŻt'å£ń)ãĂĆår¡çőąåęĆæ■d'ïijŇè£Źårźä

æĂżä¡ŞäÿŁèőšïijŇåIJĺéĚ■ç¡őçŽĎæŮűåĂŹçżŹéŮ■åŇĚæůżåŁăæŰźæşŢäijŽæIJL'æŻt'åd'ŽçŽĎåőđçŤĺåŁ
ærŤåęĆä¡ăéIJĂèęĄéĞ■ç¡őåĘĚéČĺçŁűæĂĄãĂĄåĹůæŰřçijŞåĘšåŇžãĂĄæÿĚéŹd'çijŞå■ŸæĹŮåĚűäžŰçŽĎåŔ

10 çňňåĚńçńăïijŽçśżäÿŐårźèšą

æIJňçńăäÿżèęĄåĚşæşĺçĆźçŽĎæŸŕåŠŇçśżåőŽäźL'æIJL'åĚşçŽĎåÿÿèğĄçijŰçĺŃæĺąåđŃãĂĆåŇĚæŃňèől'
çśżåřĄèčĚæŁĂæIJŕãĂĄçžğæL'£ãĂĄåĘĚå■ŸçőąçŘĘäżèåŔŁæIJL'çŤĺçŽĎèő¿èőąæĺąåijŔãĂĆ

Contents:

10.1 8.1 æŤźåŔŸårźèšąçŽĎå■ŮçňęäÿšæŸ¿çd'ž

éŮőécŸ

ä¡ăæČşæŤźåŔŸårźèšąåőđä¿ŃçŽĎæL'Şå■řæĹŰæŸ¿çd'žè¿ŞåĞžïijŇèől'åőČäžňæŻt'åĚůåŔŕèŕżæĂğãĂĆ

èğčåĘşæŰźæąĹ

èęĄæŤźåŔŸäÿĂäÿłåőđä¿ŃçŽĎå■Ůçňęäÿšèąĺçd'žïijŇåŔŕéĞ■æŰřåőŽäźL'åőČçŽĎ
`__str__()` åŠŇ `__repr__()` æŰźæşŢãĂĆä¿ŃåęĆïijŽ

```
class Pair:
    def __init__(self, x, y):
        self.x = x
        self.y = y

    def __repr__(self):
        return 'Pair({0.x!r}, {0.y!r})'.format(self)

    def __str__(self):
        return '({0.x!s}, {0.y!s})'.format(self)
```

__repr__() æŰźæşŢè£ŤåŻđäÿĂäÿłåőđä¿ŃçŽĎäžčçăĄèąĺçď'žå¡ćåijŕïijŇéĂŽåÿÿçŤĺæİěéĞ■æŰřæđĎ
åĘĚç¡őçŽĎ repr() åĞ¡æŢřè£ŤåŻđè£ŹäÿłåĄ■Ůçňęäÿšïij Ňèů§æĹŚäžňä¡£çŤĺäžď'äžŠåijŕèğčéĞŁåŹĺæŸ¿çď'žç
__str__() æŰźæşŢåřĘåőđä¿Ńè¡ňæ■ćäÿžäÿĂäÿłå■Ůçňęäÿšïij Ňä¡£çŤĺ str() æĹŰ
print() åĞ¡æŢřäijŽè¿ŞåĞžè£ŹäÿłåĄ■Ůçňęäÿšã ĂĆærŤåęĆïijŽ

```
>>> p = Pair(3, 4)
>>> p
Pair(3, 4) # __repr__() output
>>> print(p)
(3, 4) # __str__() output
>>>
```

æĹŚäžňåIJĺè£ŹéĞŇè£ŸæijŤçď'žäžĘåIJĺæăijåijŕåŇŰçŽĎæŮűåĂŹæĂŐæăůä¡£çŤĺäÿ■åŘŇçŽĎå■Ůçňęäÿ
çL'źåĹńæİěëőšïijŇ!r æăijåijŕåŇŰäžčçăĄæŇĞæŸŐè¿ŞåĞžä¡£çŤĺ
__repr__() æİěäžčæŻ£éżŸèőď'çŽĎ __str__() ãĂĆ
ä¡ăåŕŕäžěçŤĺåL'■éĺćçŽĎçśżæİěèŕŢçİĂæţŃèŕŢäÿŃïijŽ

```
>>> p = Pair(3, 4)
>>> print('p is {0!r}'.format(p))
p is Pair(3, 4)
>>> print('p is {0}'.format(p))
p is (3, 4)
>>>
```

ëőĺëőž

èĞłåőŽäźL' __repr__() åŠŇ __str__() éĂŽåÿÿæŸŕå¿Ĺåě¡çŽĎäźăæČŕïijŇåŻăäÿžåőČèČ¡çőĂåŇŰ
ä¿ŃåęĆïijŇåęĆæđIJäžĚäžĚåŘłæŸŕæL'Şå■řè¿ŞåĞžæĹŰæŮěå£Ůè¿ŞåĞžæ§Ŕäÿłåőđä¿ŃïijŇéĆčäźĹçĺŃåžŔåŠ

__repr__() çŤ§æĹŘçŽĎæŰĞæIJňå■ŮçňęäÿšæăĞåĞĘåĄŽæşŢæŸŕéIJĂèęĄèől'
eval(repr(x)) == x äÿžçIJ§ãĂĆ åęĆæđIJåőđåIJĺäÿ■èČ¡è£ŹæăůåĄ■ŘåĄŽïijŇåžŤèŕěåĹŽåžžäÿĂäÿłæIJL
< åŠŇ > æŃňètůæİěãĂĆærŤåęĆïijŽ

```
>>> f = open('file.dat')
>>> f
<_io.TextIOWrapper name='file.dat' mode='r' encoding='UTF-8'>
>>>
```

åęĆæđIJ __str__() æšąæIJL'èćńåőŽäźL'ïijŇéĆčäźĹåřšäijŽä¡£çŤĺ __repr__()
æİěäžčæŻ£è¿ŞåĞžãĂĆ

äÿŁéĺćçŽĎ format() æŰźæşŢçŽĎä¡£çŤĺçIJŃäÿŁåŐžå¿ĹæIJL'èűčïijŇæăijåijŕåŇŰäžčçăĄ
{0.x} åŕźåžŤçŽĎæŸŕçňň1äÿłåŘĆæŢřçŽĎxåšđæĂğãĂĆ åŻăæ■d'ïijŇåIJĺäÿŃéIćçŽĎåĞ¡æŢřäÿ■ïijŇ0åőđéŹ
self æIJňèžńïijŽ

```
def __repr__(self):
    return 'Pair({0.x!r}, {0.y!r})'.format(self)
```

ä¡IJäÿžè£Źçğ■åőđçŐřçŽĎäÿĂäÿłæŻ£äžčïijŇä¡ăäź§åŘŕäžěä¡£çŤĺ %
æŞ■ä¡IJçňęïijŇåřšåČŔäÿŃéIćè£ŹæăůïijŽ

```
def __repr__(self):
    return 'Pair(%r, %r)' % (self.x, self.y)
```

10.2 8.2 èĞłåőŽäźĽå■Ůçňęäÿšç ŽĎæăijåijŔåŇŰ

éŮőécŸ

ä¡ăæČşéĂŽè£Ğ format() åĞ¡æŢřåŠŇå■Ůçňęäÿšæ ŰźæşŢä¡£å¿ŮäÿĂäÿłåŕźèśąèČ¡æŤŕæŇĄèĞłåőŽäźĽ

èğčåĘşæŰźæąĹ

äÿžäžĘèĞłåőŽäźĽå■Ůçňęäÿšç ŽĎæăijåijŔåŇŰïijŇæĹŚäžňéIJĂèęĄåIJĺçśžäÿŁéĺćåőŽäźĽ __format__() æŰźæşŢãĂĆä¿ŃåęĆïijŽ

```
_formats = {
    'ymd' : '{d.year}-{d.month}-{d.day}',
    'mdy' : '{d.month}/{d.day}/{d.year}',
    'dmy' : '{d.day}/{d.month}/{d.year}'
    }

class Date:
    def __init__(self, year, month, day):
        self.year = year
        self.month = month
        self.day = day

    def __format__(self, code):
        if code == '':
            code = 'ymd'
        fmt = _formats[code]
        return fmt.format(d=self)
```

çŐřåIJĺ Date çśžçŽĎåőđä¿ŃåŔŕäžěæŤŕæŇĄæăijåijŔåŇŰæŞ■ä¡IJäžĘïijŇåęĆåŘŇäÿŃéĺćè£ŹæăůïijŽ

```
>>> d = Date(2012, 12, 21)
>>> format(d)
'2012-12-21'
>>> format(d, 'mdy')
'12/21/2012'
>>> 'The date is {:ymd}'.format(d)
'The date is 2012-12-21'
>>> 'The date is {:mdy}'.format(d)
'The date is 12/21/2012'
>>>
```

èőÍèőž

__format__() æŰźæşŢçżŹPythonçŽĎå■ŮçňęäÿšæäijåijŔåŇŰåŁ§èČ¡æŔŘä¿ŻäžĘäÿĂäÿłéŠľå■ŘãĂ
è£ŹéĞŇéIJĂèęĄçİĂéĞ■åijžèřČçŽĎæŸŕæäijåijŔåŇŰäžčçăĄçŽĎèğčæđŘåůëä¡IJåőŇåĚÍçŤśçźèĞłåůśåĘşåőŽ
ä¿ŃåęĆïijŇåŔĆèĂČäÿŃéÍćæİěèĞł datetime æĺąåİŮäÿ■çŽĎäžčçăĄïijŽ

```
>>> from datetime import date
>>> d = date(2012, 12, 21)
>>> format(d)
'2012-12-21'
>>> format(d,'%A, %B %d, %Y')
'Friday, December 21, 2012'
>>> 'The end is {:%d %b %Y}. Goodbye'.format(d)
'The end is 21 Dec 2012. Goodbye'
>>>
```

åŕźäžŐåĘĚç¡őçśžåđŃçŽĎæäijåijŔåŇŰæIJL'äÿĂäžŻæăĞåĞĘçŽĎçžęåőŽãĂĆ
åŔŕäžěåŔĆèĂČ stringæĺąåİŮæŰĞæąč èŕť'æŸŐãĂĆ

10.3 8.3 èőľåŕźèśąæŤŕæŇĄäÿŁäÿŃæŰĞçőąçŘĘå■Ŕèőő

éŮőécŸ

ä¡ăæČşèőľä¡ăçŽĎåŕźèśąæŤŕæŇĄäÿŁäÿŃæŰĞçőąçŘĘå■Ŕèőő(withèŕ■åŔě)ãĂĆ

èğčåĘşæŰźæąĹ

äÿžäžĘèőľäÿĂäÿłåŕźèśąåĚijåőź with èŕ■åŔěïijŇä¡ăéIJĂèęĄåőđçŐř __enter__()
åŠŇ __exit__() æŰźæşŢãĂĆ ä¿ŃåęĆïijŇèĂČèŹŚåęĆäÿŃçŽĎäÿĂäÿłçśžïijŇåőČèČ¡äÿžæĹŚäžňåĹŻåžžäÿ

```
from socket import socket, AF_INET, SOCK_STREAM

class LazyConnection:
    def __init__(self, address, family=AF_INET, type=SOCK_STREAM):
        self.address = address
        self.family = family
        self.type = type
        self.sock = None

    def __enter__(self):
        if self.sock is not None:
            raise RuntimeError('Already connected')
        self.sock = socket(self.family, self.type)
        self.sock.connect(self.address)
        return self.sock

    def __exit__(self, exc_ty, exc_val, tb):
```

```
        self.sock.close()
        self.sock = None
```

è£Źäÿłçśžçž ŽĎåĚşéŤőçL’źçĆźåIJÍäžŐåőČèąÍçď žäžĘäÿĂäÿłç¡ŚçżIJè£đæŐěïijÑä¡ĘæŸŕåĹİåğŃåŇŰçŽĎa
è£đæŐěçŽĎåžžçńŃåŠŇåĚşéŮ■æŸŕä¡£çŤÍ with èŕ■åŔěèĞłåŁĺåőŇæĹŘçŽĎïijÑä¿ŃåęĆïijŽ

```
from functools import partial

conn = LazyConnection(('www.python.org', 80))
# Connection closed
with conn as s:
    # conn.__enter__() executes: connection open
    s.send(b'GET /index.html HTTP/1.0\r\n')
    s.send(b'Host: www.python.org\r\n')
    s.send(b'\r\n')
    resp = b''.join(iter(partial(s.recv, 8192), b''))
    # conn.__exit__() executes: connection closed
```

èőÍèőž

çijŰåĘŹäÿŁäÿŃæŰĞçőąçŘĘåŹÍçŽĎäÿżèęĄåŐ§çŘĘæŸŕä¡ăçŽĎäžčçăĄäijŽæŤ¿åĹř
with èŕ■åŔěåİŮäÿ■æĽ’ğèąŇãĂĆ å¡ŞåĞžçŐř with èŕ■åŔěçŽĎæŮűåĂŹïijÑåŕźèśąçŽĎ
__enter__() æŰźæşŢèćńèğęåŔŚïijŇ åőČè£ŤåŻđçŽĎåĂij(åęĆæđIJæIJĽ’çŽĎèŕÍ)äijŽèćńètŃåĂijçżŹ
as åčřæŸŐçŽĎåŔŸéĞŔãĂĆçĎűåŘŐïijÑwith èŕ■åŔěåİŮéĞŇéÍćçŽĎäžčçăĄåijĂågŃæĽ’ğèąŇãĂĆ
æIJĂåŘŐïijÑ__exit__() æŰźæşŢèćńèğęåŔŚè£ŻèąŇæÿĚçŘĘåůěä¡IJãĂĆ

äÿ■çőą with äžčçăĄåİŮäÿ■åŔŚçŤ§äžĂäźĹïijÑäÿŁéÍćçŽĎæŐğåĹűæţĄéČ¡äijŽæĽ’ğèąŇåőÑïijÑåŕśçőŮ
äžŃåőđäÿŁïijÑ__exit__() æŰźæşŢçŽĎçńňäÿL’äÿłåŔĆæŢřåŇĚåŘńäžĘåijĆåÿÿçśžåđŃãĂĄåijĆåÿÿåĂijåš
__exit__() æŰźæşŢèČ¡èĞłåůśåĘşåőŽæĂŐæăůåĹ’çŤÍè£ŹäÿłåijĆåÿÿä£ąæĄŕïijŇæĹŰèĂĚå£¡çŢěåőČåźűë
åęĆæđIJ __exit__() è£ŤåŻđ True ïijŇéĆčäźĹåijĆåÿÿäijŽèćńæÿĚçl’žïijÑåŕśåě¡åČŔäžĂäźĹéČ¡æšąåŔŚçŤ
with èŕ■åŔěåŘŐéÍćçŽĎçÍŃåžŘçżğçż■åIJÍæ■čåÿÿæĽ’ğèąŇãĂĆ

è£ŸæIJĽäÿĂäÿłçżĘèŁĆéŮőécŸåŕśæŸŕ LazyConnection
çśżæŸŕåŘęåĚĄèőÿåđ’ŽäÿŁ with èŕ■åŔěæİěåţŇåěŮä¡£çŤÍè£đæŐěãĂĆ
å¿ĹæŸ¿çĎűïijÑäÿŁéÍćçŽĎåőŽäźĽäÿ■äÿĂæňąåŔŁèČ¡åĚĄèőÿäÿĂäÿłsocketè£đæŐěïijÑåęĆæđIJæ■čåIJÍä¡£çŢ
with èŕ■åŔěïijÑ åŕśäijŽäžğçŤ§äÿĂäÿłåijĆåÿÿäžĘãĂĆäÿ■è£Ğä¡ăåŔŕäžěåČŔäÿŃéÍćè£ŹæăůäŁőæŤźäÿŃäÿŁé

```
from socket import socket, AF_INET, SOCK_STREAM

class LazyConnection:
    def __init__(self, address, family=AF_INET, type=SOCK_STREAM):
        self.address = address
        self.family = family
        self.type = type
        self.connections = []

    def __enter__(self):
        sock = socket(self.family, self.type)
        sock.connect(self.address)
```

```
        self.connections.append(sock)
        return sock

    def __exit__(self, exc_ty, exc_val, tb):
        self.connections.pop().close()

# Example use
from functools import partial

conn = LazyConnection(('www.python.org', 80))
with conn as s1:
    pass
    with conn as s2:
        pass
        # s1 and s2 are independent sockets
```

åIJÍçňňäžŇäÿłçL'ĹæIJňäÿ■ïijŇLazyConnection çśžåŔŕäžěèćńçIJŃńåĄŽæŸŕæ§Řäÿłè£đæŐěåůěåŐĆã
æŕŔæňą __enter__() æŰźæşŢæL'ğèąŇçŽĎæŮűåĂŹïijŇåőČåd'■åĹűåĹŻåžžäÿĂäÿłæŰřçŽĎè£đæŐěåźűåì
__exit__() æŰźæşŢçőĂå■ŢçŽĎäžŐæăĹäÿ■åijźåĞžæIJĂåŘŐäÿĂäÿłè£đæŐěåźűåĚşéŮ■åőČãĂĆ
è£ŹéĞŇçĺ■å¿őæIJL'çĆźéŽ¿çŘĘèğčïijŇäÿ■è£ĞåőČèČ¡åĚĄèőÿåţŇåěŮä¡£çŤÍ with
èŕ■åŔěåĹŻåžžåd'Žäÿłè£đæŐěïijŇåřšåęĆäÿŁéİćæijŤçd'žçŽĎéĆčæăůãĂĆ

åIJÍéIJĂèęĄçőąçŘĘäÿĂäžŻèţĎæžŘæŕŤåęĆæŰĞäżűãĂĄç¡ŚçżIJè£đæŐěåŠŇéŤĄçŽĎçijŰçÍŃçŐŕáćČäÿ■
è£ŹäžŻèţĎæžŘçŽĎäÿĂäÿłäÿżèęĄçL'źå¿ĄæŸŕåőČäżňå£ĚéążèćńæL'ŃåŁÍçŽĎåĚşéŮ■æĹŰéĞŁæŤ¿æİěçąőä£
ä¿ŃåęĆïijŇåęĆædIJä¡ăèŕůæśĆäžĘäÿĂäÿłéŤĄïijŇéĆčäźĹä¡ăå£Ěéążçąőä£İäźŃåŘŐéĞŁæŤ¿äžĘåőČïijŇåŘęåĹ
éĂŽè£ĞåődçŐř __enter__() åŠŇ __exit__() æŰźæşŢåźűä¡£çŤÍ with
èŕ■åŔěåŔŕäžěå¿Ĺåőźæ ŸŞçŽĎéĄ£åĚ■è£ŹäžŻéŮőécŸïijŇ åŻääÿž __exit__()
æŰźæşŢåŔŕäžěèőľä¡ăæŮăéIJĂæŃĚå£Cè£ŹäžŻäžĘãĂĆ

åIJÍ contextmanager æÍąåİŮäÿ■æIJL'äÿĂäÿłæăĞåĞĘçŽĎäÿŁäÿŃæŰĞçőąçŘĘæŰźæąĹæÍąæİ£ïijŇå
åŘŇæŮűåIJÍ12.6åŕŘèŁĆäÿ■è£ŸæIJL'äÿĂäÿłåŕźæIJńèŁĆçd'žä¿ŃçÍŃåžŘçŽĎçž£çÍŃåőL'åĚÍçŽĎä£őæŤźçL'Ĺ

10.4 8.4 åĹŻåžžåd'ğéĞŔåŕźèśąæŮűèŁĆçIJĄåĘĚå■ŸæŰźæşŢ

éŮőécŸ

ä¡ăçŽĎçÍŃåžŘèęĄåĹŻåžžåd'ğéĞŔ(åŔŕèČ¡äÿŁçŹ¿äÿĞ)çŽĎåŕźèśąïijŇåŕijèĞt'å■ăçŤÍå¿Ĺåd'ğçŽĎåĘĚå■Ÿ

èğčåĘşæŰźæąĹ

åŕźäžŐäÿżèęĄæŸŕçŤÍæİěå¡ŞæĹŘçőĂå■ŢçŽĎæŢřæ■őçżŞædĎçŽĎçśżèĂŇèÍĂïijŇä¡ăåŔŕäžěéĂŽè£ĞçżŹ
__slots__ åśđæĂğæİěædĄåd'ğçŽĎåĞŔåŕŠåődä¿ŃæL'Ăå■ăçŽĎåĘĚå■ŸãĂĆærŤåęĆïijŽ

```
class Date:
    __slots__ = ['year', 'month', 'day']
    def __init__(self, year, month, day):
        self.year = year
```

```
        self.month = month
        self.day = day
```

å¡Şä¡ăåőŽäźL' __slots__ åŘŐïijŇPythonåřśäijŽäÿžåőđä¿Ńä¡£çŤĺäÿĂçğ■æŻť'åŁăçť'ğåĞŚçŽĎåĘĚéČ
åőđä¿ŃéĂŽè£ĞäÿĂäÿłå¿ĹåřŔçŽĎåŽžåőŽåđ'ğåřŔçŽĎæŢřçżĎæİěæđĎåžžïijŇèĂŇäÿ■æŸŕäÿžæŕŔäÿłåőđä¿Ń
åIJĺ __slots__ äÿ■åĹŮåĞžçŽĎåśđæĂğåŘ■åIJĺåĘĚéČĺèćńæŸăåřĎåĹřè£ŹäÿłæŢřçżĎçŽĎæŇĞåőŽåřŔæăČ
ä¡£çŤĺslotsäÿĂäÿłäÿ■åě¡çŽĎåIJræŰźåřśæŸŕæĹŚäžňäÿ■èČ¡åĘ■çżŹåőđä¿ŃæůżåŀăæŰřçŽĎåśđæĂğäžĘïijŇåĺ
__slots__ äÿ■åőŽäźL'çŽĎéĆčäžŽåśđæĂğåŘ■ãĂĆ

èőĺèőž

ä¡£çŤĺslotsåŘŐèŁĆçIJAçŽĎåĘĚå■ŸäijŽèů§å■ŸåĆĺåśđæĂğçŽĎæŢřéĞŔåŠŇçśżåđŃæIJL'åĚşãĂĆ
äÿ■è£ĞïijŇäÿĂèĹňæİěèőšïijŇä¡£çŤĺåĹřçŽĎåĘĚå■ŸæĂżéĞŔåŠŇářĘæŢřæ■őå■ŸåĆĺåIJĺäÿĂäÿłåĚĆçżĎäÿ■å
äÿžäžĘçżŹä¡ăäÿĂäÿłçŻť'èğĆèőď'èŕĘïijŇåĄĞèő¿ä¡ăäÿ■ä¡£çŤĺslotsçŻť'æŐĕå■ŸåĆĺäÿĂäÿłDateåőđä¿ŃïijŇ
åIJĺ64ä¡■çŽĎPythonäÿŁéİćèęĄå■ăçŤĺ428å■ŮèŁĆïijŇèĂŇåęĆæđIJä¡£çŤĺäžĘslotsïijŇåĘĚå■Ÿå■ăçŤĺäÿŃéŹ■
åęĆæđIJçĺŃåžŔäÿ■éIJĂèęĄåŘŇæŮűåĹŻåżžåď'ğéĞŔçŽĎæŮěæIJ§åőđä¿ŃïijŇéĆčäźLè£ŹäÿłářśèČ¡æđĄåď'ğ

år¡çőąslotsçIJŃäÿŁåŐżæŸŕäÿĂäÿłå¿ĹæIJL'çŤĺçŽĎçL'źæĂğïijŇå¿Ĺåď'ŽæŮűåĂŹä¡ăè£ŸæŸŕå¿ŮåĞŔår
PythonçŽĎå¿Ĺåď'ŽçL'źæĂğéČ¡ä¿İèţŰäžŐæŹőéĂŽçŽĎå§žäžŐå■ŮåËÿçŽĎåőđçŐřãĂĆ
åŔęåď'ŰïijŇåőŽäźL'äžĘslotsåŘŐçŽĎçśżäÿ■åĘ■æŤŕæŇĄäÿĂäžŽæŹőéĂŽçśżçL'źæĂğäžĘïijŇæŕŤåęĆåď'Žçżğ
åď'ğåď'ŽæŢřæČĚåĘţäÿŃïijŇä¡ăåžŤèŕěåŔłåIJĺéĆčäžŽçżŔåÿÿèćńä¡£çŤĺåĹřçŽĎçŤĺä¡IJæŢřæ■őçżŞædĎçŽĎçś
(æŕŤåęĆåIJĺçĺŃåžŔäÿ■éIJĂèęĄåĹŻåżžæ§ŘäÿłçśżçŽĎåĞăçŹ¿äÿĞäÿłåőđä¿Ńårźèśą)ãĂĆ

åĚşäžŐ __slots__ çŽĎäÿĂäÿłåÿÿèğĄèŕŕåŇžæŸŕåőČåŔŕäžěä¡IJäÿžäÿĂäÿłårĄèčĚåůěåĚůæİěéŸšæ■ć
år¡çőąä¡£çŤĺslotsåŔŕäžěè¿¿åĹřè£ŹæăůçŽĎçŽőçŽĎïijŇä¡ĘæŸŕè£Źäÿłåźűäÿ■æŸŕåőČçŽĎåĹİèąůãĂĆ
__slots__ æŻť'åď'ŽçŽĎæŸŕçŤĺæİěä¡IJäÿžäÿĂäÿłåĘĚå■ŸäijŸåŇŰåůěåĚůãĂĆ

10.5 8.5 åIJĺçśżäÿ■årĄèčĚåśđæĂğåŘ■

éŮőécŸ

ä¡ăæČşårĄèčĚçśżçŽĎåőđä¿ŃäÿŁéİćçŽĎâĂIJçğĄæIJL'âĂİæŢřæ■őïijŇä¡ĘæŸŕPythonèŕ■èĺĂåźűæšąæIJ

èğčåĘşæŰźæąĹ

PythonçĺŃåžŔåŚŸäÿ■åŐżä¿İèţŰèŕ■èĺĂçL'źæĂğåŐżårĄèčĚæŢřæ■őïijŇèĂŇæŸŕéĂŽè£ĞéĄţå¿łäÿĂåőŽ
çňňäÿĂäÿłçžęåőŽæŸŕäżża¡Ţäžěå■ŢäÿŃåĹŠçž£_åijĂåď'ť'çŽĎåŘ■å■ŮéČ¡åžŤèŕěæŸŕåĘĚéČĺåőđçŐřãĂĆærŤå

```
class A:
    def __init__(self):
        self._internal = 0 # An internal attribute
        self.public = 1 # A public attribute

    def public_method(self):
        '''
        A public method
```

```
        '''
        pass

    def _internal_method(self):
        pass
```

Pythonåźűäÿ■äijŽçIJ§çŽĎéŸżæ■ćåĹńäžžèő£éŮőåĘĚéČĺåŘ■çğřãĂĆä¡ĘæŸŕåęĆæđIJä¡ãè£ŹäźĹåĄŽèĆŕ
åŘŇæŮűè£ŸèęĄæşĺæĎŔåĹřïijŇä¡£çŤĺäÿŃåĹŠçž£åijĂåď'çŽĎçžęåőŽåŘŇæăůéĂĆçŤĺäžŐæĺąåİŮåŘ■åŠŇæ
ä¿ŃåęĆïijŇåęĆæđIJä¡ăçIJŃåĹřæ§ŘäÿłæĺąåİŮåŘ■äžěå■ŢäÿŃåĹŠçž£åijĂåď'(æŕŤåęĆ_socket)ïijŇéĆčåőČåř
çśżäijijçŽĎïijŇæĺąåİŮçžğåĹńåĞ¡æŢřæŕŤåęĆ `sys._getframe()`
åIJĺä¡£çŤĺçŽĎæŮűåĂŹåřśå¿ŮåŁăåĂ■åřŔå£ČäžĘãĂĆ

ä¡ãè£ŸåŔŕèČ¡äijŽéĄĞåĹřåIJĺçśżåőŽäźL'äÿ■ä¡£çŤĺäÿd'äÿłäÿŃåĹŠçž£(__)åijĂåď'çŽĎåŚ¡åŘ■ãĂĆæŕŤå

```
class B:
    def __init__(self):
        self.__private = 0

    def __private_method(self):
        pass

    def public_method(self):
        pass
        self.__private_method()
```

ä¡£çŤĺåŔŇäÿŃåĹŠçž£åijĂåğŃäijŽåŕijèĞt'èő£éŮőåŘ■çğřåŔŸæĹŘåĚűäżŰå¡ćåijŔãĂĆ
æŕŤåęĆïijŇåIJĺåL'■éĺćçŽĎçśżBäÿ■ïijŇçğĄæIJL'åśđæĂğäijŽèćńåĹĘåĹńéĞ■åŚ¡åŘ■äÿž
`_B__private` åŠŇ `_B__private_method` ãĂĆ è£ŹæŮűåĂŹä¡ăåŔŕèČ¡äijŽéŮőè£ŹæăůéĞ■åŚ¡åŘ■çŽĎ

```
class C(B):
    def __init__(self):
        super().__init__()
        self.__private = 1 # Does not override B.__private

    # Does not override B.__private_method()
    def __private_method(self):
        pass
```

è£ŹéĞŇïijŇçğĄæIJL'åŘ■çğř `__private` åŠŇ `__private_method`
èćńéĞ■åŚ¡åŘ■äÿž `_C__private` åŠŇ `_C__private_method`
ïijŇè£ŹäÿłèůšçĹűçśżBäÿ■çŽĎåŘ■çğřæŸŕåőŇåĚĺäÿ■åŔŇçŽĎãĂĆ

èőĺèőž

äÿŁéĺćæŔŘåĹřæIJL'äÿd'çğ■äÿ■åŔŇçŽĎçijŰçăĄçžęåőŽ(å■ŢäÿŃåĹŠçž£åŠŇåŔŇäÿŃåĹŠçž£)æĬěåŚ¡åŘ
åd'ğåd'ŽæŢřèĂŇèĺĂïijŇä¡ăåžŤèŕěèől'ä¡ăçŽĎéĬđåĚňåĚśåŘ■çğřäžěå■ŢäÿŃåĹŠçž£åijĂåď'ťãĂĆä¡ĘæŸŕïijŇåę
åźűäÿŤæIJL'ăžŽåĘĚéČĺåśđæĂğåžŤèŕěåIJĺå■Řçśżäÿ■éŽŘèŮŘèţůæĬěïijŇéĆčäźĹæL'■èĂČèŹŚä¡£çŤĺåŔŇäÿŃå

è£ŸæIJL'äÿĂçĆźèęĄæşĺæĎŔçŽĎæŸŕïijŇæIJL'æŮűåĂŹä¡ăåőŽäźL'çŽĎäÿĂäÿłåŔŸéĞŔåŠŇæ§Řäÿłä£Ĭç

```
lambda_ = 2.0 # Trailing _ to avoid clash with lambda keyword
```

è£ŹéĞŇæĹŚäżňåźűäÿ■ä¡£çŤĺå■ŢäÿŃåĹŠçž£åL’■çijĂçŽĎåŐ§åŻăæŸŕåőČéĄ£åĚ■èŕŕèğčåőČçŽĎä¡£çŤĺ(åęĆä¡£çŤĺå■ŢäÿŃåĹŠçž£åL’■çijĂçŽĎçŻőçŽĎæŸŕäÿžäžĘéŸšæ■ćåŚ¡åŘ■åĘšçłĄèĂŇäÿ■æŸŕæŇĞæŸŐè£ŹéĂŽè£Ğä¡£çŤĺå■ŢäÿŃåĹŠçž£åŘŐçijĂåŔŕäžěèğčåĘşè£ŹäÿłéŭőécŸãĂĆ

10.6 8.6 åĹŻåżžåŔŕçőąçŘĘçŽĎåśđæĂğ

éŮőécŸ

ä¡ăæČşçżŹæ§Řäÿłåőđä¿ŃattributeaćđåŀăéŹd’èő£éŮőäÿŐä£őæŤźäźŃåd’ŰçŽĎåĚűäżŰåd’ĎçŘĘéĂżè¿Śi

èğčåĘşæŰźæąĹ

èĞłåőŽäźL’æ§ŘäÿłåśđæĂğçŽĎäÿĂçğ■çőĂå■ŢæŰźæşŢæŸŕåřĘáőČåőŽäźL’äÿžäÿĂäÿłpropertyãĂĆ ä¿ŃåęĆïijŇäÿŃéĺćçŽĎäżčçăĄåőŽäźL’äžĘäÿĂäÿłpropertyïijŇåćđåŀăářźäÿĂäÿłåśđæĂğçőĂå■ŢçŽĎçśžåđŃæ

```
class Person:
    def __init__(self, first_name):
        self.first_name = first_name

    # Getter function
    @property
    def first_name(self):
        return self._first_name

    # Setter function
    @first_name.setter
    def first_name(self, value):
        if not isinstance(value, str):
            raise TypeError('Expected a string')
        self._first_name = value

    # Deleter function (optional)
    @first_name.deleter
    def first_name(self):
        raise AttributeError("Can't delete attribute")
```

äÿŁè£řäżčçăĄäÿ■æIJL’äÿL’äÿłçŻÿåĚşèĄŢçŽĎæŰźæşŢïijŇè£ŹäÿL’äÿłæŰźæşŢçŽĎåŘ■å■ŮéČ¡å£ĚéąžäÿçňňäÿĂäÿłæŰźæşŢæŸŕäÿĂäÿł `getter` åĞ¡æŢřïijŇåőČä¡£å¿Ů `first_name` æĹŘäÿžäÿĂäÿłåśđæĂğãĂĆ åĚűäżŰäÿd’äÿłæŰźæşŢçżŹ `first_name` åśđæĂğæůžåŁäžĘ `setter` åŠŇ `deleter` åĞ¡æŢřãĂĆ éIJĂèęĄåijžèřČçŽĎæŸŕåŔłæIJL’åIJÍ `first_name` åśđæĂğèćńåĹŻåżžåŘŐïijŇ åŘŐéÍćçŽĎäÿd’äÿłèčĚéěřåŹÍ `@first_name.setter` åŠŇ `@first_name.deleter` æL’■èČ¡èćńåőŽäźL’ãĂĆ

propertyçŽĎäÿĂäÿłåĚşéŤőçL’źå¿ĄæŸŕåőČçIJŃäÿŁåŐżèů§æŹőéĂŽçŽĎattributeæšąäżĂäźĹäÿd’æăůïijŇä¡ĘæŸŕèő£éŮőåőČçŽĎæŮűåĂŹäijŽèĞłåŁÍèğęåŔŚ `getter` ãĂĄ`setter` åŠŇ `deleter` æŰźæşŢãĂĆä¿ŃåęĆïijŽ

```
>>> a = Person('Guido')
>>> a.first_name # Calls the getter
'Guido'
>>> a.first_name = 42 # Calls the setter
Traceback (most recent call last):
    File "<stdin>", line 1, in <module>
    File "prop.py", line 14, in first_name
        raise TypeError('Expected a string')
TypeError: Expected a string
>>> del a.first_name
Traceback (most recent call last):
    File "<stdin>", line 1, in <module>
AttributeError: can`t delete attribute
>>>
```

åIJÍåőđçŐřäÿĂäÿłpropertyçŽĎæŮűůĂŹïijŇåžŢåśĆæŢřæ■ő(åęĆæđIJæIJL'çŽĎèŕİ)äż■çĎűéIJĂèęĄå■ŸåĆ åŻžæ■d'ïijŇåIJÍgetåŠŇsetæŰźæşŢäÿ■ïijŇä¡ăäijŽçIJŃåĹřářź `_first_name` åśđæĂğçŽĎæŞ■ä¡IJïijŇè£Źäź§æŸŕåőđéŹĚæŢřæ■őä£İå■ŸçŽĎåIJřæŰźãĂĆ åŔęåd'ŰïijŇä¡ăåŔŕèČ¡è£ŸäijŽéŮőäÿžäżĂäźĹ `__init__()` æŰźæşŢäÿ■èő¿ç¡őäžĘ `self.first_name` èĂŇäÿ■æŸŕ `self._first_name` ãĂĆ åIJÍè£ŹäÿłäĄ¿Ńå■Řäÿ■ïijŇæĹŚäżňåĹŻåżžäÿĂäÿłpropertyçŽĎçŽőçŽĎåřśæŸŕåIJÍèő¿ç¡őattributeçŽĎæŮűůåĂŹ åŻžæ■d'ïijŇä¡ăåŔŕèČ¡æČşåIJÍåĹİåğŃåŇŰçŽĎæŮűůåĂŹäź§è£ŻèąŇè£Źçğ■çśžådŃæčĂæ§ěãĂĆéĂŽè£Ğèő¿ç¡ `self.first_name` ïijŇèĞłåŁÍèřČçŤÍ `setter` æŰźæşŢïijŇ è£ŹäÿłæŰźæşŢéĞŇéÍćäijŽè£ŻèąŇåŔĆæŢřçŽĎæčĂæ§ěïijŇåŘęåĹŹåřśæŸŕçŻť'æŐèèő£éŮő `self._first_name` äžĘãĂĆ

è£ŸèČ¡åIJÍåůšå■ŸåIJÍçŽĎgetåŠŇsetæŰźæşŢå§žçąĂäÿŁåőŽäźL'propertyãĂĆä¿ŃåęĆïijŽ

```
class Person:
    def __init__(self, first_name):
        self.set_first_name(first_name)

    # Getter function
    def get_first_name(self):
        return self._first_name

    # Setter function
    def set_first_name(self, value):
        if not isinstance(value, str):
            raise TypeError('Expected a string')
        self._first_name = value

    # Deleter function (optional)
    def del_first_name(self):
        raise AttributeError("Can't delete attribute")

    # Make a property from existing get/set methods
    name = property(get_first_name, set_first_name, del_first_name)
```

èőÍèőž

äÿĂäÿłpropertyåśđæĂğåĚűåőđåřśæŸŕäÿĂçşżåĹŮçŻÿåĚşçżŚåőŽæŰźæşŢçŽĎéŻĘåŘĹãĂĆåęĆæđIJä¡åå
åřśäijŽåŔŚçŐřpropertyæIJňèžńçŽĎfgetãĂĄfsetåŠŇfdelåśđæĂğåřśæŸŕçśżéĞŇéÍćçŽĎæŹőéĂŽæŰźæşŢãĂĆ

```
>>> Person.first_name.fget
<function Person.first_name at 0x1006a60e0>
>>> Person.first_name.fset
<function Person.first_name at 0x1006a6170>
>>> Person.first_name.fdel
<function Person.first_name at 0x1006a62e0>
>>>
```

éĂŽåÿÿæÍěèőšïijŇä¡ääÿ■äijŽçŻť æŐěåŔŰèřČçŤÍfgetæĹŰèĂĚfsetïijŇåőČäžňäijŽåIJÍèő£éŰőpropertyçŽ

åŘłæIJL'å¡Şä¡äçąőåőđéIJĂèęĄåŕźattributeæL'ğèąŇåĚűäżŰéćÍåd'ŰçŽĎæŞ■ä¡IJçŽĎæŮűåĂŹæL'■åžŤèŕě
æIJL'æŮűåĂŹäÿĂäžŻäżŐåĚűäżŰçijŰçÍŃèŕ■èÍĂ(æŕŤåęĆJava)è£ĞæÍěçŽĎçÍŃåžŔåŚŸæĂżèőd'äÿžæL'ĂæIJL
æL'Ăäżěäž Ůäžňèőd'äÿžäżčçăĄåžŤèŕěåČŔäÿŃéÍćè£Źæăůå ĘŹijžŽ

```
class Person:
    def __init__(self, first_name):
        self.first_name = first_name

    @property
    def first_name(self):
        return self._first_name

    @first_name.setter
    def first_name(self, value):
        self._first_name = value
```

äÿ■èęĄåĘŹè£Źçğ■æšąæIJL'åĄŽäżżä¡ŢåĚűäżŰéćÍåd'ŰæŞ■ä¡IJçŽĎpropertyãĂĆ
éçŰåĚÍïijŇåőČäijŽèől'ä¡äçŽĎäżčçăĄåŔŸå¿Ůå¿ĹèĞČèĆ£ïijŇåźűäÿŤè£ŸäijŽè£ůæČŚéŸĚèŕżèĂĚãĂĆ
åĚűæňąïijŇåőČè£ŸäijŽèől'ä¡äçŽĎçÍŃåžŔè£ŘèąŇètůæÍěåŔŸæĚćå¿Ĺåd'ŽãĂĆ
æIJĂåŘŐïijŇè£ŹæăůçŽĎèő¿èőąĄźűæšąæIJL'åÿęæÍěäżżä¡ŢçŽĎåě¡åd'ĎãĂĆ
çL'źåĹńæŸŕå¡Şä¡äżěåŘŐæČşçżŹæŹőéĂŽattributeèő£éŰőæůżåŁäéćÍåd'ŰçŽĎåd'ĎçŘĘéĂżè¿ŚçŽĎæŮűåĂŹ
ä¡ääŔŕäżěåřĘåőČåŔŸæĹŘäÿĂäÿłpropertyèĂŇæŮäéIJĂæŤźåŔŸåŐ§æÍěçŽĎäżčçăĄãĂĆ
åŽääÿžèő£éŰőattributeçŽĎäżčçăĄè£ŸæŸŕä£ÍæŇĄåŐ§æäůãĂĆ

Propertiesè£ŸæŸŕäÿĂçğ■åőŽäźL'åŁĺæĂĄèőąçőŮattributeçŽĎæŰźæşŢãĂĆ
è£Źçğ■çśżåđŃçŽĎattributesåźűäÿ■äijŽècńåőđéŹĚçŽĎå■ŸåĆÍïijŇèĂŇæŸŕåIJĺéIJĂèęĄçŽĎæŮűåĂŹèőąçőŮ

```
import math
class Circle:
    def __init__(self, radius):
        self.radius = radius

    @property
    def area(self):
        return math.pi * self.radius ** 2
```

```
    @property
    def diameter(self):
        return self.radius * 2

    @property
    def perimeter(self):
        return 2 * math.pi * self.radius
```

åIJÍè£ŹéĞŇïijŇæĹŚäžňéĂŽè£Ğä¡£çŤÍpropertiesïijŇåřĘæL'ĂæIJL'çŽĎèő£éŮőæŐěåŔčå¡ćåijŔçż§äÿĂèţ
åŕźå■Łå¿ĎãĂĄçŻť'å¿ĎãĂĄåŚÍéŢ£åŠŇéÍćçğŕçŽĎèő£éŮőéČ¡æŸŕéĂŽè£ĞåšđæĂğèő£éŮőïijŇåŕśèů§èő£éŮőç
åęĆæđIJäÿ■è£ŹæăůåĄŽçŽĎèŕİïijŇéĆčäźĹåŕśèęĄåIJÍäžčçăĄäÿ■æůůåŘĹä¡£çŤÍçőĂå■ŢåšđæĂğèő£éŮőåŠŇæ
äÿŇéÍćæŸŕä¡£çŤÍçŽĎåőđä¿ŃïijŽ

```
>>> c = Circle(4.0)
>>> c.radius
4.0
>>> c.area  # Notice lack of ()
50.26548245743669
>>> c.perimeter  # Notice lack of ()
25.132741228718345
>>>
```

år¡çőąpropertiesåŔŕäžěåőđçŐřäijŸéŻĚçŽĎçijŰçÍŃæŐěåŔčïijŇä¡ĘæIJL'äžŻæŮűåĂŹä¡ăè£ŸæŸŕäijŽæČ

```
>>> p = Person('Guido')
>>> p.get_first_name()
'Guido'
>>> p.set_first_name('Larry')
>>>
```

è£Źçğ■æČĚåĘţçŽĎåĞžçŐřéĂŽåÿÿæŸŕåŻääÿžPythonäżčçăĄèćńéŻĘæĹŘåĹřäÿĂäÿłåď'ğåđŃå§žçąĂáźş
ä¿ŃåęĆïijŇæIJL'åŔŕèČ¡æŸŕäÿĂäÿłPythonçśżåĞĘåď'ĞåŁăåĚěåĹřäÿĂäÿłå§žäžŐè£IJçÍŃè£ĞçÍŃèřČçŤÍçŽĎåć
è£Źçğ■æČĚåĘţäÿŃïijŇçŻť'æŐěä¡£çŤÍget/setæŰźæşŢ(æŹőéĂŽæŰźæşŢèřČçŤÍ)èĂŇäÿ■æŸŕpropertyæĹŰèőÿ

æIJĂåŘŐäÿĂçĆźïijŇäÿ■èęĄåČŔäÿŇéÍćè£ŹæăůåĘŹæIJL'åď'ğéĞŔéĞ■åď'■äžčçăĄçŽĎpropertyåőŽäźL'ï

```
class Person:
    def __init__(self, first_name, last_name):
        self.first_name = first_name
        self.last_name = last_name

    @property
    def first_name(self):
        return self._first_name

    @first_name.setter
    def first_name(self, value):
        if not isinstance(value, str):
            raise TypeError('Expected a string')
        self._first_name = value
```

```
    # Repeated property code, but for a different name (bad!)
    @property
    def last_name(self):
        return self._last_name

    @last_name.setter
    def last_name(self, value):
        if not isinstance(value, str):
            raise TypeError('Expected a string')
        self._last_name = value
```

éĞ■åď■äžčçăĄäijŽåŕijèĞť'èĞČèĆ£ãĂĄæŸŞåĞžéŤŹåŠŇäýŚéŹŃçŽĎçÍŃåžŔãĂĆåě¡æűĹæĄŕæŸŕïijŇéÀ
åŔŕäžěåŔĆèĂČ8.9åŠŇ9.21åřŔèŁĆçŽĎåĘĚåőźãĂĆ

10.7 8.7 èřČçŤÍçĹűçśżæŰźæşŢ

éŮőécŸ

ä¡ăæČşåIJÍå■Řçśżäý■èřČçŤÍçĹűçśżçŽĎæ§ŘäýłåůšçżŔèćńèęĘçŻŰçŽĎæŰźæşŢãĂĆ

èğčåĘşæŰźæąĹ

äýžäžĘèřČçŤÍçĹűçśż(èűĚçśż)çŽĎäýĂäýłæŰźæşŢïijŇåŔŕäžěä¡£çŤÍ `super()` åĞ¡æŢřïijŇærŤåęĆïijŽ

```
class A:
    def spam(self):
        print('A.spam')

class B(A):
    def spam(self):
        print('B.spam')
        super().spam()  # Call parent spam()
```

`super()` åĞ¡æŢřçŽĎäýĂäýłåýÿèğĄçŤÍæşŢæŸŕåIJÍ `__init__()` æŰźæşŢäý■çąőä£ÍçĹűçśżèćńæ■čçąőçŽĎåĹİåğŇåŇŰäžĘïijŽ

```
class A:
    def __init__(self):
        self.x = 0

class B(A):
    def __init__(self):
        super().__init__()
        self.y = 1
```

`super()` çŽĎåŔęåď'ŰäýĂäýłåýÿèğĄçŤÍæşŢåĞžçŐřåIJÍèęĘçŻŰPythonçL'źæőŁæŰźæşŢçŽĎäžčçăĄäý

```
class Proxy:
    def __init__(self, obj):
        self._obj = obj

    # Delegate attribute lookup to internal obj
    def __getattr__(self, name):
        return getattr(self._obj, name)

    # Delegate attribute assignment
    def __setattr__(self, name, value):
        if name.startswith('_'):
            super().__setattr__(name, value) # Call original __
↪setattr__
        else:
            setattr(self._obj, name, value)
```

åIJÍäÿŁéÌćäżčçăĄäÿ■ïijŇ__setattr__() çŽĎåőđçŐřåŇĚåŘńäÿĂäÿłåŘ■å■ŮæčĂæ§ěãĂĆ åęĆæđIJæ§ŘäÿłåśđæĂğåŘ■äżěäÿŇåĹŠçž£(_)åijĂåď't'ïijŇåřśéĂŽè£Ğ `super()` èřČçŤĺåŐ§åğŃçŽĎ `__setattr__()` ïijŇ åŘęåĹŹçŽĎèŕÌåřśåğŤæť¿çżŹåĘĚéČÍçŽĎäżčçŘĘåŕźèšą `self._obj` åŐżåď'ĎçŘĘãĂĆ è£ŹçIJŃäÿŁåŐżæIJL'çĆźæĎŔæĂÌïijŇåŻääÿžåřśçőŮæšąæIJL'æŸ¿åijŔçŽĎæ `super()` äż■çĎűåŔŕäžěæIJL'æŢĹçŽĎåůěä¡IJãĂĆ

èőÍèőž

åőđéŹĚäÿŁïijŇåď'ğåőűåŕźäžŐåIJÍPythonäÿ■åęĆä¡Ţæ■čçąőä¡£çŤÍ `super()` åĞ¡æŢřæŹőéĄ■ç§ěäźŃçŤŽåřŠãĂĆ ä¡ăæIJL'æŮűåĂŹäijŽçIJŃåĹřåČŔäÿŃéÌćè£Źæăůç Żť'æŐěèřČçŤÍçĹűçśżç

```
class Base:
    def __init__(self):
        print('Base.__init__')

class A(Base):
    def __init__(self):
        Base.__init__(self)
        print('A.__init__')
```

åř¡çőąåŕźäžŐåď'ğéČÍåĹĘäžčçăĄèĂŇèÍĂè£ŹäźĹåĄŽæšąäżĂäźĹéŮőécŸïijŇä¡ĘæŸŕåIJÍæŻť'åď'■æİĆçŽĎ æŕŤåęĆïijŇèĂČèŹŠåęĆäÿŃçŽĎæČĚåĘţïijŽ

```
class Base:
    def __init__(self):
        print('Base.__init__')

class A(Base):
    def __init__(self):
        Base.__init__(self)
        print('A.__init__')

class B(Base):
```

```
    def __init__(self):
        Base.__init__(self)
        print('B.__init__')

class C(A,B):
    def __init__(self):
        A.__init__(self)
        B.__init__(self)
        print('C.__init__')
```

åęĆædIJä¡ăè£ŘèąŇè£Źæőţäżčçă Ąåřśäij ŽåŔŚçŐř `Base.__init__()` èćńèřČçŤĺäÿď æňąïijŇåęĆäÿŃæĽĂçď žïijŽ

```
>>> c = C()
Base.__init__
A.__init__
Base.__init__
B.__init__
C.__init__
>>>
```

åŔŕèČ¡äÿď æňąèřČçŤĺ `Base.__init__()` æšąäżĂäźĹåİŔåď ĎïijŇä¡ĘæIJĽæŮűåĂŹå■t'äÿ■æŸŕãĂĆ åŔęäÿĂæŰźéÍćïijŇåĄĞèő¿ä¡ăåIJĺäżčçă Ąäÿ■æ■ćæĹŘä¡£çŤĺ `super()` ïijŇçżŞædIJåřśå¿Ĺåő Ňç¿ŐäžĘïijŽ

```
class Base:
    def __init__(self):
        print('Base.__init__')

class A(Base):
    def __init__(self):
        super().__init__()
        print('A.__init__')

class B(Base):
    def __init__(self):
        super().__init__()
        print('B.__init__')

class C(A,B):
    def __init__(self):
        super().__init__()  # Only one call to super() here
        print('C.__init__')
```

è£ŘèąŇè£Źäÿ łæŰřçĽĹæIJňåŘŐïijŇä¡ăäijŽåŔŚçŐřæŕŔäÿł `__init__()` æŰźæşŢåŔłäijŽèćńèřČçŤĺäÿĂæňąäžĘïijŽ

```
>>> c = C()
Base.__init__
B.__init__
```

```
A.__init__
C.__init__
>>>
```

äÿžäžĘåijĎæÿĚåőČçŽĎåŐ§çŘĘïijŇæĹŚäžňéIJĂèęĄèŁśçĆźæŮűéŮťèğčéĞŁäÿŃPythonæŸŕåęĆä¡Ţåőđ
åŕźäžŐä¡ăåőŽäźĽçŽĎæŕŔäÿĂäÿłçśżïijŇPythonäijŽèőąçőŮåĞžäÿĂäÿłæĽĂèřŞçŽĎæŰźæşŢèğčæđŘéąžåžŔ(
è£ŹäÿłMROåĹŮèąĺåřśæŸŕäÿĂäÿłçőĂå■ŢçŽĎæĽĂæIJĽå§žçśżçŽĎçž£æĂğéąžåžŔèąĺãĂĆä¿ŃåęĆïijŽ

```
>>> C.__mro__
(<class '__main__.C'>, <class '__main__.A'>, <class '__main__.B'>,
<class '__main__.Base'>, <class 'object'>)
>>>
```

äÿžäžĘåőđçŐřçżğæĽ£ïijŇPythonäijŽåIJÍMROåĹŮèąĺäÿŁäžŐåůęåĹřåŔşåijĂåğŃæ§ěæĽ¿å§žçśżïijŇçŻť

èĂŇè£ŹäÿłMROåĹŮèąĺçŽĎæđĎéĂăæŸŕéĂŽè£ĞäÿĂäÿłC3çž£æĂğåŇŰçőŮæşŢæİěåőđçŐřçŽĎãĂĆ
æĹŚäžňäÿ■åŐżæůśçľűè£ŹäÿłçőŮæşŢçŽĎæŢřå■ęåŐ§çŘĘïijŇåőČåőđéŹĚäÿŁåřśæŸŕåŘĹåźűæĽĂæIJĽçĹűçş

- å■Řçśżäij ŽåĚĹäžŐçĹűçśżèćńæčĂæ§ě
- åd'ŽäÿłçĹűçśżäij Žæăźæ■őåőČäžňåIJĺåĹŮèąĺäÿ■çŽĎéąžåžŔèćńæčĂæ§ě
- ąęĆæđIJåŕźäÿŃäÿĂäÿłçśżå■ŸåIJĺäÿd'äÿłåŘĹæşŢçŽĎéĂĽ'æŃl'ïijŇéĂĽ'æŃl'çňňäÿĂäÿłçĹűçśż

èĂĄåőđèŕť'ïijŇä¡ăæĽĂèęĄç§ěéĄŞçŽĎåřśæŸŕMROåĹŮèąĺäÿ■çŽĎçśżéąžåžŔäijŽèől'ä¡ăåőŽäźĽçŽĎäżz

å¡Şä¡ää¡£çŤĺ `super()` åĞ¡æŢřæŰűïijŇPythonäijŽåIJÍMROåĹŮèąĺäÿŁçżğçż■æŘIJçt'ćäÿŃäÿĂäÿłçśżãĂ
åŘłèęĄæŕŔäÿłéĞ■åőŽäźĽçŽĎæŰźæşŢçż§äÿĂä¡£çŤĺ `super()`
åźűåŘłèřČçŤĺåőČäÿĂæňąïijŇ éĆčäźĹæŐğåĹűæţĄæIJĂçżĹäijŽéĄ■åŐĘåőŇæŢt'äÿłM-
ROåĹŮèąĺïijŇæŕŔäÿłæŰźæşŢäź§åŘłäijŽèćńèřČçŤĺäÿĂæňąãĂĆ
è£Žäź§æŸŕäÿžäžĂäźĹåIJĺçňňäžŇäÿłä¿Ńå■Řäÿ■ä¡ääÿ■äijŽèřČçŤĺäÿd'æňą `Base.__init__()` çŽĎåŐ§åŽãăĂĆ

`super()` æIJĽäÿłäžd'äžžåŘČæČŁçŽĎåIJřæŰźæŸŕåőČåźűäÿ■äÿĂåőŽåŐżæ§ěæĽ¿æ§Řäÿłçśżåİ JÍMRO
ä¡ăçŤŽèĞşåŘŕäžěåIJĺäÿĂäÿłæšąæIJĽçŻť'æŐěçĹűçśżçŽĎçśżäÿ■ä¡£çŤĺåőČãĂĆä¿ŃåęĆïijŇèĂČèŹŠåęĆäÿŃè

```
class A:
    def spam(self):
        print('A.spam')
        super().spam()
```

åęĆæđIJä¡ăèŕŢçİĂçŻť'æŐěä¡£çŤĺè£ŹäÿłçśżåřšäijŽåĞžéŤŹïijŽ

```
>>> a = A()
>>> a.spam()
A.spam
Traceback (most recent call last):
    File "<stdin>", line 1, in <module>
    File "<stdin>", line 4, in spam
AttributeError: 'super' object has no attribute 'spam'
>>>
```

ä¡ĘæŸŕïijŇåęĆæđIJä¡ăä¡£çŤĺåd'ŽçżğæĽ£çŽĎèŕİçIJŃçIJŃäijŽåŘŠçŤ§äžĂäźĹïijŽ

```
>>> class B:
...     def spam(self):
...         print('B.spam')
...
>>> class C(A,B):
...     pass
...
>>> c = C()
>>> c.spam()
A.spam
B.spam
>>>
```

ä¡ăåŔŕäžěçIJŃåĹřåIJĺçśżAäÿ■ä¡£çŤĺ `super().spam()` åőđéŹĚäÿŁèřČçŤĺçŽĎæŸŕèů§çśżAæŕńæŮăåĚşçşżçŽĎçśżBäÿ■çŽĎ `spam()` æŰźæşŢãĂĆ è£ŹäÿłçŤĺçśżCçŽĎMROåĹŮèąĺářśåŔŕäžěåőŇåĚĺèğčéĞŁæÿĚæěŽäžĘïijŽ

```
>>> C.__mro__
(<class '__main__.C'>, <class '__main__.A'>, <class '__main__.B'>,
<class 'object'>)
>>>
```

åIJĺåőŽäźL'æůůåĚěçśżçŽĎæŮűåĂŹè£Źæăůä¡£çŤĺ `super()` æŸŕå¿ĹæŹőéĄ■çŽĎãĂĆåŔŕäžěåŔĆèĂČ8.13åŠŇ8.18ářŔèŁĆãĂĆ

çĎűèĂŇïijŇçŤśäžŐ `super()` åŔŕèČ¡äijŽěřČçŤĺäÿ■æŸŕä¡ăæČşèęĄçŽĎæŰźæşŢïijŇä¡ăåžŤèŕěéĄţå¿łäÿ éęŰåĚĹïijŇçąőä£ÍåIJĺçżğæL'£ä¡Şçşżäÿ■æL'ĂæIJL'çŻÿåŘŇåŘ■å■ŮçŽĎæŰźæşŢæŃěæIJL'åŔŕåĚijåőźçŽĎåŔ è£ŹæăůåŔŕäžěçąőä£Í `super()` èřČçŤĺäÿĂäÿłéİđçŻt'æŐěçĹűçśżæŰźæşŢæŮűäÿ■äijŽåĞžéŤŹãĂĆ åĚűæňąïijŇæIJĂåě¡çąőä£ÍæIJĂéąűåśĆçŽĎçśżæŔŘä¿ŻäžĘè£ŹäÿłæŰźæşŢçŽĎåőđçŐřïijŇè£ŹæăůçŽĎèŕÍåIJĺ

åIJĺPythonçď¿åŇžäÿ■åŕźäžŐ `super()` çŽĎä¡£çŤĺæIJL'æŮűåĂŹäijŽåijŢæİěäÿĂäžŻäžL'èőőãĂĆ åř¡çőąåęĆæ■d'ïijŇåęĆædIJäÿĂåĹĞéąžåĹl'çŽĎèŕÍïijŇä¡ăåžŤèŕěåIJĺä¡ăæIJĂæŰřäžčçăĄäÿ■ä¡£çŤĺåőČãĂĆ Raymond Hettingeräÿžæ■d'åĘŹäžĘäÿĂçŕĞéİđåÿÿåě¡çŽĎæŰĞçńă âĂIJPythonâĂŹs super() Considered Super!âĂİ ïijŇ éĂŽè£Ğåd'ğéĞŘçŽĎä¿Ńå■ŘåŘśæĹŚäžňèğčéĞŁäžĘäÿžäžĂäźĹ `super()` æŸŕædĄåě¡çŽĎãĂĆ

10.8 8.8 å■Řçśżäÿ■æL'ľåśŢproperty

éŮőécŸ

åIJĺå■Řçśżäÿ■ïijŇä¡ăæČşèęĄæL'ľåśŢåőŽäźL'åIJĺçĹűçśżäÿ■çŽĎpropertyçŽĎåŁ§èČ¡ãĂĆ

èğčåĘşæŰźæąĹ

èĂČèŹŚåęĆäÿŃçŽĎäžčçăĄïijŇåőČåőŽäźL'äžĘäÿĂäÿłpropertyïijŽ

```
class Person:
    def __init__(self, name):
```

```
        self.name = name

    # Getter function
    @property
    def name(self):
        return self._name

    # Setter function
    @name.setter
    def name(self, value):
        if not isinstance(value, str):
            raise TypeError('Expected a string')
        self._name = value

    # Deleter function
    @name.deleter
    def name(self):
        raise AttributeError("Can't delete attribute")
```

äÿŃéİćæŸŕäÿĂäÿłçď'žä¿ŃçśżïijŇåőČçżğæĽ'£èĞłPersonåźűæĽ'ľåśŢäžĘ name åśđæĂğçŽĎåŁ§èČ¡ïijŽ

```
class SubPerson(Person):
    @property
    def name(self):
        print('Getting name')
        return super().name

    @name.setter
    def name(self, value):
        print('Setting name to', value)
        super(SubPerson, SubPerson).name.__set__(self, value)

    @name.deleter
    def name(self):
        print('Deleting name')
        super(SubPerson, SubPerson).name.__delete__(self)
```

æŐěäÿŃæİěä¡£çŤĺè£ŹäÿłæŰřçśżïijŽ

```
>>> s = SubPerson('Guido')
Setting name to Guido
>>> s.name
Getting name
'Guido'
>>> s.name = 'Larry'
Setting name to Larry
>>> s.name = 42
Traceback (most recent call last):
    File "<stdin>", line 1, in <module>
    File "example.py", line 16, in name
```

```
        raise TypeError('Expected a string')
TypeError: Expected a string
>>>
```

åęĆædIJä¡ăäżĔäżĔåŔłæČşæL'l'åśŢpropertyçŽĎæ§ŘäÿĂäÿłæŰźæşŢïijŇéĆčäźĹåŔŕäżěåČŔäÿŃéİćè£Źæ

```
class SubPerson(Person):
    @Person.name.getter
    def name(self):
        print('Getting name')
        return super().name
```

æĹŰèĂĔïijŇä¡ăåŔłæČşä£őæŤźsetteræŰźæşŢïijŇåřśè£ŹäźĹåĘŹïijŽ

```
class SubPerson(Person):
    @Person.name.setter
    def name(self, value):
        print('Setting name to', value)
        super(SubPerson, SubPerson).name.__set__(self, value)
```

èőÍèőž

åIJÍå■Řçśżäÿ■æL'l'åśŢäÿĂäÿłpropertyåŔŕèČ¡äijŽåijŢètůå¿Ĺåd'Žäÿ■æŸŞår§èğL'çŽĎéŮőécŸïijŇ åŻăäÿżäÿĂäÿłpropertyåĔűåődæŸŕ getterãĂĄsetter åŠŇ deleter æŰźæşŢçŽĎéŻĘåŘĹïijŇèĂŇäÿ■æŸŕå■ŢäÿłæŰźæşŢãĂĆ åŻăæ■d'ïijŇå¡Şä¡ăæL'l'åśŢäÿĂäÿłpropertyçŽĎæŮűåĂŹïijŇä¡ăéIJĂèęĄåĚĹçąőåőŽä¡ăæŸŕåŘęèęĄéĞ■æŰřåő

åIJÍçňňäÿĂäÿłä¿Ńå■Řäÿ■ïijŇæL'ĂæIJL'çŽĎpropertyæŰźæşŢéČ¡èćńéĞ■æŰřåőŽäźL'ãĂĆ åIJÍæŕŘäÿĂäÿłæŰźæşŢäÿ■ïijŇä¡£çŤĺäžĘ super() æİěèřČçŤĺçĹűçśżçŽĎåőđçŐřãĂĆ åIJÍ setter åĞ¡æŢřäÿ■ä¡£çŤÍ super(SubPerson, SubPerson).name.__set__(self, value) çŽĎèŕ■åŘěæŸŕæšąæIJL'éŤŹçŽĎãĂĆ äÿžäžĘåğŤæL'ŸçżŹäźŃåL'■åőŽäźL'çŽĎsetteræŰźæşŢïijŇéIJĂèęĄåřĘæŐğåĹűæİČäijäéĂŠçżŹäźŃåL'■åőŽäź __set__() æŰźæşŢãĂĆ äÿ■è£ĞïijŇèŐůåŘŰè£ŹäÿłæŰźæşŢçŽĎåŤŕäÿĂéĂŤå¿ĎæŸŕä¡£çŤĺçśżåŘŸéĞŘèĂ è£Źäź§æŸŕäÿžäžĂäźĹæĹŚäžňèęĄä¡£çŤÍ super(SubPerson, SubPerson) çŽĎåŐ§åŻãăĂĆ

åęĆædIJä¡ăåŔłæČşéĞ■åőŽäźL'åĔűäÿ■äÿĂäÿłæŰźæşŢïijŇéĆčåŔłä¡£çŤÍ @property æIJňèžńæŸŕäÿ■åd'§çŽĎãĂĆæŕŤåęĆïijŇäÿŃéİćçŽĎäžčçăĄåřśæŮăæşŢåůëä¡IJïijŽ

```
class SubPerson(Person):
    @property  # Doesn't work
    def name(self):
        print('Getting name')
        return super().name
```

åęĆædIJä¡ăèŕŢçİÄè£ŘèąŇäijŽåŔŚçŐřsetteråĞ¡æŢřæŢt'äÿłæűĹåd'śäžĘïijŽ

```
>>> s = SubPerson('Guido')
Traceback (most recent call last):
```

```
    File "<stdin>", line 1, in <module>
    File "example.py", line 5, in __init__
        self.name = name
AttributeError: can't set attribute
>>>
```

ä¡ăåžŤèřěåČŔäźŃåL’■èŕť’è£ĞçŽĎéĆčæăůä£őæŤźäžčçăĄïijŽ

```
class SubPerson(Person):
    @Person.name.getter
    def name(self):
        print('Getting name')
        return super().name
```

è£ŹäźĹåĘŹåŘŐïijŇpropertyäźŃåL’■åůšçżŔåőŽäźL’è£ĞçŽĎæŰźæşŢäijŽèćńåď’■åĹűè£ĞæİěïijŇèĂŇget

```
>>> s = SubPerson('Guido')
>>> s.name
Getting name
'Guido'
>>> s.name = 'Larry'
>>> s.name
Getting name
'Larry'
>>> s.name = 42
Traceback (most recent call last):
    File "<stdin>", line 1, in <module>
    File "example.py", line 16, in name
        raise TypeError('Expected a string')
TypeError: Expected a string
>>>
```

åIJÍè£Źäÿ łçL’źåĹńçŽĎèğčåĘşæŰźæąĹäÿ■ïijŇæĹŚäżňæšąåŁđæşŢä¡£çŤÍæŻť’åŁäéĂŽçŤÍçŽĎæŰźåijŔåČ
`Person` çśżåŘ■ãĂĆ åęĆæđIJä¡ääÿ■ç§ěéĄŞåĹřåžŢæŸŕåŞläÿłå§žçśżåőŽäźL’äžĘpropertyïijŇ
éĆčä¡ääŔłèČ¡éĂŽè£ĞéĞ■æŰřåőŽäźL’æL’ĂæIJL’propertyåźűä¡£çŤÍ `super()`
æİěářĘæŐğåĹűæİČäijäéĂŠçżŹåL’■éİćçŽĎåőđçŐřãĂĆ

åĂijçŽĎæşĺæĎŔçŽĎæŸŕäÿŁéİćæijŤçď’žçŽĎçňňäÿĂçğ■æŁĂæIJŕè£ŸåŔŕäžěèćńçŤÍæİěæL’l’åśŢäÿĂäÿłą

```
# A descriptor
class String:
    def __init__(self, name):
        self.name = name

    def __get__(self, instance, cls):
        if instance is None:
            return self
        return instance.__dict__[self.name]

    def __set__(self, instance, value):
        if not isinstance(value, str):
```

```
            raise TypeError('Expected a string')
        instance.__dict__[self.name] = value

# A class with a descriptor
class Person:
    name = String('name')

    def __init__(self, name):
        self.name = name

# Extending a descriptor with a property
class SubPerson(Person):
    @property
    def name(self):
        print('Getting name')
        return super().name

    @name.setter
    def name(self, value):
        print('Setting name to', value)
        super(SubPerson, SubPerson).name.__set__(self, value)

    @name.deleter
    def name(self):
        print('Deleting name')
        super(SubPerson, SubPerson).name.__delete__(self)
```

æIJĂåŘŐåĂijçŽĎæşÍæĎŘçŽĎæŸŕïijŇèŕżåĹřè£ŹéĞŇæŮűïijŇä¡ăåžŤèŕěäijŽåŔŠçŐřå■Řçśżå
setter åŠŇ deleter æŰźæşŢåĚűåőđæŸŕå¿ĹçőĂå■ŢçŽĎãĂĆ
è£ŹéĞŇæijŤçd'žçŽĎèğčåĘşæŰźæąĹåŘŇæăůéĂĆçŤĺïijŇä¡ĘæŸŕåIJÍ PythonçŽĎissueéąţéÍć
æŁěåŚŁçŽĎäÿĂäÿłbugïijŇæĹŰèőÿäijŽä¡£å¿ŮåřĘæÍěçŽĎPythonçL'ĹæIJñäÿ■åĞžçŐřäÿĂäÿłæŻt'åŁăçőĂæt'

10.9 8.9 åĹŻåżžæŰřçŽĎçśżæĹŰåőđä¿ŃåśđæĂğ

éŮőécŸ

ä¡ăæČşåĹŻåżžäÿĂäÿłæŰřçŽĎæŇěæIJL'äÿĂäžŻécÍåd'ŰåŁ§èČ¡çŽĎåőđä¿ŃåśđæĂğçśżådŇïijŇæŕŤåęĆç

èğčåĘşæŰźæąĹ

åęĆædIJä¡ăæČşåĹŻåżžäÿĂäÿłåĚÍæŰřçŽĎåőđä¿ŃåśđæĂğïijŇåŔŕäžěéĂŽè£ĞäÿĂäÿłæŔŔè£řåŹĺçśżçŽĎ

```
# Descriptor attribute for an integer type-checked attribute
class Integer:
    def __init__(self, name):
        self.name = name
```

```
    def __get__(self, instance, cls):
        if instance is None:
            return self
        else:
            return instance.__dict__[self.name]

    def __set__(self, instance, value):
        if not isinstance(value, int):
            raise TypeError('Expected an int')
        instance.__dict__[self.name] = value

    def __delete__(self, instance):
        del instance.__dict__[self.name]
```

äÿĂäÿłæŔŔè£řåŹÍåřśæŸŕäÿĂäÿłåðđçŐřäžĘäÿL'äÿłæäÿå£ČçŽĎåšđæĂğèő£éŮőæŞ■ä¡IJ(get, set, delete)çŽĎçśżïijŇ åĹĘåĹńäÿž __get__() ãĂĄ__set__() åŠŇ __delete__() è£ŹäÿL'äÿłçL'źæőŁçŽĎæŰźæşŢãĂĆ è£ŹäžŻæŰźæşŢæŐěåŔŮäÿĂäÿłåðđä¿Ńä¡IJäÿžè¿ŞåĚëïijŇäźŃåŔŐçŻÿäžŤçŽĎæŞ■ä¡IJåðđä¿ŃåžŢåśĆçŽĎå■

äÿžäžĘä¡£çŤÍäÿĂäÿłæŔŔè£řåŹÍïijŇéIJĂářĘè£ŹäÿłæŔŔè£řåŹÍçŽĎåðđä¿Ńä¡IJäÿžçśżåšđæĂğæŤ¿åĹřäÿĂ

```
class Point:
    x = Integer('x')
    y = Integer('y')

    def __init__(self, x, y):
        self.x = x
        self.y = y
```

å¡Şä¡ăè£ŹæăůåĄŽåŘŐïijŇæL'ĂæIJL'åŕźæŔŔè£řåŹÍåšđæĂğ(æŕŤåęĆxæĹŰy)çŽĎèő£éŮőäijŽècń __get__() ãĂĄ__set__() åŠŇ __delete__() æŰźæşŢæ■ŢèŐůåĹřãĂĆä¿ŃåęĆïijŽ

```
>>> p = Point(2, 3)
>>> p.x # Calls Point.x.__get__(p,Point)
2
>>> p.y = 5 # Calls Point.y.__set__(p, 5)
>>> p.x = 2.3 # Calls Point.x.__set__(p, 2.3)
Traceback (most recent call last):
    File "<stdin>", line 1, in <module>
    File "descrip.py", line 12, in __set__
        raise TypeError('Expected an int')
TypeError: Expected an int
>>>
```

ä¡IJäÿžè¿ŞåĚëïijŇæŔŔè£řåŹÍçŽĎæŕŔäÿĂäÿłæŰźæşŢäijŽæŐěåŔŮäÿĂäÿłæŞ■ä¡IJåðđä¿ŃãĂĆ äÿžäžĘåðđçŐřèŕůæśĆæŞ■ä¡IJïijŇäijŽçŻÿäžŤçŽĎæŞ■ä¡IJåðđä¿ŃåžŢåśĆçŽĎå■ŮåĚÿ(__dict__åšđæĂğ)ãĂĆ æŔŔè£řåŹÍçŽĎ `self.name` åšđæĂğå■ŸåĆĺäžĘåIJÍåðđä¿Ńå■ŮåĚÿäÿ■èćńåðđéŹĚä¡£çŤĺåĹřçŽĎkeyãĂĆ

èőÍèőž

æŔŔè£řåŹÍåŔŕåőđçŐřåď ğéČÍåĹĘPythonçśžçL’źæĂğäÿ■çŽĎåžŢåśĆé■ŤæşŢïijŇ åŇĚæŃň `@classmethod` ãĂĄ`@staticmethod` ãĂĄ`@property` ïijŇçŤŽèĞşæŸŕ `__slots__` çL’źæĂğãĂĆ

éĂŽè£ĞåőŽäźL’äÿĂäÿłæŔŔè£řåŹĺïijŇä¡ăåŔŕäžěåIJĺåžŢåśĆæ■ŢèŐůæäÿå£ČçŽĎåőđä¿ŃæŞ■ä¡IJ(get, set, delete)ïijŇåźűäÿŤåŔŕåőŇåĚÍèĞłåőŽäźL’åőČäžňçŽĎèąŇäÿžãĂĆ è£ŹæŸŕäÿĂäÿłåijžåď ğçŽĎåůěåĚůïijŇæIJL’äžĘåőČä¡ăåŔŕäžěåőđçŐřå¿Ĺåď ŽénŸçžğåŁ§èČ¡ïijŇåźűäÿŤåőČä

æŔŔè£řåŹÍçŽĎäÿĂäÿłæŕŤè¿ČåŽřæČŚçŽĎåIJřæŰźæŸŕåőČåŔłèČ¡åIJÍçśžçžğåĹńèćńåőŽäźL’ïijŇèĂŇäÿ■

```
# Does NOT work
class Point:
    def __init__(self, x, y):
        self.x = Integer('x') # No! Must be a class variable
        self.y = Integer('y')
        self.x = x
        self.y = y
```

åŘŇæŮűïijŇ`__get__()` æŰźæşŢåőđçŐřèţůæİěæŕŤçIJŃäÿŁåŐżèęĄåď ■æİĆå¿Ůåď ŽïijŽ

```
# Descriptor attribute for an integer type-checked attribute
class Integer:

    def __get__(self, instance, cls):
        if instance is None:
            return self
        else:
            return instance.__dict__[self.name]
```

`__get__()` çIJŃäÿŁåŐżæIJL’çĆźåď ■æİĆçŽĎåŐ§åŻää¡ŠçżŞäžŐåőđä¿ŃåŔŸéĞŔåŠŇçśžåŔŸéĞŔçŽĎ åęĆæđIJäÿĂäÿłæŔŔè£řåŹÍèćńå¡ŞåĄŽäÿĂäÿłçśžåŔŸéĞŔæİèëő£éŮőïijŇéĆčäźĹ `instance` åŔĆæŢřèćńëő¿ç¡őæĹŘ `None` ãĂĆ è£Źçğ■æČĚåĘţäÿŃïijŇæăĞåĞĘåĄŽæşŢåřśæŸŕçőĂå■ŢçŽĎè£ŤåŻđè£Źä

```
>>> p = Point(2,3)
>>> p.x # Calls Point.x.__get__(p, Point)
2
>>> Point.x # Calls Point.x.__get__(None, Point)
<__main__.Integer object at 0x100671890>
>>>
```

æŔŔè£řåŹÍéĂŽåÿÿæŸŕéĆčäźŻä¡£çŤÍåĹřečĚéěřåŹÍæĹŰåĚČçśžçŽĎåď ğåđŇæąĘæđűäÿ■çŽĎäÿĂäÿłçżĎ äÿ¿äÿłä¿Ńå■ŘïijŇäÿŃéÍćæŸŕäÿĂäźŽæŻť énŸçžğçŽĎå§žäźŐæŔŔè£řåŹÍçŽĎäžčçĂąijŇåźűæűL’åŔŁåĹřäÿĂ

```
# Descriptor for a type-checked attribute
class Typed:
    def __init__(self, name, expected_type):
        self.name = name
        self.expected_type = expected_type
    def __get__(self, instance, cls):
```

```
        if instance is None:
            return self
        else:
            return instance.__dict__[self.name]

    def __set__(self, instance, value):
        if not isinstance(value, self.expected_type):
            raise TypeError('Expected ' + str(self.expected_type))
        instance.__dict__[self.name] = value
    def __delete__(self, instance):
        del instance.__dict__[self.name]

# Class decorator that applies it to selected attributes
def typeassert(**kwargs):
    def decorate(cls):
        for name, expected_type in kwargs.items():
            # Attach a Typed descriptor to the class
            setattr(cls, name, Typed(name, expected_type))
        return cls
    return decorate

# Example use
@typeassert(name=str, shares=int, price=float)
class Stock:
    def __init__(self, name, shares, price):
        self.name = name
        self.shares = shares
        self.price = price
```

æIJĂåŘŐèęĄæŇĞåĞžçŽĎäÿĂçĆźæŸŕïijŇåęĆæđIJä¡ăåŔłæŸŕæČşçőĂå■ŢçŽĎèĞłåőŽäźL'æ§Řäÿłçśžç
è£Źçğ■æČĚåĘţäÿŃä¡£çŤĺ8.6åřŔèŁĆäżŃçż■çŽĎpropertyæŁĂæIJŕäijŽæŻt'åŁăåőźæŸŞãĂĆ
å¡ŞçÍŇåžŔäÿ■æIJL'å¿Ĺåd'ŽéĞ■åd'■äžčçăĄçŽĎđæŮűåĂŹæŔŔè£řåŹĺåřśå¿ĹæIJL'çŤĺäžĘ
(æŕŤåęĆä¡ăæČşåIJĺä¡ăäžčçăĄçŽĎå¿Ĺåd'ŽåIJřæŰźä¡£çŤĺæŔŔè£řåŹĺæŔŔä¿ŻçŽĎåŁ§èČ¡æĹŰèĂĚåřĘåőČä¡I

10.10 8.10 ä¡£çŤĺäžűè£§èőąçőŮåśđæĂğ

éŮőécŸ

ä¡ăæČşåřĘäÿĂäÿłåŔłèŕžåśđæĂğåőŽäźL'æĹŘäÿĂäÿłpropertyïijŇåźűäÿŤåŔłåIJĺèő£éŮőçŽĎæŮűåĂŹæL'n
ä¡ĘæŸŕäÿĂæŮęèćńèő£éŮőåŘŐïijŇä¡ăåÿŇæIJŻçżŞæđIJåĂijèćńçijŞå■ŸètůæİěïijŇäÿ■çŤĺærŔæňąéČ¡åŐżèőą

èğčåĘşæŰźæąĹ

åőŽäźL'äÿĂäÿłåžűè£§åśđæĂğçŽĎäÿĂçğ■énŸæŢĹæŰźæşŢæŸŕéĂŽè£Ğä¡£çŤĺäÿĂäÿłæŔŔè£řåŹĺçśžïijŇ

```
class lazyproperty:
    def __init__(self, func):
```

```
        self.func = func

    def __get__(self, instance, cls):
        if instance is None:
            return self
        else:
            value = self.func(instance)
            setattr(instance, self.func.__name__, value)
            return value
```

ä¡ăéIJĂèęĄåČŔäÿŃéİćè£ŹæăůåIJĺäÿĂäÿłçśżäÿ■ä¡£çŤĺåőČïijŽ

```
import math

class Circle:
    def __init__(self, radius):
        self.radius = radius

    @lazyproperty
    def area(self):
        print('Computing area')
        return math.pi * self.radius ** 2

    @lazyproperty
    def perimeter(self):
        print('Computing perimeter')
        return 2 * math.pi * self.radius
```

äÿŃéİćåIJĺäÿĂäÿłäžd'äžŠçŐŕåćČäÿ■æijŤçd'žåőČçŽĎä¡£çŤĺïijŽ

```
>>> c = Circle(4.0)
>>> c.radius
4.0
>>> c.area
Computing area
50.26548245743669
>>> c.area
50.26548245743669
>>> c.perimeter
Computing perimeter
25.132741228718345
>>> c.perimeter
25.132741228718345
>>>
```

äžŤçżĘèğĆåŕ§ä¡ăäijŽåŔŚçŐřæűĹæĄŕ `Computing area` åŠŇ `Computing perimeter` äżĚäžĚåĞžçŐřäÿĂæňąãĂĆ

èőÍèőž

å¿Ĺåď ŽæŮűåĂŹïijŇæđĎéĂääÿĂäÿłåžűè£§èőąçőŮåšđæĂğçŽĎäÿżèęĄçŽőçŽĎæŸŕäÿžäžĘæŔŘå■ĞæĂ
ä¿ŇåęĆïijŇä¡ääŔŕäżěéĄ£åĚ■èőąçőŮè£ŹäžŽåšđæĂğåĂijïijŇéŹď éİđä¡äçIJ§çŽĎéIJĂèęĄåőČäżñãĂĆ
è£ŹéĞŇæijŤçď žçŽĎæŰźæąĹåřśæŸŕçŤĺæİěåőđçŐřè£ŹæăůçŽĎæŢĹæđIJçŽĎïijŇ
åŔłäÿ■è£ĞåőČæŸŕéĂŽè£ĞäžěéİđåÿÿéńŸæŢĹçŽĎæŰźåijŔä¡£çŤĺæŔŔè£řåŹĺçŽĎäÿĂäÿłçš¿åęŹçĽźæĂğæİě

æ■čåęĆåIJĺåĚűäżŰåřŔèŁĆ(åęĆ8.9åřŔèŁĆ)æĽĂèőšçŽĎéĆčæăůïijŇå¡ŞäÿĂäÿłæŔŔè£řåŹĺèćńæŤ¿åĚěäÿ
æŕŔæňąèő£éŮőåšđæĂğæŮűåőČçŽĎ `__get__()` ãĂĄ`__set__()` åŠŇ `__delete__()`
æŰźæşŢåřśäijŽèćńèğęåŔŚãĂĆ äÿ■è£ĞïijŇåęĆæđIJäÿĂäÿłæŔŔè£řåŹĺäžĚäžĚåŔłåőŽäźĽäžĘäÿĂäÿł
`__get__()` æŰźæşŢçŽĎèŕİïijŇåőČæŕŤéĂŽåÿÿçŽĎåĚůæIJĽæŻťåijśçŽĎçżŚåőŽãĂĆ
çĽźåĹńåIJŕïijŇåŔłæIJĽå¡Şèćńèő£éŮőåšđæĂğäÿ■åIJĺåőđä¿ŇåžŢåśĆçŽĎå■ŮåĚÿäÿ■æŮű
`__get__()` æŰźæşŢæĽ■äijŽèćńèğęåŔŚãĂĆ

`lazyproperty` çśżåĹľçŤĺè£ŹäÿĂçĆźïijŇä¡£çŤĺ `__get__()`
æŰźæşŢåIJĺåőđä¿ŇäÿĄå■ŸåĆĺèőąçőŮåĞžæİěçŽĎåĂijïijŇ è£Źäÿłåőđä¿Ňä¡£çŤĺçŻÿåŘŇçŽĎåŘ■å■Ůä¡IJäÿž
è£ŹæăůäÿĂæİěïijŇçżŞæđIJåĂijèćńå■ŸåĆĺåIJĺåőđä¿Ňå■ŮåĚÿäÿ■åźűäÿŤäžěåŘŐářśäÿ■éIJĂèęĄåĘ■åŐžèőąçő
ä¡ääŔŕäžěåřİèŕŢæŻťæůśåĚěçŽĎä¿Ňå■ŘæİěèğĆář§çżŞæđIJïijŽ

```
>>> c = Circle(4.0)
>>> # Get instance variables
>>> vars(c)
{'radius': 4.0}

>>> # Compute area and observe variables afterward
>>> c.area
Computing area
50.26548245743669
>>> vars(c)
{'area': 50.26548245743669, 'radius': 4.0}

>>> # Notice access doesn't invoke property anymore
>>> c.area
50.26548245743669

>>> # Delete the variable and see property trigger again
>>> del c.area
>>> vars(c)
{'radius': 4.0}
>>> c.area
Computing area
50.26548245743669
>>>
```

è£Źçğ■æŰźæąĹæIJĽäÿĂäÿłåřŔçijžéŹůåřśæŸŕèőąçőŮåĞžçŽĎåĂijèćńåĹŻåżžåŘŐæŸŕåŔŕäžěèćńä£őæŤ

```
>>> c.area
Computing area
50.26548245743669
>>> c.area = 25
>>> c.area
```

```
25
>>>
```

åęĆædIJä¡ăæŃĚå£Čè£ŹäÿłéŮőécŸïijŇéĆčäźĹåŔŕäżěä¡£çŤĺäÿĂçğ■çĺ■å¿őæšąéĆčäźĹéńŸæŢĹçŽĎåőđç

```
def lazyproperty(func):
    name = '_lazy_' + func.__name__
    @property
    def lazy(self):
        if hasattr(self, name):
            return getattr(self, name)
        else:
            value = func(self)
            setattr(self, name, value)
            return value
    return lazy
```

åęĆædIJä¡ăä¡£çŤĺè£ŹäÿłçL'ĹæIJñïijŇåřśäijŽåŔŚçŐřçŐřåIJĺä£őæŤźæŞ■ä¡IJåůšçżŔäÿ■èćńåĚĄèőÿäžĘïij

```
>>> c = Circle(4.0)
>>> c.area
Computing area
50.26548245743669
>>> c.area
50.26548245743669
>>> c.area = 25
Traceback (most recent call last):
    File "<stdin>", line 1, in <module>
AttributeError: can't set attribute
>>>
```

çĎűèĂŃïijŇè£Źçğ■æŰźæąĹæIJL'äÿĂäÿłçijžçĆźåřśæŸŕæL'ĂæIJL'getæŞ■ä¡IJéČ¡å£ĚéążèćńåőŽåŘŚåĹřă
getter åĞ¡æŢřäÿŁåŐżãĂĆ è£ŹäÿłèůšäźŃåL'■çőÅå■ŢçŽĎåIJĺåőđä¿Ńå■ŮåĚÿäÿ■æšěæL'¿åĂijçŽĎæŰźæą
åęĆædIJæČşèŐůåŔŰæŻt'åď'ŽåĚşäžŐpropertyåŠŇåŔŕçőąçŘĘåśđæĂğçŽĎä£qæĄŕïijŇåŔŕäżěåŔĆèĂČ8.6åřŔ

10.11 8.11 çőĂåŇŰæŢřæ■őçżŞæđĎçŽĎåĹlåğŃåŇŰ

éŮőécŸ

ä¡ăåĘŹäžĘå¿Ĺåď'ŽäžĚäżĚçŤĺä¡IJæŢřæ■őçżŞæđĎçŽĎçśżïijŇäÿ■æČşåĘŹåď'łåď'ŽçČęäžžçŽĎ
__init__() åĞ¡æŢř

èğčåĘşæŰźæąĹ

åŔŕäżěåIJĺäÿĂäÿłå§žçśżäÿ■åĘŹäÿĂäÿłåĚñçŤĺçŽĎ __init__() åĞ¡æŢřïijŽ

```
import math

class Structure1:
    # Class variable that specifies expected fields
    _fields = []

    def __init__(self, *args):
        if len(args) != len(self._fields):
            raise TypeError('Expected {} arguments'.format(len(self.
 ↪_fields)))
        # Set the arguments
        for name, value in zip(self._fields, args):
            setattr(self, name, value)
```

çĎűåŘŐä¡£ä¡ăçŽĎçśżçżğæL'£èĞłè£Źäÿłå§žçśż:

```
# Example class definitions
class Stock(Structure1):
    _fields = ['name', 'shares', 'price']

class Point(Structure1):
    _fields = ['x', 'y']

class Circle(Structure1):
    _fields = ['radius']

    def area(self):
        return math.pi * self.radius ** 2
```

ä¡£çŤĺè£ŹäžŻçśżçŽĎçđ'žä¿ŃïijŽ

```
>>> s = Stock('ACME', 50, 91.1)
>>> p = Point(2, 3)
>>> c = Circle(4.5)
>>> s2 = Stock('ACME', 50)
Traceback (most recent call last):
    File "<stdin>", line 1, in <module>
    File "structure.py", line 6, in __init__
        raise TypeError('Expected {} arguments'.format(len(self._
 ↪fields)))
TypeError: Expected 3 arguments
```

åęĆæđIJè£ŸæČşæŤŕæŇĄåĚşéŤőå■ŮåŔĆæŢřïijŇåŔŕäžěářĘåĚşéŤőå■ŮåŔĆæŢřèő¿ç¡őäÿžåőđä¿Ńåśđæ

```
class Structure2:
    _fields = []

    def __init__(self, *args, **kwargs):
        if len(args) > len(self._fields):
            raise TypeError('Expected {} arguments'.format(len(self.
 ↪_fields)))
```

```
        # Set all of the positional arguments
        for name, value in zip(self._fields, args):
            setattr(self, name, value)

        # Set the remaining keyword arguments
        for name in self._fields[len(args):]:
            setattr(self, name, kwargs.pop(name))

        # Check for any remaining unknown arguments
        if kwargs:
            raise TypeError('Invalid argument(s): {}'.format(','.
↪join(kwargs)))
# Example use
if __name__ == '__main__':
    class Stock(Structure2):
        _fields = ['name', 'shares', 'price']

    s1 = Stock('ACME', 50, 91.1)
    s2 = Stock('ACME', 50, price=91.1)
    s3 = Stock('ACME', shares=50, price=91.1)
    # s3 = Stock('ACME', shares=50, price=91.1, aa=1)
```

ä¡ãè£ŸèČ¡åřĘäÿ■åIJĺ `_fields` äÿ■çŽĎåŘ■çğřåŁãåĚěåĹřåśđæĂğäÿ■åŐżïijŽ

```
class Structure3:
    # Class variable that specifies expected fields
    _fields = []

    def __init__(self, *args, **kwargs):
        if len(args) != len(self._fields):
            raise TypeError('Expected {} arguments'.format(len(self.
↪_fields)))

        # Set the arguments
        for name, value in zip(self._fields, args):
            setattr(self, name, value)

        # Set the additional arguments (if any)
        extra_args = kwargs.keys() - self._fields
        for name in extra_args:
            setattr(self, name, kwargs.pop(name))

        if kwargs:
            raise TypeError('Duplicate values for {}'.format(','.
↪join(kwargs)))

# Example use
if __name__ == '__main__':
    class Stock(Structure3):
```

```
        _fields = ['name', 'shares', 'price']

    s1 = Stock('ACME', 50, 91.1)
    s2 = Stock('ACME', 50, 91.1, date='8/2/2012')
```

èőÍèőž

å¡Şä¡ăéIJĂèęĄä¡£çŤÍåď ğéĞŔå¿ĹåřŔçŽĎæŢřæ■őçżŞæđĎçśżçŽĎæŮűåĂŹïijŇ çŻÿæŕŤæĽŃåůěäÿĂäÿłäÿłåőŽäźĽ `__init__()` æŰźæşŢèĂŇåůšïijŇä¡£çŤÍè£ŹçğæŰźåijŔåŔŕäžěåď ğåď ğ

åIJÍäÿŁéİćçŽĎåőđçŐřäÿ■æĹŚäžňä¡£çŤÍäžĘ `setattr()` åĞ¡æŢřçśżèő¿ç¡őåśđæĂğåĂijïijŇ ä¡ăåŔŕèČ¡äÿ■æČşçŤÍè£ŹçğæŰźåijŔïijŇèĂŇæŸŕæČşçŻť æŐěæŻť æŰřåőć

```
class Structure:
    # Class variable that specifies expected fields
    _fields= []
    def __init__(self, *args):
        if len(args) != len(self._fields):
            raise TypeError('Expected {} arguments'.format(len(self.
↪_fields)))

        # Set the arguments (alternate)
        self.__dict__.update(zip(self._fields,args))
```

åř¡çőąè£ŹäźŞåŔŕäžěæ■čåÿÿåůëä¡IJïijŇä¡ĘæŸŕå¡ŞåőŽäźĽå■ŘçśżçŽĎæŮűåĂŹéŮőécŸåŕśæİěäžĘãĂĆ å¡ŞäÿĂäÿłå■ŘçśżåőŽäźĽäžĘ `__slots__` æĹŰèĂĚéĂŽè£Ğproperty(æĹŰæŔŘè£řåŹÍ)æİěåŇĚècĚæ§Řäÿłå éĆčäźĹçŻť æŐěě£éŮőåőđä¿Ńå■ŮåĚÿåŕśäÿ■ètůä¡IJçŤÍäžĘãĂĆæĹŚäžňäÿŁéİćä¡£çŤÍ `setattr()` äijŽæŸ¿å¿ŮæŻť éĂŽçŤÍäžŽïijŇåŽääÿžåőČäź§éĂĆçŤÍäžŐå■ŘçśżæČĚåĘţãĂĆ

è£Źçğ■æŰźæşŢåŤŕäÿĂäÿ■åě¡çŽĎåIJŕæŰźåŕśæŸŕåŕźæ§ŘäžŻIDEèĂŇèÍĂïijŇåIJÍæŸ¿çď žåÿőåŁľåĞ¡æŢ

```
>>> help(Stock)
Help on class Stock in module __main__:
class Stock(Structure)
...
| Methods inherited from Structure:
|
| __init__(self, *args, **kwargs)
|
...
>>>
```

åŔŕäžěåŔĆèĂČ9.16åřŔèŁĆæİěåijžåĹűåIJÍ `__init__()` æŰźæşŢäÿ■æŇĞåőŽåŔĆæŢřçŽĎçśżåđŃç■¿åŘ■ãĂĆ

10.12 8.12 åőŽäźĽæŐěåŘčæĹŰèĂĚæŁ¡èśąå§žçśż

éŮőécŸ

ä¡ăæČşåőŽäźĽäÿĂäÿłæŐěåŘčæĹŰæŁ¡èśąçśżïijŇåźűäÿŤéĂŽè£ĞæĽğèąŇçśżåđŃæčĂæ§ěæİěçąőä£İå■Ř

èğčåĘşæŰźæąĹ

ä¡£çŤÍ abc æÍąåİŮåŘŕäżěå¿Ĺè¡żæİ¿çŽĎåőŽäźĽæŁ¡èśąå§žçśżïijŽ

```
from abc import ABCMeta, abstractmethod

class IStream(metaclass=ABCMeta):
    @abstractmethod
    def read(self, maxbytes=-1):
        pass

    @abstractmethod
    def write(self, data):
        pass
```

æŁ¡èśąçśżçŽĎäÿĂäÿłçĽźçĆźæŸŕåőČäÿ■èČ¡çŻť'æŐěèćńåőđä¿ŃåŇŰïijŇæŕŤåęĆä¡ăæČşåČŔäÿŃéİćè£Ź

```
a = IStream() # TypeError: Can't instantiate abstract class
              # IStream with abstract methods read, write
```

æŁ¡èśąçśżçŽĎçŻőçŽĎåřśæŸŕèőľ'åĹńçŽĎçśżçżğæĽ'£åőČåźűåőđçŐřçĽ'źåőŽçŽĎæŁ¡èśąæŰźæşŢïijŽ

```
class SocketStream(IStream):
    def read(self, maxbytes=-1):
        pass

    def write(self, data):
        pass
```

æŁ¡èśąå§žçśżçŽĎäÿĂäÿłäÿżèęĄçŤÍéĂŤæŸŕåIJÍäżčçăĄäÿ■æčĂæ§ěæ§ŘäžŽçśżæŸŕåŘęäÿžçĽ'źåőŽçśżåđ

```
def serialize(obj, stream):
    if not isinstance(stream, IStream):
        raise TypeError('Expected an IStream')
    pass
```

éŹđ'äžĘçżğæĽ'£è£Źçğ■æŰźåijŔåđ'ŰïijŇè£ŸåŔŕäżěéĂŽè£ĞæşĺåĘŇæŰźåijŔæİèèőľ'æ§ŘäÿłçśżåőđçŐřæ

```
import io

# Register the built-in I/O classes as supporting our interface
IStream.register(io.IOBase)
```

```
# Open a normal file and type check
f = open('foo.txt')
isinstance(f, IStream) # Returns True
```

@abstractmethod è£ŸèČ¡æşĺèğčéİŹæĂĄæŰźæşŢãĂĄçśżæŰźæşŢåŠŇ properties ãĂĆ ä¡ääŔłéIJĂä£İèŕĄè£ŹäÿłæşĺèğčçťğéİääIJĺåĞ¡æŢřåőŽäźĽåĽ■å■şåŔřïijŽ

```
class A(metaclass=ABCMeta):
    @property
    @abstractmethod
    def name(self):
        pass

    @name.setter
    @abstractmethod
    def name(self, value):
        pass

    @classmethod
    @abstractmethod
    def method1(cls):
        pass

    @staticmethod
    @abstractmethod
    def method2():
        pass
```

èőĺèőž

æăĞåĞĘåžŞäÿ■æIJL'å¿Ĺåď'ŽçŤĺåĹřæŁ¡èśąå§žçśżçŽĎåIJřæŰźãĂĆcollections æĺąåİŮåőŽäźL'äžĘå¿Ĺåď'Žèů§åőźåŹĺåŠŇè£■äžčåŹĺ(åžŔåĹŮãĂĄæŸäářĎãĂĄéŻĘåŘĹç■L')æIJL'åĚşçŽĎæŁ numbers åžŞåőŽäźL'äžĘèů§æŢřå■Ůářźèśą(æŢť'æŢřãĂĄæţőçĆźæŢřãĂĄæIJL'çŘĘæŢřç■L')æIJL'åĚşçŽĎå§ž åžŞåőŽäźL'äžĘå¿Ĺåď'Žèů§I/OæŞ■ä¡IJçŻÿåĚşçŽĎå§žçśżãĂĆ

ä¡ääŔřäžěä¡£çŤĺécĎåőŽäźL'çŽĎæŁ¡èśąçśżæİěæL'ğèąŇæŻť'éĂŽçŤĺçŽĎçśżåđŃæčĂæ§ěïijŇä¿ŃåęĆïijŽ

```
import collections

# Check if x is a sequence
if isinstance(x, collections.Sequence):
...

# Check if x is iterable
if isinstance(x, collections.Iterable):
...

# Check if x has a size
if isinstance(x, collections.Sized):
```

```
...

# Check if x is a mapping
if isinstance(x, collections.Mapping):
```

åř¡çőąABCsåŘŕäžěèőľæĹŚäžňå¿ĹæŰźä¿£çŽĎåĄŽçśžåđŃæčĂæ§ěïijŇä¡ĘæŸŕæĹŚäžňåIJĺäžčçăĄäÿ■æI
åŻääÿžPythonçŽĎæIJňèť´ĺæŸŕäÿĂéŮĺĺåŁĺæĂĄçijŰçĺŃèŕ■èĺĂïijŇåĚűçŽőçŽĎåřśæŸŕçżŹä¡ăæŻť´åď´ŽçĄţæť´ża
åijžåĹűçśžåđŃæčĂæ§ěæĹŰèőľä¡ăäžčçăĄåŔŸå¿ŮæŻť´åď´■æİĆïijŇè£ŹæăůåĄŽæŮăåijĆäžŐèĹ■æIJňæśĆæIJ

10.13 8.13 åőđçŐřæŢřæ■őæĺąåđŃçŽĎçśžåđŃçžęæİ§

éŮőécŸ

ä¡ăæČşåőŽäźL´æ§ŘäžŻåIJĺåśđæĂğètŃåĂijäÿŁéİćæIJL´éŹŘåĹűçŽĎæŢřæ■őçżŞæđĎãĂĆ

èğčåĘşæŰźæąĹ

åIJĺè£ŹäÿłéŮőécŸäÿ■ïijŇä¡ăéIJĂèęĄåIJĺářźæ§ŘäžŻåőđä¿ŃåśđæĂğètŃåĂijæŮűè£ŻèąŇæčĂæ§ěãĂĆ
æL´Ăäžěä¡ăèęĄèĞłåőŽäźL´åśđæĂğètŃåĂijåĞ¡æŢřïijŇè£Źçğ■æČĚåĘţäÿŃæIJĂåě¡ä¡£çŤĺæŔŘè£řåŹĺãĂĆ

äÿŃéİćçŽĎäžčçăĄä¡£çŤĺæŔŘè£řåŹĺåőđçŐřäžĘäÿĂäÿłçşżçż§çśžåđŃåŠŇètŃåĂijéłŇèŕĄæąĘæđűïijŽ

```
# Base class. Uses a descriptor to set a value
class Descriptor:
    def __init__(self, name=None, **opts):
        self.name = name
        for key, value in opts.items():
            setattr(self, key, value)

    def __set__(self, instance, value):
        instance.__dict__[self.name] = value


# Descriptor for enforcing types
class Typed(Descriptor):
    expected_type = type(None)

    def __set__(self, instance, value):
        if not isinstance(value, self.expected_type):
            raise TypeError('expected ' + str(self.expected_type))
        super().__set__(instance, value)


# Descriptor for enforcing values
class Unsigned(Descriptor):
    def __set__(self, instance, value):
        if value < 0:
            raise ValueError('Expected >= 0')
```

```
        super().__set__(instance, value)


class MaxSized(Descriptor):
    def __init__(self, name=None, **opts):
        if 'size' not in opts:
            raise TypeError('missing size option')
        super().__init__(name, **opts)

    def __set__(self, instance, value):
        if len(value) >= self.size:
            raise ValueError('size must be < ' + str(self.size))
        super().__set__(instance, value)
```

è£ŹäžŻçśžåřśæŸŕäą¡äèęĄåĹŻåżžçŽĎæŢřæ■őæĺąåđŃæĹŰçśżåđŃçşżçż§çŽĎå§žçąĂæđĎåżžæĺąåİŮãĂĆäÿŃéİćåřśæŸŕæĹŚäžňåőđéŹĚåőŽäźĽçŽĎåŘĎçğ■äÿ■åŘŃçŽĎæŢřæ■őçśżåđŃïijŽ

```
class Integer(Typed):
    expected_type = int

class UnsignedInteger(Integer, Unsigned):
    pass

class Float(Typed):
    expected_type = float

class UnsignedFloat(Float, Unsigned):
    pass

class String(Typed):
    expected_type = str

class SizedString(String, MaxSized):
    pass
```

çĎűåŘŐä¡£çŤĺè£ŹäžŻèĞłåőŽäźĽ'æŢřæ■őçśżåđŃïijŇæĹŚäžňåőŽäźĽ'äÿĂäÿłçśżïijŽ

```
class Stock:
    # Specify constraints
    name = SizedString('name', size=8)
    shares = UnsignedInteger('shares')
    price = UnsignedFloat('price')

    def __init__(self, name, shares, price):
        self.name = name
        self.shares = shares
        self.price = price
```

çĎűåŘŐæţŃèŕŢè£ŹäÿłçśżçŽĎåśđæĂğèţŃåĂijçžęæİ§ïijŇåŔŕåŔŚçŐřåŕźæ§ŘäžŻåśđæĂğçŽĎèţŃåĂijè£İ

```
>>> s.name
'ACME'
>>> s.shares = 75
>>> s.shares = -10
Traceback (most recent call last):
    File "<stdin>", line 1, in <module>
    File "example.py", line 17, in __set__
        super().__set__(instance, value)
    File "example.py", line 23, in __set__
        raise ValueError('Expected >= 0')
ValueError: Expected >= 0
>>> s.price = 'a lot'
Traceback (most recent call last):
    File "<stdin>", line 1, in <module>
    File "example.py", line 16, in __set__
        raise TypeError('expected ' + str(self.expected_type))
TypeError: expected <class 'float'>
>>> s.name = 'ABRACADABRA'
Traceback (most recent call last):
    File "<stdin>", line 1, in <module>
    File "example.py", line 17, in __set__
        super().__set__(instance, value)
    File "example.py", line 35, in __set__
        raise ValueError('size must be < ' + str(self.size))
ValueError: size must be < 8
>>>
```

è£ŸæIJL'äÿĂäžŻæŁĂæIJŕåŔŕäżěçőĂåŇŰäÿŁéÍćçŽĎäžčçăĄïijŇåĚűäÿ■äÿĂçğ■æŸŕä¡£çŤĺçśżèčĚéěřåŹĺ

```
# Class decorator to apply constraints
def check_attributes(**kwargs):
    def decorate(cls):
        for key, value in kwargs.items():
            if isinstance(value, Descriptor):
                value.name = key
                setattr(cls, key, value)
            else:
                setattr(cls, key, value(key))
        return cls

    return decorate

# Example
@check_attributes(name=SizedString(size=8),
                  shares=UnsignedInteger,
                  price=UnsignedFloat)
class Stock:
    def __init__(self, name, shares, price):
        self.name = name
        self.shares = shares
```

```
        self.price = price
```

åŔęåď Űäÿ Ăçğ■æŰźåijŔæŸŕä¡£çŤĺåĚČçśżïijŽ

```
# A metaclass that applies checking
class checkedmeta(type):
    def __new__(cls, clsname, bases, methods):
        # Attach attribute names to the descriptors
        for key, value in methods.items():
            if isinstance(value, Descriptor):
                value.name = key
        return type.__new__(cls, clsname, bases, methods)

# Example
class Stock2(metaclass=checkedmeta):
    name = SizedString(size=8)
    shares = UnsignedInteger()
    price = UnsignedFloat()

    def __init__(self, name, shares, price):
        self.name = name
        self.shares = shares
        self.price = price
```

èőÍèőž

æIJňèŁĆä¡£çŤĺäžĘå¿Ĺåď ŽéńŸçžğæŁĂæIJŕïijŇåŇĚæŃňæŔŔè£řåŹĺãĂĄæůůåĚěçśżãĂĄsuper() çŽĎä¡£çŤĺãĂĄçśżèčĚéěřåŹĺåŠŇåĚČçśżãĂĆ äÿ■åŔŕèČ¡åIJĺè£ŹéĞŇäÿĂäÿĂèŕęçżĘåśŢåijĂæİěèőšïijŇä¡ĘæŸ ä¡ĘæŸŕïijŇæĹŠåIJĺè£ŹéĞŇè£ŸæŸŕèęĄæŔŘäÿĂäÿŃåĞääÿłéIJĂèęĄæşĺæĎŔçŽĎçĆźãĂĆ

éęŰåĚĹïijŇåIJÍ Descriptor å§žçśżäÿ■ä¡ăäijŽçIJŃåĹřæIJL'äÿł __set__() æŰźæşŢïijŇå■ť'æšąæIJL'çŽÿåžŤçŽĎ __get__() æŰźæşŢãĂĆ åęĆæđIJäÿĂäÿłæŔŔè£řäżĚäżĚæŸŕäżŐåžŢåśĆåőđä¿Ńå■ŮåĚÿäÿ■èŐůåŔŰæ§ŘäÿłåśđæĂğåĂijçŽĎèŕÍïijŇéĆ __get__() æŰźæşŢãĂĆ

æL'ĂæIJL'æŔŔè£řåŹĺçśżéČ¡æŸŕå§žäžŐæůůåĚěçśżæİěåőđçŐřçŽĎãĂĆærŤåęĆ Unsigned åŠŇ MaxSized èęĄèů§åĚűäżŰçżğæL'£èĞł Typed çśżæůůåĚěãĂĆ è£ŹéĞŇåĹ'çŤĺåď Žçżğæ L'£æİěåőđçŐřçŽÿåžŤçŽĎåŁ§èČ¡ãĂĆ

æůůåĚěçśżçŽĎäÿĂäÿłærŤè¿ČéŽ¿çŘęğčçŽĎåIJřæŰźæŸŕïijŇèřČçŤĺ super() åĞ¡æŢřæŮűïijŇä¡ăăźűäÿ■ç§ěéĄŞçl'űçń§èęĄèřČçŤĺåŞłäÿłåĚůä¡ŞçśżãĂĆ ä¡ăéIJĂèęĄèů§åĚűäżŰçśżçżŞåŘĹåŘŐæL'■èČ¡æ■čçąőçŽĎä¡£çŤĺïijŇäź§åřśæŸŕå£ĚéążåŘĹä¡IJæL'■èČ¡äžğçŤ

ä¡£çŤĺçśżèčĚéěřåŹĺåŠŇåĚČçśżéĂŽåÿÿåŔŕäżěçőĂåŇŰäżčçăĄãĂĆäÿŁéİćäÿd'äÿłä¿Ńå■Řäÿ■ä¡ăäijŽåŔŞ

```
# Normal
class Point:
    x = Integer('x')
    y = Integer('y')
```

```
# Metaclass
class Point(metaclass=checkedmeta):
    x = Integer()
    y = Integer()
```

æĽĂæIJĽæŰźæşŢäÿ■ïijŇçśżèčĚéěřåŹĺæŰźæąĹåžŤèřěæŸřæIJĂçĄţæť żåŠŇæIJĂéńŸæŸŐçŽĎãĂĆ éęŰåĚĹïijŇåőČåźűäÿ■ä¿İèţŰäżżä¡ŢåĚűäżŰæŰřçŽĎæŁĂæIJřïijŇæŕŤåęĆåĚČçśżãĂĆåĚűæňąïijŇèčĚéěřåŹĺå

æIJĂåŘŐïijŇèčĚéěřåŹĺè£ŸèČ¡ä¡IJäÿžæůůåĚěçśżçŽĎæŻ£äżčæŁĂæIJræİěåőđçŐřåŘŇæăůçŽĎæŢĹæđIJ

```
# Decorator for applying type checking
def Typed(expected_type, cls=None):
    if cls is None:
        return lambda cls: Typed(expected_type, cls)
    super_set = cls.__set__

    def __set__(self, instance, value):
        if not isinstance(value, expected_type):
            raise TypeError('expected ' + str(expected_type))
        super_set(self, instance, value)

    cls.__set__ = __set__
    return cls


# Decorator for unsigned values
def Unsigned(cls):
    super_set = cls.__set__

    def __set__(self, instance, value):
        if value < 0:
            raise ValueError('Expected >= 0')
        super_set(self, instance, value)

    cls.__set__ = __set__
    return cls


# Decorator for allowing sized values
def MaxSized(cls):
    super_init = cls.__init__

    def __init__(self, name=None, **opts):
        if 'size' not in opts:
            raise TypeError('missing size option')
        super_init(self, name, **opts)

    cls.__init__ = __init__

    super_set = cls.__set__
```

```
    def __set__(self, instance, value):
        if len(value) >= self.size:
            raise ValueError('size must be < ' + str(self.size))
        super_set(self, instance, value)

    cls.__set__ = __set__
    return cls


# Specialized descriptors
@Typed(int)
class Integer(Descriptor):
    pass


@Unsigned
class UnsignedInteger(Integer):
    pass


@Typed(float)
class Float(Descriptor):
    pass


@Unsigned
class UnsignedFloat(Float):
    pass


@Typed(str)
class String(Descriptor):
    pass


@MaxSized
class SizedString(String):
    pass
```

è£Źçğ■æŰźåijŔåőŽäźL’çŽĎçśżèů§äźŃåL’■çŽĎæŢĹæđIJäÿĂæăůïijŇèĂŇäÿŤæL’ğèąŇéĂ§åžęäijŽæŻť’å
èő¿ç¡őäÿĂäÿłçőĂå■ŢçŽĎçśżåđŃåśđæĂğçŽĎåĂijïijŇèčĚéěřåŹĺæŰźåijŔèęĄæŕŤäźŃåL’■çŽĎæůůåĚěçśżçŽĎ
çŐřåIJĺä¡ăåžŤèŕěåžĘáźÿèĞłåůśèŕżåőŇäžĘæIJňèŁĆåĚĺéČĺåĘĚåőźäžĘåŘğïij§^_^

10.14 8.14 åőđçŐřèĞłåőŽäźL’åőźåŹĺ

éŮőécŸ

ä¡ăæČşåőđçŐřäÿĂäÿłèĞłåőŽäźL’çŽĎçśżæİěæĺąæŃ§åĘĚç¡őçŽĎåőźåŹĺçśżåŁ§èČ¡ïijŇæŕŤåęĆåĹŮèąĺåŠ

èğčåĘşæŰźæąĹ

collections åőŽäźL'äžEå¿Ĺåd'ŽæŁ¡èśąå§žçśżïijŇå¡Şä¡äæČşèĞłåőŽäźL'åőźåŹĺçśżçŽĎæŮűåĂŹåőČ
æŕŤåęĆä¡äæČşèől'ä¡äçŽĎçśżæŤŕæŇĄè£■äžčïijŇéĆčåřśèől'ä¡äçŽĎçśżçżğæL'£
collections.Iterable å■şåŔřïijŽ

```
import collections
class A(collections.Iterable):
    pass
```

äÿ■è£Ğä¡äéIJĂèęĄåőđçŐř collections.Iterable
æL'ĂæIJL'çŽĎæŁ¡èśąæŰźæşŢïijŇåŘęĺŹäijŽæŁěéŤŹ:

```
>>> a = A()
Traceback (most recent call last):
    File "<stdin>", line 1, in <module>
TypeError: Can't instantiate abstract class A with abstract methods␣
 ↪__iter__
>>>
```

ä¡ääŔłèęĄåőđçŐř __iter__() æŰźæşŢåřśäÿ■äijŽæŁěéŤŹäžĘ(åŔĆèĂČ4.2åŠŇ4.7åřŔèŁĆ)ãĂĆ

ä¡ääŔŕäžěåĚĹèŕŢçİĂåŐżåőđä¿ŃåŇŰäÿĂäÿłåŕźèśąïijŇåIJĺéŤŹèŕŕæŔŘçđ'žäÿ■åŔŕäžěæL'¿åĹřéIJĂèęĄåő

```
>>> import collections
>>> collections.Sequence()
Traceback (most recent call last):
    File "<stdin>", line 1, in <module>
TypeError: Can't instantiate abstract class Sequence with abstract␣
 ↪methods \
__getitem__, __len__
>>>
```

äÿŃéİćæŸŕäÿĂäÿłçőĂå■ŢçŽĎçđ'žä¿ŃïijŇçżğæL'£èĞłäÿŁéİćSequenceæŁ¡èśąçśżïijŇåźűäÿŤåőđçŐřåĚČ

```
class SortedItems(collections.Sequence):
    def __init__(self, initial=None):
        self._items = sorted(initial) if initial is not None else []

    # Required sequence methods
    def __getitem__(self, index):
        return self._items[index]

    def __len__(self):
        return len(self._items)

    # Method for adding an item in the right location
    def add(self, item):
        bisect.insort(self._items, item)
```

```
items = SortedItems([5, 1, 3])
print(list(items))
print(items[0], items[-1])
items.add(2)
print(list(items))
```

åŔŕäžěçIJŃåĹřïijŇSortedItemsèů§æŹőéĂŽçŽĎåžŔåĹŮæšąäżĂäźĹäÿd'æăůïijŇæŤŕæŇĄæL'ĂæIJL'åÿÿç

è£ŹéĞŇéİćä¡£çŤĺåĹřäžĘ `bisect` æĺąåİŮïijŇåőČæŸŕäÿĂäÿłåIJĺæŐŠåžŔåĹŮèąĺäÿ■æŔŠåĚěåĚČçt'ăçŽ

èőĺèőž

ä¡£çŤĺ `collections` äÿ■çŽĎæŁ¡èśąå§žçśżåŔŕäžěçąőä£İä¡äèĞłåőŽäźL'çŽĎåőźåŹĺåőđçŐřäžĘæL'ĂæI
ä¡ăçŽĎèĞłåőŽäźL'åőźåŹĺäijŽæżąèűşåđ'ğéČĺåĹĘçśżåđŃæčĂæ§ěéIJĂèęĄïijŇåęĆäÿŃæL'Ăçđ'žïijŽ

```
>>> items = SortedItems()
>>> import collections
>>> isinstance(items, collections.Iterable)
True
>>> isinstance(items, collections.Sequence)
True
>>> isinstance(items, collections.Container)
True
>>> isinstance(items, collections.Sized)
True
>>> isinstance(items, collections.Mapping)
False
>>>
```

`collections` äÿ■å¿Ĺåđ'ŽæŁ¡èśąçśżäijŽäÿžäÿĂäžŻåÿÿèğĄåőźåŹĺæŞ■ä¡IJæŔŘä¿Żéżŷèőđ'çŽĎåőđçČ
è£Źæăůäÿ ĂæİěäĄăåŔłéIJĂèęĄåőđçŐřéĆčäžŻä¡ăæIJĂæĎ§åĚt'èűčçŽĎæŰźæşŢå■şåŔŕãĂĆåĄĞèő¿ä¡ăçŽĎçśż
`collections.MutableSequence` ïijŇåęĆäÿŃïijŽ

```
class Items(collections.MutableSequence):
    def __init__(self, initial=None):
        self._items = list(initial) if initial is not None else []

    # Required sequence methods
    def __getitem__(self, index):
        print('Getting:', index)
        return self._items[index]

    def __setitem__(self, index, value):
        print('Setting:', index, value)
        self._items[index] = value

    def __delitem__(self, index):
        print('Deleting:', index)
        del self._items[index]
```

```
    def insert(self, index, value):
        print('Inserting:', index, value)
        self._items.insert(index, value)

    def __len__(self):
        print('Len')
        return len(self._items)
```

åęĆædIJä¡ăåĹŻåżž `Items` çŽĎåőđä¿ŃïijŇä¡ăäijŽåŔŚçŐřåőČæŤŕæŇĄåĞäázŐæL'ĂæIJL'çŽĎæäÿå£Čå
äÿŃéİćæŸŕä¡£çŤĺæijŤçd'žïijŽ

```
>>> a = Items([1, 2, 3])
>>> len(a)
Len
3
>>> a.append(4)
Len
Inserting: 3 4
>>> a.append(2)
Len
Inserting: 4 2
>>> a.count(2)
Getting: 0
Getting: 1
Getting: 2
Getting: 3
Getting: 4
Getting: 5
2
>>> a.remove(3)
Getting: 0
Getting: 1
Getting: 2
Deleting: 2
>>>
```

æIJňářŔèŁĆåŔłæŸŕářźPythonæŁ¡èšąçšžåŁ§èČ¡çŽĎæŁŻçăŰåijŢçŐL'ãĂĆnumbers
æĺąåİŮæŔŘä¿ŻäžĘäÿĂäÿłçšżäijijçŽĎèů§æŢť'æŢřçšżåđŃçŻÿåĚşçŽĎæŁ¡èšąçšžåđŃéŻĘåŘĹãĂĆ
åŔŕäžěåŔĆèĂČ8.12ářŔèŁĆæİěædĎéĂăæŽť'åd'ŽèĞłåőŽäźL'æŁ¡èšąå§žçšżãĂĆ

10.15 8.15 åšđæĂğçŽĎäžčçŘĘèő£éŮő

éŮőécŸ

ä¡ăæČşářĘæ§Řäÿłåőđä¿ŃçŽĎåšđæĂğèő£éŮőäžčçŘĘåĹřåĘĚéČĺåŔęäÿĂäÿłåőđä¿Ńäÿ■åŐżïijŇçŻőçŽĎå

èğčåĘşæŰźæąĹ

çőĂå■Ţæİěèŕť˙ïijŇäžčçŘĘæŸŕäÿĂçğ■çijŰçĺŃæĺąåijŔïijŇåőČåřĘæ§Řäÿłæş■ä¡IJè¡ňçğžçżŹåŔęåď˙ŰäÿĂæIJĂçőĂå■ŢçŽĎå¡ćåijŔåŔŕèČ¡æŸŕåČŔäÿŃéİćè£Źæăůïijž

```
class A:
    def spam(self, x):
        pass

    def foo(self):
        pass


class B1:
    """çőĂå■ŢçŽĎäžčçŘĘ"""

    def __init__(self):
        self._a = A()

    def spam(self, x):
        # Delegate to the internal self._a instance
        return self._a.spam(x)

    def foo(self):
        # Delegate to the internal self._a instance
        return self._a.foo()

    def bar(self):
        pass
```

åęĆædIJäžĚäžĚåřśäÿď˙äÿłæŰźæşŢéIJĂèęĄäžčçŘĘïijŇéĆčäźĹåČŔè£ŹæăůåĘŹåřśèűşåď˙§äžĘãĂĆä¡ĘæŸéĆčäźĹä¡£çŤÍ `__getattr__()` æŰźæşŢæĹŰèőÿæĹŰæŻť˙åě¡äžŻïijž

```
class B2:
    """ä¡£çŤÍ__getattr__çŽĎäžčçŘĘïijŇäžčçŘĘæŰźæşŢærŤè¿Čåd’ŽæŮűåĂŹ"""

    def __init__(self):
        self._a = A()

    def bar(self):
        pass

    # Expose all of the methods defined on class A
    def __getattr__(self, name):
        ""
↪"è£ŹäÿłæŰźæşŢåIJĺèő£éŮőçŽĎattributeäÿ■å■ŸåIJĺçŽĎæŮűåĂŹèćńèřČçŤÍ
        the __getattr__() method is actually a fallback method
        that only gets called when an attribute is not found"""
        return getattr(self._a, name)
```

`__getattr__` æŰźæşŢæŸŕåIJĺèő£éŮőattributeäÿ■å■ŸåIJĺçŽĎæŮűåĂŹèćńèřČçŤÍïijŇä¡£çŤÍæijŤçd’ži

```
b = B()
b.bar() # Calls B.bar() (exists on B)
b.spam(42) # Calls B.__getattr__('spam') and delegates to A.spam
```

åŔęåď Űäÿ Ääÿłäżčç ŘĘä¿Ńå■ŘæŸŕåőđçŐřäżčçŘĘæĺąåijŔïijŇä¿ŃåęĆïijŽ

```
# A proxy class that wraps around another object, but
# exposes its public attributes
class Proxy:
    def __init__(self, obj):
        self._obj = obj

    # Delegate attribute lookup to internal obj
    def __getattr__(self, name):
        print('getattr:', name)
        return getattr(self._obj, name)

    # Delegate attribute assignment
    def __setattr__(self, name, value):
        if name.startswith('_'):
            super().__setattr__(name, value)
        else:
            print('setattr:', name, value)
            setattr(self._obj, name, value)

    # Delegate attribute deletion
    def __delattr__(self, name):
        if name.startswith('_'):
            super().__delattr__(name)
        else:
            print('delattr:', name)
            delattr(self._obj, name)
```

ä¡£çŤĺè£ŹäÿłäżčçŘĘçśżæŮűïijŇä¡ăåŔłéIJĂèęĄçŤĺåőČæĺěåŇĚèčĚäÿŃåĚűäżŰçśżå■şåŔŕïijŽ

```
class Spam:
    def __init__(self, x):
        self.x = x

    def bar(self, y):
        print('Spam.bar:', self.x, y)

# Create an instance
s = Spam(2)
# Create a proxy around it
p = Proxy(s)
# Access the proxy
print(p.x)  # Outputs 2
p.bar(3)  # Outputs "Spam.bar: 2 3"
p.x = 37  # Changes s.x to 37
```

éĂŽè£ĞèĞłåőŽäźL’åśđæĂğèő£éŮőæŰźæşŢïijŇä¡ääŔŕäžěçŤĺäÿ■åŘŇæŰźåijŔèĞłåőŽäźL’äžčçŘĘçśżèąŇ

èőĺèőž

äžčçŘĘçśżæIJL’æŮűåĂŹåŔŕäžěä¡IJäÿžçżğæL’£çŽĎæŻ£äžčæŰźæąĹãĂĆä¿ŃåęĆïijŇäÿĂäÿłçőĂå■ŢçŽĎ

```
class A:
    def spam(self, x):
        print('A.spam', x)
    def foo(self):
        print('A.foo')

class B(A):
    def spam(self, x):
        print('B.spam')
        super().spam(x)
    def bar(self):
        print('B.bar')
```

ä¡£çŤĺäžčçŘĘçŽĎèŕĭijŇåřśæŸŕäÿŃéİćè£ŹæăůïijŽ

```
class A:
    def spam(self, x):
        print('A.spam', x)
    def foo(self):
        print('A.foo')

class B:
    def __init__(self):
        self._a = A()
    def spam(self, x):
        print('B.spam', x)
        self._a.spam(x)
    def bar(self):
        print('B.bar')
    def __getattr__(self, name):
        return getattr(self._a, name)
```

å¡Şåőđç Őŕäžčç ŘĘæĺąåijŔæŮűïijŇè£ŸæIJL’äžŻçżĘèŁĆéIJĂèęĄæşĺæĎŔãĂĆ
éęŰåĚĹïijŇ__getattr__() åőđéŹĚæŸŕäÿĂäÿłåŘŐåď ĞæŰźæşŢïijŇåŔłæIJL’åIJĺåśđæĂğäÿ■å■ŸåIJĺæŮű
åŻăæ■ď’ïijŇåęĆæđIJäžčçŘĘçśżåőđä¿ŃæIJňèžńæIJL’è£ŹäÿłåśđæĂğçŽĎèŕĭijŇéĆčäźĹäÿ■äijŽèğęåŔŚè£ŹäÿłąåŔęåď ŰïijŇ__setattr__() åŠŇ __delattr__() éIJĂèęĄéćİåď ŰçŽĎé■ŤæşŢæİěåŇžåĹĘäžčçŘĘåőđ
_obj çŽĎåśđæĂğãĂĆ äÿĂäÿłéĂŽåÿÿçŽĎçžęåőŽæŸŕåŔłäžčçŘĘéĆčäźŻäÿ■äžëäÿŃåĹŠçž£
_ åijĂåď’t çŽĎåśđæĂğ(äžčçŘĘçśżåŔłæŽť éIJšèćńäžčçŘĘçśżçŽĎåĚňåĚśåśđæĂğ)ãĂĆ

è£ŸæIJL’äÿĂçĆźéIJĂèęĄæşĺæĎŔçŽĎæŸŕïijŇ__getattr__()
åŕźäžŐåď ğéČĺåĹĘäžěåŔŇäÿŃåĹŠçž£(__)åijĂåğŃåŠŇçżŞår¿çŽĎåśđæĂğåźűäÿ■éĂĆçŤĺãĂĆ
æŕŤåęĆïijŇèĂČèŹŚåęĆäÿŃçŽĎçśżïijŽ

```
class ListLike:
    """__getattr__
↪åŕźäžŐåŔŇäÿŃåĹŠçž£åijĂåğŃåŠŇçżŞår¿çŽĎæŰźæşŢæŸŕäÿ■èČ¡çŤÍçŽĎïijŇéIJĂèęĄäÿĂäÿłäÿł
↪"""

    def __init__(self):
        self._items = []

    def __getattr__(self, name):
        return getattr(self._items, name)
```

åęĆæđIJæŸŕåĹŻåżžäÿĂäÿłListLikeåŕźèśąïijŇäijŽåŔŚçŐřåőČæŤŕæŇĄæŹőéĂŽçŽĎåĹŮèąÍæŰźæşŢïijŇä¡ĘæŸŕå■t’äÿ■æŤŕæŇĄlen()ãĂĄåĚČçt’ăæ§ěæL’¿ç■L’ãĂĆä¿ŃåęĆïijŽ

```
>>> a = ListLike()
>>> a.append(2)
>>> a.insert(0, 1)
>>> a.sort()
>>> len(a)
Traceback (most recent call last):
    File "<stdin>", line 1, in <module>
TypeError: object of type 'ListLike' has no len()
>>> a[0]
Traceback (most recent call last):
    File "<stdin>", line 1, in <module>
TypeError: 'ListLike' object does not support indexing
>>>
```

äÿžäžĘèől’åőČæŤŕæŇĄè£ŹäžŻæŰźæşŢïijŇä¡åå£ĚéążæL’ŃåŁÍçŽĎåőđçŐřè£ŹäžŻæŰźæşŢäžčçŘĘïijŽ

```
class ListLike:
    """__getattr__
↪åŕźäžŐåŔŇäÿŃåĹŠçž£åijĂåğŃåŠŇçżŞår¿çŽĎæŰźæşŢæŸŕäÿ■èČ¡çŤÍçŽĎïijŇéIJĂèęĄäÿĂäÿłäÿł
↪"""

    def __init__(self):
        self._items = []

    def __getattr__(self, name):
        return getattr(self._items, name)

    # Added special methods to support certain list operations
    def __len__(self):
        return len(self._items)

    def __getitem__(self, index):
        return self._items[index]

    def __setitem__(self, index, value):
        self._items[index] = value
```

```
    def __delitem__(self, index):
        del self._items[index]
```

11.8åřŔèŁĆè£ŸæIJL'äÿĂäÿłåIJÍè£IJçÍŃæŰźæşŢèřČçŤÍçŐřåćČäÿ■ä¡£çŤÍäžčçŘEçŽĎä¿Ńå■ŘãĂĆ

10.16 8.16 åIJÍçśżäÿ■åőŽäźĽåďŽäÿłæđĎéĂäåŹÍ

éŮőécŸ

ä¡ăæČşåőđçŐřäÿĂäÿłçśżïijŇéŹď'äžĘä¡£çŤÍ `__init__()` æŰźæşŢåď'ŰïijŇè£ŸæIJL'åĚűäžŰæŰźåijŔåŔŕäžěåĹİåğŃåŇŰåőČãĂĆ

èğčåĘşæŰźæąĹ

äÿžäžĘåőđçŐřåď'ŽäÿłæđĎéĂäåŹÍïijŇä¡ăéIJĂèęĄä¡£çŤÍåĹřçśżæŰźæşŢãĂĆä¿ŃåęĆïijŽ

```
import time

class Date:
    """æŰźæşŢäÿĂïijŽä¡£çŤÍçśżæŰźæşŢ"""
    # Primary constructor
    def __init__(self, year, month, day):
        self.year = year
        self.month = month
        self.day = day

    # Alternate constructor
    @classmethod
    def today(cls):
        t = time.localtime()
        return cls(t.tm_year, t.tm_mon, t.tm_mday)
```

çŽť'æŐèèřČçŤÍçśżæŰźæşŢå■şåŔŕïijŇäÿŃéİćæŸŕä¡£çŤÍçď'žä¿ŃïijŽ

```
a = Date(2012, 12, 21) # Primary
b = Date.today() # Alternate
```

èőÍèőž

çśżæŰźæşŢçŽĎäÿĂäÿłäÿżèęĄçŤÍéĂŤåřśæŸŕåőŽäźĽåď'ŽäÿłæđĎéĂäåŹÍãĂĆåőČæŐěåŔŮäÿĂäÿł `class` ä¡IJäÿžçňňäÿĂäÿłåŔĆæŢř(cls)ãĂĆ ä¡ääžŤèŕěæşÍæĎŔåĹřäžĘè£ŹäÿłçśżèćńçŤÍæİěåĹŻåžžåźűè£ŤåŽđa

```
class NewDate(Date):
    pass
```

```
c = Date.today() # Creates an instance of Date (cls=Date)
d = NewDate.today() # Creates an instance of NewDate (cls=NewDate)
```

10.17 8.17 åĹŻåżžäÿ■èřČçŤĺnitæŰźæşŢçŽĎåőđä¿Ń

éŮőécŸ

ä¡ăæČşåĹŻåżžäÿĂäÿłåőđä¿ŃïijŇä¡ĘæŸŕåÿŇæIJŻçżŢè£ĞæĽ'ğèąŇ `__init__()` æŰźæşŢãĂĆ

èğčåĘşæŰźæąĹ

åŘŕäžěéĂŽè£Ğ `__new__()` æŰźæşŢåĹŻåżžäÿĂäÿłæIJłåĹİåğŃåŇŰçŽĎåőđä¿ŃãĂĆä¿ŃåęĆèĂČèŹŚåę

```
class Date:
    def __init__(self, year, month, day):
        self.year = year
        self.month = month
        self.day = day
```

äÿŃéİćæijŤçd'žåęĆä¡Ţäÿ■èřČçŤĺ `__init__()` æŰźæşŢæİěåĹŻåżžè£ŹäÿłDateåőđä¿ŃïijŽ

```
>>> d = Date.__new__(Date)
>>> d
<__main__.Date object at 0x1006716d0>
>>> d.year
Traceback (most recent call last):
    File "<stdin>", line 1, in <module>
AttributeError: 'Date' object has no attribute 'year'
>>>
```

çżŞædIJåŘŕäžěçIJŃåĹřïijŇè£ŹäÿłDateåőđä¿ŃçŽĎåšđæĂğyearè£Ÿäÿ■å■ŸåIJĺïijŇæĽ'Ääžěä¡ăéIJĂèęĄæ

```
>>> data = {'year':2012, 'month':8, 'day':29}
>>> for key, value in data.items():
...     setattr(d, key, value)
...
>>> d.year
2012
>>> d.month
8
>>>
```

èőÍèőž

å¡ŞæĹŚäžňåIJĺåŔ■åžŔåĹŮåŕźèśąæĹŰèĂĚåőđçŐřæ§Řäÿłçśżæ Ű źæş Ţæđ Đé Ăăå Ğ¡æŢřæŮűéIJĂèęĄçżŢè
`__init__()` æŰźæş Ţæİěå ĹŻåžžåŕźèśąãĂĆ ä¿ŃåęĆïijŇåŕźäžŐäÿŁéİćçŽĎDateæİèèőšïijŇæIJL'æŮűåĂŹä¡ă
`today()` ïijŽ

```
from time import localtime

class Date:
    def __init__(self, year, month, day):
        self.year = year
        self.month = month
        self.day = day

    @classmethod
    def today(cls):
        d = cls.__new__(cls)
        t = localtime()
        d.year = t.tm_year
        d.month = t.tm_mon
        d.day = t.tm_mday
        return d
```

åŘŇæăůïijŇåIJĺä¡ăåŔ■åžŔåĹŮåŇŰJSONæŢřæ■őæŮűäžğçŤ§äÿĂäÿłåęĆäÿŃçŽĎå■ŮåĚÿåŕźèśąïijŽ

```
data = { 'year': 2012, 'month': 8, 'day': 29 }
```

åęĆæđIJä¡ăæČşåřĘåőČè¡ňæ■ćæĹŘäÿĂäÿłDateçśżåđŃåőđä¿ŃïijŇåŔŕäžěä¡£çŤĺäÿŁéİćçŽĎæŁĂæIJŕãĂĆ

å¡Şä¡ăéĂŽè£Ğè£Źçğ■éİđåÿÿèğĎæŰźåijŔæİěåĹŻåžžåőđä¿ŃçŽĎæŮűåĂŹïijŇæIJĂåě¡äÿ■èęĄçŻť'æŐěåĆ
åŘęåĹŹçŽĎèŕİïijŇåęĆæđIJè£Źäÿłçśżä¡£çŤĺäžĘ `__slots__` ãĂĄproperties ãĂĄdescriptors æĹŰåĚűäžŰéńŸçžğæŁĂæIJŕçŽĎæŮűåĂŹäžčçăĄåřśäijŽåď śæŢĹãĂĆ
èĂŇè£ŹæŮűåĂŹä¡£çŤĺ `setattr()` æŰźæş ŢäijŽèől'ä¡ăçŽĎäžčçăĄåŔŸå¿ŮæŻť'åŁäéĂŽçŤĺãĂĆ

10.18 8.18 åĽ'çŤĺMixinsæĽ'åśŢçśżåŁ§èČ¡

éŮőécŸ

ä¡ăæIJL'å¿Ĺåd'ŽæIJL'çŤĺçŽĎæŰźæş ŢïijŇæčşä¡£çŤĺåőČäžňæİěæL'l'åśŢåĚűäžŰçśżçŽĎåŁ§èČ¡ãĂĆä¡Ęą
åŻăæ■d'ä¡ääÿ■èČ¡çőĂå■ŢçŽĎårĘè£ŹäžŽæŰźæş ÞæŤ¿åĚëäÿĂäÿłå§žçśżïijŇçĎűåŘŐècńåĚűäžŰçśżçżğæL'£ã

èğčåĘşæŰźæąĹ

éĂŽåÿÿå¡Şä¡ăæČşèĞłåőŽäźL'çśżçŽĎæŮűåĂŹäijŽçćřäÿŁè£ŹäžŽéŮőécŸãĂĆåŔŕèČ¡æŸŕæ§ŘäÿłåžŞæŔ
ä¡ăåŔŕäžěåĹl'çŤĺåőČäžňæİěæđĎéĂăä¡äèĞłåůśçŽĎçśżãĂĆ

åĄĞèő¿ä¡ăæČşæL'l'åśŢæŸăårĎåŕźèśąïijŇçżŹåőČäžňæůżåŁăæŮěå£ŮãĂĄåŤŕäÿĂæĂğèő¿ç¡őãĂĄçśżåđl

```
class LoggedMappingMixin:
    """
    Add logging to get/set/delete operations for debugging.
    """
    __slots__ = ()  #␣
↪æůůåĚěçśżéČ¡æšąæIJL’åőđä¿ŃåŔŸéĞŔïijŇåŽääÿžçŻt’æŐěåőđä¿ŃåŇŰæůůåĚěçśżæšąæIJL’äżż

    def __getitem__(self, key):
        print('Getting ' + str(key))
        return super().__getitem__(key)

    def __setitem__(self, key, value):
        print('Setting {} = {!r}'.format(key, value))
        return super().__setitem__(key, value)

    def __delitem__(self, key):
        print('Deleting ' + str(key))
        return super().__delitem__(key)


class SetOnceMappingMixin:
    '''
    Only allow a key to be set once.
    '''
    __slots__ = ()

    def __setitem__(self, key, value):
        if key in self:
            raise KeyError(str(key) + ' already set')
        return super().__setitem__(key, value)


class StringKeysMappingMixin:
    '''
    Restrict keys to strings only
    '''
    __slots__ = ()

    def __setitem__(self, key, value):
        if not isinstance(key, str):
            raise TypeError('keys must be strings')
        return super().__setitem__(key, value)
```

è£ŹäžŻçśżå■ŢçŃňä¡£çŤĺèţůæİěæšąæIJL’äżżä¡ŢæĎŔäźL’ïijŇäžŃåőđäÿŁåęĆæđIJä¡ääŐżåőđä¿ŃåŇŰäżżäåőČäžňæŸŕçŤĺæİěéĂŽè£ĞåđŽçżğæL’£æİěåŠŇåĚűäżŰæŸäářĎářźèśąæůůåĚëä¡£çŤĺçŽĎãĂĆä¿ŃåęĆïijŽ

```
class LoggedDict(LoggedMappingMixin, dict):
    pass

d = LoggedDict()
```

```
d['x'] = 23
print(d['x'])
del d['x']

from collections import defaultdict

class SetOnceDefaultDict(SetOnceMappingMixin, defaultdict):
    pass


d = SetOnceDefaultDict(list)
d['x'].append(2)
d['x'].append(3)
# d['x'] = 23  # KeyError: 'x already set'
```

è£Źäÿłä¿Ńå■Řäÿ■ïijŇåŔŕäžěçIJŇåĹřæůůåĚěçśżèů§åĚűäžŰåůšå■ŸåIJĺçŽĎçśż(æŕŤåęĆdictãĂĄdefaultd
çżŞåŘĹåŘŐåřśèČ¡åŔŚæŇěæ■čåÿÿåŁ§æŢĹäžĘãĂĆ

èőĺèőž

æůůåĚěçśżåIJĺæăĞåĞĘåžŞäÿ■å¿Ĺåď'ŽåIJřæŰźéČ¡åĞžçŐřè£ĞïijŇéĂŽåÿÿéČ¡æŸŕçŤĺæİěåČŔäŸŁéİćéĆ
åőČäžňäź§æŸŕåď'Žçżğæ L'£çŽĎäÿĂäÿłäÿżèęĄçŤĺéĂŤãĂĆæŕŤåęĆïijŇå¡Şä¡äçijŰåĘŹç¡ŚçżIJäžčçăĄæŮűåĂŹ
ä¡ăäijŽçżŘåÿÿä¡£çŤĺ `socketserver` æĺąåİŮäÿ■çŽĎ `ThreadingMixIn`
æİěçżŹåĚűäžŰç¡ŚçżIJçŽÿåĚşçśżåćđåŁååď'Žçž£çĺŇæŤŕæŇĄãĂĆ
ä¿ŇåęĆïijŇäÿŇéİćæŸŕäÿĂäÿłåď'Žçž£çĺŇçŽĎXML-RPCæIJ■åŁąïijŽ

```
from xmlrpc.server import SimpleXMLRPCServer
from socketserver import ThreadingMixIn
class ThreadedXMLRPCServer(ThreadingMixIn, SimpleXMLRPCServer):
    pass
```

åŘŇæŮűåIJĺäÿĂäžŻåď'ğåđŇåžŞåŠŇæąĘæđűäÿ■äź§äijŽåŔŚçŐřæůůåĚěçśżçŽĎä¡£çŤĺïijŇçŤĺéĂŤåŘŇæ

åŕźäžŐæůůåĚěçśżïijŇæIJL'åĞăçĆźéIJĂèęĄèőŕä¡ŔãĂĆéęŰåĚĹæŸŕïijŇæůůåĚěçśżäÿ■èČ¡çŻt'æŐèèćńåő
åĚűæňąïijŇæůůåĚěçśżæšąæIJL'èĞłåůśçŽĎçŁűæĂĄä£ąæĄŕïijŇäź§åřśæŸŕèŕť'åőČäžňåźűæšąæIJL'åőŽäźL'
`__init__()` æŰźæşŢïijŇåźűäÿŤæšąæIJL'åőđä¿ŃåśđæĂğãĂĆ
è£Źäź§æŸŕäÿžäžĂäźĹæĹŚäžňåIJĺäÿŁéİćæŸŐçąőåőŽäźL'äžĘ `__slots__ = ()` ãĂĆ

è£ŸæIJL'äÿĂçğ■åőđçŐřæůůåĚěçśżçŽĎæŰźåijŔåřśæŸŕä¡£çŤĺçśżèčĚéěřåŹĺïijŇąęĆäÿŃæL'Ăçđ'žïijŽ

```
def LoggedMapping(cls):
    """çňñäžŇçğ■æŰźåijŔïijžä¡£çŤĺçśżèčĚéěřåŹĺ"""
    cls_getitem = cls.__getitem__
    cls_setitem = cls.__setitem__
    cls_delitem = cls.__delitem__

    def __getitem__(self, key):
        print('Getting ' + str(key))
        return cls_getitem(self, key)
```

```
    def __setitem__(self, key, value):
        print('Setting {} = {!r}'.format(key, value))
        return cls_setitem(self, key, value)

    def __delitem__(self, key):
        print('Deleting ' + str(key))
        return cls_delitem(self, key)

    cls.__getitem__ = __getitem__
    cls.__setitem__ = __setitem__
    cls.__delitem__ = __delitem__
    return cls


@LoggedMapping
class LoggedDict(dict):
    pass
```

è£Źäÿ łæŢĹæđIJèů§äźŃåL’■çŽĎæŸŕäÿĂæăůçŽĎïijŇèĂŇäÿŤäÿ■åĘ■éIJĂèęĄä¡£çŤĺåď’Žçżğæ L’£äžĘãĂ
åŔĆèĂČ8.13åřŔèŁĆæ§ěçIJŃæŻt’åď’ŽæůůåĚěçśżåŠŇçśżèčĚéěřåŹĺçŽĎä¿Ńå■ŘãĂĆ

10.19 8.19 åőđçŐřçŁűæĂĄåŕźèśąæĹŰèĂĚçŁűæĂĄælJž

éŮőécŸ

ä¡ăæČşåőđçŐřäÿĂäÿłçŁűæĂĄæIJžæĹŰèĂĚæŸŕåIJĺäÿ■åŘŇçŁűæĂĄäÿŃæL’ğèąŇæŞ■ä¡IJçŽĎåŕźèśąïijĺ

èğčåĘşæŰźæąĹ

åIJĺå¿Ĺåď’ŽçĺŃåžŔäÿ■ïijŇæIJL’äžŻåŕźèśąäijŽæăźæ■őçŁűæĂĄçŽĎäÿ■åŘŇæİěæL’ğèąŇäÿ■åŘŇçŽĎæŞı

```
class Connection:
    """æŹőéĂŽæŰźæąĹïijŇåě¡åd’ŽäÿłåĹd’æŰ■èŕ■åŔěïijŇæŢĹçŐĞä¡ŐäÿŃ~~"""

    def __init__(self):
        self.state = 'CLOSED'

    def read(self):
        if self.state != 'OPEN':
            raise RuntimeError('Not open')
        print('reading')

    def write(self, data):
        if self.state != 'OPEN':
            raise RuntimeError('Not open')
        print('writing')

    def open(self):
```

```
        if self.state == 'OPEN':
            raise RuntimeError('Already open')
        self.state = 'OPEN'

    def close(self):
        if self.state == 'CLOSED':
            raise RuntimeError('Already closed')
        self.state = 'CLOSED'
```

è£Źæăůå ĘŹæIJL’å¿Ĺåď’ŽçijžçĆźïijŇéęŰåĚĹæŸŕäžčçăĄåď’łåď’■æİĆäžĘïijŇåě¡åď’ŽçŽĎæİąäżűåĹď’æŰ■åŻăäÿžäÿĂäžŽåÿÿèğĄçŽĎæŞ■ä¡IJærŤåęĆread()ãĂĄwrite()æŕŔæñąæL’ğèąŇåL’■éČ¡éIJĂèęĄæL’ğèąŇæčĂæş

äÿĂäÿłæŻť’åě¡çŽĎåŁđæşŢæŸŕäÿžæŕŔäÿłçŁűæĂĄåőŽäźL’äÿĂäÿłåŕźèśąïijŽ

```
class Connection1:
    """æŰřæŰźæąĹâĂŤâĂŤåŕźæŕŔäÿłçŁűæĂĄåőŽäźL’äÿĂäÿłçśż"""

    def __init__(self):
        self.new_state(ClosedConnectionState)

    def new_state(self, newstate):
        self._state = newstate
        # Delegate to the state class

    def read(self):
        return self._state.read(self)

    def write(self, data):
        return self._state.write(self, data)

    def open(self):
        return self._state.open(self)

    def close(self):
        return self._state.close(self)


# Connection state base class
class ConnectionState:
    @staticmethod
    def read(conn):
        raise NotImplementedError()

    @staticmethod
    def write(conn, data):
        raise NotImplementedError()

    @staticmethod
    def open(conn):
        raise NotImplementedError()
```

```
    @staticmethod
    def close(conn):
        raise NotImplementedError()


# Implementation of different states
class ClosedConnectionState(ConnectionState):
    @staticmethod
    def read(conn):
        raise RuntimeError('Not open')

    @staticmethod
    def write(conn, data):
        raise RuntimeError('Not open')

    @staticmethod
    def open(conn):
        conn.new_state(OpenConnectionState)

    @staticmethod
    def close(conn):
        raise RuntimeError('Already closed')


class OpenConnectionState(ConnectionState):
    @staticmethod
    def read(conn):
        print('reading')

    @staticmethod
    def write(conn, data):
        print('writing')

    @staticmethod
    def open(conn):
        raise RuntimeError('Already open')

    @staticmethod
    def close(conn):
        conn.new_state(ClosedConnectionState)
```

äÿŃéİćæŸŕä¡£çŤĺæijŤçďžïijŽ

```
>>> c = Connection()
>>> c._state
<class '__main__.ClosedConnectionState'>
>>> c.read()
Traceback (most recent call last):
    File "<stdin>", line 1, in <module>
    File "example.py", line 10, in read
```

```
        return self._state.read(self)
    File "example.py", line 43, in read
        raise RuntimeError('Not open')
RuntimeError: Not open
>>> c.open()
>>> c._state
<class '__main__.OpenConnectionState'>
>>> c.read()
reading
>>> c.write('hello')
writing
>>> c.close()
>>> c._state
<class '__main__.ClosedConnectionState'>
>>>
```

èőÍèőž

åęĆædIJäżčçăĄäÿ■åĞžçŐřåď'łåď'ŽçŽĎæİąäżűåĹď'æŰ■èŕ■åŔěçŽĎèŕİïijÑäżčçăĄåřśäijŽåŔŸå¿ŮéŽ¿äžě
è£ŹéĞŇçŽĎèğčåĘşæŰźæąĹæŸřářĘæŕŔäÿłçŁűæĂĄæŁ¡åŔŰåĞžæİěåőŽäźĽ'æĹŘäÿĂäÿłçśžãĂĆ

è£ŹéĞŇçIJŃäÿŁåŐżæIJL'çĆźåěĞæĂłïijÑæŕŔäÿłçŁűæĂĄåŕźèśąéČ¡åŔłæIJL'éİŹæĂĄæŰźæşŢïijÑåźűæš
åőđéŹĚäÿŁïijÑæĽĂæIJL'çŁűæĂĄä£ąæĄŕéČ¡åŔłå■ŸåĆĺåIJĺ `Connection`
åőđä¿Ńäÿ■ãĂĆ åIJĺå§žçśżäÿ■åőŽäźĽ'çŽĎ `NotImplementedError`
æŸřäÿžäžĘçąőä£Ìå■ŘçśżåőđçŐřäžĘçŻÿåžŢçŽĎæŰźæşŢãĂĆ è£ŹéĞŇä¡äæĹŰèőÿè£ŸæČşä¡£çŢĺ8.12åřŔèŁĆ

èő¿èőąæĺąåijŔäÿ■æIJL'äÿĂçğ■æĺąåijŔåŔńçŁűæĂĄæĺąåijŔïijÑè£ŹäÿĂåřŔèŁĆçőŮæŸřäÿĂäÿłåĹİæ■ěåĚ

10.20 8.20 éĂŽè£Ğå■ŮçňęäÿšèřČçŢĺåŕźèśąæŰźæşŢ

éŮőécŸ

ä¡äæIJL'äÿĂäÿłå■Ůçňęäÿšå¡ćåijŔçŽĎæŰźæşŢåŘ■çğřïijÑæČşéĂŽè£ĞåőČèřČçŢĺæ§ŘäÿłåŕźèśąçŽĎåŕźå

èğčåĘşæŰźæąĹ

æIJĂçőĂå■ŢçŽĎæČĚåĘţïijÑåŔŕäżěä¡£çŢĺ `getattr()` ïijŽ

```
import math

class Point:
    def __init__(self, x, y):
        self.x = x
        self.y = y

    def __repr__(self):
        return 'Point({!r:},{!r:})'.format(self.x, self.y)
```

```
    def distance(self, x, y):
        return math.hypot(self.x - x, self.y - y)


p = Point(2, 3)
d = getattr(p, 'distance')(0, 0)  # Calls p.distance(0, 0)
```

åŔęåď'ŰäÿĂçğ■æŰźæşŢæŸŕä¡£çŤÍ `operator.methodcaller()` ïijŇä¿ŃåęĆïijŽ

```
import operator
operator.methodcaller('distance', 0, 0)(p)
```

å¡Şä¡ăéIJĂèęĄéĂŽè£ĞçŻÿåŘŇçŽĎåŔĆæŢřåď'Žæňąèřĉç̀ŤÍæ§Řäÿ̀łæŰźæşŢæŮűïijŇä¡£çŤÍ `operator.methodcaller` åřśå¿ĹæŰźä¿£ăžĘãĂĆ ærŤåęĆä¡ăéIJĂèęĄæŐŠåžŔäÿĂçşżåĹŮçŽĎçĆźïijŇåř

```
points = [
    Point(1, 2),
    Point(3, 0),
    Point(10, -3),
    Point(-5, -7),
    Point(-1, 8),
    Point(3, 2)
]
# Sort by distance from origin (0, 0)
points.sort(key=operator.methodcaller('distance', 0, 0))
```

èőÍèőž

èřĈçŤÍäÿĂäÿłæŰźæşŢåőđéŹĚäÿŁæŸŕäÿď'éČÍçŃňçńŃæŞ■ä¡IJïijŇçňňäÿĂæ■ěæŸŕæ§ěæL'¿åśđæĂğïijŇçåŻăæ■d'ïijŇäÿžäžĘèřĈçŤÍæ§ŘäÿłæŰźæşŢïijŇä¡ăåŔŕäżěéęŮåĚĹéĂŽè£Ğ `getattr()` æİěæ§ěæL'¿åĹřè£ŹäÿłåśđæĂğïijŇçĎůåŘŐåĘ■åŐżäžěåĞ¡æŢřæŰźåijŔèřĈçŤÍåőČå■şåŔŕãĂĆ

`operator.methodcaller()` åĹŻåżžäÿĂäÿłåŔŕèřĈçŤÍåŕźèśąïijŇåźűåŘŇæŮűæŔŘä¿ŻæL'ĂæIJL'å£çĎůåŘŐèřĈçŤÍçŽĎæŮűåĂŹåŔłéIJĂèęĄåřĘåőđä¿ŃåŕźèśąäijăéĂŠçżŹåőČå■şåŔŕïijŇæŕŤåęĆïijŽ

```
>>> p = Point(3, 4)
>>> d = operator.methodcaller('distance', 0, 0)
>>> d(p)
5.0
>>>
```

éĂŽè£ĞæŰźæşŢåŘ■çğřå■ŮçňęäÿšæİèèřĈçŤÍæŰźæşŢéĂŽåÿÿåĞžçŐřåIJĺéIJĂèęĄæĺąæŃ§ `case` èŕ■åŔèæĹŰåőđçŐřèő£éŮőèĂĚæĺąåijŔçŽĎæŮűåĂŹãĂĆ åŔĆèĂČäÿŃäÿĂåřŔèŁĆèŐůåŔŰæŻt'åď'ŽéńŸçžğä¿Ńå■ŘãĂĆ

10.21 8.21 åőđçŐřèő£éŮőèĂĚæÍąåijŔ

éŮőécŸ

ä¡ăèęĄåď'ĎçŘĘçŤšåď'ğéĞŔäÿ■åŘŇçśżåđŃçŽĎåŕźèšąçżĎæĹŘçŽĎåď'■æİĆæŢřæ■őçżŞæđĎïijŇæŕŔäÿĂ
æŕŤåęĆïijŇéĄ■åŐĘäÿĂäÿłæăŠå¡ćçżŞæđĎïijŇçĎűåŘŐæăźæ■őæŕŔäÿłèŁĆçĆźçŽĎçŻÿåžŤçŁűæĂĄæĽ'ğèąŇ

èğčåĘşæŰźæąĹ

è£ŹéĞŇéĄĞåĹřçŽĎéŮőécŸåIJĺçijŰçĺŃécĘå§§äÿ■æŸŕå¿ĹæŹőéĄ■çŽĎïijŇæIJL'æŮűåĂŹäijŽæđĎåżžä
åĄĞèő¿ä¡ăèęĄåĘŹäÿĂäÿłèąĺçď'žæŢřå■ęèąĺè¿¿åijŔçŽĎçĺŃåžŔïijŇéĆčäźĹä¡ăåŔŕèČ¡éIJĂèęĄåőŽäźL'åęĆäÿŃ

```
class Node:
    pass

class UnaryOperator(Node):
    def __init__(self, operand):
        self.operand = operand

class BinaryOperator(Node):
    def __init__(self, left, right):
        self.left = left
        self.right = right

class Add(BinaryOperator):
    pass

class Sub(BinaryOperator):
    pass

class Mul(BinaryOperator):
    pass

class Div(BinaryOperator):
    pass

class Negate(UnaryOperator):
    pass

class Number(Node):
    def __init__(self, value):
        self.value = value
```

çĎűåŘŐåĹl'çŤĺè£ŹäžŻçśżæđĎåżžåţŇåěŮæŢřæ■őçżŞæđĎïijŇåęĆäÿŃæL'Ăçď'žïijŽ

```
# Representation of 1 + 2 * (3 - 4) / 5
t1 = Sub(Number(3), Number(4))
t2 = Mul(Number(2), t1)
```

```
t3 = Div(t2, Number(5))
t4 = Add(Number(1), t3)
```

è£ŹæăůåĄŽçŽĎéŮőécŸæŸŕåŕźäžŐæŕŔäÿłèąĺè¿¿åijŔïijŇæŕŔæňąéČ¡èęĄéĞ■æŰřåőŽäźĽäÿĂéĄ■ïijŇæ
è£ŹéĞŇæĹŚäżňä¡£çŤĺèő£éŮőèĂĚæĺąåijŔåŔŕäžèè¿¿åĹřè£ŹæăůçŽĎçŻőçŽĎïijŽ

```
class NodeVisitor:
    def visit(self, node):
        methname = 'visit_' + type(node).__name__
        meth = getattr(self, methname, None)
        if meth is None:
            meth = self.generic_visit
        return meth(node)

    def generic_visit(self, node):
        raise RuntimeError('No {} method'.format('visit_' +␣
↪type(node).__name__))
```

äÿžäžĘä¡£çŤĺè£ŹäÿłçśżïijŇåŔŕäžèåőŽäźĽäÿĂäÿłçśżçżğæĽ£åőČåźűäÿŤåőđçŐřåŘĎçğ■
visit_Name() æŰźæşŢïijŇåĚűäÿ■NameæŸŕnodeçśżåđŃãĂĆ
ä¿ŃåęĆïijŇåęĆæđIJä¡ăæČşæśĆèąĺè¿¿åijŔçŽĎåĂijïijŇåŔŕäžèè£ŹæăůåĘŹïijŽ

```
class Evaluator(NodeVisitor):
    def visit_Number(self, node):
        return node.value

    def visit_Add(self, node):
        return self.visit(node.left) + self.visit(node.right)

    def visit_Sub(self, node):
        return self.visit(node.left) - self.visit(node.right)

    def visit_Mul(self, node):
        return self.visit(node.left) * self.visit(node.right)

    def visit_Div(self, node):
        return self.visit(node.left) / self.visit(node.right)

    def visit_Negate(self, node):
        return -node.operand
```

ä¡£çŤĺçd'žä¿ŃïijŽ

```
>>> e = Evaluator()
>>> e.visit(t4)
0.6
>>>
```

ä¡IJäÿžäÿĂäÿłäÿ■åŘŇçŽĎä¿Ńå■ŘïijŇäÿŃéİćåőŽäźĽäÿĂäÿłçśżåIJĺäÿĂäÿłæăĹäÿŁéİćářĘäÿĂäÿłèąĺè¿¿å

```
class StackCode(NodeVisitor):
    def generate_code(self, node):
        self.instructions = []
        self.visit(node)
        return self.instructions

    def visit_Number(self, node):
        self.instructions.append(('PUSH', node.value))

    def binop(self, node, instruction):
        self.visit(node.left)
        self.visit(node.right)
        self.instructions.append((instruction,))

    def visit_Add(self, node):
        self.binop(node, 'ADD')

    def visit_Sub(self, node):
        self.binop(node, 'SUB')

    def visit_Mul(self, node):
        self.binop(node, 'MUL')

    def visit_Div(self, node):
        self.binop(node, 'DIV')

    def unaryop(self, node, instruction):
        self.visit(node.operand)
        self.instructions.append((instruction,))

    def visit_Negate(self, node):
        self.unaryop(node, 'NEG')
```

ä¡£çŤĺçď žä¿ŃïijŽ

```
>>> s = StackCode()
>>> s.generate_code(t4)
[('PUSH', 1), ('PUSH', 2), ('PUSH', 3), ('PUSH', 4), ('SUB',),
('MUL',), ('PUSH', 5), ('DIV',), ('ADD',)]
>>>
```

èőĺèőž

åĹŽåijĂåğŃçŽĎæŮűåĂŹä¡ăåŔŕèČ¡äijŽåĘŹåď ğéĞŔçŽĎif/elseèŕ■åŘěæİěåőđçŐřïijŇè£ŹéĞŇèő£éŮőèĂĚæĺąåijŔçŽĎåě¡åď ĎåřśæŸŕéĂŽè£Ğ `getattr()` æİěèŐůåŔŰçŻÿåžŢçŽĎæŰźæşŢïijŇåźűåĹl’çŤĺéĂŠå¡ŠæİěéĄ■åŐĘæL’ĂæIJL’çŽĎèŁĆçĆźïijŽ

```
def binop(self, node, instruction):
    self.visit(node.left)
```

```
    self.visit(node.right)
    self.instructions.append((instruction,))
```

è£ŸæIJL'äÿĂçĆźéIJĂèęĄæŇĞåĞžçŽĎæŸŕïijŇè£Źçğ■æŁĂæIJŕäź§æŸŕåőđçŐřåĔűäżŰèŕ■èĺĂäÿ■switch
æŕŤåęĆïijŇåęĆæđIJä¡ăæ■čåIJĺåĘŹäÿĂäÿłHTTPæąĘæđűïijŇä¡ăåŔŕèČ¡äijŽåĘŹè£Źæăůäÿ ÄäÿłèŕůæśĆåĹĘåŔ

```
class HTTPHandler:
    def handle(self, request):
        methname = 'do_' + request.request_method
        getattr(self, methname)(request)
    def do_GET(self, request):
        pass
    def do_POST(self, request):
        pass
    def do_HEAD(self, request):
        pass
```

èő£éŮőèĂĔæĺąåijŔäÿĂäÿłçijžçĆźåřśæŸŕåőČäÿěéĞ■ä¿İèţŰéĂŠå¡ŠïijŇåęĆæđIJæŢřæ■őçżŞæđĎåţŇåěŮ
æIJL'æŮűåĂŹäijŽèűĚè£ĞPythonçŽĎéĂŠå¡ŠæůśåžęéŹŘåĹű(åŔĆèĂČ sys.
getrecursionlimit())ãĂĆ

åŔŕäżěåŔĆçĚğ8.22åřŔèŁĆïijŇåĹl'çŤĺçŤ§æĹŘåŹĺæĹŰè£■äżčåŹĺæİěåőđçŐřéİđéĂŠå¡ŠéĄ■åŐĘçőŮæşŢ

åIJĺèů§èğčæđŘåŠŇçijŰèŕŚçŻÿåĚşçŽĎçijŰçĺŃäÿ■ä¡£çŤĺèő£éŮőèĂĔæĺąåijŔæŸŕéİđåÿÿåÿÿèğĄçŽĎãĂĆ
PythonæIJňèžńçŽĎ ast æĺąåİŮåĂijçŽĎåĚşæşĺäÿŃïijŇåŔŕäżěåŐżçIJŃçIJŃæžŘçăĄãĂĆ
9.24åřŔèŁĆæijŤçd'žäžĘäÿĂäÿłåĹl'çŤĺ ast æĺąåİŮæİěåd'ĎçŘĘPythonæžŘäżčçăĄçŽĎä¿Ńå■ŘãĂĆ

10.22 8.22 äÿ■çŤĺéĂŠå¡ŠåőđçŐřèő£éŮőèĂĔæĺąåijŔ

éŮőécŸ

ä¡ăä¡£çŤĺèő£éŮőèĂĔæĺąåijŔéĄ■åŐĘäÿĂäÿłå¿ĹæůśçŽĎåţŇåěŮæăŠå¡ćæŢřæ■őçżŞæđĎïijŇåźűäÿŤåŻäă
ä¡ăæČşæűĹéŹd'éĂŠå¡ŠïijŇåźűåŘŇæŮűä£ÍæŇĄèő£éŮőèĂĔçijŰçĺŃæĺąåijŔãĂĆ

èğčåĘşæŰźæąĹ

éĂŽè£Ğåůğåę́ŹçŽĎä¡£çŤĺçŤ§æĹŘåŹĺåŕäżěåIJĺæăŚéĄ■åŐĘæĹŰæŘIJçt'écőŮæşŢäÿ■æűĹéŹd'éĂŠå¡Š
åIJĺ8.21åřŔèŁĆäÿ■ïijŇæĹŚäžňçżŹåĞžäžĘäÿĂäÿłèő£éŮőèĂĔçśžãĂĆ
äÿŃéİćæĹŚäžňåĹl'çŤĺäÿĂäÿłæăĹåŠŇçŤ§æĹŘåŹĺéĞ■æŰřåőđçŐřè£Źäÿłçśžïijž

```
import types

class Node:
    pass

class NodeVisitor:
    def visit(self, node):
        stack = [node]
```

```
        last_result = None
        while stack:
            try:
                last = stack[-1]
                if isinstance(last, types.GeneratorType):
                    stack.append(last.send(last_result))
                    last_result = None
                elif isinstance(last, Node):
                    stack.append(self._visit(stack.pop()))
                else:
                    last_result = stack.pop()
            except StopIteration:
                stack.pop()

        return last_result

    def _visit(self, node):
        methname = 'visit_' + type(node).__name__
        meth = getattr(self, methname, None)
        if meth is None:
            meth = self.generic_visit
        return meth(node)

    def generic_visit(self, node):
        raise RuntimeError('No {} method'.format('visit_' +␣
↪type(node).__name__))
```

åęĆæđIJä¡ăä¡£çŤĺè£Źäÿłçśżïij Ñäź§èČ¡è¿¿åĹřçŻÿåŘŇçŽĎæŢĹæđIJãĂĆäžŇåőđäÿŁä¡ăåőŇåĚĺåŔřäżěåřĿèĂČèŹŚåęĆäÿŇäżčçăĄïijŇéĄ■åŐĘäÿĂäÿłèąĺè¿¿åijŔçŽĎæăŚïijŽ

```
class UnaryOperator(Node):
    def __init__(self, operand):
        self.operand = operand

class BinaryOperator(Node):
    def __init__(self, left, right):
        self.left = left
        self.right = right

class Add(BinaryOperator):
    pass

class Sub(BinaryOperator):
    pass

class Mul(BinaryOperator):
    pass

class Div(BinaryOperator):
    pass
```

```
class Negate(UnaryOperator):
    pass

class Number(Node):
    def __init__(self, value):
        self.value = value

# A sample visitor class that evaluates expressions
class Evaluator(NodeVisitor):
    def visit_Number(self, node):
        return node.value

    def visit_Add(self, node):
        return self.visit(node.left) + self.visit(node.right)

    def visit_Sub(self, node):
        return self.visit(node.left) - self.visit(node.right)

    def visit_Mul(self, node):
        return self.visit(node.left) * self.visit(node.right)

    def visit_Div(self, node):
        return self.visit(node.left) / self.visit(node.right)

    def visit_Negate(self, node):
        return -self.visit(node.operand)

if __name__ == '__main__':
    # 1 + 2*(3-4) / 5
    t1 = Sub(Number(3), Number(4))
    t2 = Mul(Number(2), t1)
    t3 = Div(t2, Number(5))
    t4 = Add(Number(1), t3)
    # Evaluate it
    e = Evaluator()
    print(e.visit(t4))  # Outputs 0.6
```

åęĆædIJåţŇåěŮåśĆæňąåd'łæůśéĆčäźĹäÿŁè£řçŽĎEvaluatorářšäijŽåd'śæŢĹïijŽ

```
>>> a = Number(0)
>>> for n in range(1, 100000):
...     a = Add(a, Number(n))
...
>>> e = Evaluator()
>>> e.visit(a)
Traceback (most recent call last):
...
  File "visitor.py", line 29, in _visit
    return meth(node)
```

```
    File "visitor.py", line 67, in visit_Add
return self.visit(node.left) + self.visit(node.right)
RuntimeError: maximum recursion depth exceeded
>>>
```

çŐřåIJÍæĹŚäžňçÍ■å¿őä£őæŤźäÿŃäÿŁéİćçŽĎEvaluatorïijŽ

```
class Evaluator(NodeVisitor):
    def visit_Number(self, node):
        return node.value

    def visit_Add(self, node):
        yield (yield node.left) + (yield node.right)

    def visit_Sub(self, node):
        yield (yield node.left) - (yield node.right)

    def visit_Mul(self, node):
        yield (yield node.left) * (yield node.right)

    def visit_Div(self, node):
        yield (yield node.left) / (yield node.right)

    def visit_Negate(self, node):
        yield - (yield node.operand)
```

åĘ■æňąè£ŘèąŇïijŇářśäÿ■äijŽæŁěéŤŹäžĘïijŽ

```
>>> a = Number(0)
>>> for n in range(1,100000):
...     a = Add(a, Number(n))
...
>>> e = Evaluator()
>>> e.visit(a)
4999950000
>>>
```

åęĆæđIJä¡ăè£ŸæČşæůżåŁăåĚűäžŰèĞłåőŽäźĽéĂżè¿Śäź§æšąéŮőécŸïijŽ

```
class Evaluator(NodeVisitor):
    ...
    def visit_Add(self, node):
        print('Add:', node)
        lhs = yield node.left
        print('left=', lhs)
        rhs = yield node.right
        print('right=', rhs)
        yield lhs + rhs
    ...
```

äÿŃéİćæŸŕçőĂå■ŢçŽĎæţŃèŕŢïijŽ

```
>>> e = Evaluator()
>>> e.visit(t4)
Add: <__main__.Add object at 0x1006a8d90>
left= 1
right= -0.4
0.6
>>>
```

èőÍèőž

è£ŹäÿĂåřŔèŁĆæĹŚäžňæijŢçd'žäžĘçŢ§æĹŘåŹĺåŠŇå■ŔçÍŃåIJÍçÍŃåžŔæŐğåĹűæţĄæŰźéİćçŽĎåijžåd'ğ
éĄ£åĚ■éĂŠå¡ŠçŽĎäÿĂäÿłéĂŽåÿÿæŰźæşŢæŸŕä¡£çŢĺäÿĂäÿłæăĹæĹŰéŸ§åĹŮçŽĎæŢřæ■őçżŞæđĎãĂĆ
ä¿ŃåęĆïijŇæůšåžęäijŸåĚĹçŽĎéĄ■åŐĘçőŮæşŢïijŇçňňäÿĂæňąçćřåĹřäÿĂäÿłèŁĆçĆźæŮűåřĘåĚűåŐŃåĚěæă
æŰźæşŢçŽĎæäÿå£ČæĂİèůŕåřśæŸŕè£Źæăůã ĂĆ

åŔęåd'ŰäÿĂäÿłéIJĂèęĄçŘĘèğčçŽĎåřśæŸŕçŢ§æĹŘåŹĺäÿ■yieldèŕ■åŔěãĂĆå¡Şçćřå Ĺřyieldèŕ■åŔěæŮűïij
äÿŁéİćçŽĎä¿Ńå■Řä¡£çŢĺè£ŹäÿłæŁĂæIJŕæİěäžčæŻ£äžĘéĂŠå¡ŠãĂĆä¿ŃåęĆïijŇäźŃåL'■æĹŚäžňæŸŕè£Źæăů

```
value = self.visit(node.left)
```

çŐřåIJÍæ■ćæĹŘyieldèŕ■åŔëijŽ

```
value = yield node.left
```

åőČäijŽåřĘ `node.left` è£ŤåŻđçżŹ `visit()` æŰźæşŢïijŇçĎűåŘŐ `visit()` æŰźæşŢèřČçŢĺéĆčäÿłèŁĆçĆźçŻÿåžŢçŽĎ `visit_Name()` æŰźæşŢãĂĆ yield-æŽĆæŮűåřĘçÍŃåžŔæŐğåĹűåŹĺèőľ'åĞžçżŹèřČçŢĺèĂĚïijŇå¡ŞæL'ğèąŇåőŇåŘŐïijŇçżŞæđIJäijŽèţŃåĂijçżŹv

çIJŃåőŇè£ŹäÿĂåřŔèŁĆïijŇä¡ääź§èőÿæČşåŐżåŕżæL'¿åĚűåőČæšąæIJL'yieldèŕ■åŔęçŽĎæŰźæąĹãĂĆä¡E
ä¿ŃåęĆïijŇäÿžäžĘæűĹéŹđ'éĂŠå¡ŠïijŇä¡ää£ĚéążèęĄçżt'æŁđ'äÿĂäÿłæăĹçżŞæđĎïijŇåęĆæđIJäÿ■ä¡£çŢĺçŢ§a
åőđéŹĚäÿŁïijŇä¡£çŢĺyieldèŕ■åŔěåŔŕäžěèőľ'ä¡ääĘŹåĞžéİđåÿÿæijĆäžőçŽĎäżčçăĄïijŇåőČæűĹéŹđ'äžĘéĂŠå¡

10.23 8.23 å¿łçŐŕåijŢçŢĺæŢřæ■őçżŞæđĎçŽĎåĘĚå■Ÿçőąçŕę

éŮőécŸ

ä¡ăçŽĎçÍŃåžŔåĹŻåżžäžĘå¿Ĺåđ'Žå¿łçŐŕåijŢçŢĺæŢřæ■őçżŞæđĎ(æŕŤåęĆæăŚãĂĄåŻ¿ãĂĄèğĆår§èĂĚæ

èğčåĘşæŰźæąĹ

äÿĂäÿłçőÅå■ŢçŽĎå¿łçŐŕåijŢçŢĺæŢřæ■őçżŞæđĎä¿Ńå■Řåřśæ Ÿŕäÿ Ääÿłæăŝå¡ćçżŞæđĎïijŇåŔŇäžšèŁĆ
è£Źçğ■æČĚåĘţäÿŃïijŇåŔŕäżěèĂČèŹŚä¡£çŢĺ `weakref` åžŞäÿ■çŽĎåijśåijŢçŢĺãĂĆä¿ŃåęĆïijŽ

```
import weakref

class Node:
```

```
    def __init__(self, value):
        self.value = value
        self._parent = None
        self.children = []

    def __repr__(self):
        return 'Node({!r:})'.format(self.value)

    # property that manages the parent as a weak-reference
    @property
    def parent(self):
        return None if self._parent is None else self._parent()

    @parent.setter
    def parent(self, node):
        self._parent = weakref.ref(node)

    def add_child(self, child):
        self.children.append(child)
        child.parent = self
```

è£Źçğ■æŸŕæČşæŰźåijŔåĚĄèőÿparentéİŹéżŸçżĹæ■ćãĂĆä¿ŃåęĆïijŽ

```
>>> root = Node('parent')
>>> c1 = Node('child')
>>> root.add_child(c1)
>>> print(c1.parent)
Node('parent')
>>> del root
>>> print(c1.parent)
None
>>>
```

èőÍèőž

å¿łçŐŕåijŢçŤÍçŽĎæŢřæ■őçżŞæđĎåIJÍPythonäÿ■æŸŕäÿĂäÿłå¿ĹæčŸæĽ'ŃçŽĎéŮőécŸïijŇåŻääÿžæ■čåÿä¿ŃåęĆèĂČèŹŚåęĆäÿŃäżčçăĄïijŽ

```
# Class just to illustrate when deletion occurs
class Data:
    def __del__(self):
        print('Data.__del__')

# Node class involving a cycle
class Node:
    def __init__(self):
        self.data = Data()
        self.parent = None
        self.children = []
```

```
    def add_child(self, child):
        self.children.append(child)
        child.parent = self
```

äÿŃéİćæĹŚäżñä¡£çŤĺè£ŹäÿłäżčçăĄæİěåĄŽäÿĂäžŽåđČåIJ¿åŻđæŤűèŕŢéłŃïijŽ

```
>>> a = Data()
>>> del a # Immediately deleted
Data.__del__
>>> a = Node()
>>> del a # Immediately deleted
Data.__del__
>>> a = Node()
>>> a.add_child(Node())
>>> del a # Not deleted (no message)
>>>
```

åŘŕäżěçIJŃåĹřïijŇæIJĂåŘŐäÿĂäÿłçŽĎåĹăéŹď'æŮűæL'Şå■řèŕ■åŘěæšąæIJL'åĞžçŐřãĂĆåŐ§åŻăæŸŕPy
å¡ŞäÿĂäÿłåŕźèśąçŽĎåijŢçŤĺæŢřåŔŸæĹŘ0çŽĎæŮűåĂŹæL'■äijŽçńŇå■şåĹăéŹď'æŐL'ãĂĆèĂŇåŕźäžŐå¿łçŐŕ
åŻăæ■d'ïijŇåIJĺäÿŁéİć㿊Ňå■ŘäÿæIJĂåŘŐéČĺåĹĘïijŇçĹűèŁĆçĆźåŠŇå■l'å■ŘèŁĆçĆźäžŠçŻÿæŃěæIJL'åŕźa

PythonæIJL'åŘęåď'ŰçŽĎåđČåIJ¿åŻđæŤűåŹĺæİěäÿŞéŮĺéŠĹåŕźå¿łçŐŕåijŢçŤĺçŽĎïijŇä¡ĘæŸŕä¡ăæřÿè£IJ
åŘęåď'Űä¡ăè£ŸåŘŕäżěæL'ŃåŁĺçŽĎèğęåŘŠåőČïijŇä¡ĘæŸŕäżčçăĄçIJŃäÿŁåŐżå¿ĹæŇńïijŽ

```
>>> import gc
>>> gc.collect() # Force collection
Data.__del__
Data.__del__
>>>
```

åęĆæđIJå¿łçŐŕåijŢçŤĺçŽĎåŕźèśąèĞłåůśè£ŸåőŽäźL'äžĘèĞłåůśçŽĎ
__del__() æŰźæşŢïijŃéĆčäźĹäijŽèőľ'æČĚåĘţåŘŸå¿ŮæŻt'çş§çşŢãĂĆ
åĄĞèő¿ä¡ăåČŔäÿŃéİć㣹ŹæăůçżŹNodeåőŽäźL'èĞłåůśçŽĎ __del__() æŰźæşŢïijŽ

```
# Node class involving a cycle
class Node:
    def __init__(self):
        self.data = Data()
        self.parent = None
        self.children = []

    def add_child(self, child):
        self.children.append(child)
        child.parent = self

    # NEVER DEFINE LIKE THIS.
    # Only here to illustrate pathological behavior
    def __del__(self):
        del self.data
        del.parent
```

```
        del.children
```

è£Źçğ■æČĚåĘţäÿŃïijŇåđČåIJ¿åŻđæŤűæřÿè£IJéČ¡äÿ■äijŽåŐżåŻđæŤűè£ŹäÿłářźèśąçŽĎïijŇè£ŸäijŽářij
åęĆæđIJä¡ăèřŢçİĂåŐżè£ŘèąŇåőČäijŽåŔŚçŐřïijŇData.__del__
æűĹæĄŕæřÿè£IJäÿ■äijŽåĞžçŐřäžĘ,çŤŽèĞşåIJĺä¡ăåijžåĹűåĘĚå■ŸåŻđæŤűæŮűïijŽ

```
>>> a = Node()
>>> a.add_child(Node())
>>> del a # No message (not collected)
>>> import gc
>>> gc.collect() # No message (not collected)
>>>
```

åijśåijŢçŤĺæűĹéŹd'äžĘåijŢçŤĺå¿łçŐŕçŽĎè£ŹäÿłéŮőécŸïijŇæIJňèt'ĺæİèèőšïijŇåijśåijŢçŤĺářśæŸŕäÿĂäÿ
ä¡ăåŔŕäžěéĂŽè£Ğ weakref æİěåĹŽåžžåijśåijŢçŤĺãĂĆä¿ŃåęĆïijŽ

```
>>> import weakref
>>> a = Node()
>>> a_ref = weakref.ref(a)
>>> a_ref
<weakref at 0x100581f70; to 'Node' at 0x1005c5410>
>>>
```

äÿžäžĘèő£éŮőåijśåijŢçŤĺæL'ĂåijŢçŤĺçŽĎåŕźèśąïijŇä¡ăåŔŕäžěåČŔåĞ¡æŢřäÿĂæăůåŐżèřČçŤĺåőČå■şåŔ
çŤśäžŐåŐ§ågŃåŕźèśąçŽĎåijŢçŤĺèőąæŢřæšąæIJL'åćđåŁäïijŇéĆčäźĹåřśåŔŕäžěåŐżåĹăéŹd'åőČäžĘãĂĆä¿Ńåę

```
>>> print(a_ref())
<__main__.Node object at 0x1005c5410>
>>> del a
Data.__del__
>>> print(a_ref())
None
>>>
```

éĂŽè£Ğè£ŹéĞŇæijŤçd'žçŽĎåijśåijŢçŤĺæŁĂæIJŕïijŇä¡ăäijŽåŔŚçŐřäÿ■åĘ■æIJL'å¿łçŐŕåijŢçŤĺéŮőécŸ
ä¡ăè£ŸèČ¡åŔĆèĂČ8.25ařŔèŁĆåĚşäžŐåijśåijŢçŤĺçŽĎåŔęåd'ŰäÿĂäÿłä¿Ńå■ŘãĂĆ

10.24 8.24 èőľçśżæŤŕæŇĄæŕŤè¿ČæŞ■ä¡IJ

éŮőécŸ

ä¡ăæČşèőľæ§ŘäÿłçśżçŽĎåőđä¿ŃæŤŕæŇĄæăĞåĞĘçŽĎæŕŤè¿Čè£ŘçőŮ(æŕŤåęĆ>=,!=,<=,<ç■L')ïijŇä¡E

èğčåĘşæŰźæąĹ

PythonçśżåŕźæŕŔäÿłæŕŤè¿ČæŞ■ä¡IJéČ¡éIJĂèęĄåőđçŐřäÿĂäÿłçL'źæőŁæŰźæşŢæİěæŤŕæŇĄãĂĆ
ä¿ŃåęĆäÿžäžĘæŤŕæŇĄ>=æŞ■ä¡IJçňęïijŇä¡ăéIJĂèęĄåőŽäźL'äÿĂäÿł __ge__()
æŰźæşŢãĂĆ år¡çőąåőŽäźL'äÿĂäÿłæŰźæşŢæšąäžĂäźĹéŮőécŸïijŇä¡ĘåęĆæđIJèęĄä¡ăåőđçŐřæL'ĂæIJL'åŔŕè

èčĚéěřåŹÍ `functools.total_ordering` åřśæŸŕçŤÍæİěçőĂåŇŰè£Źäÿłåď'ĎçŘĘçŽĎãĂĆä¡£çŤÍåőČæİěèčĚéěřäÿĂäÿłæİěïijŇä¡ăåŔłéIJĂåőŽäźL'äÿĂäÿł `__eq__()` æŰźæşŢïijŇåď'ŰåŁăåĚűäżŰæŰźæşŢ(__lt__, __le__, __gt__, or __ge__)äÿ■çŽĎäÿĂäÿłå■şåŔŕãĂĆçĎűåŘŐèčĚéěřåŹÍäijŽèĞłåŁÍäÿžä¡ăåąńåĚĚåĚűåőČæŕŤè¿ČæŰźæşŢãĂĆ

ä¡IJäÿžä¿Ńå■ŘïijŇæĹŚäżňædĎåżžäÿĂäžŽæĹ£å■ŘïijŇçĎűåŘŐçżŹåőČäżňåćđåŁääÿĂäžŽæĹ£éŮt'ïijŇæ

```
from functools import total_ordering

class Room:
    def __init__(self, name, length, width):
        self.name = name
        self.length = length
        self.width = width
        self.square_feet = self.length * self.width

@total_ordering
class House:
    def __init__(self, name, style):
        self.name = name
        self.style = style
        self.rooms = list()

    @property
    def living_space_footage(self):
        return sum(r.square_feet for r in self.rooms)

    def add_room(self, room):
        self.rooms.append(room)

    def __str__(self):
        return '{}: {} square foot {}'.format(self.name,
                self.living_space_footage,
                self.style)

    def __eq__(self, other):
        return self.living_space_footage == other.living_space_
↪footage

    def __lt__(self, other):
        return self.living_space_footage < other.living_space_
↪footage
```

è£ŹéĞŇæĹŚäżňåŘłæŸŕçżŹHouseçśżåőŽäźL'äžĘäÿď'äÿłæŰźæşŢïijŽ`__eq__()` åŠŇ `__lt__()` ïijŇåőČåřśèČ¡æŤŕæŇĄæL'ĂæIJL'çŽĎæŕŤè¿ČæŞ■ä¡IJïijŽ

```
# Build a few houses, and add rooms to them
h1 = House('h1', 'Cape')
h1.add_room(Room('Master Bedroom', 14, 21))
h1.add_room(Room('Living Room', 18, 20))
h1.add_room(Room('Kitchen', 12, 16))
```

```
h1.add_room(Room('Office', 12, 12))
h2 = House('h2', 'Ranch')
h2.add_room(Room('Master Bedroom', 14, 21))
h2.add_room(Room('Living Room', 18, 20))
h2.add_room(Room('Kitchen', 12, 16))
h3 = House('h3', 'Split')
h3.add_room(Room('Master Bedroom', 14, 21))
h3.add_room(Room('Living Room', 18, 20))
h3.add_room(Room('Office', 12, 16))
h3.add_room(Room('Kitchen', 15, 17))
houses = [h1, h2, h3]
print('Is h1 bigger than h2?', h1 > h2) # prints True
print('Is h2 smaller than h3?', h2 < h3) # prints True
print('Is h2 greater than or equal to h1?', h2 >= h1) # Prints False
print('Which one is biggest?', max(houses)) # Prints 'h3: 1101-
↪square-foot Split'
print('Which is smallest?', min(houses)) # Prints 'h2: 846-square-
↪foot Ranch'
```

èőÍèőž

åĚűåőđ `total_ordering` èčĚéěřåŹÍäź§æšąéĆčäźĹçěđçğŸãĂĆ åőČåřśæŸŕåőŽäźĽäžĘäÿĂäÿłäżŐæŕŔäÿłæŕŤè¿ČæŤŕæŇĄæŰźæşŢåĹřæĽĂæIJĽéIJĂèęĄåőŽäźĽçŽĎåĚűäżŰ æŕŤåęĆä¡ăåőŽäźĽäžĘ `__le__()` æŰźæşŢïijŇéĆčäźĹåőČåřśèćńçŤÍæÌěæđĎåžžæĽĂæIJĽåĚűäżŰçŽĎéIJĂè åőđéŹĚäÿŁåřśæŸŕåIJÍçśžéĞŇéÌćåČŔäÿŇéÌćè£ŹæăůåőŽäźĽäžĘäÿĂäžŻçĽźæőŁæŰźæşŢïijŽ

```
class House:
    def __eq__(self, other):
        pass
    def __lt__(self, other):
        pass
    # Methods created by @total_ordering
    __le__ = lambda self, other: self < other or self == other
    __gt__ = lambda self, other: not (self < other or self == other)
    __ge__ = lambda self, other: not (self < other)
    __ne__ = lambda self, other: not self == other
```

å¡ŞçĎűïijŇä¡äèĞłåůśåŐżåĘŹäź§å¿ĹåőźæŸŞïijŇä¡ĘæŸŕä¡£çŤÍ `@total_ordering` åŘŕäžěçőĂåŇŰäžčçăĄïijŇä¡ŢäźŘèĂŇäÿ■äÿžåŚćãĂĆ

10.25 8.25 åĹŻåžžçijŞå■Ÿåőđä¿Ń

éŮőécŸ

åIJĺåĹŻåžžäÿĂäÿłçśžçŽĎåŕźèśąæŮűïijŇåęĆæđIJäźŃåL’■ä¡£çŤĺåŘŇæăůåŔĆæŢřåĹŻåžžè£Ğè£Źäÿłåŕźèś ä¡ăæČşè£ŤåŻđåőČçŽĎçijŞå■ŸåijŢçŤÍãĂĆ

èğčåĘşæŰźæąĹ

è£Źçğ■éĂŽåÿÿæŸŕåŽääÿžä¡ăåÿŇæIJŻçŻÿåŘŇåŔĆæŢřåĹŻåžžçŽĎåŕźèśąæŮűå■Ţä¿ŃçŽĎãĂĆ åIJĺå¿Ĺåď'ŽåžŞäÿ■éČ¡æIJL'åőđéŹĚçŽĎä¿Ńå■ŘïijŇærŤåęĆ `logging` æĺąåİŮïijŇä¡£çŤĺçŻÿåŘŇçŽĎåŘ■çğřåĹŻåžžçŽĎ `logger` åőđä¿ŃæřÿèIJåŔłæIJL'äÿĂäÿłãĂĆä¿ŃåęĆïijŽ

```
>>> import logging
>>> a = logging.getLogger('foo')
>>> b = logging.getLogger('bar')
>>> a is b
False
>>> c = logging.getLogger('foo')
>>> a is c
True
>>>
```

äÿžäžĘè¿¿åĹřè£ŹæăůçŽĎæŢĹæđIJïijŇä¡äéIJĂèęĄä¡£çŤĺäÿĂäÿłåŠŇçśżæIJňèžńåĹĘåijĂçŽĎåůěåŐĆåĞ

```
# The class in question
class Spam:
    def __init__(self, name):
        self.name = name

# Caching support
import weakref
_spam_cache = weakref.WeakValueDictionary()
def get_spam(name):
    if name not in _spam_cache:
        s = Spam(name)
        _spam_cache[name] = s
    else:
        s = _spam_cache[name]
    return s
```

çĎűåŘŐåĄŽäÿĂäÿłæţŃèŕŢïijŇä¡ääijŽåŔŠçŐřèů§äźŃåL'■éĆčäÿłæŮěå£ŮåŕźèśąçŽĎåĹŻåžžèąŇäÿžæŸŕ

```
>>> a = get_spam('foo')
>>> b = get_spam('bar')
>>> a is b
False
>>> c = get_spam('foo')
>>> a is c
True
>>>
```

èőÍèőž

çijŰåĘŹäÿĂäÿłåůěåŐĆåĞ¡æŢřæİěä£őæŤźæŹőéĂŽçŽĎåőđä¿ŃåĹŻåžžèąŇäÿžéĂŽåÿÿæŸŕäÿĂäÿłærŤè¿ ä¡ĘæŸŕæĹŠäžňè£ŸèČ¡åŘęæL'¿åĹřæŻť'äijŸéŻĚçŽĎèğčåĘşæŰźæąĹåŠćïij§

ä¿ŃåęĆïijŇä¡ăåŔŕèČ¡äijŽèĂČèŹŚéĞ■æŰřåőŽäźL’çśżçŽĎ `__new__()` æŰźæşŢïijŇåřśåČŔäÿŃéİćè£ŹæăůïijŽ

```
# Note: This code doesn't quite work
import weakref

class Spam:
    _spam_cache = weakref.WeakValueDictionary()
    def __new__(cls, name):
        if name in cls._spam_cache:
            return cls._spam_cache[name]
        else:
            self = super().__new__(cls)
            cls._spam_cache[name] = self
            return self
    def __init__(self, name):
        print('Initializing Spam')
        self.name = name
```

åĹİçIJŃètůæİěåě¡åČŔåŔŕäżěè¿¿åĹřécĎæIJ§æŢĹæđIJïijŇä¡EąæŸŕéŮőécŸæŸŕ `__init__()` æŕŔæñąéČ¡äijŽècńěřČçŤĺïijŇäÿ■çőąè£Źäÿłåőđä¿ŃæŸŕåŘęècńçijŞå■ŸäžEąĂĆä¿ŃåęĆïijŽ

```
>>> s = Spam('Dave')
Initializing Spam
>>> t = Spam('Dave')
Initializing Spam
>>> s is t
True
>>>
```

è£ŹäÿłæĹŰèőÿäÿ■æŸŕä¡ăæČşèęĄçŽĎæŢĹæđIJïijŇåŻăæ■d’è£Źçğ■æŰźæşŢåźűäÿ■åŔŕåŘŰãĂĆ

äÿŁéİćæĹŚäžñä¡£çŤĺåĹřäžEąäijśåijŢçŤĺèőąæŢřïijŇårźäžŐåđČåIJ¿åŻđæŤűæİèèőšæŸŕå¿ĹæIJL’åÿőåŁl’çŽ å¡ŞæĹŚäžñä£ÍæŇĄåőđä¿ŃçijŞå■ŸæŮűïijŇä¡ăåŔŕèČ¡åŘłæČşåIJÍçÍŃåžŔäÿ■ä¡£çŤĺåĹřåőČäžñæŮűæL’■ä£Íå■ äÿĂäÿł `WeakValueDictionary` åőđä¿ŃåŘłäijŽä£Íå■ŸéĆčäžŻåIJĺåĚűåőČåIJřæŰźè£ŸåIJÍècńä¡£çŤĺçŽĎå åŘęåĹŹçŽĎèŕİïijŇåŘłèęĄåőđä¿Ńäÿ■åĘ■ècńä¡£çŤĺäžEïijŇåőČårśäžŐå■ŮåĚÿäÿ■ècńçğżéŹd’äžEąĂĆèğĆår§ă

```
>>> a = get_spam('foo')
>>> b = get_spam('bar')
>>> c = get_spam('foo')
>>> list(_spam_cache)
['foo', 'bar']
>>> del a
>>> del c
>>> list(_spam_cache)
['bar']
>>> del b
>>> list(_spam_cache)
[]
>>>
```

årźäžŐåd’ğéČĺåĹEçÍŃåžŔèĂŇåůšïijŇè£ŹéĞŇäžčçăĄåůšçżŔåd’§çŤĺäžEąĂĆäÿ■è£Ğè£ŸæŸŕæIJL’äÿĂä

éęŰåĚĹæŸŕè£ŹéĞŇä¡£çŤĺåĹřäžĘäÿĂäÿłåĚĺåśĂåŔŸéĞŔïijŇåźűäÿŤåůěåŐĆåĞ¡æŢřèů§çśżæŤ¿åIJĺäÿĂ

```
import weakref

class CachedSpamManager:
    def __init__(self):
        self._cache = weakref.WeakValueDictionary()

    def get_spam(self, name):
        if name not in self._cache:
            s = Spam(name)
            self._cache[name] = s
        else:
            s = self._cache[name]
        return s

    def clear(self):
            self._cache.clear()

class Spam:
    manager = CachedSpamManager()
    def __init__(self, name):
        self.name = name

    def get_spam(name):
        return Spam.manager.get_spam(name)
```

è£ŹæăůçŽĎèŕÍäžčçăĄæŻť æÿĚæŹřïijŇåźűäÿŤäź§æŻť çĄţæť żïijŇæĹŚäžňåŔŕäžěåćđåŁăæŻť åď ŽçŽĎçij

è£ŸæIJL’äÿĂçĆźářśæŸŕïijŇæĹŚäžňæŻť éIJšäžĘçśżçŽĎåőđä¿ŃåŇŰçżŹçŤĺæĹůïijŇçŤĺæĹůå¿Ĺåőźæ ŸŞ

```
>>> a = Spam('foo')
>>> b = Spam('foo')
>>> a is b
False
>>>
```

æIJL’åĞăçğ■æŰźåijŔåŔŕäžěéŸšæ■ćçŤĺæĹůè£ŹæăůåĄŽïijŇçňňäÿĂäÿłæŸŕårĘçśżçŽĎåŘ■å■Ůä£őæŤźäÿ çňňäžŇçğ■ářśæŸŕèőľè£ŹäÿłçśżçŽĎ `__init__()` æŰźæşŢæŁŻåĞžäÿĂäÿłåijĆåÿÿïijŇèőľåőČäÿ■èČ¡ècńåĹ

```
class Spam:
    def __init__(self, *args, **kwargs):
        raise RuntimeError("Can't instantiate directly")

    # Alternate constructor
    @classmethod
    def _new(cls, name):
        self = cls.__new__(cls)
        self.name = name
```

çĎűåŘŐä£őæŤźçijŞå■ŸçőąçŘĘåŹĺäžčçăĄïijŇä¡£çŤĺ `Spam._new()` æĺěåĹŻåžžåőđä¿ŃïijŇèĂŇäÿ■æŸŕçŻť æŐěěřČçŤĺ `Spam()` æđĎéĂäåĞ¡æŢřïijŽ

```
# ------------------------æIJÄåŘŐçŽĎä£őæ■čæŰźæąĹ----------------------
 ↪---
class CachedSpamManager2:
    def __init__(self):
        self._cache = weakref.WeakValueDictionary()

    def get_spam(self, name):
        if name not in self._cache:
            temp = Spam3._new(name)  # Modified creation
            self._cache[name] = temp
        else:
            temp = self._cache[name]
        return temp

    def clear(self):
            self._cache.clear()

class Spam3:
    def __init__(self, *args, **kwargs):
        raise RuntimeError("Can't instantiate directly")

    # Alternate constructor
    @classmethod
    def _new(cls, name):
        self = cls.__new__(cls)
        self.name = name
        return self
```

æIJÄåŘŐè£ŹæăůçŽĎæŰźæąĹåřśåůšçżŔèűşåď§åě¡äžĘãÄĆ
çijŞå■ŸåŠŇåĚűäžŰæđĎéĂăæĺąåijŔè£ŸåŔřäžěä¡£çŤĺ9.13åřŔèŁĆäÿ■çŽĎåĚČçśżåőđçŐřçŽĎæŻť äijŸéŻĚäÿ

11 çňňäźİçńäïijŽåĚČçijŰçÍŃ

è¡ŕäžűåijĂåŔŚéćĘå§§äÿ■æIJÄçżŔåĚÿçŽĎåŔčåď'ť çęĚåřśæŸŕâĂIJdonâĂŹt repeat yourselfâĂİãĂĆ äź§åřśæŸŕèřť'ïijŇäžżä¡ŢæŮűåĂŹå¡Şä¡ăçŽĎçÍŃåžŔäÿ■å■ŸåIJĺéńŸåžęéĞ■åď'■(æĹŰèĂĚæŸŕéĂ
åIJÍPythonå¡Şäÿ■ïijŇéĂŽåÿÿéČ¡åŔŕäžěéĂŽè£ĞåĚČçijŰçÍŃæİěèğčåĘşè£ŹçśżéŮőécŸãĂĆ
çőĂèĂŇèÍĂäźŃïijŇåĚČçijŰçÍŃåřśæŸŕåĚşäžŐåĹŻåžžæŞ■ä¡IJæžŘäžčçăĄ(æŕŤåęĆä£őæŤźãĂĄçŢ§æĹŘæĹŰ
äÿżèęĄæŁĂæIJŕæŸŕä¡£çŤĺèčĚéěřåŹĺãĂĄçśżèčĚéěřåŹĺåŠŇåĚČçśżãĂĆäÿ■è£Ğè£ŸæIJL'äÿĂäžŻåĚűäžŰæŁĂ
åŇĚæŃńç■¿åŘ■åŕźèśąãĂĄä¡£çŤĺ`exec()` æL'ğèąŇäžčçăĄäżěåŔŁåŕźåĘĚéČĺåĞ¡æŢřåŠŇçśżçŽĎåŔ■åřĎæŁ
æIJńçńäçŽĎäÿżèęĄçŽőçŽĎæŸŕåŘŚåď'ğåőűäžŃçż■è£ŹäžŻåĚČçijŰçÍŃæŁĂæIJŕïijŇåźűäÿŤçżŹåĞžåőđä¿Ńæ

Contents:

11.1 9.1 åIJÍåĞ¡æŢřäÿŁæůżåŁääÿĂäÿłåŇĚèčĚåŹÍ

éŮőécŸ

ä¡ăæČşåIJÍåĞ¡æŢřäÿŁæůżåŁääÿĂäÿłåŇĚèčĚåŹÍïijŇåćđåŁäécÍåd'ŰçŽĎæŞ■ä¡IJåd'ĎçŘĘ(æŕŤåęĆæŮěå‡

èğčåĘşæŰźæąĹ

åęĆæđIJä¡ăæČşä¡£çŤÍécÍåd'ŰçŽĎäžčçăĄåŇĚèčĚäÿĂäÿłåĞ¡æŢřijŇåŕŕäżěåőŽäźL'äÿĂäÿłèčĚéěřåŹÍåĞ

```
import time
from functools import wraps

def timethis(func):
    '''
    Decorator that reports the execution time.
    '''
    @wraps(func)
    def wrapper(*args, **kwargs):
        start = time.time()
        result = func(*args, **kwargs)
        end = time.time()
        print(func.__name__, end-start)
        return result
    return wrapper
```

äÿŇéÍćæŸŕä¡£çŤÍèčĚéěřåŹÍçŽĎä¿Ňå■ŘïijŽ

```
>>> @timethis
... def countdown(n):
...     '''
...     Counts down
...     '''
...     while n > 0:
...         n -= 1
...
>>> countdown(100000)
countdown 0.008917808532714844
>>> countdown(10000000)
countdown 0.87188299392912
>>>
```

èőÍèőž

äÿĂäÿłèčĚéěřåŹÍåřśæŸŕäÿĂäÿłåĞ¡æŢřïijŇåőČæŐěåŔŮäÿĂäÿłåĞ¡æŢřä¡IJäÿžåŔĆæŢřåźűè£ŤåŻđäÿĂäÿ
å¡Şä¡ăåČŔäÿŇéÍćè£ŹæăůåĘŹïijŽ

```
@timethis
def countdown(n):
    pass
```

èů§åČŔäÿŃéİćè£ŹæăůåĘŹåĚűåőđæŢĹæđIJæŸŕäÿĂæăůçŽĎïijŽ

```
def countdown(n):
    pass
countdown = timethis(countdown)
```

éąžä¿£èŕťäÿĂäÿŃïijŇåĘĚç¡őçŽĎèčĚéěřåŹĺæŕŤåęĆ `@staticmethod`, `@classmethod`,`@property` åŐ§çŘĘäź§æŸŕäÿĂæăůçŽĎãĂĆ ä¿ŃåęĆïijŇäÿŃéİćè£ŹäÿďäÿłäžčçăĄçL'ĞæőţæŸŕç■L'äžůçŽĎïijŽ

```
class A:
    @classmethod
    def method(cls):
        pass

class B:
    # Equivalent definition of a class method
    def method(cls):
        pass
    method = classmethod(method)
```

åIJĺäÿŁéİćçŽĎ `wrapper()` åĞ¡æŢřäÿ■ïijŇ èčĚéěřåŹĺåĘĚéČĺåőŽäźL'äžĘäÿĂäÿłä¡£çŢĺ `*args` åŠŇ `**kwargs` æİěæŐěåŔŮäżżæĎŔåŔĆæŢřçŽĎåĞ¡æŢřãĂĆ åIJĺè£ŹäÿłåĞ¡æŢréĞŇéİćèřČçŢĺäžĘåŐ§ågŃåĞ¡æŢřázűårĘåĚűçżŞæđIJè£ŤåŻđïijŇäÿ■è£Ğä¡ăè£ŸåŔŕäżěæůżçĎűåŘŐè£ŹäÿłæŰřçŽĎåĞ¡æŢřåŇĚèčĚåŹĺèćńä¡IJäÿžçżŞæđIJè£ŤåŻđæİěäżčæŻ£åŐ§ågŃåĞ¡æŢřãĂĆ

éIJĂèęĄåijžěřČçŽĎæŸŕèčĚéěřåŹĺázűäÿ■äijŽä£őæŤźåŐ§ågŃåĞ¡æŢřçŽĎåŔĆæŢřç■¿åŘ■äżěåŔŁè£ŤåŻ ä¡£çŢĺ `*args` åŠŇ `**kwargs` çŻőçŽĎåřśæŸŕçąőä£İäżżä¡ŢåŔĆæŢřéČ¡èČ¡éĂĆçŢĺãĂĆ èĂŇè£ŤåŻđçżŞæđIJåĂijå§žæIJńéČ¡æŸŕèřČçŢĺåŐ§ågŃåĞ¡æŢř `func(*args, **kwargs)` çŽĎè£ŤåŻđçżŞæđIJïijŇåĚűäÿ■funcåřśæŸŕåŐ§ågŃåĞ¡æŢřãĂĆ

åĹŽåijĂåğŃå■ęäźăèčĚéěřåŹĺçŽĎæŮűåĂŹïijŇäijŽä¡£çŢĺäÿĂäžŻçőĂå■ŢçŽĎä¿Ńå■ŘæİèèŕťæŸŐïijŇæŕ äÿ■è£ĞåőđéŹĚåIJžæŹŕä¡£çŢĺæŮűïijŇè£ŸæŸŕæIJL'äÿĂäžŻçżĘèŁĆéŮőécŸèęĄæşĺæĎŔçŽĎãĂĆ æŕŤåęĆäÿŁéİćä¡£çŢĺ `@wraps(func)` æşĺèğčæŸŕå¿ĹéĞ■èęĄçŽĎïijŇ åőČèČ¡ä£İçŢŹåŐ§ågŃåĞ¡æŢřçŽĎåĚČæŢřæ■ő(äÿŃäÿĂåřŔèŁĆäijŽèőšåĹř)ïijŇæŰřæL'ŃçżŘåÿÿäijŽå£¡çŢěè æŐěäÿŃæİěçŽĎåĞääÿłåřŔèŁĆæĹŚäžňäijŽæŻť'åŁăæůśåĚěçŽĎèőšèğčèčĚéěřåŹĺåĞ¡æŢřçŽĎçżĘèŁĆéŮőécŸ

11.2 9.2 åĹŽåżżèčĚéěřåŹĺæŮűä£İçŢŹåĞ¡æŢřåĚČä£ąæĄŕ

éŮőécŸ

ä¡ăåĘŹäžĘäÿĂäÿłèčĚéěřåŹĺä¡IJçŤĺåIJĺæ§ŘäÿłåĞ¡æŢřäŸŁïijŇä¡ĘæŸŕè£ŹäÿłåĞ¡æŢřçŽĎéĞ■èęĄçŽĎåĚ

èğčåĘşæŰźæąĹ

äżżä¡ŢæŮűåĂŹä¡ăåőŽäźL'èčĚéěřåŹÍçŽĎæŮűåĂŹïijŇéČ¡ážŤèŕěä¡£çŤÍ `functools` ážŞäÿ■çŽĎ `@wraps` èčĚéěřåŹÍæİěæşÍèğčåžŢåśĆåŇĚèčĚåĞ¡æŢřãĂĆä¿ŃåęĆïijŽ

```
import time
from functools import wraps
def timethis(func):
    '''
    Decorator that reports the execution time.
    '''
    @wraps(func)
    def wrapper(*args, **kwargs):
        start = time.time()
        result = func(*args, **kwargs)
        end = time.time()
        print(func.__name__, end-start)
        return result
    return wrapper
```

äÿŃéİćæĹŚäżñä¡£çŤÍè£ŹäÿłèćńåŇĚèčĚåŘŐçŽĎåĞ¡æŢřåźűæčĂæ§ěåőČçŽĎåĚČä£ąæĄŕïijŽ

```
>>> @timethis
... def countdown(n):
...     '''
...     Counts down
...     '''
...     while n > 0:
...         n -= 1
...
>>> countdown(100000)
countdown 0.008917808532714844
>>> countdown.__name__
'countdown'
>>> countdown.__doc__
'\n\tCounts down\n\t'
>>> countdown.__annotations__
{'n': <class 'int'>}
>>>
```

èőÍèőž

åIJÍçijŰåĘŹèčĚéěřåŹÍçŽĎæŮűåĂŹåd'■åĹűåĚČä£ąæĄŕæŸŕäÿĂäÿłéİđåÿÿéĞ■èęĄçŽĎéČÍåĹĘãĂĆåęĆæ `@wraps` ïijŇ éĆčäźĹä¡ääijŽåŔŚçŐřèćńèčĚéěřåĞ¡æŢřäÿćåd'šäžĘæL'ĂæIJL'æIJL'çŤÍçŽĎä£ąæĄŕãĂĆæŕŤåęĆ `@wraps` åŘŐçŽĎæŢĹæđIJæŸŕäÿŃéİćè£ŹæăůçŽĎïijŽ

```
>>> countdown.__name__
'wrapper'
>>> countdown.__doc__
```

```
>>> countdown.__annotations__
{}
>>>
```

@wraps æIJL'äÿĂäÿłéĞ■èęĄçL'źå¿ĄæŸŕåőČèČ¡èől'ä¡ăéĂŽè£ĞåšđæĂğ __wrapped__ çŻť'æŐěèő£éŮőèćńåŇĚèčĚåĞ¡æŢřãĂĆä¿ŃåęĆ:

```
>>> countdown.__wrapped__(100000)
>>>
```

__wrapped__ åšđæĂğè£ŸèČ¡èől'èćńèčĚéěřåĞ¡æŢřæ■čçąőæŽť'éIJšåžŢåšĆçŽĎåŔĆæŢřç■¿åŘ■ä£ąæA

```
>>> from inspect import signature
>>> print(signature(countdown))
(n:int)
>>>
```

äÿĂäÿłå¿ĹæŹőéĄ■çŽĎéŮőécŸæŸŕæĂŐæăůèől'èčĚéěřåŹĺåŐżçŻť'æŐěåď'■åĹűåŐ§ågŃåĞ¡æŢřçŽĎåŔĆ åęĆædIJæČşèĞłåůśæĽŃåŁĺåőđçŐřçŽĎèŕÍéIJĂèęĄåĄŽåď'ğéĞŔçŽĎåůěä¡IJïijŇæIJĂåě¡åřśçőĂå■ŢçŽĎä¡£çŤ @wraps èčĚéěřåŹĺãĂĆ éĂŽè£ĞåžŢåšĆçŽĎ __wrapped__ åšđæĂğeő£éŮőåĹřåĞ¡æŢřç■¿åŘ■ä£ąæĄfãĂĆæŻť'åď'ŽåĚşäžŐç■¿åŘ■çŽĎåĘĚåőźåŔŕäżěåŔĆèĂČ9.16åřŔèŁ

11.3 9.3 èğčéŹď'äÿĂäÿłècĚéěřåŹĺ

éŮőécŸ

äÿĂäÿłècĚéěřåŹĺåůšçżŔä¡IJçŤĺåIJĺäÿĂäÿłåĞ¡æŢřäŸŁïijŇä¡ăæČşæŠď'éŤĂåőČïijŇçŻť'æŐèő£éŮőåŐ§åğ

èğčåĘşæŰźæąĹ

åĄĞèő¿èčĚéěřåŹĺæŸŕéĂŽè£Ğ @wraps (åŔĆèĂČ9.2åřŔèŁĆ)æİěåőđçŐřçŽĎïijŇéĆčäźĹä¡ăåŔŕäżěéĂŽè __wrapped__ åšđæĂğæİèèő£éŮőåŐ§åğŃåĞ¡æŢřïijŽ

```
>>> @somedecorator
>>> def add(x, y):
...     return x + y
...
>>> orig_add = add.__wrapped__
>>> orig_add(3, 4)
7
>>>
```

èőĺèőž

çŻť'æŐèő£éŮőæIJłåŇĚèčĚçŽĎåŐ§åğŃåĞ¡æŢřåIJĺèřČèŕŢãĂĄåĘĚçIJĄåŠŇåĚűäżŰåĞ¡æŢřæŞ■ä¡IJæŮ ä¡ĘæŸŕæĹŚäżňè£ŹéĞŇçŽĎæŰźæąĹäżĚäżĚéĂĆçŤĺäžŐåIJĺåŇĚèčĚåŹĺäÿ■æ■čçąőä¡£çŤĺäžĘ

@wraps æĹŰèĂĚçŻťæŐèèő¿ç¡őäžĘ __wrapped__ åšđæĂğçŽĎæČĚåĘţãĂĆ

åęĆæđIJæIJL'åđ'Žäÿ łåŇĚèčĚåŹĺïijŇéĆčäźĹèő£éŮő __wrapped__ åšđæĂğçŽĎèąŇäÿžæŸŕäÿ■åŔŕéćĎç§ěçŽĎïijŇåžŤèŕěéĄ£åĚ■è£Źæăůå ĄŽãĂĆ åIJĺPython3.3äÿ■ïijŇåőČäijŽçŢèè£ĞæL'ĂæIJL'çŽĎåŇĚèčĚåśĆïijŇæŕŤåęĆïijŇåĄĞåęĆä¡ăæIJL'åęĆäÿŃçŽĎ

```
from functools import wraps

def decorator1(func):
    @wraps(func)
    def wrapper(*args, **kwargs):
        print('Decorator 1')
        return func(*args, **kwargs)
    return wrapper

def decorator2(func):
    @wraps(func)
    def wrapper(*args, **kwargs):
        print('Decorator 2')
        return func(*args, **kwargs)
    return wrapper

@decorator1
@decorator2
def add(x, y):
    return x + y
```

äÿŃéİćæĹŚäžňåIJĺPython3.3äÿŃæţŃèŕŢïijŽ

```
>>> add(2, 3)
Decorator 1
Decorator 2
5
>>> add.__wrapped__(2, 3)
5
>>>
```

äÿŃéİćæĹŚäžňåIJĺPython3.4äÿŃæţŃèŕŢïijŽ

```
>>> add(2, 3)
Decorator 1
Decorator 2
5
>>> add.__wrapped__(2, 3)
Decorator 2
5
>>>
```

æIJĂåŘŐèęĄèŕť'çŽĎæŸŕïijŇåźűäÿ■æŸŕæL'ĂæIJL'çŽĎèčĚéěřåŹĺéČ¡ä¡£çŤĺäžĘ @wraps ïijŇåŽăæ■d'è£ŹéĞŇçŽĎæŰźæąĹåźűäÿ■åĚĺéČĺéĂĆçŤĺãĂĆçL'źåĹńçŽĎïijŇåĘĚç¡őçŽĎèčĚéěřåŹĺ @staticmethod åŠŇ @classmethod

åřśæšąæIJL'éĄţå¿łè£Źäÿłçžęåőž (åőČäżňæŁŁåŐ§åğŃåĞ¡æŢřå■ŸåĆĺåIJĺåśđæĂğ __func__ äÿ■)ãĂĆ

11.4 9.4 åőŽäźL'äÿĂäÿłåŸęåŔĆæŢřçŽĎèčĚéěřåŹÍ

éŮőécŸ

ä¡ăæČşåőŽäźL'äÿĂäÿłåŔŕäżěæŐěåŔŮåŔĆæŢřçŽĎèčĚéěřåŹÍ

èğčåĘşæŰźæąĹ

æĹŚäżňçŤĺäÿĂäÿłä¿Ńå■Řèŕęçżę́ÿŘè£řäÿŃæŐěåŔŮåŔĆæŢřçŽĎåď'ĎçŘĘè£ĞçÍŃãĂĆ åĄĞèő¿ä¡ăæČşåĘŹäÿĂäÿłècĚéěřåŹÍïijŇçżŹåĞ¡æŢřæůżåŁăæŮěå£ŮåŁ§èČ¡ïijŇåŘŇæŮűåĚąèőÿçŤĺæĹůæŇ äÿŃéIćæŸŕè£ŹäÿłècĚéěřåŹÍçŽĎåőŽäźL'åŠŇä¡£çŤĺçď'žä¿Ńïij Ž

```
from functools import wraps
import logging

def logged(level, name=None, message=None):
    """
    Add logging to a function. level is the logging
    level, name is the logger name, and message is the
    log message. If name and message aren't specified,
    they default to the function's module and name.
    """
    def decorate(func):
        logname = name if name else func.__module__
        log = logging.getLogger(logname)
        logmsg = message if message else func.__name__

        @wraps(func)
        def wrapper(*args, **kwargs):
            log.log(level, logmsg)
            return func(*args, **kwargs)
        return wrapper
    return decorate

# Example use
@logged(logging.DEBUG)
def add(x, y):
    return x + y

@logged(logging.CRITICAL, 'example')
def spam():
    print('Spam!')
```

åĹİçIJŃèţůæİěïijŇè£Źçğ■åőđçŐřçIJŃäÿŁåŐżå¿Łåď'■æİĆïijŇä¡ĘæŸŕæäÿå£ČæĂİæČşå¿ŁçőĂå■ŢãĂĆ æIJĂåď'ŰåśĆçŽĎåĞ¡æŢř `logged()` æŐěåŔŮåŔĆæŢřåźűářĘåőČäżňä¡IJçŤĺåIJĺåĘĚéČĺçŽĎèčĚéěřåŹĺåĞ¡æ

åĘĚåśĆçŽĎåĞ¡æŢř `decorate()` æŐěåŔŮäÿĂäÿłåĞ¡æŢřä¡IJäÿžåŔĆæŢřïijŇçĎűåŘŐåIJĺåĞ¡æŢřäÿŁéİćæŤ
è£ŹéĞŇçŽĎåĔşéŤőçĆźæŸŕåŇĚèčĚåŹĺæŸŕåŔŕäżěä¡£çŤĺäijåéĂŠçżŹ `logged()`
çŽĎåŔĆæŢřçŽĎãĂĆ

èőÍèőž

åőŽäźĽäÿĂäÿłæŐěåŔŮåŔĆæŢřçŽĎåŇĚèčĚåŹĺçIJŃäÿŁåŐżæŕŤè¿Čåd'■æİĆäÿžèęĄæŸŕåŻääÿžåžŢåśĆ

```
@decorator(x, y, z)
def func(a, b):
    pass
```

èčĚéěřåŹĺåd'ĎçŘĘè£ĞçÍŃèů§äÿŃéİćçŽĎèřČçŤĺæŸŕç■L'æŢĹçŽĎ;

```
def func(a, b):
    pass
func = decorator(x, y, z)(func)
```

`decorator(x, y, z)` çŽĎè£ŤåŻđçżŞæđIJå£ĚéążæŸŕäÿĂäÿłåŔŕèřČçŤĺårźèśąïijŇåőČæŐěåŮäÿĂ
åŘŕäžěåŔĆèĂČ9.7åřŔèŁĆäÿ■åŔęåd'ŰäÿĂäÿłåŘŕæŐěåŔŮåŔĆæŢřçŽĎåŇĚèčĚåŹĺä¿Ńå■ŘãĂĆ

11.5 9.5 åŘŕèĞłåőŽäźĽåśđæĂğçŽĎèčĚéěřåŹĺ

éŮőécŸ

ä¡ăæČşåĘŹäÿĂäÿłèčĚéěřåŹĺæİěåŇĚèčĚäÿĂäÿłåĞ¡æŢřïijŇåźűäÿŤåĚĄèőÿçŤĺæĹůæŔŘä¿ŻåŔĆæŢřåIJĺè

èğčåĘşæŰźæąĹ

åijŢåĚěäÿĂäÿłèő£éŮőåĞ¡æŢřïijŇä¡£çŤĺ `nonlocal` æİěä£őæŤźåĘĚéČĺåŔŸéĞŔãĂĆ
çĎűåŘŐè£Źäÿłèő£éŮőåĞ¡æŢřèćńä¡IJäÿžäÿĂäÿłåśđæĂğètŃåĂijçżŹåŇĚèčĚåĞ¡æŢřãĂĆ

```
from functools import wraps, partial
import logging
# Utility decorator to attach a function as an attribute of obj
def attach_wrapper(obj, func=None):
    if func is None:
        return partial(attach_wrapper, obj)
    setattr(obj, func.__name__, func)
    return func

def logged(level, name=None, message=None):
    '''
    Add logging to a function. level is the logging
    level, name is the logger name, and message is the
    log message. If name and message aren't specified,
    they default to the function's module and name.
```

```
    '''
    def decorate(func):
        logname = name if name else func.__module__
        log = logging.getLogger(logname)
        logmsg = message if message else func.__name__

        @wraps(func)
        def wrapper(*args, **kwargs):
            log.log(level, logmsg)
            return func(*args, **kwargs)

        # Attach setter functions
        @attach_wrapper(wrapper)
        def set_level(newlevel):
            nonlocal level
            level = newlevel

        @attach_wrapper(wrapper)
        def set_message(newmsg):
            nonlocal logmsg
            logmsg = newmsg

        return wrapper

    return decorate

# Example use
@logged(logging.DEBUG)
def add(x, y):
    return x + y

@logged(logging.CRITICAL, 'example')
def spam():
    print('Spam!')
```

äÿŃéÌćæŸŕäžd'äžŠçŐŕåćČäÿŃçŽĎä¡£çŤĺä¿Ńå■ŘïijŽ

```
>>> import logging
>>> logging.basicConfig(level=logging.DEBUG)
>>> add(2, 3)
DEBUG:__main__:add
5
>>> # Change the log message
>>> add.set_message('Add called')
>>> add(2, 3)
DEBUG:__main__:Add called
5
>>> # Change the log level
>>> add.set_level(logging.WARNING)
>>> add(2, 3)
```

```
WARNING:__main__:Add called
5
>>>
```

èőÍèőž

è£ŹäÿĂåřŔèŁĆçŽĎåĚşéŤőçĆźåIJÍäžŐèő£éŮőåĞ¡æŢř(åęĆ `set_message()` åŠŇ `set_level()`)ïijŇåőČäžňèćńä¡IJäÿžåśđæĂğètŃçżŹåŇĚèčĚåŹÍãĂĆ æŕŔäÿłèő£éŮőåĞ¡æŢřåĚĄèőÿä¡£çŤÍ `nonlocal` æÌěä£őæŤźåĞ¡æŢřåĘĚéČÍçŽĎåŔŸéĞŔãĂĆ

è£ŸæIJL'äÿĂäÿłäżd'äžžåŘČæČŁçŽĎåIJřæŰźæŸŕèő£éŮőåĞ¡æŢřäijŽåIJÍåd'ŽåśĆèčĚéěřåŹÍéŮt'äijăæŠ■ `@functools.wraps` æşÍèğč)ãĂĆ ä¿ŃåęĆïijŇåĄĞèő¿ä¡ååijŢåĚěåŔęåd'ŰäÿĂäÿłèčĚéěřåŹÍïijŇæŕŤåęĆ9.2å `@timethis` ïijŇåČŔäÿŃéÌćè£Źæăůïijž

```
@timethis
@logged(logging.DEBUG)
def countdown(n):
    while n > 0:
        n -= 1
```

ä¡ăäijŽåŔŠçŐřèő£éŮőåĞ¡æŢřä¿ÌæŮğæIJL'æŢĹïijž

```
>>> countdown(10000000)
DEBUG:__main__:countdown
countdown 0.8198461532592773
>>> countdown.set_level(logging.WARNING)
>>> countdown.set_message("Counting down to zero")
>>> countdown(10000000)
WARNING:__main__:Counting down to zero
countdown 0.8225970268249512
>>>
```

ä¡ăè£ŸäijŽåŔŠçŐřå■şä¡£èčĚéěřåŹÍåČŔäÿŃéÌćè£ŹæăůäžěçżÿåŔ■çŽĎæŰźåŘŠæŐŠæŤ¿ïijŇæŢĹæđIJäź

```
@logged(logging.DEBUG)
@timethis
def countdown(n):
    while n > 0:
        n -= 1
```

è£ŸèČ¡éĂŽè£Ğä¡£çŤÍlambdaèąÍè¿¿åijŔäžčçăĄæÌěèőľ'èő£éŮőåĞ¡æŢřçŽĎè£ŤåŻđäÿ■åŘŇçŽĎèő¿åőŽå

```
@attach_wrapper(wrapper)
def get_level():
    return level

# Alternative
wrapper.get_level = lambda: level
```

äÿĂäÿłæŕŤè¿ČéŽ¿çŘĘèğčçŽĎåIJřæŰźåřśæŸŕåŕźäžŐèő£éŮőåĞ¡æŢřçŽĎéęŰæňąä¡£çŤĺãĂĆä¿ŃåęĆïijŇ

```
@wraps(func)
def wrapper(*args, **kwargs):
    wrapper.log.log(wrapper.level, wrapper.logmsg)
    return func(*args, **kwargs)

# Attach adjustable attributes
wrapper.level = level
wrapper.logmsg = logmsg
wrapper.log = log
```

è£ŹäÿłæŰźæşŢäź§åŘŕèČ¡æ■čåÿÿåůëä¡IJïijŇä¡EąL'■æŔŘæŸŕåőČå£ĚéążæŸŕæIJĂåď'ŰåśÇçŽĎèčĚéěřåŹ
åęĆæđIJåőČçŽĎäÿŁéİćè£ŸæIJL'åŘęåď'ŰçŽĎèčĚéěřåŹÍ(æŕŤåęĆäÿŁéİćæŔŘåĹřçŽĎ
`@timethis` ä¿Ńå■Ř)ïijŇéĆčäźĹåőČäijŽéŽŘèŮŔåžŢåśĆåśđæĂğïijŇä¡£å¿Ůä£őæŤźåőČäžñæšąæIJL'äżżä¡Ţ
èĂŇéĂŽè£Ğä¡£çŤĺèő£éŮőåĞ¡æŢřåŕśèČ¡éĄ£åĚ■è£ŹæăůçŽĎåśĂéŹŘæĂğãĂĆ

æIJĂåŘŐæŔŘäÿĂçĆźïijŇè£ŹäÿĂåřŔèŁĆçŽĎæŰźæąĹäź§åŘŕäżěä¡IJäÿž9.9åřŔèŁĆäÿ■èčĚéěřåŹĺçśżçŽĺ

11.6 9.6 åÿęåŘŕéĂĽåŘĆæŢřçŽĎèčĚéěřåŹÍ

éŮőécŸ

ä¡ăæČşåĘŹäÿĂäÿłèčĚéěřåŹĺïijŇæŮćåŘŕäżěäÿ■äijăåŘĆæŢřçżŹåőČïijŇæŕŤåęĆ
`@decorator` ïijŇ äź§åŘŕäżěäijăéĂŠåŘŕéĂĽåŘĆæŢřçżŹåőČïijŇæŕŤåęĆ
`@decorator(x,y,z)` ãĂĆ

èğčåĘşæŰźæąĹ

äÿŃéİćæŸŕ9.5åřŔèŁĆäÿ■æŮěå£ŮèčĚéěřåŹĺçŽĎäÿĂäÿłä£őæŤźçĽ'ĹæIJñïijŽ

```
from functools import wraps, partial
import logging

def logged(func=None, *, level=logging.DEBUG, name=None,␣
↪message=None):
    if func is None:
        return partial(logged, level=level, name=name,␣
↪message=message)

    logname = name if name else func.__module__
    log = logging.getLogger(logname)
    logmsg = message if message else func.__name__

    @wraps(func)
    def wrapper(*args, **kwargs):
        log.log(level, logmsg)
        return func(*args, **kwargs)
```

```
    return wrapper

# Example use
@logged
def add(x, y):
    return x + y

@logged(level=logging.CRITICAL, name='example')
def spam():
    print('Spam!')
```

åŘŕäžěçIJŃåĹřïijŇ@logged èčĚéěřåŹĺåŘŕäžěåŘŇæŮűäÿ■åÿęåŘĆæŢřæĹŰåÿęåŘĆæŢřãĂĆ

èőĺèőž

è£ŹéĞŇæŔŘåĹřçŽĎè£ŹäÿłéŮőécŸåřśæŸŕéĂŽåÿÿæL'Ăèŕť'çŽĎçijŰçĺŃäÿĂèĞť'æĂğéŮőécŸãĂĆ
å¡ŞæĹŚäžňä¡£çŤĺèčĚéěřåŹĺçŽĎæŮűåĂŹïijŇåď'ğéČĺåĹĘçĺŃåžŔåŚŸäźăæČŕäžĘèęĄäźĹäÿ■çżŹåőČäžňäijåéĂ
åĚűåőđäżŐæŁĂæIJŕäÿŁæİěèőšïijŇæĹŚäžňåŔŕäžěåőŽäźL'äÿĂäÿłæL'ĂæIJL'åŔĆæŢřéČ¡æŸŕåŔŕéĂL'çŽĎèčĚ

```
@logged()
def add(x, y):
    return x+y
```

ä¡ĘæŸŕïijŇè£Źçğ■åĘŹæşŢåźűäÿ■çňęåŘĹæĹŚäžňçŽĎäźăæČŕïijŇæIJL'æŮűåĂŹçĺŃåžŔåŚŸå£Ÿèőřå£ăä
è£ŹéĞŇæĹŚäžňåŘŚä¡ăåśŢçď'žäžĘåęĆä¡Ţäžěäÿ'ĂèĞť'çŽĎçijŰçĺŃéčŐæăijæİěåŘŇæŮűæżąèűşæšąæIJL'æŃňå

äÿžäžĘçŘĘèğčäžčçăĄæŸŕåęĆä¡Ţåůěä¡IJçŽĎïijŇä¡ăéIJĂèęĄéİđåÿÿçE§æĆL'èčĚéěřåŹĺæŸŕåęĆä¡Ţä¡IJçŤ
åŕźäžŐäÿĂäÿłåČŔäÿŃéİćè£ŹæăůçŽĎçőĂå■ŢèčĚéěřåŹĺïijŽ

```
# Example use
@logged
def add(x, y):
    return x + y
```

è£ŹäÿłèřČçŤĺåžŔåĹŮèů§äÿŃéİćç■L'äžůïijŽ

```
def add(x, y):
    return x + y

add = logged(add)
```

è£ŹæŮűåĂŹïijŇèćńèčĚéěřåĞ¡æŢřäijŽèćńå¡ŞåĄŽçňňäÿĂäÿłåŔĆæŢřçŻť'æŐěäijăéĂŠçżŹ
logged èčĚéěřåŹĺãĂĆ åŽăæ■d'ïijŇlogged() äÿ■çŽĎçňňäÿĂäÿłåŔĆæŢřářśæŸŕèćńåŇĚèčĚåĞ¡æŢřæIJňè

èĂŇářźäžŐäÿĂäÿłäÿŃéİćè£ŹæăůæIJL'åŔĆæŢřçŽĎèčĚéěřåŹĺïijŽ

```
@logged(level=logging.CRITICAL, name='example')
def spam():
    print('Spam!')
```

èřČçŤÍåžŔåĹŮèů§äÿŃéİćç■L’äžůïijŽ

```
def spam():
    print('Spam!')
spam = logged(level=logging.CRITICAL, name='example')(spam)
```

åĹİåğŃèřČçŤÍ `logged()` åĞ¡æŢřæŮűïijŃèćńåŇĚèčĚåĞ¡æŢřåźűæšąæIJL’äijăéĂŠè£ŻæİěãĂĆ åŻăæ■ď’åIJÍèčĚéěřåŹÍåĘĚïijŇåőČå£Ěéążæ˙ŸŕåŔŕéĂL’çŽĎãĂĆè£ŹäÿłåŔ■è£ĞæİěäijŽè£ńä¡£åĚűäžŮåŔĆæŢřă åźűäÿŤïijŇä¡Ęè£ŹäžŻåŔĆæŢřèćńäijăéĂŠè£ŻæİěåŘŐïijŃèčĚéěřåŹÍèęĄè£ŤåŻđäÿĂäÿłæŐěåŔŮäÿĂäÿłåĞ¡æŢ äÿžäžĘè£ŹæăůåĄŽïijŇæĹŚäžňä¡£çŤÍäžĘäÿĂäÿłæŁĂåůğïijŇářśæŸŕåĹľçŤÍ `functools.partial` ãĂĆ åőČäijŽè£ŤåŻđäÿĂäÿłæIJłåőŇåĚÍåĹİåğŃåŇŰçŽĎèĞłežńïijŃéŹď’äžĘèćńåŇĚèčĚåĞ¡æŢřåď’ åŔŕäžěåŔĆèĂČ7.8ářŔèŁĆèŐůåŔŰæŻť’åď’Ž `partial()` æŰźæşŢçŽĎç§èèŕĘãĂĆ

11.7 9.7 åĹľçŤÍèčĚéěřåŹÍåijžåĹűåĞ¡æŢřäŸŁçŽĎçśžåđŃæčĂæ§ě

éŮőécŸ

ä¡IJäÿžæ§Řçğ■çijŰçÍŃèğĎçžęïijŃä¡ăæČşåIJÍåŕźåĞ¡æŢřåŔĆæŢřè£ŻèąŇåijžåĹűçśžåđŃæčĂæ§ěãĂĆ

èğčåĘşæŰźæąĹ

åIJÍæijŤçď’žåőđéŹĚäžčçăĄåL’■ïijŇåĚĹèŕť’æŸŐæĹŚäžňçŽĎçŻőæăĞïijŽèČ¡åŕźåĞ¡æŢřåŔĆæŢřçśžåđŃè

```
>>> @typeassert(int, int)
... def add(x, y):
...     return x + y
...
>>>
>>> add(2, 3)
5
>>> add(2, 'hello')
Traceback (most recent call last):
    File "<stdin>", line 1, in <module>
    File "contract.py", line 33, in wrapper
TypeError: Argument y must be <class 'int'>
>>>
```

äÿŃéİćæŸŕä¡£çŤÍèčĚéěřåŹÍæŁĂæIJŕæİěåőđçŐř `@typeassert` ïijŽ

```
from inspect import signature
from functools import wraps

def typeassert(*ty_args, **ty_kwargs):
    def decorate(func):
        # If in optimized mode, disable type checking
        if not __debug__:
            return func
```

```
        # Map function argument names to supplied types
        sig = signature(func)
        bound_types = sig.bind_partial(*ty_args, **ty_kwargs).
↪arguments

        @wraps(func)
        def wrapper(*args, **kwargs):
            bound_values = sig.bind(*args, **kwargs)
            # Enforce type assertions across supplied arguments
            for name, value in bound_values.arguments.items():
                if name in bound_types:
                    if not isinstance(value, bound_types[name]):
                        raise TypeError(
                            'Argument {} must be {}'.format(name,␣
↪bound_types[name])
                            )
            return func(*args, **kwargs)
        return wrapper
    return decorate
```

åŔŕäžěçIJŃåĞžè£ŹäýłèčĚéěřåŹĺéİđåýÿçĄţæť żïijŇæŮćåŔŕäžěæŇĞåőŽæĽĂæIJĽåŔĆæŢřçśžåđŃïijŇäź
åźűäýŤåŔŕäžěéĂŽè£Ğä¡■ç¡őæĹŰåĚşéŤőå■ŮæİěæŇĞåőŽåŔĆæŢřçśžåđŃãĂĆäýŃéĺćæŸŕä¡£çŤĺçď žä¿ŃïijŽ

```
>>> @typeassert(int, z=int)
... def spam(x, y, z=42):
...     print(x, y, z)
...
>>> spam(1, 2, 3)
1 2 3
>>> spam(1, 'hello', 3)
1 hello 3
>>> spam(1, 'hello', 'world')
Traceback (most recent call last):
File "<stdin>", line 1, in <module>
File "contract.py", line 33, in wrapper
TypeError: Argument z must be <class 'int'>
>>>
```

èőĺèőž

è£ŹèŁĆæŸŕéńŸçžğècĚéěřåŹĺçď žä¿ŃïijŇåijŢåĚěäžĘå¿Ĺåď ŽéĞ■èęĄçŽĎæęĆå£ţãĂĆ

éęŰåĚĹïijŇècĚéěřåŹĺåŔłäijŽåIJĺåĞ¡æŢřåőŽäźĽæŮűècńèřČçŤĺäÿĂæňąãĂĆ
æIJĽæŮűåĂŹä¡ääŐżæŐĽèčĚéěřåŹĺçŽĎåŁ§èČ¡ïijŇéĆčäźĹä¡ääŔłéIJĂèęĄçőĂå■ŢçŽĎè£ŤåŽđècńèčĚéěřåĞ¡
äÿŃéİćçŽĎäžčçăĄäÿ■ïijŇåęĆæđIJåĚĺåśĂåŔŸéĞŘãĂĂ__debug__
èćńèő¿ç¡őæĹŘäžĘFalse(å¡Şä¡ää¡£çŤĺ-OæĹŰ-OOåŔĆæŢřçŽĎäijŸåŇŰæĺąåijŔæĽğèąŇçĺŃåžŔæŮű)ïijŇ
éĆčäźĹåřśçŻť æŐèè£ŤåŽđæIJłä£őæŤźè£ĞçŽĎåĞ¡æŢřæIJňèžńïijŽ

```
def decorate(func):
    # If in optimized mode, disable type checking
    if not __debug__:
        return func
```

åĚűæňąïijŇè£ŹéĞŇè£ŸåŕźèćńåŇĚèčĚåĞ¡æŢřçŽĎåŔĆæŢřç■¿åŘ■è£Żèą
inspect.signature() åĞ¡æŢřãĂĆ çőÅå■ŢæİěëőšïijŇåőČè£ŘèąÑä¡ăæŔŘåŔŰäÿĂäÿłåŔŕěřČçŤĺåŕźèšą

```
>>> from inspect import signature
>>> def spam(x, y, z=42):
...     pass
...
>>> sig = signature(spam)
>>> print(sig)
(x, y, z=42)
>>> sig.parameters
mappingproxy(OrderedDict([('x', <Parameter at 0x10077a050 'x'>),
('y', <Parameter at 0x10077a158 'y'>), ('z', <Parameter at␣
↪0x10077a1b0 'z'>)]))
>>> sig.parameters['z'].name
'z'
>>> sig.parameters['z'].default
42
>>> sig.parameters['z'].kind
<_ParameterKind: 'POSITIONAL_OR_KEYWORD'>
>>>
```

èčĚéěřåŹÍçŽĎåijĂåğŃéČĺåĹĘïijŇæĹŚäžňä¡£çŤĺäžĘ bind_partial()
æŰźæşŢæİěæĽ’ğèąŇäżŐæŇĞåőŽçśžåđŃåĹřåŘ■çğřçŽĎéČĺåĹĘçżŚåőŽãĂĆ
äÿŃéİćæŸŕä¿Ńå■ŘæijŤçď’žïijŽ

```
>>> bound_types = sig.bind_partial(int,z=int)
>>> bound_types
<inspect.BoundArguments object at 0x10069bb50>
>>> bound_types.arguments
OrderedDict([('x', <class 'int'>), ('z', <class 'int'>)])
>>>
```

åIJÍè£ŹäÿłéČĺåĹĘçżŚåőŽäÿ■ïijŇä¡ăåŔŕäžěæşÍæĎŔåĹřçijžåď’śçŽĎåŔĆæŢřèćńå£¡çŢěäžĘ(æŕŤåęĆåźűæš
äÿ■è£ĞæIJĂéĞ■èęĄçŽĎæŸŕåĹŻåżžäžĘäÿĂäÿłæIJL’åžŔå■ŮåĚÿ bound_types.
arguments ãĂĆ è£Źäÿłå■ŮåĚÿäijŽåřĘåŔĆæŢřåŘ■äžěåĞ¡æŢřç■¿åŘ■äÿ■çŽÿåŘŇéąžåžŔæŸăåřĎåĹřæŇĞå
åIJÍæĹŚäžňçŽĎèčĚéěřåŹÍä¿Ńå■Řäÿ■ïijŇè£ŹäÿłæŸăåřĎåŇĚåŘńäžĘæĹŚäžňèęĄåijžåĹűæŇĞåőŽçŽĎçśžåđŇ

åIJÍèčĚéěřåŹÍåĹŻåżžçŽĎåőđéŹĚåŇĚèčĚåĞ¡æŢřäÿ■ä¡£çŤĺåŕžĘ
sig.bind() æŰźæşŢãĂĆ bind() èů§ bind_partial()
çśžäijijïijŇä¡ĘæŸŕåőČäÿ■åĚĄèőÿå£¡çŢěäżžä¡ŢåŔĆæŢřãĂĆåŻăæ■d’æIJL’äžĘäÿŃéİćçŽĎçżŞæđIJïijŽ

```
>>> bound_values = sig.bind(1, 2, 3)
>>> bound_values.arguments
OrderedDict([('x', 1), ('y', 2), ('z', 3)])
>>>
```

ä¡£çŤÍè£ŹäýłæŸäářĎæĹŚäžňåŔŕäžěå¿Ĺè¡żæİ¿çŽĎåőđçŐřæĹŚäžňçŽĎåijžåĹűçśžåđŃæčĂæ§ěïijŽ

```
>>> for name, value in bound_values.arguments.items():
...     if name in bound_types.arguments:
...         if not isinstance(value, bound_types.arguments[name]):
...             raise TypeError()
...
>>>
```

äý■è£Ğè£ŹäýłæŰźæąĹè£ŸæIJL'çĆźářŔçŚŢçŰţïijŇåőČářźäžŐæIJL'éżŸèőd'åĂijçŽĎåŔĆæŢřåźűäý■éĂ
ærŤåęĆäýŃéİćçŽĎäžčçăĄåŔŕäžěæ■čåÿÿåůëä¡IJïijŇář¡çőąitemsçŽĎçśžåđŃæŸŕéŤŹèŕŕçŽĎïijŽ

```
>>> @typeassert(int, list)
... def bar(x, items=None):
...     if items is None:
...         items = []
...     items.append(x)
...     return items
>>> bar(2)
[2]
>>> bar(2,3)
Traceback (most recent call last):
    File "<stdin>", line 1, in <module>
    File "contract.py", line 33, in wrapper
TypeError: Argument items must be <class 'list'>
>>> bar(4, [1, 2, 3])
[1, 2, 3, 4]
>>>
```

æIJĂåŘŐäýĂçĆźæŸŕåĚşäžŐéĂĆçŤÍèčĚéěřåŹĺåŔĆæŢřåŠŇåĞ¡æŢřæşÍèğčäźŃéŮt'çŽĎäžL'èőžãĂĆ
ä¿ŃåęĆïijŇäÿžäžĂäźĹäý■åČŔäýŃéİćè£Źæăůå ĘŹäýĂäýłèčĚéěřåŹĺæİěæ§ěæL'¿åĞ¡æŢřäý■çŽĎæşÍèğčåŚćïij§

```
@typeassert
def spam(x:int, y, z:int = 42):
    print(x,y,z)
```

äýĂäýłåŔŕèČ¡çŽĎåŐ§åŽăæŸŕåęĆæđIJä¡£çŤÍäžĘåĞ¡æŢřåŔĆæŢřæşÍèğčïijŇéĆčäźĹåřśèćńéŹŘåĹűäžĘãA
åęĆæđIJæşÍèğčèćńçŤÍæİěåĄŽçśžåđŃæčĂæ§ěåřśäý■èČ¡åĄŽåĚűäžŰäžŃæČĚäžĘãĂĆèĂŃäýŤ
@typeassert äý■èČ¡åĘ■çŤÍäžŐä¡£çŤÍæşÍèğčåĄŽåĚűäžŰäžŃæČĚçŽĎåĞ¡æŢřäžĘãĂĆ
èĂŃä¡£çŤÍäýŁéİćçŽĎèčĚéěřåŹĺåŔĆæŢřçĄţæť'žæĂğåď'ğåď'ŽäžĘïijŇäźš§æŽť'åŁäéĂŽçŤÍãĂĆ

åŔŕäžěåIJÍPEP 362äžěåŔŁ inspect æÍąåİŮäý■æL'¿åĹřæŽť'åď'ŽåĚşäžŐåĞ¡æŢřåŔĆæŢřåŕźèśąçŽĎä£ą

11.8 9.8 åřĘèčĚéěřåŹĺåőŽäźL'äÿžçśžçŽĎäÿĂéČĺåĹĘ

éŮőécŸ

ä¡ăæČşåIJÍçśžäý■åőŽäźL'èčĚéěřåŹĺïijŇåźűåřĘåĚűä¡IJçŤÍåIJÍåĚűäžŰåĞ¡æŢřæĹŰæŰźæşŢäýŁãĂĆ

èğčåĘşæŰźæąĹ

åIJÍçśżéĞŇéİćåőŽäźĽ'èčĚéěřåŹÍå¿ĹçőĂå■ŢïijŇä¡ĘæŸŕä¡ăéęŰåĚĹèęĄçąőèőď'åőČçŽĎä¡£çŤÍæŰźåijŔãÁäÿŃéİćæĹŚäżñçŤÍä¿Ńå■ŘæİěéŸŘè£řåőČäżñçŽĎäÿ■åŘŇïijŽ

```
from functools import wraps

class A:
    # Decorator as an instance method
    def decorator1(self, func):
        @wraps(func)
        def wrapper(*args, **kwargs):
            print('Decorator 1')
            return func(*args, **kwargs)
        return wrapper

    # Decorator as a class method
    @classmethod
    def decorator2(cls, func):
        @wraps(func)
        def wrapper(*args, **kwargs):
            print('Decorator 2')
            return func(*args, **kwargs)
        return wrapper
```

äÿŃéİćæŸŕäÿĂä¡£çŤÍä¿Ńå■ŘïijŽ

```
# As an instance method
a = A()
@a.decorator1
def spam():
    pass
# As a class method
@A.decorator2
def grok():
    pass
```

äžŤçżĘèğĆåŕ§åŔŕäžěåŔŚçŐřäÿĂäÿłæŸŕåőđä¿ŃèřČçŤÍïijŇäÿĂäÿłæŸŕçśżèřČçŤÍãĂĆ

èőÍèőž

åIJÍçśżäÿ■åőŽäźĽ'èčĚéěřåŹÍåĹİçIJŃäÿŁåŐżåě¡åČŔå¿ĹåěĞæĂłïijŇä¡ĘæŸŕåIJÍæăĞåĞĘåžŞäÿ■æIJL'å¿ĹçĽźå Ĺńç ŽĎïijŇ@property èčĚéěřåŹÍåőđéŹĚäÿŁæŸŕäÿĂäÿłçśżïijŇåőČéĞŇéİćåőŽäźĽ'äžĘäÿĽ'äÿłæŰźæş Ţ getter(), setter(), deleter(), æŕŘäÿĂäÿłæŰźæş ŢéČ¡æŸŕäÿĂäÿłèčĚéěřåŹÍãĂĆä¿ŃåęĆïijŽ

```
class Person:
    # Create a property instance
    first_name = property()

    # Apply decorator methods
```

```
    @first_name.getter
    def first_name(self):
        return self._first_name

    @first_name.setter
    def first_name(self, value):
        if not isinstance(value, str):
            raise TypeError('Expected a string')
        self._first_name = value
```

åőČäÿžäżĂäźĹèęĄè£ŹäźĹåőŽäźL'çŽĎäÿżèęĄåŐ§åŻäæŸŕåŘĎçğ■äÿ■åŘŇçŽĎèčĚéěřåŹĺæŰźæşŢäijŽåI
`property` åőđä¿ŃäÿŁæŞ■ä¡IJåőČçŽĎçŁűæĂĄãĂĆ åŻăæ■d'ïijŇäżżä¡ŢæŮűåĂŹåŘłèęĄä¡ăçćřåĽřéIJĂèęĄå

åIJĺçśżäÿ■åőŽäźL'èčĚéěřåŹĺæIJL'äÿłéŽ¿çŘĘèğčçŽĎåIJřæŰźåřśæŸŕåŕźäžŐéćÍåd'ŰåŔĆæŢř
`self` æĹŰ `cls` çŽĎæ■čçąőä¡£çŤĺãĂĆ åř¡çőąæIJĂåd'ŰåśĆçŽĎèčĚéěřåŹĺåĞ¡æŢřæŕŤåęĆ
`decorator1()` æĹŰ `decorator2()` éIJĂèęĄæŔŘä¿ŻäÿĂäÿł `self`
æĹŰ `cls` åŔĆæŢřïijŇ ä¡ĘæŸŕåIJĺäÿd'äÿłèčĚéěřåŹĺåĘĚéČĺèćńåĹŻåżžçŽĎ
`wrapper()` åĞ¡æŢřåźűäÿ■éIJĂèęĄåŇĚåŘńè£Źäÿł `self` åŔĆæŢřãĂĆ
ä¡ăåŤŕäÿĂéIJĂèęĄè£ŹäÿłåŔĆæŢřæŸŕåIJĺä¡äçąőåőđèęĄèő£éŮőåŇĚèčĚåŹĺäÿ■è£Źäÿłåőđä¿ŃçŽĎæ§ŘäżŽéC

åŕźäžŐçśżéĞŇéİćåőŽäźL'çŽĎåŇĚèčĚåŹĺè£ŸæIJL'äÿĂçĆźæŕŤè¿ČéŽ¿çŘĘèğčïijŇåŕśæŸŕåIJĺæűL'åŘŁåĺ
ä¿ŃåęĆïijŇåĄĞèő¿ä¡ăæČşèőľ'åIJĺAäÿ■åőŽäźL'çŽĎèčĚéěřåŹĺä¡IJçŤĺåIJĺå■ŘçśżBäÿ■ãĂĆä¡ăéIJĂèęĄåČŔäÿŇ

```
class B(A):
    @A.decorator2
    def bar(self):
        pass
```

äź§åŕśæŸŕèŕt'ïijŇèčĚéěřåŹĺèęĄèćńåőŽäźL'æĹŘçśżæŰźæşŢåźűäÿŤä¡ăå£ĚéążæŸ¿åijŔçŽĎä¡£çŤĺçĹűçśż
ä¡ăäÿ■èČ¡ä¡£çŤĺ `@B.decorator2` ïijŇåŽăäÿžåIJĺæŰźæşŢåőŽäźL'æŮűïijŇè£ŹäÿłçśżBè£ŸæšąæIJL'èćńåĹŻ

11.9 9.9 åřĘèčĚéěřåŹĺåőŽäźL'äÿžçśż

éŮőécŸ

ä¡ăæČşä¡£çŤĺäÿĂäÿłèčĚéěřåŹĺåŐżåŇĚèčĚåĞ¡æŢřïijŇä¡EæŸŕåÿŇæIJŻè£ŤåŽđäÿĂäÿłåŔŕèřČçŤĺçŽĎåő
ä¡ăéIJĂèęĄèőľä¡äçŽĎèčĚéěřåŹĺåŔŕäżěåŘŇæŮűåůěä¡IJåIJĺçśżåőŽäźL'çŽĎåĘĚéČĺåŠŇåd'ŰéČĺãĂĆ

èğčåĘşæŰźæąĹ

äÿžäžĘåřĘèčĚéěřåŹĺåőŽäźL'æĹŘäÿĂäÿłåőđä¿ŃïijŇä¡ăéIJĂèęĄçąőä£ÍåőČåőđçŐřäžĘ
`__call__()` åŠŇ `__get__()` æŰźæşŢãĂĆ ä¿ŃåęĆïijŇäÿŃéİćçŽĎäżčçăĄåőŽäźL'äžĘäÿĂäÿłçśżïijŇåőČå

```
import types
from functools import wraps

class Profiled:
    def __init__(self, func):
```

```
        wraps(func)(self)
        self.ncalls = 0

    def __call__(self, *args, **kwargs):
        self.ncalls += 1
        return self.__wrapped__(*args, **kwargs)

    def __get__(self, instance, cls):
        if instance is None:
            return self
        else:
            return types.MethodType(self, instance)
```

ä¡ääŔŕäžěářĘåőČå¡ŞåĄŽäÿĂäÿłæŹőéĂŽçŽĎèčĚéěřåŹĺæİěä¡£çŤĺïijŇåIJĺçśžéĞŇéİćæĹŰåď˙ŰéİćéČ¡åŔŕ

```
@Profiled
def add(x, y):
    return x + y

class Spam:
    @Profiled
    def bar(self, x):
        print(self, x)
```

åIJĺäžď˙äžŠçŐŕåćČäÿ■çŽĎä¡£çŤĺçď˙žä¿ŃïijŽ

```
>>> add(2, 3)
5
>>> add(4, 5)
9
>>> add.ncalls
2
>>> s = Spam()
>>> s.bar(1)
<__main__.Spam object at 0x10069e9d0> 1
>>> s.bar(2)
<__main__.Spam object at 0x10069e9d0> 2
>>> s.bar(3)
<__main__.Spam object at 0x10069e9d0> 3
>>> Spam.bar.ncalls
3
```

èőĺèőž

åřĘèčĚéěřåŹĺåőŽäźL˙æĹŘçśžéĂŽåÿÿæŸŕå¿ĹçőĂå■ŢçŽĎãĂĆä¡ĘæŸŕè£ŹéĞŇè£ŸæŸŕæIJL˙äÿĂäžŻçżĘ

éęŰåĚĹïijŇä¡£çŤĺ `functools.wraps()` åĞ¡æŢřçŽĎä¡IJçŤĺèů§äźŇåL˙■è£ŸæŸŕäÿĂæăůïijŇåřĘèćńå

åĚűæňąïijŇéĂŽåÿÿå¿Ĺåőźæ˙ŸŞäijŽå£¡èğĘäÿŁéİćçŽĎ `__get__()` æŰźæşŢãĂĆåęĆæđIJä¡åå£¡çŢěåőČïijŇä£ÍæŇĄåĚűäžŰäžčçăĄäÿ■åŔŸåĘ■æňąè£ŘèąŇïijŇ

ä¡ääijŽåŔŚçŐřå¡Şä¡ääŐżèřČçŤĺèćńèčĚéěřåőđä¿ŃæŰźæşŢæŮűåĞžçŐřå¿ĹåěĞæĂłçŽĎéŮőécŸãĂĆä¿ŃåęĆï

```
>>> s = Spam()
>>> s.bar(3)
Traceback (most recent call last):
...
TypeError: bar() missing 1 required positional argument: 'x'
```

åĞžéŤŹåŐ§åŻäæŸřå¡ŞæŰźæşŢåĞ¡æŢřåIJĺäÿĂäÿłçśżäÿ■èćńæ§ěæL'¿æŮűïijŇåőČäżňçŽĎ __get__() æŰźæşŢä¿İæ■őæŔŔè£řåŹĺå■ŔèőőèćńèřČçŤĺïijŇ åIJĺ8.9åřŔèŁĆåůšçżŔèőšè£řè£ĞæŔŔè£řåŹĺå■Ŕèőőäž Ęã ĂĆåIJĺè£ŹéĞŇïijŇ__get__() çŽĎçŽőçŽĎæŸřåĽŻåżžäÿĂäÿłçżŚåőŽæŰźæşŢåŕźèšą (æIJĂçżĹäijŽçżŹè£ŹäÿłæŰźæşŢäijåéĂŠselfåŔĆæŢř)ã

```
>>> s = Spam()
>>> def grok(self, x):
...     pass
...
>>> grok.__get__(s, Spam)
<bound method Spam.grok of <__main__.Spam object at 0x100671e90>>
>>>
```

__get__() æŰźæşŢæŸřäÿžäžEçąőä£İçżŚåőŽæŰźæşŢåŕźèšąèČ¡èćńæ■čçąőçŽĎåĽŻåżžãĂĆ type.MethodType() æĽŃåŁĺåĽŻåżžäÿĂäÿłçżŚåőŽæŰźæşŢæİěä¡£çŤĺãĂĆåŔłæIJL'å¡Şåőđä¿ŃèćńäĄ£çŤ åęĆæđIJè£ŹäÿłæŰźæşŢæŸřåIJĺçśżäÿŁéİćæİěèő£éŮőïijŇ éĆčäźĹ __get__() äÿ■çŽĎin-stanceåŔĆæŢřäijŽèćńèő¿ç¡őæĽŘNoneåźűçŻt'æŐěè£ŤåŻđ Profiled åőđä¿ŃæIJňèžńãĂĆ è£ŹæåůçŽĎèřİæĹŚäžňåřšåŔřäżěæŔŘåŔŰåőČçŽĎ ncalls åšđæĂğäžEãĂĆ

åęĆæđIJä¡ăæČşéĄ£åĚ■äÿĂäžŻæůůäźšïijŇäź§åŔřäżěèĂČèŹŚåŔęåd'ŰäÿĂäÿłä¡£çŤĺéŮ■åŇĚåŠŇ nonlocal åŔŸéĞŘåőđçŐřçŽĎèčĚéěřåŹĺïijŇè£ŹäÿłåIJĺ9.5åřŔèŁĆæIJL'èőšåĽřãĂĆä¿ŃåęĆïijŽ

```
import types
from functools import wraps

def profiled(func):
    ncalls = 0
    @wraps(func)
    def wrapper(*args, **kwargs):
        nonlocal ncalls
        ncalls += 1
        return func(*args, **kwargs)
    wrapper.ncalls = lambda: ncalls
    return wrapper

# Example
@profiled
def add(x, y):
    return x + y
```

è£ŹäÿłæŰźåijŔèů§äźŃåL'■çŽĎæŢĹæđIJåĞääźŐäÿĂæăůïijŇéŹd'äžĘåŕźäžŐ ncalls çŽĎèő£éŮőçŐřåIJĺæŸřéĂŽè£ĞäÿĂäÿłèćńçżŚåőŽäÿžåšđæĂğçŽĎåĞ¡æŢřæİěåőđçŐřïijŇä¿ŃåęĆïijŽ

```
>>> add(2, 3)
5
>>> add(4, 5)
9
>>> add.ncalls()
2
>>>
```

11.10 9.10 äÿžçśżåŠŇéİŹæĂĄæŰźæşŢæŔŘä¿ŻèčĚéěřåŹÍ

éŮőécŸ

ä¡ăæČşçżŹçśżæĹŰéİŹæĂĄæŰźæşŢæŔŘä¿ŻèčĚéěřåŹÍãĂĆ

èğčåĘşæŰźæąĹ

çżŹçśżæĹŰéİŹæĂĄæŰźæşŢæŔŘä¿ŻèčĚéěřåŹÍæŸřå¿ĹçőĂå■ŢçŽĎïijŇäÿ■è£ĞèęAçąőä£İèčĚéěřåŹÍåIJ
`@classmethod` æĹŰ `@staticmethod` äźŃåL’■ãĂĆä¿ŃåęĆïijŽ

```
import time
from functools import wraps

# A simple decorator
def timethis(func):
    @wraps(func)
    def wrapper(*args, **kwargs):
        start = time.time()
        r = func(*args, **kwargs)
        end = time.time()
        print(end-start)
        return r
    return wrapper

# Class illustrating application of the decorator to different␣
↪kinds of methods
class Spam:
    @timethis
    def instance_method(self, n):
        print(self, n)
        while n > 0:
            n -= 1

    @classmethod
    @timethis
    def class_method(cls, n):
        print(cls, n)
        while n > 0:
```

```
            n -= 1

    @staticmethod
    @timethis
    def static_method(n):
        print(n)
        while n > 0:
            n -= 1
```

èčĚéěřåŘŐçŽĎçśżåŠŇéİŹæĂĄæŰźæşŢåŔŕæ■čåÿÿåůěä¡IJïijŇåŔłäÿ■è£Ğåćđå£ăäžĘéćİåđ’ŰçŽĎèőąæŮ

```
>>> s = Spam()
>>> s.instance_method(1000000)
<__main__.Spam object at 0x1006a6050> 1000000
0.11817407608032227
>>> Spam.class_method(1000000)
<class '__main__.Spam'> 1000000
0.11334395408630371
>>> Spam.static_method(1000000)
1000000
0.11740279197692871
>>>
```

èőÍèőž

åęĆæđIJä¡ăæŁŁèčĚéěřåŹÍçŽĎéąžåžŔåĘŹéŤŹäžĘářśäijŽåĞžéŤŹãĂĆä¿ŃåęĆïijŇåĄĞèő¿ä¡ăåČŔäÿŃéİć

```
class Spam:
    @timethis
    @staticmethod
    def static_method(n):
        print(n)
        while n > 0:
            n -= 1
```

éĆčäźĹä¡ăèřČçŤÍè£ŹäÿłéİŹæĂĄæŰźæşŢæŮűůářśäijŽæŁěéŤŹïijŽ

```
>>> Spam.static_method(1000000)
Traceback (most recent call last):
File "<stdin>", line 1, in <module>
File "timethis.py", line 6, in wrapper
start = time.time()
TypeError: 'staticmethod' object is not callable
>>>
```

éŮőécŸåIJÍäžŐ `@classmethod` åŠŇ `@staticmethod` åőđéŹĚäÿŁåźűäÿ■äijŽåĹŽåžžåŔŕçŻt’æŐěřČçŤÍçŽĎåŕźèśąïijŇ
èĂŇæŸŕåĹŽåžžçL’źæőŁçŽĎæŔŔè£ŕåŹÍåŕźèśą(åŔĆèĂČ8.9åřŔèŁĆ)ãĂĆåŻãæ■d’å¡Şä¡ăèŕŢçİĂåIJÍåĚűäžŰèč
çąőä£Ìè£Źçğ■èčĚéěřåŹÍåĞžçŐřåIJÍèčĚéěřåŹÍéŞ¿äÿ■çŽĎçňňäÿĂäÿłä¡■ç¡őåŔŕäžëä£őåd’■è£ŹäÿłéŮőécŸãĂĆ

å¡ŞæĹŚäžňåIJÍæŁ¡èśąå§žçśżäÿ■åőŽäźL’çśżæŰźæşŢåŠŇéİŹæĂĄæŰźæşŢ(åŔĆèĂČ8.12åřŔèŁĆ)æŮűïijŇ
ä¿ŇåęĆïijŇåęĆæđIJä¡äæČşåőŽäźL’äÿĂäÿłæŁ¡èśąçśżæŰźæşŢïijŇåŔřäžěä¡£çŤĺçśżäijijäÿŇéİćçŽĎäžčçăĄïijŽ

```
from abc import ABCMeta, abstractmethod
class A(metaclass=ABCMeta):
    @classmethod
    @abstractmethod
    def method(cls):
        pass
```

åIJÍè£Źæőţäžčçă Ąäÿ■ïijŇ@classmethod èů§ @abstractmethod äÿd’èĂĚçŽĎéąžåžŘæŸŕæIJL’èőšçl’űçŽĎïijŇåęĆæđIJä¡ăèřČæ■ćåőČäžňçŽĎéąžåžŘåřśäijŽåĞžéŤŹãĂĆ

11.11 9.11 èčĚéěřåŹĺäÿžèćńåŇĚèčĚåĞ¡æŢřåćđåŁääŔĆæŢř

éŮőécŸ

ä¡ăæČşåIJÍèčĚéěřåŹĺäÿ■çżŹèćńåŇĚèčĚåĞ¡æŢřåćđåŁäécİåd’ŰçŽĎåŔĆæŢřïijŇä¡ĘæŸŕäÿ■èČ¡å¡śåŞ■è£Ź

èğčåĘşæŰźæąĹ

åŘŕäžěä¡£çŤĺåĚşéŤőå■ŮåŔĆæŢřæİěçżŹèćńåŇĚèčĚåĞ¡æŢřåćđåŁäécİåd’ŰåŔĆæŢřãĂĆèĂČèŹŚäÿŇéİć

```
from functools import wraps

def optional_debug(func):
    @wraps(func)
    def wrapper(*args, debug=False, **kwargs):
        if debug:
            print('Calling', func.__name__)
        return func(*args, **kwargs)

    return wrapper
```

```
>>> @optional_debug
... def spam(a,b,c):
...     print(a,b,c)
...
>>> spam(1,2,3)
1 2 3
>>> spam(1,2,3, debug=True)
Calling spam
1 2 3
>>>
```

èőÍèőž

éĂŽè£ĞèčĚéěřåŹÍæİěçżŹèćńåŇĚèčĚåĞ¡æŢřåćđåŁååŔĆæŢřçŽĎåĄŽæşŢåźűäÿ■åÿÿèğĄãĂĆ
år¡çőąåęĆæ■ď’ïijŇæIJL’æŮűåĂŹåőČåŔŕäžěéĄ£åĚ■äÿĂäžŻéĞ■åď’■äžčçăĄãĂĆä¿ŃåęĆïijŇåęĆæđIJä¡ăæIJL’

```
def a(x, debug=False):
    if debug:
        print('Calling a')

def b(x, y, z, debug=False):
    if debug:
        print('Calling b')

def c(x, y, debug=False):
    if debug:
        print('Calling c')
```

éĆčäźĹä¡ăåŔŕäžěåřĘåĚűéĞ■æđĎæĹŘè£Źæăůïijž

```
from functools import wraps
import inspect

def optional_debug(func):
    if 'debug' in inspect.getargspec(func).args:
        raise TypeError('debug argument already defined')

    @wraps(func)
    def wrapper(*args, debug=False, **kwargs):
        if debug:
            print('Calling', func.__name__)
        return func(*args, **kwargs)
    return wrapper

@optional_debug
def a(x):
    pass

@optional_debug
def b(x, y, z):
    pass

@optional_debug
def c(x, y):
    pass
```

è£Źçğ■åőđçŐřæŰźæąĹäźŃæL’ĂäžěèąŇå¿ŮéĂŽïijŇåIJÍäžŐåijžåĹűåĚşéŤőå■ŮåŔĆæŢřå¿Ĺåőźæ
`*args` åŠŇ `**kwargs` åŔĆæŢřçŽĎåĞ¡æŢřäÿ■ãĂĆ éĂŽè£Ğä¡£çŤĺåijžåĹűåĚşéŤőå■ŮåŔĆæŢřïijŇåőČèćńä
åźűäÿŤæŐěäÿŃæİěäžĚäžĚä¡£çŤĺåL’l’ä¡ŹçŽĎä¡■ç¡őåŠŇåĚşéŤőå■ŮåŔĆæŢřåŐżèřČçŤĺè£ŹäÿłåĞ¡æŢřæŮűïij
äź§åřśæŸŕèŕť’ïijŇåőČåźűäÿ■äijŽèćńçžşåĚěåĹř `**kwargs` äÿ■åŐžãĂĆ

è£ŸæIJL’äÿĂäÿłéŽ¿çĆźåřśæŸŕåęĆä¡ŢåŐžåď’ĎçŘĘèćńæůžåŁăçŽĎåŔĆæŢřäÿŐèćńåŇĚèčĚåĞ¡æŢřåŔĆ

ä¿ÑåęĆïijÑåęĆæđIJèčĚéěřåŹÍ `@optional_debug` ä¡IJçŤĺåIJĺäÿĂäÿłåůšçżŘæŃěæIJL'äÿĂäÿł `debug` åŘĆæŢřçŽĎåĞ¡æŢřäÿŁæŮűäijŽæIJL'éŮőécŸãĂĆ è£ŹéĞŇæĹŚäžňáćđåŁääžĘäÿĂæ■ěåŘ■å■ŮæčĂæ

äÿŁéİćçŽĎæŰźæąĹè£ŸåŔŕäżěæŻť'åőÑç¿ŐäÿĂçĆźïijÑåŽääÿžçš¿æŸŐçŽĎçÍÑåžŔåŚŸåžŤèŕěåŔŚçŐřäž

```
>>> @optional_debug
... def add(x,y):
...     return x+y
...
>>> import inspect
>>> print(inspect.signature(add))
(x, y)
>>>
```

éĂŽè£ĞåęĆäÿÑçŽĎä£őæŤźïijÑåŔŕäżěèğčåĘşè£ŹäÿłéŮőécŸïijŽ

```
from functools import wraps
import inspect

def optional_debug(func):
    if 'debug' in inspect.getargspec(func).args:
        raise TypeError('debug argument already defined')

    @wraps(func)
    def wrapper(*args, debug=False, **kwargs):
        if debug:
            print('Calling', func.__name__)
        return func(*args, **kwargs)

    sig = inspect.signature(func)
    parms = list(sig.parameters.values())
    parms.append(inspect.Parameter('debug',
                inspect.Parameter.KEYWORD_ONLY,
                default=False))
    wrapper.__signature__ = sig.replace(parameters=parms)
    return wrapper
```

éĂŽè£Ğè£ŹæăůçŽĎä£őæŤźïijÑåŇĚèčĚåŘŐçŽĎåĞ¡æŢřç■¿åŘ■åřśèČ¡æ■čçąőçŽĎæŸ¿çd'ž `debug` åŘĆæŢřçŽĎå■ŸåIJĺäžĘąĂĆä¿ÑåęĆïijŽ

```
>>> @optional_debug
... def add(x,y):
...     return x+y
...
>>> print(inspect.signature(add))
(x, y, *, debug=False)
>>> add(2,3)
5
>>>
```

åŘĆèĂČ9.16åřŔèŁĆèŐůåŘŰæŻť'åd'ŽåĚşäžŐåĞ¡æŢřç■¿åŘ■çŽĎä£ąæĄŕãĂĆ

11.12 9.12 ä¡£çŤÍèčĚéěřåŹÍæĽľåĚĚçśżçŽĎåŁ§èČ¡

éŮőécŸ

ä¡ăæČşéĂŽè£ĞåŔ■çIJĄæĹŰèĂĚéĞ■åĘŹçśżåőŽäźĽ'çŽĎæ§ŘéČÍåĹĘæİëä£őæŤźåőČçŽĎèąŇäÿžïijŇä¡E

èğčåĘşæŰźæąĹ

è£Źçğ■æČĚåĘţåŔřèČ¡æŸŕçśżèčĚéěřåŹÍæIJĂåě¡çŽĎä¡£çŤÍåIJžæŹřäžĘãĂĆä¿ŃåęĆïijŇäÿŃéİćæŸŕäÿĂä
__getattribute__ çŽĎçśżèčĚéěřåŹÍïijŇ åŔřäžěæĽ'Şå■řæŮěå£ŮïijŽ

```
def log_getattribute(cls):
    # Get the original implementation
    orig_getattribute = cls.__getattribute__

    # Make a new definition
    def new_getattribute(self, name):
        print('getting:', name)
        return orig_getattribute(self, name)

    # Attach to the class and return
    cls.__getattribute__ = new_getattribute
    return cls

# Example use
@log_getattribute
class A:
    def __init__(self,x):
        self.x = x
    def spam(self):
        pass
```

äÿŃéİćæŸŕä¡£çŤÍæŢĹæđIJïijŽ

```
>>> a = A(42)
>>> a.x
getting: x
42
>>> a.spam()
getting: spam
>>>
```

èőÍèőž

çśżèčĚéěřåŹÍéĂŽåÿÿåŔřäžěä¡IJäÿžåĚűäżŰéńŸçžğæŁĂæIJŕæŕŤåęĆæůůåĚěæĹŰåĚČçśżçŽĎäÿĂçğ■éİđă
æŕŤåęĆïijŇäÿŁéİćçd'žä¿Ńäÿ■çŽĎåŔęåd'ŰäÿĂçğ■åőđçŐřä¡£çŤÍåĹřçžğæL'£ïijŽ

```
class LoggedGetattribute:
    def __getattribute__(self, name):
        print('getting:', name)
        return super().__getattribute__(name)

# Example:
class A(LoggedGetattribute):
    def __init__(self,x):
        self.x = x
    def spam(self):
        pass
```

è£Źçğ■æŰźæąĹäź§èąŇå¿ŮéĂŽïijŇä¡ĘæŸŕäÿžäžĘåŐżçŘĘèğčåőČïijŇä¡ăářśå£Ěéążç§ěéĄŞæŰźæşŢèřČ
äžěåŔŁåĚŰåőČ8.7ářŔèŁĆäżŃçż■çŽĎçżğæL’£ç§ěèŕĘãĂĆ æ§Řçğ■çĺŃåžęäÿŁæİěèőšïijŇçśžèčĚéěřåŹĺæŰźæą
åŽääÿžäžŰåźűäÿ■ä¿İèţŰ `super()` åĞ¡æŢřãĂĆ

åęĆæđIJä¡ăçşżæČşåIJĺäÿĂäÿłçśżäÿŁéİć䡣çŤĺåď’ŽäÿłçśžèčĚéěřåŹĺïijŇéĆčäźĹářśéIJĂèęĄæşĺæĎŔäÿŃé
ä¿ŃåęĆïijŇäÿĂäÿłèčĚéěřåŹĺAäijŽářĘåĚűèčĚéěřçŽĎæŰźæşŢåőŇæŢť’æŽ£æ■ćæĹŘåŔęäÿĂçğ■åőđçŐřïijŇ
èĂŇåŔęäÿĂäÿłèčĚéěřåŹĺBåŔłæŸŕçőĂå■ŢçŽĎåIJĺåĚűèčĚéěřçŽĎæŰźæşŢäÿ■æůžåŁăçĆźéćĺåď’ŰéĂżè¿ŚãĂ
éĆčäźĹè£ŹæŮűåĂŹèčĚéěřåŹĺAářśéIJĂèęĄæŤ¿åIJĺèčĚéěřåŹĺBçŽĎåL’■éİćãĂĆ

ä¡ăè£ŸåŔŕäžěåŽđéą¿äÿĂäÿŃ8.13ářŔèŁĆåŔęåď’ŰäÿĂäÿłåĚşäžŐçśżèčĚéěřåŹĺçŽĎæIJL’çŤĺçŽĎä¿Ńå■Ř

11.13 9.13 ä¡£çŤĺåĚČçśżæŐğåĹűåőđä¿ŃçŽĎåĹŽäžž

éŮőécŸ

ä¡ăæČşéĂŽè£ĞæŤźåŔŸåőđä¿ŃåĹŽäžžæŰźåijŔæİèåőđçŐřå■Ţä¿ŃãĂĄçijŞå■ŸæĹŰåĚűäžŰçśżäijijçŽĎ

èğčåĘşæŰźæąĹ

PythonçĺŃåžŔåŚŸéČ¡ç§ěéĄŞïijŇåęĆæđIJä¡ăåőŽäźL’äžĘäÿĂäÿłçśżïijŇářśèČ¡åČŔåĞ¡æŢřäÿĂæăůçŽĎè

```
class Spam:
    def __init__(self, name):
        self.name = name

a = Spam('Guido')
b = Spam('Diana')
```

åęĆæđIJä¡ăæČşèĞłåőŽäźL’è£Źäÿłæ■ěélď’ïijŇä¡ăåŔŕäžěåőŽäźL’äÿĂäÿłåĚČçśżåźűèĞłåůšåőđçŐř
`__call__()` æŰźæşŢãĂĆ

äÿžäžĘæijŤçď’žïijŇåĄĞèő¿ä¡ăäÿ■æČşäżżä¡ŢäžžåĺŽäžžè£ŹäÿłçśżçŽĎåőđä¿ŃïijŽ

```
class NoInstances(type):
    def __call__(self, *args, **kwargs):
        raise TypeError("Can't instantiate directly")
```

```
# Example
class Spam(metaclass=NoInstances):
    @staticmethod
    def grok(x):
        print('Spam.grok')
```

è£Źæăůç ŽĎèřÍïijŇçŤĺæĹůåŔłèČ¡èřČçŤĺè£Źäÿłçśżç ŽĎéİŹæĂĄæŰźæşŢïijŇèĂŇäÿ■èČ¡ä¡£çŤĺéĂŽåÿÿç

```
>>> Spam.grok(42)
Spam.grok
>>> s = Spam()
Traceback (most recent call last):
    File "<stdin>", line 1, in <module>
    File "example1.py", line 7, in __call__
        raise TypeError("Can't instantiate directly")
TypeError: Can't instantiate directly
>>>
```

çŐřåIJÍïijŇåĄĞåęĆä¡ăæČşåőđçŐřå■Ţä¿ŃæÍąåijŔïijĹåŔłèČ¡åĹŻåżžåŤŕäÿĂåőđä¿ŃçŽĎçśżïijL’ïijŇåőđçĆ

```
class Singleton(type):
    def __init__(self, *args, **kwargs):
        self.__instance = None
        super().__init__(*args, **kwargs)

    def __call__(self, *args, **kwargs):
        if self.__instance is None:
            self.__instance = super().__call__(*args, **kwargs)
            return self.__instance
        else:
            return self.__instance

# Example
class Spam(metaclass=Singleton):
    def __init__(self):
        print('Creating Spam')
```

éĆčäźĹSpamçśżåřśåŔłèČ¡åĹŻåżžåŤŕäÿĂçŽĎåőđä¿ŃäžĘïijŇæijŤçd’žåęĆäÿŃïijŽ

```
>>> a = Spam()
Creating Spam
>>> b = Spam()
>>> a is b
True
>>> c = Spam()
>>> a is c
True
>>>
```

æIJĂåŘŐïijŇåĄĞèő¿ä¡ăæČşåĹŻåżž8.25åřŔèŁĆäÿ■éĆčæăůçŽĎçijŞå■Ÿåőđä¿ŃãĆäÿŃéİćæĹŚäžňåŔŕä

```
import weakref

class Cached(type):
    def __init__(self, *args, **kwargs):
        super().__init__(*args, **kwargs)
        self.__cache = weakref.WeakValueDictionary()

    def __call__(self, *args):
        if args in self.__cache:
            return self.__cache[args]
        else:
            obj = super().__call__(*args)
            self.__cache[args] = obj
            return obj

# Example
class Spam(metaclass=Cached):
    def __init__(self, name):
        print('Creating Spam({!r})'.format(name))
        self.name = name
```

çĎűåŘŐæĹŚäź§æİěæţŃèŕŢäÿĂäÿŃïijŽ

```
>>> a = Spam('Guido')
Creating Spam('Guido')
>>> b = Spam('Diana')
Creating Spam('Diana')
>>> c = Spam('Guido') # Cached
>>> a is b
False
>>> a is c # Cached value returned
True
>>>
```

èőÍèőž

åĹľçŤĺåĚČçśżåőđçŐřåď'Žçğ■åőđä¿ŃåĹŻåżžæÍąåijŔéĂŽåÿÿèęĄæŕŤäÿ■ä¡£çŤĺåĚČçśżçŽĎæŰźåijŔäijŸ

åĄĞèő¿ä¡ääÿ■ä¡£çŤĺåĚČçśżïijŇä¡ăåŔřèČ¡éIJĂèęĄåřĘçśżéŽŘèŮŔåIJÍæ§ŘäžŻåůěåŐĆåĞ¡æŢřåŘŐéİćãĂ
æŕŤåęĆäÿžäžĘåőđçŐřäÿĂäÿłå■Ţä¿ŃïijŇä¡ää¡ăåŔřèČ¡äijŽåČŔäÿŃéİćè£ŹæăůåĘŹïijŽ

```
class _Spam:
    def __init__(self):
        print('Creating Spam')

_spam_instance = None

def Spam():
    global _spam_instance
```

```
    if _spam_instance is not None:
        return _spam_instance
    else:
        _spam_instance = _Spam()
        return _spam_instance
```

åř¡çőąä¡£çŤĺåĚČçśżåŔŕèČ¡äijŽæűĽ’åŔŁåĹřæŕŤè¿ČéńŸçžğçĆźçŽĎæŁĂæIJŕïijŇä¡ĘæŸŕåőČçŽĎäżčçăĄ

æŻť’åď’ŽåĚşäžŐåĹŻåżžçijŞå■Ÿåőđä¿ŃãĂĄåijśåijŢçŤĺç■Ľ’åĘĚåőźïijŇèŕůåŔĆèĂČ8.25ářŔèŁĆãĂĆ

11.14 9.14 æ■ŢèŐůçśżçŽĎåśđæĂğåőŽäźĽéąžåžŔ

éŮőécŸ

ä¡ăæČşèĞłåŁĺèőřå¡ŢäÿĂäÿłçśżäÿ■åśđæĂğåŠŇæŰźæşŢåőŽäźĽçŽĎéąžåžŔïijŇ
çĎűåŘŐåŔŕäżčåĹl’çŤĺåőČæİěåĄŽå¿Ĺåď’ŽæŞ■ä¡IJïijĹæŕŤåęĆåžŔåĹŮåŇŰãĂĄæŸäářĎåĹřæŢřæ■őåžŞç■Ľ’ç

èğčåĘşæŰźæąĹ

åĹl’çŤĺåĚČçśżåŔŕäżčå¿Ĺåőźæ ŸŞçŽĎæ■ŢèŐůçśżçŽĎåőŽäźĽ’ä£ąæĄŕãĂĆäÿŇéİćæŸŕäÿĂäÿłä¿Ňå■ŘïijŇ

```
from collections import OrderedDict

# A set of descriptors for various types
class Typed:
    _expected_type = type(None)
    def __init__(self, name=None):
        self._name = name

    def __set__(self, instance, value):
        if not isinstance(value, self._expected_type):
            raise TypeError('Expected ' + str(self._expected_type))
        instance.__dict__[self._name] = value

class Integer(Typed):
    _expected_type = int

class Float(Typed):
    _expected_type = float

class String(Typed):
    _expected_type = str

# Metaclass that uses an OrderedDict for class body
class OrderedMeta(type):
    def __new__(cls, clsname, bases, clsdict):
        d = dict(clsdict)
```

```
        order = []
        for name, value in clsdict.items():
            if isinstance(value, Typed):
                value._name = name
                order.append(name)
        d['_order'] = order
        return type.__new__(cls, clsname, bases, d)

    @classmethod
    def __prepare__(cls, clsname, bases):
        return OrderedDict()
```

åIJÍè£ŹäýłåĚČçśżäÿ■ïijŇæL’ğèąŇçśżäÿżä¡ŞæŮűæŔŕè£řåŹÍçŽĎåőŽäźL’éąžåžŕäijŽèćńäÿĂäýł
OrderedDict``æ■ŢèŐůåĹřïijŇ çŤ$æĹŘçŽĎæIJL’åžŕåŘ■çğřäżŐå■ŮåĚÿäÿ■æŔŘåŔŰåĞžæİě
``_order äÿ■ãĂĆè£ŹæăůçŽĎèŕÍçśżäÿ■çŽĎæŰźæşŢåŔŕäżěéĂŽè£Ğåď’Žçğ■æŰźåijŕæİěä¡£çŤĺåőČãĂĆ
ä¿ŇåęĆïijŇäÿŇéİćæŸŕäÿĂäýłçőĂå■ŢçŽĎçśżïijŇä¡£çŤÍè£ŹäýłæŐŠåžŕå■ŮåĚÿæİěåőđçŐřårĘäÿĂäýłçśżåőđă

```
class Structure(metaclass=OrderedMeta):
    def as_csv(self):
        return ','.join(str(getattr(self,name)) for name in self._
 ↪order)

# Example use
class Stock(Structure):
    name = String()
    shares = Integer()
    price = Float()

    def __init__(self, name, shares, price):
        self.name = name
        self.shares = shares
        self.price = price
```

æĹŚäžňåIJĺäžd’äžŠåijŔçŐŕåćČäÿ■æţŃèŕŢäÿĂäÿŃè£ŹäýłStockçśżïijŽ

```
>>> s = Stock('GOOG',100,490.1)
>>> s.name
'GOOG'
>>> s.as_csv()
'GOOG,100,490.1'
>>> t = Stock('AAPL','a lot', 610.23)
Traceback (most recent call last):
    File "<stdin>", line 1, in <module>
    File "dupmethod.py", line 34, in __init__
TypeError: shares expects <class 'int'>
>>>
```

èőÍèőž

æIJňèŁĆäÿĂäÿłåĚşéŤőçĆźåřśæŸŕOrderedMetaåĚČçśżäÿ■åőŽäźL’çŽĎ ‘‘ __pre-
pare__()‘‘ æŰźæşŢãĂĆ è£ŹäÿłæŰźæşŢäijŽåIJĺåijĂåğŃåőŽäźL’çśżåŠŇåőČçŽĎçĹűçśżçŽĎæŮűåĂŹèćńæL’ğè
æĹŚäžňè£ŹéĞŇéĂŽè£Ğè£ŤåŻđäžĘäÿĂäÿłOrderedDictèĂŇäÿ■æŸŕäÿĂäÿłæŹőéĂŽçŽĎå■ŮåĚÿïijŇåŔŕäžěå

åęĆæđIJä¡ăæČşæđĎéĂăèĞłåůśçŽĎçśżå■ŮåĚÿåŕźèśąïijŇåŔŕäžěå¿Ĺåőźæ ŸŞçŽĎæL’l’åśŢè£ŹäÿłåŁ§èČ¡ă

```
from collections import OrderedDict

class NoDupOrderedDict(OrderedDict):
    def __init__(self, clsname):
        self.clsname = clsname
        super().__init__()
    def __setitem__(self, name, value):
        if name in self:
            raise TypeError('{} already defined in {}'.format(name,␣
↪self.clsname))
        super().__setitem__(name, value)

class OrderedMeta(type):
    def __new__(cls, clsname, bases, clsdict):
        d = dict(clsdict)
        d['_order'] = [name for name in clsdict if name[0] != '_']
        return type.__new__(cls, clsname, bases, d)

    @classmethod
    def __prepare__(cls, clsname, bases):
        return NoDupOrderedDict(clsname)
```

äÿŃéİćæĹŚäžňæţŃèŕŢéĞ■åď■çŽĎåőŽäźL’äijŽåĞžçŐřäżĂäźĹæČĚåĘţïijŽ

```
>>> class A(metaclass=OrderedMeta):
...     def spam(self):
...         pass
...     def spam(self):
...         pass
...
Traceback (most recent call last):
    File "<stdin>", line 1, in <module>
    File "<stdin>", line 4, in A
    File "dupmethod2.py", line 25, in __setitem__
        (name, self.clsname))
TypeError: spam already defined in A
>>>
```

æIJĂåŘŐè£ŸæIJL’äÿĂçĆźå¿ĹéĞ■èęĄïijŇåřśæŸŕåIJĺ __new__()
æŰźæşŢäÿ■åŕźäžŐåĚČçśżäÿ■èćńä£őæŤźå■ŮåĚÿçŽĎåď ĎçŘĘãĂĆ
åř¡çőąçśżä¡£çŤĺäžĘåŔęåď ŰäÿĂäÿłå■ŮåĚÿæİěåőŽäźL’ïijŇåIJĺæđĎéĂăæIJĂçźĹçŽĎ class
åŕźèśąçŽĎæŮűåĂŹïijŇ æĹŚäžňäż■çĎűéIJĂèęĄåřĘè£Źäÿłå■ŮåĚÿè¡ňæ■ćäÿžäÿĂäÿłæ■čçąőçŽĎ
dict åőđä¿ŃãĂĆ éĂŽè£Ğèŕ■åŘě d = dict(clsdict)

æÌěåőŇæĹŘè£ŹäÿłæŢĹæđIJãĂĆ

åŕźäžŐå¿Ĺåď˙ŽåžŤçŤĺçĺŃåžŔèĂŇåůšïijŇèČ¡åď˙§æ■ŢèŐůçśżåőŽäźL˙çŽĎéąžåžŔæŸŕäÿĂäÿłçIJŃäijijäÿ■ä¿ŃåęĆïijŇåIJĺåŕźèśąåĚşçşżæŸăåřĎäÿ■ïijŇæĹŚäžňéĂŽåÿÿäijŽçIJŃåĹřäÿŃéÍćè£Źçğ■æŰźåijŔåőŽäźL˙çŽĎç

```
class Stock(Model):
    name = String()
    shares = Integer()
    price = Float()
```

åIJÍæąĘæđűåžŢåśĆïijŇæĹŚäžňå£Ěéążæ■ŢèŐůåőŽäźL˙çŽĎéąžåžŔæÌěåřĘåŕźèśąæŸăåřĎåĹřåĚČçżĎæĹÚ
`as_csv()` çŽĎåŁ§èČ¡ïijL˙ãĂĆ è£ŹèŁĆæijŤçd˙žçŽĎæŁĂæIJŕéÍđåÿÿçőĂå■ŢïijŇåźűäÿŤéĂŽåÿÿäijŽæŕŤåĚű

11.15 9.15 åőŽäźL˙æIJL˙åŔŕéĂL˙åŔĆæŢřçŽĎåĚČçśż

éŮőécŸ

ä¡ăæČşåőŽäźL˙äÿĂäÿłåĚČçśżïijŇåĚĄèőÿçśżåőŽäźL˙æŮűæŔŘä¿ŻåŔŕéĂL˙åŔĆæŢřïijŇè£ŹæăůåŔŕäžěæĆ

èğčåĘşæŰźæąĹ

åIJÍåőŽäźL˙çśżçŽĎæŮűåĂŹïijŇPythonåĚĄèőÿæĹŚäžňä¡£çŤÍ
“‘metaclass‘‘åĚşéŤőå■ŮåŔĆæŢřæÌěæŇĞåőŽçL˙źåőŽçŽĎåĚČçśżãĂĆ
ä¿ŃåęĆä¡£çŤÍæŁ¡èśąå§žçśżïijŽ

```
from abc import ABCMeta, abstractmethod
class IStream(metaclass=ABCMeta):
    @abstractmethod
    def read(self, maxsize=None):
        pass

    @abstractmethod
    def write(self, data):
        pass
```

çĎűèĂŇïijŇåIJÍèĞłåőŽäźL˙åĚČçśżäÿ■æĹŚäžňè£ŸåŕźäžěæŔŘä¿ŻåĚűäžŰçŽĎåĚşéŤőå■ŮåŔĆæŢřïijŇå

```
class Spam(metaclass=MyMeta, debug=True, synchronize=True):
    pass
```

äÿžäžĘä¡£åĚČçśżæŤŕæŇĄè£ŹäžŻåĚşéŤőå■ŮåŔĆæŢřïijŇä¡ää£Ěéążçąőä£ÌåIJÍ
`__prepare__()` , `__new__()` åŠŇ `__init__()` æŰźæşŢäÿ■
éČ¡ä¡£çŤÍåijžåĹűåĚşéŤőå■ŮåŔĆæŢřãĂĆåŕśåČŔäÿŃéÍćè£ŹæăůïijŽ

```
class MyMeta(type):
    # Optional
    @classmethod
    def __prepare__(cls, name, bases, *, debug=False,␣
↪synchronize=False):
```

```
        # Custom processing
        pass
        return super().__prepare__(name, bases)

    # Required
    def __new__(cls, name, bases, ns, *, debug=False,␣
↪synchronize=False):
        # Custom processing
        pass
        return super().__new__(cls, name, bases, ns)

    # Required
    def __init__(self, name, bases, ns, *, debug=False,␣
↪synchronize=False):
        # Custom processing
        pass
        super().__init__(name, bases, ns)
```

èőÍèőž

çžŹäÿĂäÿłåĚČçśżæůżåŁååŔŕéĂĽåĚşéŤőå■ŮåŔĆæŢřéIJĂèęĄä¡ăåőŇåĚĺåijĎæĞĆçśżåĹŻåžžçŽĎæĽĂa
åŻăäÿžè£ŹäžŻåŔĆæŢřäijŽèćńäijăéĂŠçžŹæŕŔäÿĂäÿłçŻÿåĚşçŽĎæŰźæşŢãĂĆ
__prepare__() æŰźæşŢåIJÍæĽĂæIJL'çśżåőŽäźĽåijĂåğŇæĽ'ğèąŇåĽ'■éęŰåĚĹèćńèřČçŤĺïijŇçŤĺæİěåĹŻ
éĂŽåÿÿæİěëőšïijŇè£ŹäÿłæŰźæşŢåŔłæŸŕçőĂå■ŢçŽĎè£ŤåŻđäÿĂäÿłå■ŮåĚÿæĹŰåĚűäžŰæŸăářĎářźèśąãĂĆ
__new__() æŰźæşŢèćńçŤĺæİěåőđä¿ŃåŇŰæIJĂçżĹçŽĎçśżåŕźèśąãĂĆåőČåIJÍçśżçŽĎäÿżä¡Şèćńæ L'ğèąŇåő
__init__() æŰźæşŢæIJĂåŘŐèćńèřČçŤĺïijŇçŤĺæİěæL'ğèąŇåĚűäžŰçŽĎäÿĂäžŻåĹİåğŃåŇŰåůěä¡IJãĂĆ

å¡ŞæĹŚäžňædĎéĂäåĚČçśżçŽĎæŮŰůåĂŹïijŇéĂŽåÿÿåŔłéIJĂèęĄåőŽäźL'äÿĂäÿł
__new__() æĹŰ __init__() æŰźæşŢïijŇä¡Ęäÿ■æŸŕäÿď'äÿłéČ¡åőŽäźL'ãĂĆ
ä¡ĘæŸŕïijŇåęĆædIJéIJĂèęĄæŐěåŔŮåĚűäžŰçŽĎåĚşéŤőå■ŮåŔĆæŢřçŽĎèŕİïijŇè£Źäÿď'äÿłæŰźæşŢåŕśèęĄå
éżŸèőď'çŽĎ __prepare__() æŰźæşŢæŐěåŔŮäžżæĎŘçŽĎåĚşéŤőå■ŮåŔĆæŢřïijŇä¡ĘæŸŕäijŽå£¡çŢěåő
æĽ'Ăäżěå ŔłæIJL'å¡Şè£ŹäžŻécİåď'ŰçŽĎåŔĆæŢřåŔŕèČ¡äijŽå¡śåŞ■åĹřçśżåŠ¡åŘ■çľ'žéŮť'çŽĎåĹŻåžżæŮűä¡ăa
__prepare__() æŰźæşŢãĂĆ

éĂŽè£Ğä¡£çŤĺåijžåĹűåĚşéŤőå■ŮåŔĆæŢřïijŇåIJÍçśżçŽĎåĹŻåžžè£ĞçÍÑäÿ■æĹŚäžňå£ĚéążéĂŽè£ĞåĚş

ä¡£çŤĺåĚşéŤőå■ŮåŔĆæŢřéĚ■ç¡őäÿĂäÿłåĚČçśżè£ŸåŕŕäžěèğĘä¡IJåŕźçśżåŔŸéĞŔçŽĎäÿĂçğ■æŻ£äžčæ

```
class Spam(metaclass=MyMeta):
    debug = True
    synchronize = True
    pass
```

åřĘè£ŹäžŻåśđæĂğåőŽäźL'äÿžåŔĆæŢřçŽĎåě¡åď'ĎåIJÍäžŐåőČäžňäÿ■äijŽæśąæ§ŞçśżçŽĎåŘ■çğřçľ'žéŮť
è£ŹäžŻåśđæĂğäźĚäžĚåŔłäžŐåśđäžŐçśżçŽĎåĹŻåžžéŸűæőţïijŇèĂŇäÿ■æŸŕçśżäÿ■çŽĎèŕ■åŘěæL'ğèąŇéŸűa
åŘęåď'ŰïijŇåőČäžňåIJÍ __prepare__() æŰźæşŢäÿ■æŸŕåŕŕäžěèćńèő£éŰőçŽĎïijŇåŻăäÿžè£ŹäÿłæŰźæşŢ
ä¡ĘæŸŕçśżåŔŸéĞŔåŔłèČ¡åIJÍåĚČçśżçŽĎ __new__() åŠŇ __init__()
æŰźæşŢäÿ■åŔŕèğĄãĂĆ

11.16 9.16 *argsåŠŇ**kwargsçŽĎåijžåĹűåŔĆæŢřç■¿åŘ■

éŮőécŸ

ä¡ăæIJL'äÿĂäÿłåĞ¡æŢřæĹŰæŰźæşŢïijŇåőČä¡£çŤĺ*argsåŠŇ**kwargsä¡IJäÿžåŔĆæŢřïijŇè£ŹæăůäŀŁå¿Ů
ä¡ĘæIJL'æŮűåĂŹä¡ăæČşæčĂæ§ěäijăéĂŠè£ŻæİěçŽĎåŔĆæŢřæŸŕäÿ■æŸŕæ§Řäÿłä¡ăæČşèęĄçŽĎçśžåđŇãĂĆ

èğčåĘşæŰźæąĹ

åŕźäżżä¡ŢæűL'åŔŁåĹřæŞ■ä¡IJåĞ¡æŢřèřČçŤĺç■¿åŘ■çŽĎéŮőécŸïijŇä¡ăéČ¡åžŤèŕěä¡£çŤĺ
`inspect` æĺąåİŮäÿ■çŽĎç■¿åŘ■çL'źæĂğãĂĆ æĹŚäżňæIJĂäÿżèęĄåĚşæşĺäÿd'äÿłçśżïijŽ`Signature` åŠŇ `Parameter` ãĂĆäÿŇéİćæŸŕäÿĂäÿłåĹŻåżžåĞ¡æŢřåL'■éİćçŽĎäžd'äžŠä¿Ňå■ŘïijŽ

```
>>> from inspect import Signature, Parameter
>>> # Make a signature for a func(x, y=42, *, z=None)
>>> parms = [ Parameter('x', Parameter.POSITIONAL_OR_KEYWORD),
...           Parameter('y', Parameter.POSITIONAL_OR_KEYWORD,␣
 ↪default=42),
...           Parameter('z', Parameter.KEYWORD_ONLY, default=None) ]
>>> sig = Signature(parms)
>>> print(sig)
(x, y=42, *, z=None)
>>>
```

äÿĂæŮęä¡ăæIJL'äžĘäÿĂäÿłç■¿åŘ■åŕźèśąïijŇä¡ăåřšåŔŕäżěä¡£çŤĺåőČçŽĎ `bind()` æŰźæşŢå¿Ĺåőźæ ŸŞçŽĎåřĘåőČçżŚåőŽåĹř `*args` åŠŇ `**kwargs` äÿŁåŐžãĂĆ äÿŇéİćæŸŕäÿĂäÿłçőĂå■ŢçŽĎæijŤçd'žïijŽ

```
>>> def func(*args, **kwargs):
...     bound_values = sig.bind(*args, **kwargs)
...     for name, value in bound_values.arguments.items():
...         print(name,value)
...
>>> # Try various examples
>>> func(1, 2, z=3)
x 1
y 2
z 3
>>> func(1)
x 1
>>> func(1, z=3)
x 1
z 3
>>> func(y=2, x=1)
x 1
y 2
>>> func(1, 2, 3, 4)
Traceback (most recent call last):
...
```

```
    File "/usr/local/lib/python3.3/inspect.py", line 1972, in _bind
        raise TypeError('too many positional arguments')
TypeError: too many positional arguments
>>> func(y=2)
Traceback (most recent call last):
...
    File "/usr/local/lib/python3.3/inspect.py", line 1961, in _bind
        raise TypeError(msg) from None
TypeError: 'x' parameter lacking default value
>>> func(1, y=2, x=3)
Traceback (most recent call last):
...
    File "/usr/local/lib/python3.3/inspect.py", line 1985, in _bind
        '{arg!r}'.format(arg=param.name))
TypeError: multiple values for argument 'x'
>>>
```

åŘŕäžěçIJŃåĞžæİěïijŇéĂŽè£ĞářEç■¿åŘ■åŠŇäijăéĂŠçŽĎåŔĆæŢřçżŚåőŽèţůæİěïijŇåŔŕäžěåijžåĹűåĞ¡a

äÿŃéİćæŸŕäÿĂäÿłåijžåĹűåĞ¡æŢřç■¿åŘ■æŻťˇåĚůä¡ŞçŽĎä¿Ńå■ŘãĂĆåIJĺäžčçăĄäÿ■ïijŇæĹŚäžňåIJĺå§žç
`__init__()` æŰźæşŢïijŇ çĎűåŘŐæĹŚäžňåijžåĹűæL'ĂæIJL'çŽĎå■Řçśżå£Ěéążæŕŕä¿ŻäÿĂäÿłçL'źåőŽçŽĹ

```
from inspect import Signature, Parameter

def make_sig(*names):
    parms = [Parameter(name, Parameter.POSITIONAL_OR_KEYWORD)
             for name in names]
    return Signature(parms)

class Structure:
    __signature__ = make_sig()
    def __init__(self, *args, **kwargs):
        bound_values = self.__signature__.bind(*args, **kwargs)
        for name, value in bound_values.arguments.items():
            setattr(self, name, value)

# Example use
class Stock(Structure):
    __signature__ = make_sig('name', 'shares', 'price')

class Point(Structure):
    __signature__ = make_sig('x', 'y')
```

äÿŃéİćæŸŕä¡£çŤĺè£ŹäÿłStock çśżçŽĎçďžä¿ŃïijŽ

```
>>> import inspect
>>> print(inspect.signature(Stock))
(name, shares, price)
>>> s1 = Stock('ACME', 100, 490.1)
>>> s2 = Stock('ACME', 100)
Traceback (most recent call last):
```

```
...
TypeError: 'price' parameter lacking default value
>>> s3 = Stock('ACME', 100, 490.1, shares=50)
Traceback (most recent call last):
...
TypeError: multiple values for argument 'shares'
>>>
```

èőÍèőž

åIJÍæĹŚäžňéIJĂèęĄæđĎåžžéĂŽçŤÍåĞ¡æŢřåžŞãĂĄçijŰåĘŹèčĚéěřåŹÍæĹŰåőđçŐřäžčçŘĘçŽĎæŮűåĂŹ
*args åŠŇ **kwargs çŽĎä¡£çŤÍæŸŕå¿ĹæŹőéĄ■çŽĎãĂĆ
ä¡ĘæŸŕïijŇè£ŹæăůçŽĎåĞ¡æŢřæIJL'äÿĂäÿłçijžçĆźåřśæŸŕå¡Şä¡ăæČşèęĄåőđçŐřèĞłåůśçŽĎåŔĆæŢřæčĂéłŇ
è£ŹæŮűåĂŹæĹŚäžňåŔŕäžěéĂŽè£ĞäÿĂäÿłç■¿åŘ■åŕźèśąæİěçőĂåŇŰåőČãĂĆ

åIJÍæIJĂåŘŐçŽĎäÿĂäÿłæŰźæąĹåőđä¿Ńäÿ■ïijŇæĹŚäžňè£ŸåŔŕäžěéĂŽè£Ğä¡£çŤÍèĞłåőŽäźL'åĚČçśżæİ

```
from inspect import Signature, Parameter

def make_sig(*names):
    parms = [Parameter(name, Parameter.POSITIONAL_OR_KEYWORD)
             for name in names]
    return Signature(parms)

class StructureMeta(type):
    def __new__(cls, clsname, bases, clsdict):
        clsdict['__signature__'] = make_sig(*clsdict.get('_fields',
↪[]))
        return super().__new__(cls, clsname, bases, clsdict)

class Structure(metaclass=StructureMeta):
    _fields = []
    def __init__(self, *args, **kwargs):
        bound_values = self.__signature__.bind(*args, **kwargs)
        for name, value in bound_values.arguments.items():
            setattr(self, name, value)

# Example
class Stock(Structure):
    _fields = ['name', 'shares', 'price']

class Point(Structure):
    _fields = ['x', 'y']
```

å¡ŞæĹŚäžňèĞłåőŽäźL'ç■¿åŘ■çŽĎæŮűåĂŹïijŇårĘç■¿åŘ■å■ŸåĆĺåIJÍçL'źåőŽçŽĎåšđæĂğ
__signature__ äÿ■éĂŽåÿÿæŸŕå¿ĹæIJL'çŤÍçŽĎãĂĆ è£ŹæăůçŽĎèŕÍïijŇåIJÍä¡£çŤÍ
inspect æÍąåİŮæL'ğèąŇåĘĚçIJAçŽĎäžčçăĄåŕśèČ¡åŔŚçŐřç■¿åŘ■åźűåŕĘåőČä¡IJäÿžèřČçŤÍçžęåőŽãĂĆ

```
>>> import inspect
>>> print(inspect.signature(Stock))
(name, shares, price)
>>> print(inspect.signature(Point))
(x, y)
>>>
```

11.17 9.17 åIJÍçśżäÿŁåijżåĹűä¡£çŤÍçijŰçÍŃèğĎçžę

éŮőécŸ

ä¡ăçŽĎçÍŃåžŔåŇĚåŘńäÿĂäÿłå¿Ĺåď ğçŽĎçśżçżğæL'£ä¡ŞçşżïijŇä¡ăåÿŇæIJŻåijżåĹűæL'ğèąŇæ§ŘäžŻçij

èğčåĘşæŰźæąĹ

åęĆædIJä¡ăæČşçŻŚæŐğçśżçŽĎåőŽäźL'ïijŇéĂŽåÿÿåŔräżěéĂŽè£ĞåőŽäźL'äÿĂäÿłåĚČçśżãĂĆäÿĂäÿłå§ type åźűéĞ■åőŽäźL'åőČçŽĎ __new__() æŰźæşŢ æĹŰèĂĚæŸŕ __init__() æŰźæşŢãĂĆæŕŤåęĆïijŽ

```
class MyMeta(type):
    def __new__(self, clsname, bases, clsdict):
        # clsname is name of class being defined
        # bases is tuple of base classes
        # clsdict is class dictionary
        return super().__new__(cls, clsname, bases, clsdict)
```

åŘęäÿĂçğ■æŸŕïijŇåőŽäźL' __init__() æŰźæşŢïijŽ

```
class MyMeta(type):
    def __init__(self, clsname, bases, clsdict):
        super().__init__(clsname, bases, clsdict)
        # clsname is name of class being defined
        # bases is tuple of base classes
        # clsdict is class dictionary
```

äÿžäžĘä¡£çŤÍè£ŹäÿłåĚČçśżïijŇä¡ăéĂŽåÿÿèęĄåřĘåőČæŤ¿åĹřåĹřäÿĂäÿłéąűçžğçĹűçśżåőŽäźL'äÿ■ïijŇçĹ

```
class Root(metaclass=MyMeta):
    pass

class A(Root):
    pass

class B(Root):
    pass
```

åĚČçśžçŽĎäÿĂäÿłåĚşéŤőçĽźçĆźæŸŕåőČåĚĄèőÿä¡ååIJĺåőŽäźĽçŽĎæŮűåĂŹæčĂæ§ěçśžçŽĎåĘĚåőźã
__init__() æŰźæşŢäÿ■ïijŇ ä¡ăåŔŕäžěå¿Ĺè¡żæİ¿çŽĎæčĂæ§ěçśžå■ŮåĚÿãĂĄçĹűçśžç■Ľç■Ľ˜ãĂĆåźűäÿŤi
åŻăæ■ď˜ïijŇäÿĂäÿłæąĘæđűçŽĎæđĎåžžèĂĚåřśèČ¡åIJĺåď˜gåđŃçŽĎçžğæĽ£ä¡Şçşžäÿ■éĂŽè£ĞçźŹäÿĂäÿłéąű

ä¡IJäÿžäÿĂäÿłåĚůä¡ŞçŽĎåžŤçŤĺä¿Ńå■ŘïijŇäÿŃéİćåőŽäźĽäžĘäÿĂäÿłåĚČçśžïijŇåőČäijŽæŃŠçżİäżżä¡

```
class NoMixedCaseMeta(type):
    def __new__(cls, clsname, bases, clsdict):
        for name in clsdict:
            if name.lower() != name:
                raise TypeError('Bad attribute name: ' + name)
        return super().__new__(cls, clsname, bases, clsdict)

class Root(metaclass=NoMixedCaseMeta):
    pass

class A(Root):
    def foo_bar(self): # Ok
        pass

class B(Root):
    def fooBar(self): # TypeError
        pass
```

ä¡IJäÿžæŻť énŸçžğåŠŇåőđçŤĺçŽĎä¿Ńå■ŘïijŇäÿŃéİćæIJĽäÿĂäÿłåĚČçśžïijŇåőČçŤĺæİěæčĂæţŃéĞ■è¡¡

```
from inspect import signature
import logging

class MatchSignaturesMeta(type):

    def __init__(self, clsname, bases, clsdict):
        super().__init__(clsname, bases, clsdict)
        sup = super(self, self)
        for name, value in clsdict.items():
            if name.startswith('_') or not callable(value):
                continue
            # Get the previous definition (if any) and compare the␣
↪signatures
            prev_dfn = getattr(sup,name,None)
            if prev_dfn:
                prev_sig = signature(prev_dfn)
                val_sig = signature(value)
                if prev_sig != val_sig:
                    logging.warning('Signature mismatch in %s. %s !
↪= %s',
                                    value.__qualname__, prev_sig,␣
↪val_sig)

# Example
class Root(metaclass=MatchSignaturesMeta):
    pass
```

```
class A(Root):
    def foo(self, x, y):
        pass

    def spam(self, x, *, z):
        pass

# Class with redefined methods, but slightly different signatures
class B(A):
    def foo(self, a, b):
        pass

    def spam(self,x,z):
        pass
```

åęĆædIJä¡ăè£Řèąňè£Źæőţäżčçă Ąïij Ňářśäij Žå¿ŮåĹřäÿŃéİćè£Źæăůç ŽĎè¿ŞåĞžçżŞædIJïijŽ

```
WARNING:root:Signature mismatch in B.spam. (self, x, *, z) != (self,
↪ x, z)
WARNING:root:Signature mismatch in B.foo. (self, x, y) != (self, a,␣
↪b)
```

è£Źçğ■è■ęåŚŁä£ąæĄřářźäžŐæ■ŢèŐůäÿĂäžŻå¿őåęŹçŽĎçÍŃåžŔbugæŸřå¿ĹæIJL'çŤÍçŽĎãĂĆä¿ŃåęĆïij éĆčäźĹå¡Şå■ŘçśżæŤźåŔŸåŔĆæŢřåŘ■å■ŮçŽĎæŮűůåĂŹářśäijŽèřČçŤĺåĞžéŤŹãĂĆ

èőÍèőž

åIJÍåď ğåđŃéİćåŘŚářźèśąçŽĎçÍŃåžŔäÿ■ïijŇéĂŽåÿÿářĘçśżçŽĎåőŽäźL'æŤ¿åIJÍåĚČçśżäÿ■æŐğåĹűæŸřå ĚČçśżåŔřäžěçŻŚæŐğçśżçŽĎåőŽäźL'ïijŇè■ęåŚŁçijŰçÍŃäžžåŚŸæ§ŘäžŻæšąæIJL'æşÍæĎŔåĹřçŽĎåŔřèČ¡åĞ

æIJL'äžžåŔřèČ¡äijŽèŕť'ïijŇåČŔè£Źæăůç ŽĎéŤŹèŕřåŔřäžěéĂŽè£ĞçÍŃåžŔåĹĘæđŘåůěåĚůæĹŰIDEåŐżå ä¡ĘæŸřïijŇåęĆædIJä¡ăåIJÍæđĎåžžäÿĂäÿłæąĘæđűæĹŰåĞ¡æŢřåžŞä¿ŻåĚűäžŰäžžä¡£çŤÍïijŇéĆčäźĹä¡ăæšąåĽ åŻăæ■d'ïijŇářźäžŐè£Źçğ■çśżåđŃçŽĎçÍŃåžŔïijŇåęĆædIJåŘřäžěåIJÍåĚČçśżäÿ■åĄŽæčĂæţŃæĹŰèőÿåŘřäžěś

åIJÍåĚČçśżäÿ■éĂL'æŃl'éĞ■æŰřåőŽäźL' `__new__()` æŰźæşŢè£ŸæŸř `__init__()` æŰźæşŢåŘŰåĘşäžŐä¡ăæČşæĂŐæăůä¡£çŤÍçżŞædIJçśżãĂĆ `__new__()` æŰźæşŢåIJÍçśżåĹŻåžžäźŃåL'■èćńèřČçŤÍïijŇéĂŽåÿÿçŤÍäžŐéĂŽè£ĞæŞŘçğ■æŰźåijŔïijĹæŕŤåęĆéĂŽè£ĞæŤ èĂŃ `__init__()` æŰźæşŢæŸřåIJÍçśżèćńåĹŻåžžäźŃåŘŐèćńèřČçŤÍïijŇå¡Şä¡ăéIJĂèęĄåőŇæŢť'ædĎåžžçśż åIJÍæIJĂåŘŐäÿĂäÿłä¿Ńå■Řäÿ■ïijŇè£ŹæŸřå£ĚèęĄçŽĎïijŇåŻăäÿžåőČä¡£çŤÍäžĘ `super()` åĞ¡æŢřæİěæŘIJçť'ćäźŃåL'■çŽĎåőŽäźL'ãĂĆ åőČåŔłèČ¡åIJÍçśżçŽĎåőđä¿Ńèćńå ĹŻåžžäźŃåŘŐïijŇåźűäÿŤçŻ

æIJĂåŘŐäÿĂäÿłä¿Ńå■Řè£ŸæijŤçď'žäžĘPythonçŽĎåĞ¡æŢřç■¿åŘ■åŕźèśąçŽĎä¡£çŤÍãĂĆ åőđéŹĚäÿŁïijŇåĚČçśżåřĘæŕŘäÿłåŔřèřČçŤÍåőŽäźL'æŤ¿åIJÍäÿĂäÿłçśżäÿ■ïijŇæŘIJçť'ćåL'■äÿĂäÿłåőŽäźL'ïijĹ çĎűåŘŐéĂŽè£Ğä¡£çŤÍ `inspect.signature()` æİěçőĂå■ŢçŽĎæŕŤè¿ČåőČäžňçŽĎèřČçŤÍç■¿åŘ■ãĂĆ

æIJĂåŘŐäÿĂçĆźïijŇäžčçăĄäÿ■æIJL'äÿĂèąŇä¡£çŤÍäžĘ `super(self, self)` åźűäÿ■æŸřæŐŠçL'ĹéŤŹèŕřãĂĆ å¡Şä¡£çŤÍåĚČçśżçŽĎæŮűůåŹïijŇæĹŠäžňèęĄæŮűůåĹżèőřä¡ŔäÿĂçĆźåřśæŸ `self` åőđéŹĚäÿŁæŸřäÿĂäÿłçśżåřźèśąãĂĆ åŻăæ■d'ïijŇè£Źæİąéŕ■åŘěåĚűåőđåřśæŸřçŤÍæİěåŕżæL'¿ä¡■äžŐçž `self` çĹűçśżçŽĎåőŽäźL'ãĂĆ

11.18 9.18 äžěçijŰçÍNæŰźåijŔåőŽäźĽ'çśż

éŮőécŸ

ä¡ăåIJÍåĘŹäÿĂæőţäžčçăĄïijŇæIJĂçżĹéIJĂèęĄåĹŻåžžäÿĂäÿłæŰřçŽĎçśżåŕźèśąăĂĆä¡äèĂČèŹŚåřĘçśżçŽ
åźűäÿŤä¡£çŤÍåĞ¡æŢřæŕŤåęĆ `exec()` æİěæĽ'ğèąŇåőČïijŇä¡ĘæŸŕä¡äæČşåŕżæĽ'¿äÿĂäÿłæŻť'åŁääijŸéŻĚçŽ

èğčåĘşæŰźæąĹ

ä¡ăåŔŕäžěä¡£çŤÍåĞ¡æŢř `types.new_class()` æİěåĹİåğŃåŇŰæŰřçŽĎçśżåŕźèśąăĂĆ
ä¡ăéIJĂèęĄåĄŽçŽĎåŔłæŸŕæŔŘä¿ŻçśżçŽĎåŘ■å■ŮãĂĄçĹűçśżåĚČçżĎãĂĄåĚşéŤőå■ŮåŔĆæŢřïijŇäžěåŔŁ

```
# stock.py
# Example of making a class manually from parts

# Methods
def __init__(self, name, shares, price):
    self.name = name
    self.shares = shares
    self.price = price
def cost(self):
    return self.shares * self.price

cls_dict = {
    '__init__' : __init__,
    'cost' : cost,
}

# Make a class
import types

Stock = types.new_class('Stock', (), {}, lambda ns: ns.update(cls_
↪dict))
Stock.__module__ = __name__
```

è£Źçğ■æŰźåijŔäijŽæđĎåžžäÿĂäÿłæŹőéĂŽçŽĎçśżåŕźèśąïijŇåźűäÿŤæŇL'çĚgä¡äçŽĎæIJ§æIJŻåůěä¡IJïj

```
>>> s = Stock('ACME', 50, 91.1)
>>> s
<stock.Stock object at 0x1006a9b10>
>>> s.cost()
4555.0
>>>
```

è£Źçğ■æŰźæşŢäÿ■ïijŇäÿĂäÿłæŕŤè¿ČéŽ¿çŘĘèğčçŽĎåIJřæŰźæŸŕåIJÍèřČçŤÍåőŇ
`types.new_class()` åŕź `Stock.__module__` çŽĎèţŇåĂijãĂĆ
æŕŔæňąå¡ŞäÿĂäÿłçśżèćńåőŽäźĽ'åŘŐïijŇåőČçŽĎ `__module__`
åśđæĂğåŇĚåŘńåőŽäźĽ'åőČçŽĎæÍąåİŮåŘ■ãĂĆ è£ŹäÿłåŘ■å■ŮçŤÍäžŐçŤ§æĹŘ

__repr__() æŰźæşŢçŽĎè¿ŞåĞžãĂĆåőČåŘŇæăůäź§èćńçŤĺäžŐå¿Ĺåď'ŽåžŞïijŇæŕŤåęĆ pickle ãĂĆ åŻäæ■ď'ïijŇäÿžäžĘèőľä¡ăåĹŻåżžçŽĎçśżæŸŕâĂIJæ■čçąőâĂİçŽĎïijŇä¡ăéIJĂèęĄçąőä£Ìè£ŹäÿŁ

åęĆæđIJä¡ăæČşåĹŻåżžçŽĎçśżéIJĂèęĄäÿĂäÿłäÿ■åŘŇçŽĎåĚČçśżïijŇåŕŕäżěéĂŽè£Ğ types.new_class() çňňäÿL'äÿłåŔĆæŢřäijăéĂŠçżŹåőČãĂĆä¿ŃåęĆïijŽ

```
>>> import abc
>>> Stock = types.new_class('Stock', (), {'metaclass': abc.ABCMeta},
...                         lambda ns: ns.update(cls_dict))
...
>>> Stock.__module__ = __name__
>>> Stock
<class '__main__.Stock'>
>>> type(Stock)
<class 'abc.ABCMeta'>
>>>
```

çňňäÿL'äÿłåŔĆæŢřè£ŸåŕŕäżěåŇĚåŘńåĚűäżŰçŽĎåĚşéŤőå■ŮåŔĆæŢřãĂĆæŕŤåęĆïijŇäÿĂäÿłçśżçŽĎåć

```
class Spam(Base, debug=True, typecheck=False):
    pass
```

éĆčäźĹåŕŕäżěářĘåĚűç£żèŕŚæĹŘåęĆäÿŃçŽĎ new_class() èřĈçŤĺå¡ćåijŕïijŽ

```
Spam = types.new_class('Spam', (Base,),
                       {'debug': True, 'typecheck': False},
                       lambda ns: ns.update(cls_dict))
```

new_class() çňňåŻŽäÿłåŔĆæŢřæIJĂçěđçğŸïijŇåőČæŸŕäÿĂäÿłçŤĺæİěæŐěåŔŮçśżåŚ¡åŘ■çľ'žéŮť'çŽ éĂŽåÿÿè£ŹæŸŕäÿĂäÿłæŹőéĂŽçŽĎå■ŮåĚÿïijŇä¡ĘæŸŕåőČåőđéŹĚäÿŁæŸŕ __prepare__() æŰźæşŢè£ŤåŽđçŽĎäżżæĎŘåŕźèśąïijŇè£ŹäÿłåIJĺ9.14åřŔèŁĆåůšçżŔäżŃçż■è£ĞäžĘãĂĆ è£ŹäÿłåĞ¡æŢřéIJĂèęĄä¡£çŤĺäÿŁéİćæijŤçd'žçŽĎ update() æŰźæşŢçżŹåŚ¡åŘ■çľ'žéŮť'åćđåŁååĘĚåőźãĂĆ

èőĺèőž

å¿Ĺåď'ŽæŮűåĂŹåęĆæđIJèČ¡æđĎéĂäæŰřçŽĎçśżåŕźèśąæŸŕå¿ĹæIJL'çŤĺçŽĎãĂĆ æIJL'äÿłå¿ĹçĘ§æĆL'çŽĎä¿Ńå■ŘæŸŕèřČçŤĺ collections.namedtuple() åĞ¡æŢřïijŇä¿ŃåęĆïijŽ

```
>>> Stock = collections.namedtuple('Stock', ['name', 'shares',
↪'price'])
>>> Stock
<class '__main__.Stock'>
>>>
```

namedtuple() ä¡£çŤĺ exec() èĂŇäÿ■æŸŕäÿŁéİćäżŃçż■çŽĎæŁĂæIJŕãĂĆä¡ĘæŸŕïijŇäÿŃéİćéĂŽè æĹŚäžňçŽť'æŐěåĹŻåżžäÿĂäÿłçśżïijŽ

```
import operator
import types
import sys

def named_tuple(classname, fieldnames):
    # Populate a dictionary of field property accessors
    cls_dict = { name: property(operator.itemgetter(n))
                 for n, name in enumerate(fieldnames) }

    # Make a __new__ function and add to the class dict
    def __new__(cls, *args):
        if len(args) != len(fieldnames):
            raise TypeError('Expected {} arguments'.
↪format(len(fieldnames)))
        return tuple.__new__(cls, args)

    cls_dict['__new__'] = __new__

    # Make the class
    cls = types.new_class(classname, (tuple,), {},
                          lambda ns: ns.update(cls_dict))

    # Set the module to that of the caller
    cls.__module__ = sys._getframe(1).f_globals['__name__']
    return cls
```

è£ŹæőţäžčçăÇžĎæIJĂåŘŐéČĺåĹĘä¡£çŤĺäžĘäÿĂäÿłæL’ĂèřŞçŽĎâĂİæąĘæđűé■ŤæşŢâĂİïijŇéĂŽè£Ğè sys._getframe() æİěèŐůåŔŰèřČçŤĺèĂĚçŽĎæĺąåİŮůåŘ■ãĂĆ åŔęåd’ŰäÿĂäÿłæąĘæđűé■ŤæşŢä¿Ńå■ŘåIJĺ2.15åřŔèŁĆäÿ■æIJL’äžŃçż■è£ĞãĂĆ

äÿŃéİćçŽĎä¿Ńå■ŘæijŤçd’žäžĘåL’■éİćçŽĎäžčçĂąæŸŕåęĆä¡Ţåůěä¡IJçŽĎïijŽ

```
>>> Point = named_tuple('Point', ['x', 'y'])
>>> Point
<class '__main__.Point'>
>>> p = Point(4, 5)
>>> len(p)
2
>>> p.x
4
>>> p.y
5
>>> p.x = 2
Traceback (most recent call last):
    File "<stdin>", line 1, in <module>
AttributeError: can't set attribute
>>> print('%s %s' % p)
4 5
>>>
```

è£ŹéąźæĂæIJŕäÿĂäÿłå¿ĹéĞ■èęĄçŽĎæŰźéİćæŸŕåőČårźäžŐåĚČçśżçŽĎæ■čçąőä¡£çŤĺãĂĆ

ä¡ăåŔŕèČ¡åČŔéĂŽè£ĞçŻť æŐěåðđä¿ŃåŇŰäÿĂäÿłåĚČçśżæÌěçŻť æŐěåĹŻåžžäÿĂäÿłçśżïijŽ

```
Stock = type('Stock', (), cls_dict)
```

è£Źçğ■æŰźæşŢçŽĎéŮőécŸåIJĺäžŐåőČå£¡çŢěäžĘäÿĂäžŻåĚşéŤőæ■ěéłd'ïijŇæŕŤåęĆåŕźäžŐåĚČçśżäÿ■ `__prepare__()` æŰźæşŢçŽĎèŕČçŤĺãĂĆ éĂŽè£ĞäĄ£çŤĺ `types.new_class()` ïijŇä¡ăåŔŕäžěä£ÌèŕĄæL'ĂæIJL'çŽĎå£ĚèęĄåĹìåğŃåŇŰæ■ěéłd'éČ¡èČ¡å¿ŮåĹřæL'ğèąŇãĂĆ æŕŤåęĆïijŇ`types.new_class()` çňňåŻŻäÿłåŔĆæŢřçŽĎåŻđèŕČåĞ¡æŢřæŐěåŔŮ `__prepare__()` æŰźæşŢè£ŤåŻđçŽĎæŸäărĎåŕźèśąãĂĆ

åęĆædIJä¡ăäżĚäżĚåŔłæŸŕæČşæL'ğèąŇåĞĘåd'Ğæ■ěéłd'ïijŇåŔŕäžěä¡£çŤĺ `types.prepare_class()` ãĂĆä¿ŃåęĆïijŽ

```
import types
metaclass, kwargs, ns = types.prepare_class('Stock', (), {'metaclass
↪': type})
```

åőČäijŽæ§ěæL'¿åŘĹéĂĆçŽĎåĚČçśżåźűèřČçŤĺåőČçŽĎ `__prepare__()` æŰźæşŢãĂĆ çĎűåŘŐè£ŹäÿłåĚČçśżä£Ìå■ŸåőČçŽĎåĘşéŤőå■ŮåŔĆæŢřïijŇåĞĘåd'ĞåŚ¡åŘ■çľžéŮť'åŘŐèćńè

æŻť'åd'Žä£ąæĄŕ, èŕůåŔĆèĂČ PEP 3115 , äžěåŔŁ Python documentation .

11.19 9.19 åIJĺåőŽäźL'çŽĎæŮűåĂŹåĹìåğŃåŇŰçśżçŽĎæĹŘåŚŸ

éŮőécŸ

ä¡ăæČşåIJĺçśżèćńåőŽäźL'çŽĎæŮűåĂŹåřśåĹìåğŃåŇŰäÿĂéČĺåĹĘçśżçŽĎæĹŘåŚŸïijŇèĂŇäÿ■æŸŕèęĄç

èğčåĘşæŰźæąĹ

åIJĺçśżåőŽäźL'æŮűåřśæL'ğèąŇåĹìåğŃåŇŰæĹŰèő¿ç¡őæŞ■ä¡IJæŸŕåĚČçśżçŽĎäÿĂäÿłåĚÿåđŃåžŢçŤĺåIJ è£ŹæŮűåĂŹä¡ăåŔŕäžěæL'ğèąŇäÿĂäžŻéćÌåd'ŰçŽĎæŞ■ä¡IJãĂĆ

äÿŃéÌćæŸŕäÿĂäÿłä¿Ńå■ŘïijŇåĹl'çŤĺè£ŹäÿłæĂÌèůŕæÌěåĹŻåžžçśżäijijäžŐ `collections` æĺąåÌŮäÿ■çŽĎåŚ¡åŘ■åĚČçżĎçŽĎçśżïijŽ

```
import operator

class StructTupleMeta(type):
    def __init__(cls, *args, **kwargs):
        super().__init__(*args, **kwargs)
        for n, name in enumerate(cls._fields):
            setattr(cls, name, property(operator.itemgetter(n)))

class StructTuple(tuple, metaclass=StructTupleMeta):
    _fields = []
    def __new__(cls, *args):
        if len(args) != len(cls._fields):
```

```
            raise ValueError('{} arguments required'.format(len(cls.
↪_fields)))
        return super().__new__(cls,args)
```

è£Źæőţäžčçă Ąå Řŕäžěç Ť Ílæ Ìěåő Žäź L'çő Ăå■ Ţç Ž Ď å§žäž Őå Ě Čçż Dç Ž Ď æ Ţřæ■őçż Şæđ Ď ïijŇåę Ćäÿ Ň æ L' Äç

```
class Stock(StructTuple):
    _fields = ['name', 'shares', 'price']

class Point(StructTuple):
    _fields = ['x', 'y']
```

äÿŃéÌćæijŤçd'žåőČåę Ća¡Ţåůěä¡IJïijŽ

```
>>> s = Stock('ACME', 50, 91.1)
>>> s
('ACME', 50, 91.1)
>>> s[0]
'ACME'
>>> s.name
'ACME'
>>> s.shares * s.price
4555.0
>>> s.shares = 23
Traceback (most recent call last):
    File "<stdin>", line 1, in <module>
AttributeError: can't set attribute
>>>
```

èőÍèőž

è£ŹäÿĂåřŔèŁĆäÿ■ïijŇçśż `StructTupleMeta` èŐůåŔŰåĹřçśżåśđæĂğ `_fields` äÿ■çŽĎåśđæĂğåŘ■å■ŮåĹŮèąÍïijŇ çĎűåŘŐåřĘåőČäžňè¡ňæ■ćæĹŘçŻÿåžŤçŽĎåŔřèő£éŰőçL'źåőŽåĚČçżĎæ `operator.itemgetter()` åĹŻåžžäÿĂäÿłèő£éŰőåŹĺåĞ¡æŢřijŇ çĎűåŘŐ `property()` åĞ¡æŢřářĘåĚűè¡ňæ■ćæĹŘäÿĂäÿłåśđæĂğãĂĆ

æIJňèŁĆæIJĂéŽ¿æĞĆçŽĎéČĺåĹĘæŸŕç§ěéĄŞäÿ■åŘŇçŽĎåĹİåğŃåŇŰæ■ěéłd'æŸŕäżĂäźĹæŮűåĂŹåŔŞ `StructTupleMeta` äÿ■çŽĎ `__init__()` æŰźæşŢåŔłåIJĺæŕŘäÿłçśżèćńåőŽäźL'æŮűèćńěŕČçŤĺäÿĂæňąă `cls` åŔĆæŢřářśæŸŕéĆčäÿłèćńåőŽäźL'çŽĎçśżãĂĆåőđéŹĚäÿŁïijŇäÿŁè£ŕäžčçăĄä¡£çŤĺäžĘ `_fields` çśżåŔŸéĞŔæİěä£İå■ŸæŰřçŽĎèćńåőŽäźL'çŽĎçśżïijŇ çĎűåŘŐçżŹåőČåĘ■æůżåŁääÿĂçĆźæŰřçŽĎäÿIJèě£ãĂĆ

`StructTuple` çśżä¡IJäÿžäÿĂäÿłæŹőéĂŽçŽĎå§žçśżïijŇä¿ŻåĚűäžŰä¡£çŤĺèĂĚæİěçżğæL'£ãĂĆ è£Źäÿłçśżäÿ■çŽĎ `__new__()` æŰźæşŢçŤĺæİěædĎéĂäæŰřçŽĎåőđä¿ŃãĂĆ è£ŹéĞŇä¡£çŤĺ `__new__()` åźűäÿ■æŸŕå¿Ĺåÿÿèğ ĄïijŇäÿžèę Ąæ Ÿŕå Žääÿžæ ĹŚäžňèę Ąä£őæŤźåĚČçżĎçŽĎèŕČçŤĺç■¿åŘ■ïijä¡£å¿ŮæĹŚäžňåŔŕäžěåČŔæŹőéĂŽçŽĎåőđä¿ŃèŕČçŤĺéĆčæůůåĹŻåžžåőđä¿ŃãĂĆåŕšåČŔäÿŃéÌćè£ŹæůůïijŽ

```
s = Stock('ACME', 50, 91.1) # OK
s = Stock(('ACME', 50, 91.1)) # Error
```

èů§ `__init__()` äÿ■åŘŇçŽĎæŸŕïijŇ`__new__()` æŰźæşŢåIJĺåőđä¿ŃèćńåĹŻåžžäźŃåĽ■èćńèğęåŔŚ
çŤśäžŐåĚČçżĎæŸŕäÿ■åŔŕä£őæŤźçŽĎïijŇæĽĂäžëäÿĂæŮęåőČäžňèćńåĹŻåžžäžĘåřśäÿ■åŔŕèČ¡åŕźåőČåĄŽä
`__init__()` äijŽåIJĺåőđä¿ŃåĹŻåžžçŽĎæIJĂåŘŐèćńèğęåŔŚïijŇ
è£Źæăůç ŽĎèŕÍæĹŚäžňåřśåŔŕäžëåĄŽæĹŚäžňæČşåĄŽçŽĎäžĘãĂĆè£Źäź§æŸŕäÿžäżĂäźĹ
`__new__()` æŰźæşŢåůšçżŔèćńåőŽäźĽäžĘãĂĆ

åř¡çőąæIJňèŁĆå¿Łç§■ïijŇè£ŸæŸŕéIJĂèęĄä¡ăèČ¡äžŢçżĘçăŤèŕżïijŇæůśåĚěæĂÍèĂČPythonçśżæŸŕåęĆä
è£ŸæIJĽåŕśæŸŕåĚČçśżåŠŇçśżçŽĎåŘĎäÿłäÿ■åŘŇçŽĎæŰźæşŢçľűçń§åIJĺäžĂäźĹæŮűåĂŹèćńèřČçŤĺãĂĆ

PEP 422 æŔŘä¿ŽäžĘäÿĂäÿłèğčåĘşæIJňèŁĆéŮőécŸçŽĎåŔęåď ŰäÿĂçğ■æŰźæşŢãĂĆ
ä¡ĘæŸŕïijŇæĹłæ■ćåĽræĹŚåĘŹè£ŹæIJňäźęçŽĎæŮűåĂŹïijŇåőČè£Ÿæšąèćńé ĞĞçžşåŠŇæŐěåŔŮãĂĆ
åř¡çőąåęĆæ■ď ïijŇåęĆæđIJä¡ăä¡£çŤĺçŽĎæŸŕPython 3.3æĹŰæŽť éńŸçŽĎçĽĹæIJňïijŇéĆčäźĹè£ŸæŸŕåĂijå

11.20 9.20 åĹľçŤĺåĞ¡æŢřæşÍèğčåőđçŐřæŰźæşŢéĞ■è¡¡

éŮőécŸ

ä¡ăåůšçżŔå■ęè£ĞæĂŐæăůä¡£çŤĺåĞ¡æŢřåŔĆæŢřæşÍèğčïijŇéĆčäźĹä¡ăåŔŕèČ¡äijŽæČşåĹľçŤĺåőČæÍěåőđ
ä¡ĘæŸŕä¡ăäÿ■çąőåőŽåžŤèŕěæĂŐæăůåŐžåőđçŐřïijĹæĹŰèĂĚåĹřåžŢèąŇå¿ŮéĂŽäÿ■ïijĽãĂĆ

èğčåĘşæŰźæąĹ

æIJňåřŔèŁĆçŽĎæŁĂæIJŕæŸŕå§žäžŐäÿĂäÿłçőĂå■ŢçŽĎæŁĂæIJŕïijŇéĆčåřśæŸŕPythonåĚĄèőÿåŔĆæŢ

```
class Spam:
    def bar(self, x:int, y:int):
        print('Bar 1:', x, y)

    def bar(self, s:str, n:int = 0):
        print('Bar 2:', s, n)

s = Spam()
s.bar(2, 3)  # Prints Bar 1: 2 3
s.bar('hello')  # Prints Bar 2: hello 0
```

äÿŃéIćæŸŕæĹŚäžňçňňäÿĂæ■ěçŽĎåřÍèŕŢïijŇä¡£çŤĺåĹřäžĘäÿĂäÿłåĚČçśżåŠŇæŔŘè£řåŹĺïijŽ

```
# multiple.py
import inspect
import types

class MultiMethod:
    '''
    Represents a single multimethod.
    '''
    def __init__(self, name):
        self._methods = {}
        self.__name__ = name
```

```
    def register(self, meth):
        '''
        Register a new method as a multimethod
        '''
        sig = inspect.signature(meth)

        # Build a type signature from the method's annotations
        types = []
        for name, parm in sig.parameters.items():
            if name == 'self':
                continue
            if parm.annotation is inspect.Parameter.empty:
                raise TypeError(
                    'Argument {} must be annotated with a type'.
↪format(name)
                )
            if not isinstance(parm.annotation, type):
                raise TypeError(
                    'Argument {} annotation must be a type'.
↪format(name)
                )
            if parm.default is not inspect.Parameter.empty:
                self._methods[tuple(types)] = meth
            types.append(parm.annotation)

        self._methods[tuple(types)] = meth

    def __call__(self, *args):
        '''
        Call a method based on type signature of the arguments
        '''
        types = tuple(type(arg) for arg in args[1:])
        meth = self._methods.get(types, None)
        if meth:
            return meth(*args)
        else:
            raise TypeError('No matching method for types {}'.
↪format(types))

    def __get__(self, instance, cls):
        '''
        Descriptor method needed to make calls work in a class
        '''
        if instance is not None:
            return types.MethodType(self, instance)
        else:
            return self

class MultiDict(dict):
    '''
```

```
    Special dictionary to build multimethods in a metaclass
    '''
    def __setitem__(self, key, value):
        if key in self:
            # If key already exists, it must be a multimethod or␣
↪callable
            current_value = self[key]
            if isinstance(current_value, MultiMethod):
                current_value.register(value)
            else:
                mvalue = MultiMethod(key)
                mvalue.register(current_value)
                mvalue.register(value)
                super().__setitem__(key, mvalue)
        else:
            super().__setitem__(key, value)

class MultipleMeta(type):
    '''
    Metaclass that allows multiple dispatch of methods
    '''
    def __new__(cls, clsname, bases, clsdict):
        return type.__new__(cls, clsname, bases, dict(clsdict))

    @classmethod
    def __prepare__(cls, clsname, bases):
        return MultiDict()
```

äÿžäžĘä¡£çŤĺè£ŹäÿłçśżïijŇä¡ăåŔŕäżěåČŔäÿŃéİćè£ŹæăůåĘŹïijŽ

```
class Spam(metaclass=MultipleMeta):
    def bar(self, x:int, y:int):
        print('Bar 1:', x, y)

    def bar(self, s:str, n:int = 0):
        print('Bar 2:', s, n)

# Example: overloaded __init__
import time

class Date(metaclass=MultipleMeta):
    def __init__(self, year: int, month:int, day:int):
        self.year = year
        self.month = month
        self.day = day

    def __init__(self):
        t = time.localtime()
        self.__init__(t.tm_year, t.tm_mon, t.tm_mday)
```

äÿŃéİćæŸŕäÿĂäÿłäžd'äžŠçd'žä¿ŃæİěéłŇèŕĄåőČèČ¡æ■čçąőçŽĎåůěä¡IJïijŽ

```
>>> s = Spam()
>>> s.bar(2, 3)
Bar 1: 2 3
>>> s.bar('hello')
Bar 2: hello 0
>>> s.bar('hello', 5)
Bar 2: hello 5
>>> s.bar(2, 'hello')
Traceback (most recent call last):
    File "<stdin>", line 1, in <module>
    File "multiple.py", line 42, in __call__
        raise TypeError('No matching method for types {}'.
 ↪format(types))
TypeError: No matching method for types (<class 'int'>, <class 'str
 ↪'>)
>>> # Overloaded __init__
>>> d = Date(2012, 12, 21)
>>> # Get today's date
>>> e = Date()
>>> e.year
2012
>>> e.month
12
>>> e.day
3
>>>
```

èőÍèőž

åÍęçŹ¡æÍèèőšïijŇçŻÿåŕźäžŐéĂŽåÿÿçŽĎäžčçăĄèĂŇåůšæIJňèŁĆä¡£çŤÍåĹřäžĘå¿Ĺåď’ŽçŽĎé■ŤæşŢäžčçă
ä¡ĘæŸŕïijŇåőČå■t’èČ¡èőľ’æĹŚäžňæůśåĚěçŘĘèğčåĚČçśżåŠŇæŔŔè£řåŹÍçŽĎåžŢåśĆåůěä¡IJåŐ§çŘĘïijŇ
åźűèČ¡åŁäæůśåŕźè£ŹäžŻæęĆå£ţçŽĎå■řèśąãĂĆåŻäæ■d’ïijŇåŕśçőŮä¡äåźűäÿ■äijŽçńŇå■şåŐżåžŢçŤÍæIJňèŁĆ
åőČçŽĎäÿĂäžŻåžŢåśĆæĂÍæČşå■t’äijŽå¡śåŞ■åĹřåĚűåőČæűĽ’åŔŁåĹřåĚČçśżãĂĄæŔŔè£řåŹÍåŠŇåĞ¡æŢřæş

æIJňèŁĆçŽĎåőđçŐřäÿ■çŽĎäÿżèęĄæĂÍèůřåĚűåőđæŸŕå¿ĹçőĂå■ŢçŽĎãĂĆMutipleMeta
åĚČçśżä¡£çŤÍåőČçŽĎ `__prepare__()` æŰźæşŢ æÍèæŔŘä¿ŻäÿĂäÿłä¡IJäÿž `MultiDict`
åőđä¿ŃçŽĎèĞłåőŽäźĽå■ŮåĚÿãĂĆè£Źäÿłèů§æŹőéĂŽå■ŮåĚÿäÿ■äÿĂæäůçŽĎæŸŕïijŇ
`MultiDict` äijŽåIJÍåĚČçt’ăèćńèő¿ç¡őçŽĎæŮűåĂŹæčĂæ§ěæŸŕåŘęåůšçżŔå■ŸåIJÍïijŇåęĆæđIJå■ŸåIJÍçŽĎ
`MultiMethod` åőđä¿Ńäÿ■åŘĹåźűãĂĆ

`MultiMethod` åőđä¿ŃéĂŽè£ĞæđĎåžžäžŐçśżåđŃç■¿åŘ■åĹřåĞ¡æŢřçŽĎæŸäåřĎæÍěæŤűéŻĘæŰźæşŢ
åIJÍè£ŹäÿłæđĎåžžè£ĞçÍŃäÿ■ïijŇåĞ¡æŢřæşÍèğčèćńçŤÍæÍěæŤűéŻĘè£ŹäžŻç■¿åŘ■çĎűåŘŐæđĎåžžè£ŹäÿłæŸ
è£Źäÿłè£ĞçÍŃåIJÍ `MultiMethod.register()` æŰźæşŢäÿ■åőđçŐřãĂĆ
è£Źçğ■æŸäåřĎçŽĎäÿĂäÿłåĚşéŤőçĽźçĆźæŸŕåŕźäžŐåď’ŽäÿłæŰźæşŢïijŇæĽ’ĂæIJĽåŔĆæŢřçśżåđŃéČ¡å£Ěé

äÿžäžĘèőľ’ `MultiMethod` åőđä¿ŃæĺąæŃ§äÿĂäÿłèřČçŤÍïijŇåőČçŽĎ
`__call__()` æŰźæşŢèćńåőđçŐřäžĘãĂĆ è£ŹäÿłæŰźæşŢäžŐæĽ’ĂæIJĽ’æŐŠéŹd’ `slef`
çŽĎåŔĆæŢřäÿ■æđĎåžžäÿĂäÿłçśżåđŃåĚČçžĎïijŇåIJÍåĘĚéČÍmapäÿ■æ§ěæĽ’¿è£ŹäÿłæŰźæşŢïijŇ
çĎűåŘŐèřČçŤÍçŽÿåžŤçŽĎæŰźæşŢãĂĆäÿžäžĘèČ¡èőľ’ `MultiMethod`

åőđä¿ŃåIJÍçśżåőŽäźĽæŮűæ■čçąőæŞ■ä¡IJïijŃ__get__()　æŸŕå£Ěéążå¿Ůåőđ̧ÓřçŽĎãĂĆ
åőČèćńçŤÍæÌěæđĎåżžæ■čçąőçŽĎçżŚåőŽæŰźæşŢãĂĆærŤåęĆïijŽ

```
>>> b = s.bar
>>> b
<bound method Spam.bar of <__main__.Spam object at 0x1006a46d0>>
>>> b.__self__
<__main__.Spam object at 0x1006a46d0>
>>> b.__func__
<__main__.MultiMethod object at 0x1006a4d50>
>>> b(2, 3)
Bar 1: 2 3
>>> b('hello')
Bar 2: hello 0
>>>
```

äÿ■è£ĞæIJňèŁĆçŽĎåőđçÓřè£ŸæIJL'äÿĂäžŻéŹŘåĹűïijŃåĚűäÿ■äÿĂäÿłæŸŕåőČäÿ■èČ¡ä¡£çŤÍåĚşéŤőå■

```
>>> s.bar(x=2, y=3)
Traceback (most recent call last):
    File "<stdin>", line 1, in <module>
TypeError: __call__() got an unexpected keyword argument 'y'

>>> s.bar(s='hello')
Traceback (most recent call last):
    File "<stdin>", line 1, in <module>
TypeError: __call__() got an unexpected keyword argument 's'
>>>
```

äź§èőÿæIJL'åĚűäžŰçŽĎæŰźæşŢèČ¡æůżåŁäè£Źçğ■æŤŕæŇĄïijŃä¡ĘæŸŕåőČéIJĂèęĄäÿĂäÿłåőŇåĚÍäÿ■a
éŮőécŸåIJÍäžŐåĚşéŤőå■ŮåŔĆæŢřçŽĎåĞžçŐřæŸŕæšąæIJL'éąžåžŔçŽĎãĂĆå¡ŞåőČèů§ä¡■ç¡őåŔĆæŢřæůůåĚ
éĆčä¡ăçŽĎåŔĆæŢřářśäijŽåŔŸå¿ŮærŤè¿ČæůůäźśäžĕïijŃè£ŹæŮűåĂŹä¡ääÿ■å¿Ůäÿ■åIJÍ
__call__() æŰźæşŢäÿ■åĚĹåŐżåĄŽäÿłæŐŠåžŔãĂĆ

åŘŇæăůářźäžŐçżğæL'£äź§æŸŕæIJL'éŹŘåĹűçŽĎïijŃä¿ŃåęĆïijŃçśżäijijäÿŃéÍćè£Źçğ■äžčçăĄářśäÿ■èČ¡

```
class A:
    pass

class B(A):
    pass

class C:
    pass

class Spam(metaclass=MultipleMeta):
    def foo(self, x:A):
        print('Foo 1:', x)

    def foo(self, x:C):
        print('Foo 2:', x)
```

åŐ§åŽäæŸŕåŽääÿž `x : A` æşĺèğčäÿ■èČ¡æĹŘåŁ§åŇźéĚ■å■Řçśžåőđä¿ŃïijĹæŕŤåęĆBçŽĎåőđä¿ŃïijĽïijŇå

```
>>> s = Spam()
>>> a = A()
>>> s.foo(a)
Foo 1: <__main__.A object at 0x1006a5310>
>>> c = C()
>>> s.foo(c)
Foo 2: <__main__.C object at 0x1007a1910>
>>> b = B()
>>> s.foo(b)
Traceback (most recent call last):
    File "<stdin>", line 1, in <module>
    File "multiple.py", line 44, in __call__
        raise TypeError('No matching method for types {}'.
 ↪format(types))
TypeError: No matching method for types (<class '__main__.B'>,)
>>>
```

ä¡IJäÿžä¡£çŤĺåĚČçśžåŠŇæşĺèğčçŽĎäÿĂçğ■æŻ£äžčæŰźæąĹïijŇåŔŕäžěéĂŽè£ĞæŔŔè£ŕåŹĺæİěåőđçŐřç

```
import types

class multimethod:
    def __init__(self, func):
        self._methods = {}
        self.__name__ = func.__name__
        self._default = func

    def match(self, *types):
        def register(func):
            ndefaults = len(func.__defaults__) if func.__defaults__␣
 ↪else 0
            for n in range(ndefaults+1):
                self._methods[types[:len(types) - n]] = func
            return self
        return register

    def __call__(self, *args):
        types = tuple(type(arg) for arg in args[1:])
        meth = self._methods.get(types, None)
        if meth:
            return meth(*args)
        else:
            return self._default(*args)

    def __get__(self, instance, cls):
        if instance is not None:
            return types.MethodType(self, instance)
        else:
            return self
```

äÿžäžĘä¡£çŤÍæŔŔè£řåŹÍçĽ'ĹæIJñïijÑä¡ăéIJĂèęĄåČŔäÿŃéİćè£ŹæăůåĘŹïijŽ

```
class Spam:
    @multimethod
    def bar(self, *args):
        # Default method called if no match
        raise TypeError('No matching method for bar')

    @bar.match(int, int)
    def bar(self, x, y):
        print('Bar 1:', x, y)

    @bar.match(str, int)
    def bar(self, s, n = 0):
        print('Bar 2:', s, n)
```

æŔŔè£řåŹÍæŰźæąĹåŘŇæăůäź§æIJL'åL'■éİćæŔŘåĹřçŽĎéŹŘåĹűïijĹäÿ■æŤŕæŇĄåĚşéŤőå■ŮåŔĆæŢřåŠ

æL'ĂæIJL'äžŃçL'l'éČ¡æŸŕåźşç■L'çŽĎïijŇæIJL'åě¡æIJL'åİŔïijŇäź§èőÿæIJĂåě¡çŽĎåŁđæşŢåŕśæŸŕåIJÍæŽ
äÿ■è£ĞæIJL'äžŻçL'źæőŁæČĚåĘţäÿŃè£ŸæŸŕæIJL'æĎŔäźL'çŽĎïijŇærŤåęĆå§žäžŐæĺąåijŔåŇźéĚ■çŽĎæŰźá
äÿ¿äÿłä¿Ńå■ŘïijŇ8.21åřŔèŁĆäÿ■çŽĎè£éŮőèĂĚæĺąåijŔåŕŕäžëä£őæŤźäÿžäÿĂäÿłä¡£çŤÍæŰźæşŢéĞ■è¡¡çŽ
ä¡ĘæŸŕïijŇéŹd'äžĘè£Źäÿłäžëåd'ŰïijŇéĂŽåÿÿäÿ■åžŤèŕëä¡£çŤÍæŰźæşŢéĞ■è¡¡ïijĹåŕśçőÅå■ŢçŽĎä¡£çŤĺäÿ■å

åIJÍPythonçd'¿åŇžåŕźäžŐåőđçŐřæŰźæşŢéĞ■è¡¡çŽĎèőÍèőžåůšçżŔçŤśæİěåůšäźĚãĂĆ
åŕźäžŐåijŢåŘŚè£ŹäÿłäžL'èőžçŽĎåŐ§åŻäïijŇåŕŕäžëåŔĆèĂČäÿŃGuido van RossumçŽĎè£ŹçŕĞå■Žåőćïij Five-Minute Multimethods in Python

11.21 9.21 éĄ£åĚ■éĞ■åd'■çŽĎåśđæĂğæŰźæşŢ

éŮőécŸ

ä¡ăåIJÍçśżäÿ■éIJĂèęĄéĞ■åd'■çŽĎåőŽäźL'äÿĂäžŻæL'ğèąŇçŻÿåŘŇéĂżè¿ŚçŽĎåśđæĂğæŰźæşŢïijŇærŤ

èğčåĘşæŰźæąĹ

èĂČèŹŠäÿŃäÿĂäÿłçőĂå■ŢçŽĎçśżïijŇåőČçŽĎåśđæĂğçŤśåśđæĂğæŰźæşŢåŇĚèčĚïijŽ

```
class Person:
    def __init__(self, name ,age):
        self.name = name
        self.age = age

    @property
    def name(self):
        return self._name

    @name.setter
    def name(self, value):
        if not isinstance(value, str):
```

```
            raise TypeError('name must be a string')
        self._name = value

    @property
    def age(self):
        return self._age

    @age.setter
    def age(self, value):
        if not isinstance(value, int):
            raise TypeError('age must be an int')
        self._age = value
```

åŔŕäžěçIJŃåĹřïijŇäÿžäžĘåőđçŐřåśđæĂğåĂijçŽĎçśżåđŃæčĂæ§ěæĹŚäżňåĘŹäžĘå¿Ĺåď'ŽçŽĎéĞ■åď'■ä
åŔłèęĄä¡ääžěåŘŐçIJŃåĹřçśżäijijè£ŹæăůçŽĎäżčçăĄïijŇä¡ăéČ¡åžŤèŕěæČşåŁđæşŢåŐżçőĂåŇŰåőČãĂĆ
äÿĂäÿłåŔŕèąŇçŽĎæŰźæşŢæŸŕåĹŻåžžäÿĂäÿłåĞ¡æŢřçŤĺæÍěåőŽäźĽåśđæĂğåźűè£ŤåŽđåőČãĂĆä¿ŃåęĆïijŽ

```
def typed_property(name, expected_type):
    storage_name = '_' + name

    @property
    def prop(self):
        return getattr(self, storage_name)

    @prop.setter
    def prop(self, value):
        if not isinstance(value, expected_type):
            raise TypeError('{} must be a {}'.format(name, expected_
↪type))
        setattr(self, storage_name, value)

    return prop

# Example use
class Person:
    name = typed_property('name', str)
    age = typed_property('age', int)

    def __init__(self, name, age):
        self.name = name
        self.age = age
```

èőÍèőž

æIJňèŁĆæĹŚäžňæijŤçď'žåĘĚéČĺåĞ¡æŢřæĹŰèĂĚéŮ■åŇĚçŽĎäÿĂäÿłéĞ■èęĄçL'źæĂğïijŇåőČäžňå¿ĹåC
`typed_property()` çIJŃäÿŁåŐżæIJL'çĆźéŽ¿çŘĘèğčïijŇåĚűåőđåőČæL'ĂåĄŽçŽĎäżĚäżĚåřśæŸŕäÿžä¡ăç
åŽăæ■ď'ïijŇå¡ŞåIJĺäÿĂäÿłçśżäÿ■ä¡£çŤĺåőČçŽĎæŮűåĂŹïijŇæŢĹæđIJèů§åřĘåőČéĞŇéİćçŽĎäżčçăĄæŤ¿åĹř
åř¡çőąåśđæĂğçŽĎ `getter` åŠŇ `setter` æŰźæşŢèő£éŮőäžĘæIJňåIJřåŔŸéĞŔåęĆ `name` ,
`expected_type` äžěåŘŁ `storate_name` ïijŇè£ŹäÿłåĹæ■čåÿÿïijŇè£ŹäžŽåŔŸéĞŔçŽĎåĂijäijŽä£İå■Ÿ

æĹŚäžňè£ŸåŔŕäžěä¡£çŤĺ `functools.partial()` æİěçĺ■çĺ■æŤźåŔŸäÿŃè£Źäÿłä¿Ńå■ŘïijŇå¿ĹæIJI

```
from functools import partial

String = partial(typed_property, expected_type=str)
Integer = partial(typed_property, expected_type=int)

# Example:
class Person:
    name = String('name')
    age = Integer('age')

    def __init__(self, name, age):
        self.name = name
        self.age = age
```

åĚűåðđä¡ăåŔŕäžěåŔŚçŐřïijŇè£ŹéĞŇçŽĎäžčçăĄèů§8.13åřŔèŁĆäÿ■çŽĎçśžåđŃçşżçż§æŔŔè£řåŹĺäžčçă

11.22 9.22 åőŽäźĽäÿŁäÿŃæŰĞçőąçŘĘåŹĺçŽĎçőÅå■ŢæŰźæşŢ

éŮőécŸ

ä¡ăæČşèĞłåůśåŐżåőđçŐřäÿĂäÿłæŰřçŽĎäÿŁäÿŃæŰĞçőąçŘĘåŹĺïijŇäžěä¿£ä¡£çŤĺwithèŕ■åŘěãĂĆ

èğčåĘşæŰźæąĹ

åőđçŐřäÿĂäÿłæŰřçŽĎäÿŁäÿŃæŰĞçőąçŘĘåŹĺçŽĎæIJĂçőÅå■ŢçŽĎæŰźæşŢåřśæŸŕä¡£çŤĺ `contexlib` æĺąåİŮäÿ■çŽĎ `@contextmanager` èčĚéěřåŹĺãĂĆ äÿŃéİćæŸŕäÿĂäÿłåőđçŐřäžĘäžčçăĄåİÙèőąæŮűåŁ§èČ¡çŽĎäÿŁäÿŃæŰĞçőąçŘĘåŹĺä¿Ńå■ŘïijŽ

```
import time
from contextlib import contextmanager

@contextmanager
def timethis(label):
    start = time.time()
    try:
        yield
    finally:
        end = time.time()
        print('{}: {}'.format(label, end - start))

# Example use
with timethis('counting'):
    n = 10000000
    while n > 0:
        n -= 1
```

åIJÍåĞ¡æŢř `timethis()` äÿ■ïijŇ`yield`äźŃåĽ■çŽĎäżčçăĄäijŽåIJÍäÿŁäÿŃæŰĞçőąçŘĘåŹÍäÿ■ä¡IJäÿ `__enter__()` æŰźæşŢæĽğèąŇïijŇ æĽĂæIJĽåIJÍ `yield` äźŃåŘŐçŽĎäżčçăĄäijŽä¡IJäÿž `__exit__()` æŰźæşŢæĽğèąŇãĂĆ åęĆæđIJåĞžçŐřäžĘåijĆåÿÿïijŇåijĆåÿÿäijŽåIJÍyield-èí■åŘééĆčéĞŇæŁŻåĞžãĂĆ

äÿŃéÍćæŸŕäÿĂäÿłæŻťåŁäéńŸçžğäÿĂçĆźçŽĎäÿŁäÿŃæŰĞçőąçŘĘåŹĺïijŇåőđçŐřäžĘåĹŮèąĺåŕźèśąäÿŁç

```
@contextmanager
def list_transaction(orig_list):
    working = list(orig_list)
    yield working
    orig_list[:] = working
```

è£Źæőţäżčçă Ąç ŽĎä¡IJçŤÍæŸŕäżżä¡Ţåŕźå ĹŮèąÍçŽĎä£őæŤźåŘłæIJĽå¡ŞæĽĂæIJĽäżčçăĄè£ŘèąŇåőŇæ äÿŃéÍćæĹŚäžňæÍěæijŤçd'žäÿĂäÿŃïijŽ

```
>>> items = [1, 2, 3]
>>> with list_transaction(items) as working:
...     working.append(4)
...     working.append(5)
...
>>> items
[1, 2, 3, 4, 5]
>>> with list_transaction(items) as working:
...     working.append(6)
...     working.append(7)
...     raise RuntimeError('oops')
...
Traceback (most recent call last):
    File "<stdin>", line 4, in <module>
RuntimeError: oops
>>> items
[1, 2, 3, 4, 5]
>>>
```

èőÍèőž

éĂŽåÿÿæČĚåĘţäÿŃïijŇåęĆæđIJèęĄåĘŹäÿĂäÿłäÿŁäÿŃæŰĞçőąçŘĘåŹĺïijŇä¡ăéIJĂèęĄåőŽäźĽäÿĂäÿłç `__enter__()` åŠŇäÿĂäÿł `__exit__()` æŰźæşŢïijŇåęĆäÿŃæĽĂçd'žïijŽ

```
import time

class timethis:
    def __init__(self, label):
        self.label = label

    def __enter__(self):
        self.start = time.time()

    def __exit__(self, exc_ty, exc_val, exc_tb):
```

```
        end = time.time()
        print('{}: {}'.format(self.label, end - self.start))
```

åř¡çőąè£Źäÿłäźšäÿ■éŽ¿åĘŹïijŇä¡ĘæŸŕçŻÿæŕŤè¿ČåĘŹäÿĂäÿłçőĂå■ŢçŽĎä¡£çŤÍ `@contextmanager` æşĺèğčçŽĎåĞ¡æŢřèĂŇèĺĂè£ŸæŸŕçĺ■æŸ¿äźŔåŚşãĂĆ

`@contextmanager` åžŤèřëäžĚäżĚçŤĺæĺěåĘŹèĞłåŇĚåŘńçŽĎäÿŁäÿŃæŰĞçőąçŘĘåĞ¡æŢřãĂĆ åęĆæđIJä¡ăæIJL'äÿĂäžŻåŕźèšą(æŕŤåęĆäÿĂäÿłæŰĞäžűãĂĄç¡ŚçżIJè£đæŐěæĹŰéŤA)ïijŇéIJĂèęĄæŤŕæŇĄ `with` èŕ■åŘěïijŇéĆčäźĹä¡ăåŕšéIJĂèęĄå■ŢçŃňåőđçŐř `__enter__()` æŰźæşŢåŠŇ `__exit__()` æŰźæşŢãĂĆ

11.23 9.23 åIJĺåšĂéČĺåŔŸéĞŘå§§äÿ■æL'ğèąŇäžčçăĄ

éŮőécŸ

ä¡ăæČşåIJĺä¡£çŤĺèŇČåŻť'åĘĚæL'ğèąŇæ§Řäÿłäžčçă ĄçL'Ğæőţïij Ňåźűäÿ Ťåÿ ŇæIJŻåIJĺæL'ğèąŇåŘŐæL'Ă

èğčåĘşæŰźæąĹ

äÿžäžĘçŘĘèğčè£ŹäÿłéŮőécŸïijŇåĚĹèŕŢèŕŢäÿĂäÿłçőĂå■ŢåIJżæŹŕăĂĆéęŮåĚĹïijŇåIJĺåĚĺåśĂåŚ¡åŘ■ç

```
>>> a = 13
>>> exec('b = a + 1')
>>> print(b)
14
>>>
```

çĎűåŘŐïijŇåĘ■åIJĺäÿĂäÿłåĞ¡æŢřäÿ■æL'ğèąŇåŘŇæăůçŽĎäžčçăĄïijŽ

```
>>> def test():
...     a = 13
...     exec('b = a + 1')
...     print(b)
...
>>> test()
Traceback (most recent call last):
    File "<stdin>", line 1, in <module>
    File "<stdin>", line 4, in test
NameError: global name 'b' is not defined
>>>
```

åŔŕäžěçIJŃåĞžïijŇæIJĂåŘŐæŁŻåĞžäžĘäÿĂäÿłNameErroråijĆåÿÿïijŇåŕśèů§åIJĺ `exec()` èŕ■åŘěäžŐæšąæL'ğèąŇè£ĞäÿĂæăůãĂĆ èęĄæŸŕä¡ăæČşåIJĺåŘŐéĺćçŽĎèőąçőŮäÿ■ä¡£çŤĺåĹř `exec()` æL'ğèąŇçżŞæđIJçŽĎèŕİåŕšäijŽæIJL'éŮőécŸäžĘãĂĆ

äÿžäžĘä£őæ■čè£ŹæăůçŽĎéŤŹèŕŕïijŇä¡ăéIJĂèęĄåIJĺèŕČçŤĺ `exec()` äźŃåL'■ä¡£çŤĺ `locals()` åĞ¡æŢřæİěå¿ŮåĹřäÿĂäÿłåśĂéČĺåŔŸéĞŘå■ŮåĚÿãĂĆ äźŃåŘŐä¡ăåŕšèČ¡äžŐåśĂéČĺå■ŮåĚÿäÿ■èŐůåŘŰä£őæŤźè£ĞåŘŐçŽĎåŔŸéĞŘåĂijäžĘãĂĆä¿ŃåęĆïijŽ

```
>>> def test():
...     a = 13
...     loc = locals()
...     exec('b = a + 1')
...     b = loc['b']
...     print(b)
...
>>> test()
14
>>>
```

èőÍèőž

åőđéŹĚäÿŁåŕźäžŐ exec() çŽĎæ■čçąőä¡£çŤĺæŸŕæŕŤè¿ČéŽ¿çŽĎãĂĆåď ğåď ŽæŢřæČĚåĘţäÿŃå¡Şä¡ăè exec() çŽĎæŮűåĂŹïijŇ è£ŸæIJĽåŔęåď ŰæŻť åě¡çŽĎèğčåĘşæŰźæąĹïijĹæŕŤåęĆèčĚéěřåŹĺãĂĄéŮ■åŇĚã

çĎűèĂŇïijŇåęĆæđIJä¡ääż■çĎűèęĄä¡£çŤĺ exec() ïijŇæIJňèŁĆåĹŮåĞžäžĘäÿĂäžŻåęĆä¡Ţæ■čçąőä¡£ç éżŸèőď æČĚåĘţäÿŃïijŇexec() äijŽåIJĺěřČçŤĺèĂĚåśĂéČĺåŠŇåĚĺåśĂèŇČåŻť åĘĚæĽğèąŇäžčçăĄąãĂĆçĎű äijăéĂŠçżŹ exec() çŽĎåśĂéČĺèŇČåŻť æŸŕæŃůèť ÌåőđéŹĚåśĂéČĺåŔŸéĞŔçżĎæĹŘçŽĎäÿĂäÿłå■ŮåĚÿãĂ åŻăæ■ď ïijŇåęĆæđIJ exec() åęĆæđIJæĽğèąŇäžĘä£őæŤźæŞ■ä¡IJïijŇè£Źçğ■ä£őæŤźåŘŐçŽĎçżŞæđIJåŕźåő äÿŃéÌćæŸŕåŔęåď ŰäÿĂäÿłæijŤçď žåőČçŽĎä¿Ńå■ŘïijŽ

```
>>> def test1():
...     x = 0
...     exec('x += 1')
...     print(x)
...
>>> test1()
0
>>>
```

äÿŁéÌćäżčçăĄéĞŇïijŇå¡Şä¡ăèřČçŤĺ locals() èŐůåŔŰåśĂéČĺåŔŸéĞŔæŮűïijŇä¡ăèŐůå¿ŮçŽĎæŸŕäi exec() çŽĎåśĂéČĺåŔŸéĞŔçŽĎäÿĂäÿłæŃůèť ÌãĂĆ éĂŽè£ĞåIJĺäžčçăĄæĽğèąŇåŘŐåőąæ§ěè£Źäÿłå■ŮåĚÿ

```
>>> def test2():
...     x = 0
...     loc = locals()
...     print('before:', loc)
...     exec('x += 1')
...     print('after:', loc)
...     print('x =', x)
...
>>> test2()
before: {'x': 0}
after: {'loc': {...}, 'x': 1}
x = 0
>>>
```

äžŤçżĘèğĆår§æIJĂåŘŐäÿĂæ■ęçŽĎè¿ŞåĞžïijŇéŹď éÌđä¡ăårĘ loc

äÿ■èćńä£őæŤźåŘŐçŽĎåĂijæĽŃåŁĹèţŃåĂijçżŹxïijŇåŘęåĹŹxåŔŸéĞŔåĂijæŸŕäÿ■äijŽåŔŸçŽĎãĂĆ

åIJĺä¡£çŤĺ `locals()` çŽĎæŮűåĂŹïijŇä¡ăéIJĂèęĄæşĺæĎŔæŞ■ä¡IJéąžåžŔãĂĆærŔæňąåőČèćńèřČçŤĺçŹ `locals()` äijŽèŐůåŔŰåśĂéČĺåŔŸéĞŔåĂijäÿ■çŽĎåĂijåźűèęĘçŻŰå■ŮåĚÿäÿ■çŻÿåžŤçŽĎåŔŸéĞŔãĂĆ èřůæşĺæĎŔèğĆår§äÿŃäÿŃéİćè£ŹäÿłèŕŢélŇçŽĎè¿ŞåĞžçżŞæđIJïijŽ

```
>>> def test3():
...     x = 0
...     loc = locals()
...     print(loc)
...     exec('x += 1')
...     print(loc)
...     locals()
...     print(loc)
...
>>> test3()
{'x': 0}
{'loc': {...}, 'x': 1}
{'loc': {...}, 'x': 0}
>>>
```

æşĺæĎŔæIJĂåŘŐäÿĂæňąèřČçŤĺ `locals()` çŽĎæŮűåĂŹxçŽĎåĂijæŸŕåęĆä¡Ţèćńèę€çŻŰæŐL'çŽĎãĂ

ä¡IJäÿž `locals()` çŽĎäÿĂäÿłæŻ£äžčæŰźæąĹïijŇä¡ăåŔŕäžëä¡£çŤĺä¡ăèĞłåůśçŽĎå■ŮåĚÿïijŇåźűåřĘåő `exec()` ãĂĆä¿ŃåęĆïijŽ

```
>>> def test4():
...     a = 13
...     loc = { 'a' : a }
...     glb = { }
...     exec('b = a + 1', glb, loc)
...     b = loc['b']
...     print(b)
...
>>> test4()
14
>>>
```

åd'ğéČĺåĹĘæČĚåĘţäÿŃïijŇè£ŹçğæŰźåijŔæŸŕä¡£çŤĺ `exec()` çŽĎæIJĂä¡şåőđèůţãĂĆ ä¡ăåŔłéIJĂèęĄä£ÌèŕĄåĚĺåśĂåŠŇåśĂéČĺå■ŮåĚÿåIJĺåŘŐéİcäžčçăĄèő£éŰőæŰűåůšçżŔèćńåĹÌåğŃåŇŰãĂĆ

è£ŸæIJL'äÿĂçĆźïijŇåIJĺä¡£çŤĺ `exec()` äźŃåL'■ïijŇä¡ăåŔŕèČ¡éIJĂèęĄéŮőäÿŃèĞłåůśæŸŕåŘęæIJL'åĚű åd'ğåd'ŽæŢřæČĚåĘţäÿŃå¡Şä¡ăèęĄèĂČèŹŚä¡£çŤĺ `exec()` çŽĎæŰűåĂŹïijŇ è£ŸæIJL'åŘęåd'ŰæŻt'åě¡çŽĎèğčåĘşæŰźæąĹïijŇærŤåęĆèčĚéěřåŹĺãĂĄéŮ■åŇĚãĂĄåĚČçśżïijŇæĹŰåĚűäżŰ

11.24 9.24 èğčæđŘäÿŐåĹĘæđŘPythonæžŘçăĄ

éŮőécŸ

ä¡ăæČşåĘŹèğčæđŘåźűåĹĘæđŘPythonæžŘäžčçăĄçŽĎçĺŃåžŘãĂĆ

èğčåĘşæŰźæąĹ

åď ğéČĺåĹĘçÍŃåžŘåŚŸç§ěéĄŞPythonèČ¡åď §èőąçőŮæĹŰæĽ ğèąŇå■Ůçňęäÿšå¡ćåijŔçŽĎæžŘäžčçăĄãĂ

```
>>> x = 42
>>> eval('2 + 3*4 + x')
56
>>> exec('for i in range(10): print(i)')
0
1
2
3
4
5
6
7
8
9
>>>
```

åř¡çőąåęĆæ■ď ïijŇast æĺąåİŮèČ¡èćńçŤĺæİěåřĘPythonæžŘçăĄçijŰèřŚæĹŘäÿĂäÿłåŔřèćńåĹĘæđŘçŽĎa

```
>>> import ast
>>> ex = ast.parse('2 + 3*4 + x', mode='eval')
>>> ex
<_ast.Expression object at 0x1007473d0>
>>> ast.dump(ex)
"Expression(body=BinOp(left=BinOp(left=Num(n=2), op=Add(),
right=BinOp(left=Num(n=3), op=Mult(), right=Num(n=4))), op=Add(),
right=Name(id='x', ctx=Load())))"

>>> top = ast.parse('for i in range(10): print(i)', mode='exec')
>>> top
<_ast.Module object at 0x100747390>
>>> ast.dump(top)
"Module(body=[For(target=Name(id='i', ctx=Store()),
iter=Call(func=Name(id='range', ctx=Load()), args=[Num(n=10)],
keywords=[], starargs=None, kwargs=None),
body=[Expr(value=Call(func=Name(id='print', ctx=Load()),
args=[Name(id='i', ctx=Load())], keywords=[], starargs=None,
kwargs=None))], orelse=[])])"
>>>
```

åĹĘæđŘæžŘçăĄæăŚéIJĂèęĄä¡äèĞłåůśæŻť åď ŽçŽĎå■ęäźăïijŇåőČæŸŕçŤśäÿĂçşżåĹŮASTèŁĆçĆźçżĎ
åĹĘæđŘè£ŹäžŻèŁĆçĆźæIJĂçőĂå■ŢçŽĎæŰźæşŢåřśæŸŕåőŽäźĽäÿĂäÿłèő£éŮőèĂĚçśżïijŇåőđçŐřå¿Łåď Ž
`visit_NodeName()` æŰźæşŢïijŇ `NodeName()` åŇźéĚ■éĆčäžŻä¡äæĎ§åĚť èűčçŽĎèŁĆçĆźãĂĆäÿŃéÍćæ

```
import ast

class CodeAnalyzer(ast.NodeVisitor):
    def __init__(self):
```

```
        self.loaded = set()
        self.stored = set()
        self.deleted = set()

    def visit_Name(self, node):
        if isinstance(node.ctx, ast.Load):
            self.loaded.add(node.id)
        elif isinstance(node.ctx, ast.Store):
            self.stored.add(node.id)
        elif isinstance(node.ctx, ast.Del):
            self.deleted.add(node.id)

# Sample usage
if __name__ == '__main__':
    # Some Python code
    code = '''
    for i in range(10):
        print(i)
    del i
    '''

    # Parse into an AST
    top = ast.parse(code, mode='exec')

    # Feed the AST to analyze name usage
    c = CodeAnalyzer()
    c.visit(top)
    print('Loaded:', c.loaded)
    print('Stored:', c.stored)
    print('Deleted:', c.deleted)
```

åęĆædIJä¡ăè£ŘèąŇè£ŹäýłçÍŃåžŔïijŇä¡ăäijŽå¿ŮåĹřäýŃéİćè£ŹæăůçŽĎè¿ŞåĞžïijŽ

```
Loaded: {'i', 'range', 'print'}
Stored: {'i'}
Deleted: {'i'}
```

æIJĂåŘŐïijŇASTåŔŕäżěéĂŽè£Ğ `compile()` åĞ¡æŢřæİěçijŰèŕŚåźűæL'ğèąŇãĂĆä¿ŃåęĆïijŽ

```
>>> exec(compile(top,'<stdin>', 'exec'))
0
1
2
3
4
5
6
7
8
9
>>>
```

èőÍèőž

å¡Şä¡ãèČ¡åď§åĹĘæđŘæžŘäžčçăĄåźűäżŐäÿ■èŐůåŔŰä£ąæĄŕçŽĎæŮűåĂŹïijŇä¡ăářśèČ¡åĘŹå¿Ĺåď'Žäžč
ä¿ŇåęĆïijŇçŻÿæŕŤçŻšçŽőçŽĎäijãéĂŠäÿĂäžŽäžčçăĄçĽĞæőţåĹřçśžäijij
exec() åĞ¡æŢřäÿ■ïijŇä¡ãåŔŕäžěåĚĹåřĘåőČè¡ňæ■ćæĹŘäÿĂäÿłASTïijŇ
çĎűåŘŐèğĆår§åőČçŽĎçżĘèŁĆçIJŃåőČåĹřåžŢæŸŕæĂŐæăůåĄŽçŽĎãĂĆ
ä¡ãè£ŸåŔŕäžěåĘŹäÿĂäžŽåůěåĚůæİěæ§ěçIJŃæ§Řäÿłæĺąå İŮçŽĎåĚĺéČĺæžŘçăĄïijŇåźűäÿŤåIJĺæ■ď'å§žçąĂäÿ

éIJĂèęĄæşĺæĎŘçŽĎæŸŕïijŇåęĆæđIJä¡ăç§ěéĄŞèĞłåůšåIJĺåźšåŢěïijŇä¡ãè£ŸèČ¡åď'§éĞ■åĘŹASTæİěèą
äÿŃéİćæŸŕäÿĂäÿłèčĚéěřåŹĺä¿Ńå■ŘïijŇåŔŕäžěéĂŽè£ĞéĞ■æŰřèğčæđŘåĞ¡æŢřä¡ŞæžŘçăĄãĂĄ
éĞ■åĘŹASTåźűéĞ■æŰřåĹŻåžžåĞ¡æŢřäžčçăĄåŕźèśąæİěåřĘåĚĺåśĂèő£éŮőåŔŸéĞŔéŹ■äÿžåĞ¡æŢřä¡Şä¡IJçŤ

```
# namelower.py
import ast
import inspect

# Node visitor that lowers globally accessed names into
# the function body as local variables.
class NameLower(ast.NodeVisitor):
    def __init__(self, lowered_names):
        self.lowered_names = lowered_names

    def visit_FunctionDef(self, node):
        # Compile some assignments to lower the constants
        code = '__globals = globals()\n'
        code += '\n'.join("{0} = __globals['{0}']".format(name)
                          for name in self.lowered_names)
        code_ast = ast.parse(code, mode='exec')

        # Inject new statements into the function body
        node.body[:0] = code_ast.body

        # Save the function object
        self.func = node

# Decorator that turns global names into locals
def lower_names(*namelist):
    def lower(func):
        srclines = inspect.getsource(func).splitlines()
        # Skip source lines prior to the @lower_names decorator
        for n, line in enumerate(srclines):
            if '@lower_names' in line:
                break

        src = '\n'.join(srclines[n+1:])
        # Hack to deal with indented code
        if src.startswith((' ','\t')):
            src = 'if 1:\n' + src
```

```
        top = ast.parse(src, mode='exec')

        # Transform the AST
        cl = NameLower(namelist)
        cl.visit(top)

        # Execute the modified AST
        temp = {}
        exec(compile(top,'','exec'), temp, temp)

        # Pull out the modified code object
        func.__code__ = temp[func.__name__].__code__
        return func
    return lower
```

äÿžäžĘä¡£çŤÍè£ŹäÿłäżčçăĄïijŇä¡ääŘŕäžěåČŘäÿŃéÍćè£ŹæăůåĘŹïijŽ

```
INCR = 1
@lower_names('INCR')
def countdown(n):
    while n > 0:
        n -= INCR
```

èčĚéěřåŹÍäijŽåřĘ `countdown()` åĞ¡æŢřéĞ■åĘŹäÿžçśżäijijäÿŃéÍćè£Źæăůåŕ■ŘïijŽ

```
def countdown(n):
    __globals = globals()
    INCR = __globals['INCR']
    while n > 0:
        n -= INCR
```

åIJÍæĂğèČ¡æţŃèŕŢäÿ■ïijŇåőČäijŽèőľåĞ¡æŢřè£ŘèąŇå£ń20%

çŐřåIJÍïijŇä¡ăæŸŕäÿ■æŸŕæČşäÿžä¡ăæĽĂæIJL’çŽĎåĞ¡æŢřéČ¡åŁääÿŁè£ŹäÿłèčĚéěřåŹÍåŚćïij§æĹŰèőÿä¡ĘæŸŕïijŇè£Źå■t’æŸŕåŕźäžŐäÿĂäžŻéńŸçžğæŁĂæIJŕæŕŤåęCASTæŞ■ä¡IJãĂĄæžŘçăĄæŞ■ä¡IJç■L’ç■L’çŽĎ

æIJňèŁĆåŘŮåŘęåd’ŰäÿĂäÿłåIJÍ `ActiveState` äÿ■åd’ĎçŘĘPythonå■ŮèŁĆçăĄçŽĎçńăèŁĆçŽĎåŘŕçää¡£çŤÍASTæŸŕäÿĂäÿłæŻt’åŁăéńŸçžğçĆźçŽĎæŁĂæIJŕïijŇåźűäÿŤäź§æŻt’çőĂå■ŢäžŻãĂĆåŘĆèĂČäÿŃéÍćäÿ

11.25 9.25 æŃĘèğčPythonå■ŮèŁĆçăĄ

éŮőécŸ

ä¡ăæČşéĂŽè£ĞåřĘä¡ăçŽĎäżčçăĄåŘ■çijŰèŕŚæĹŘä¡Őçžğ çŽĎå■ŮèŁĆçăĄæÍěæ§ěçIJŃåőČåžŢåśĆçŽĎå

èğčåĘşæŰźæąĹ

`dis` æÍąåİŮåŘŕäżěèćńçŤÍæÍěè¿ŞåĞžäżżä¡ŢPythonåĞ¡æŢřçŽĎåŘ■çijŰèŕŚçżŞæđIJãĂĆä¿ŃåęĆïijŽ

```
>>> def countdown(n):
...     while n > 0:
...         print('T-minus', n)
...         n -= 1
...     print('Blastoff!')
...
>>> import dis
>>> dis.dis(countdown)
...
>>>
```

èőÍèőž

å¡Şä¡ăæČşèęAç§ěéĄŞä¡ăçŽĎçÍŃåžŔåžŢåśĆçŽĎè£ŘèąŇæIJžåĹűçŽĎæŮűåĂŹïijŇdis æÍąåİŮæŸŕå¿ĹæIJL'çŤÍçŽĎãĂĆæŕŤåęĆåęĆæđIJä¡ăæČşèŕŢçİĂçŘĘèğčæĂğèČ¡çL'źå¿ĄãĂĆ èćń dis() åĞ¡æŢřèğčæđŘçŽĎåŐ§åğŃå■ŮèŁĆçăĄåęĆäÿŇæL'Ăçđ'žïijŽ

```
>>> countdown.__code__.co_code
b"x
 ↪'\x00|\x00\x00d\x01\x00k\x04\x00r)\x00t\x00\x00d\x02\x00|\x00\x00\x83
\x02\x00\x01|\x00\x00d\x03\x008}
 ↪\x00\x00q\x03\x00Wt\x00\x00d\x04\x00\x83
\x01\x00\x01d\x00\x00S"
>>>
```

åęĆæđIJä¡ăæČşèĞłåůśèğčéĞŁè£Źæőţäžčçă ĄïijŇä¡ăéIJĂèęĄä¡£çŤÍäÿĂäžŽåIJÍ opcode æÍąåİŮäÿ■åőŽäźL'çŽĎåÿÿéĞŔãĂĆä¿ŃåęĆïijŽ

```
>>> c = countdown.__code__.co_code
>>> import opcode
>>> opcode.opname[c[0]]
>>> opcode.opname[c[0]]
'SETUP_LOOP'
>>> opcode.opname[c[3]]
'LOAD_FAST'
>>>
```

åěĞæĂłçŽĎæŸŕïijŇåIJÍ dis æÍąåİŮäÿ■åźűæšąæIJL'åĞ¡æŢřèőľä¡ääžěçijŰçÍŃæŰźåijŔå¿Ĺåőźæ ŸŞçŽĎääÿ■è£ĞïijŇäÿŃéİćçŽĎçŤ§æĹŘåŹÍåĞ¡æŢřåŔŕäžěåřĘåŐ§åğŃå■ŮèŁĆçăĄåžŔåĹŮè¡ñæ■ćæĹŘ opcodes åŠŇåŔĆæŢřãĂĆ

```
import opcode

def generate_opcodes(codebytes):
    extended_arg = 0
    i = 0
    n = len(codebytes)
    while i < n:
        op = codebytes[i]
```

```
        i += 1
        if op >= opcode.HAVE_ARGUMENT:
            oparg = codebytes[i] + codebytes[i+1]*256 + extended_arg
            extended_arg = 0
            i += 2
            if op == opcode.EXTENDED_ARG:
                extended_arg = oparg * 65536
                continue
        else:
            oparg = None
        yield (op, oparg)
```

ä¡£çŤÍæŰźæşŢåęĆäÿŃïijŽ

```
>>> for op, oparg in generate_opcodes(countdown.__code__.co_code):
...     print(op, opcode.opname[op], oparg)
```

è£Źçğ■æŰźåijŕå¿ĹåřŚæIJL'äžžç§ěéĄŞïijŇä¡ăåŔŕäżěåĹl'çŤÍåőČæŻ£æ■ćäżä¡Ţä¡äæČşèęĄæŻ£æ■ćçŽĎäÿŃéİćæĹŚäżňçŤÍäÿĂäÿłçď'žä¿ŃæİěæijŤçď'žæŢť'äÿłè£ĞçÍŃïijŽ

```
>>> def add(x, y):
...     return x + y
...
>>> c = add.__code__
>>> c
<code object add at 0x1007beed0, file "<stdin>", line 1>
>>> c.co_code
b'|\x00\x00|\x01\x00\x17S'
>>>
>>> # Make a completely new code object with bogus byte code
>>> import types
>>> newbytecode = b'xxxxxxx'
>>> nc = types.CodeType(c.co_argcount, c.co_kwonlyargcount,
...     c.co_nlocals, c.co_stacksize, c.co_flags, newbytecode, c.co_
 ↪consts,
...     c.co_names, c.co_varnames, c.co_filename, c.co_name,
...     c.co_firstlineno, c.co_lnotab)
>>> nc
<code object add at 0x10069fe40, file "<stdin>", line 1>
>>> add.__code__ = nc
>>> add(2,3)
Segmentation fault
```

ä¡ăåŔŕäżěåČŔè£ŹæăůèĂ■åď'ğæŃŻèől'èğčéĞŁåŹĺåěŤæžČãĂĆä¡ĘæŸŕïijŇårźäžŐçijŰåĘŹæŻť'énŸçžğäi
äžŰäžňåŔŕèČ¡çIJ§çŽĎéIJĂèęĄéĞ■åĘŹå■ŮèŁĆçăĄãĂĆæIJňèŁĆæIJĂåŘŐçŽĎéČĺåĹĘæijŤçď'žäžĘè£ŹäÿłæŸ
this code on ActiveState

12 çňňå■Ąçńäïij Žæĺąåİ Ůäÿ Őå ŇĚ

æĺąåİŮäÿŐåŇĚæŸŕäżżä¡Ţåď ğåđŃçĺŃåžŔçŽĎæäÿå£ČïijŇåřśè£đPythonåőL'èčĚçĺŃåžŔæIJňèžńäź§æŸŕ

Contents:

12.1 10.1 æđĎåżžäÿĂäÿłæĺąåİŮçŽĎåśĆçžğåŇĚ

éŮőécŸ

ä¡ăæČşåřĘä¡ăçŽĎäžčçăAçżĎçżĞæĹŘçŤśå¿Ĺåď ŽåĹĘåśĆæĺąåİŮæđĎæĹŘçŽĎåŇĚãĂĆ

èğčåĘşæŰźæąĹ

åřĄèčĚæĹŘåŇĚæŸŕå¿ĹçőĂå■ŢçŽĎãĂĆåIJĺæŰĞäżűçşżçż§äÿŁçżĎçżĞä¡ăçŽĎäžčçăĄïijŇåźűçąőä£İæŕ
ä¿ŃåęĆïijŽ

```
graphics/
    __init__.py
    primitive/
        __init__.py
        line.py
        fill.py
        text.py
    formats/
        __init__.py
        png.py
        jpg.py
```

äÿĂæŮęä¡ăåĄŽåĹřäžĘè£ŹäÿĂçĆźïijŇä¡ăåžŤèŕěèČ¡åď §æĽğèąŇåŘĎçğ■importèŕ■åŔěïijŇåęĆäÿŃïijŽ

```
import graphics.primitive.line
from graphics.primitive import line
import graphics.formats.jpg as jpg
```

èőÍèőž

åőŽäźĽ'æĺąåİŮçŽĎåśĆæňąçżŞæđĎåřśåČŔåIJĺæŰĞäżűçşżçż§äÿŁåžžçńŃçŽőå¡ŢçżŞæđĎäÿĂæăůåőźæŸ
æŰĞäżű__init__.pyçŽĎçŽőçŽĎæŸŕèęĄåŇĚåŘńäÿ■åŘŇè£ŘèąŇçžğåĹńçŽĎåŇĚçŽĎåŔŕéĂĽ'çŽĎåĹİåğŃåŇ
äÿ¿äÿłä¿Ńå■ŘïijŇåęĆæđIJä¡ăæĽğèąŇäžĘèŕ■åŔěimport graphicsïijŇ æŰĞäżűgraph-
ics/__init__.pyåřĘèćńåŕijåĚě,åžžçńŃgraphicsåŚ¡åŘ■çľžéŮť'çŽĎåĘĚåőźãĂĆåČŔimport
graphics.format.jpgè£ŹæăůåŕijåĚěïijŇæŰĞäżűgraphics/__init__.pyåŠŇæŰĞäżűgraphics/formats/__init__.py

çżİåď ğéČĺåĹĘæŮűůåĂŹèőľ__init__.pyçľžçİĂåřśåě¡ãĂĆä¡ĘæŸŕæIJL'äžŻæČĚåĘţäÿŃåŔŕèČ¡åŇĚåŘńäżč
äÿ¿äÿłä¿Ńå■ŘïijŇ__init__.pyèČ¡åď §çŤĺæİěèĞłåŁĺåŁăè¡¡å■ŘæĺąåİŮ:

```
# graphics/formats/__init__.py
from . import jpg
from . import png
```

åČŔè£Źæăůäÿ Ăäÿłæ ŰĞäžű,çŤĺæĹůåŔŕäžëäžĚäžĚéĂŽè£Ğimport grahpics.formatsæİěäžčæŻ£import graphics.formats.jpgäžěåŔŁimport graphics.formats.pngãĂĆ

__init__.pyçŽĎåĚűäžŰåÿÿçŤĺçŤĺæşŢåŇĚæŃňåřĘåď Žäÿłæ ŰĞäžűåŘĹåźűåĹřäÿ Ăäÿłéäžè¿ŚåŠ¡åŘ■çl'žé

æŢŔéŤŘçŽĎçĺŃåžŔåŚŸäijŽåŘŚçŐřïijŇå■şä¡£æšąæIJL'__init__.pyæŰĞäžűå■ŸåIJĺïijŇpythonäž■çĎűä

12.2 10.2 æŐğåĹűæĺąåİŮèćńåĚĺéČĺåŕijåĚěçŽĎåĘĚåőź

éŮőécŸ

å¡Şä¡£çŤĺâĂŹfrom module import *âĂŹ èŕ■åŔěæŮűïijŇåÿŇæIJŻåŕźäžŐæĺąåİŮæĹŰåŇĚåŕijåĞžçŽĎçňę

èğčåĘşæŰźæąĹ

åIJĺä¡äçŽĎæĺąåİŮäÿ■åőŽäźL'äÿĂäÿłåŔŸéĞŔ __all__ æİěæŸŐçąőåIJřåĹŮåĞžéIJĂèęĄåŕijåĞžçŽĎåĘĚå

äÿ¿äÿłä¿Ńå■Ř:

```
# somemodule.py
def spam():
    pass

def grok():
    pass

blah = 42
# Only export 'spam' and 'grok'
__all__ = ['spam', 'grok']
```

èőĺèőž

åř¡çőąåijžçČĹåŔ■åŕźä¡£çŤĺ âĂŸfrom module import *âĂŹ, ä¡ĘæŸŕåIJĺåőŽäźL'äžĘåď ğéĞŔåŔŸéĞŔåŘ■çŽĎæĺąåİŮäÿ■écŚçźĄä¡£çŤĺãĂĆ åęĆæđIJä¡ääÿ■åĄŽäžżä¡ŢäžŃ, è£ŹæăůçŽĎåŕijåĚěåřĘäijŽåŕijåĚěæL'ĂæIJL'äÿ■äžěäÿŃåĹŠçž£åijĂåď t'çŽĎã åŘęäÿĂæŰźéIć,åęĆæđIJåőŽäźL'äžĘ __all__ , éĆčäźĹåŔłæIJL'èćńåĹŮäÿ¿åĞžçŽĎäÿIJèě£äijŽèćńåŕijåĞžãĂĆ

åęĆæđIJä¡ăåřĘ __all__ åőŽäźL'æĹŘäÿĂäÿłçl'žåĹŮèąĺ, æšąæIJL'äÿIJèě£åřĘèćńåŕijåĚěãĂĆ åęĆæđIJ __all__ åŇĚåŘńæIJłåőŽäźL'çŽĎåŘ■å■Ů, åIJĺåŕijåĚěæŮűåijŢètůAttributeErrorãĂĆ

12.3 10.3 ä¡£çŤĺçŻÿåŕźèůŕå¿ĎåŘ■åŕijåĚěåŇĚäÿ■å■ŘæĺąåİŮ

éŮőécŸ

åřĘäžčçăĄçżĎçżĞæĹŘåŇĚ,æČşçŤĺimportèŕ■åŔěäžŐåŔęäÿĂäÿłåŇĚåŘ■æšąæIJL'çąňçijŰçăĄè£ĞçŽĎå

èğčåĘşæŰźæąĹ

ä¡£çŤĺåŇĚçŽĎçŻÿåŕźåŕijåĚěïijŇä¡£äÿĂäÿłæĺąåİŮåŕijåĚěåŘŇäÿĂäÿłåŇĚçŽĎåŔęäÿĂäÿłæĺąåİŮ
äÿ¿äÿłä¿Ńå■ŘïijŇåĄĞèő¿åIJĺä¡ăçŽĎæŰĞäžűçşżçż§äÿŁæIJL'mypackageåŇĚïijŇçżĎçżĞåęĆäÿŇïijŽ

```
mypackage/
    __init__.py
    A/
        __init__.py
        spam.py
        grok.py
    B/
        __init__.py
        bar.py
```

åęĆæđIJæĺąåİŮmypackage.A.spamèęĄåŕijåĚěåŘŇçŻőå¡ŢäÿŇçŽĎæĺąåİŮgrokïijŇåőČåžŤèŕěåŇĚæŃňçŽ

```
# mypackage/A/spam.py
from . import grok
```

åęĆæđIJæĺąåİŮmypackage.A.spamèęĄåŕijåĚëäÿ■åŘŇçŻőå¡ŢäÿŇçŽĎæĺąåİŮB.barïijŇåőČåžŤèŕěä¡£çŤĺ

```
# mypackage/A/spam.py
from ..B import bar
```

äÿd'äÿłimportèŕ■åŔééČ¡æšąåŇĚåŘńéąűåśĆåŇĚåŘ■ïijŇèĂŇæŸŕä¡£çŤĺäžĘspam.pyçŽĎçŻÿåŕźèůŕå¿ĎãĂ

èőÍèőž

åIJĺåŇĚåĘĚïijŇæŮćåŔŕäžěä¡£çŤĺçŻÿåŕźèůŕå¿Ďäź§åŔŕäžěä¡£çŤĺçżÌåŕźèůŕå¿ĎæÌěåŕijåĚěãĂĆ
äÿ¿äÿłä¿Ńå■ŘïijŽ

```
# mypackage/A/spam.py
from mypackage.A import grok # OK
from . import grok # OK
import grok # Error (not found)
```

åČŔmypackage.Aè£Źæăůä¡£çŤĺçżÌåŕźèůŕå¿ĎåŘ■çŽĎäÿ■åĹl'äźŃåd'ĎæŸŕè£ŹåřĘéąűåśĆåŇĚåŘ■çąňçijŮ
äÿ¿äÿłä¿Ńå■ŘïijŇåęĆæđIJä¡ăæŤźåŔŸäžĘåŇĚåŘ■ïijŇä¡ăåřśå£ĚéążæčĂæ§ěæL'ĂæIJL'æŰĞäžűæÌěä£őæ■čæ
åŘŇæăůïijŇçąňçijŰçăĄçŽĎåŘ■çğřäijŽä¡£çğżåĹÍäžčçăĄåŔŸå¿ŮåŻŕéŽ¿ãĂĆäÿ¿äÿłä¿Ńå■ŘïijŇäź§èőÿæIJL'ä
åęĆæđIJä¡£çŤĺçŻÿåŕźåŕijåĚěïijŇéĆčäÿĂåĹĞéČ¡okïijŇçĎűèĂŇä¡£çŤĺçżÌåŕźèůŕå¿ĎåŘ■å¿ĹåŔŕèČ¡äijŽåĞžéŮ

importèŕ■åŔěçŽĎ . åŠŇ . . çIJŃèţůæİěå¿ĹæżŚçĺ¡, ä¡ĘåőČæŇĞåőŽçŻőå¡ŢåŘ■.äÿžå¡ŞåĽ’■çŻőå¡ŢïijŇ..BäÿžçŻőå¡Ţ../BãĂĆè£Źçğ■èŕ■æşŢåŔłéĂĆçŤĺäžŐimport äÿ¿äÿłä¿Ńå■ŘïijŽ

```
from . import grok # OK
import .grok # ERROR
```

åř¡çőąä¡£çŤĺçŽÿåŕźåŕijåĚěçIJŃèţůæİěåČŔæŸŕæţŔèğĹæŰĞäžűçşżçż§ïijŇä¡ĘæŸŕäÿ■èČ¡åĹřåőŽäźL’åŇĚ

æIJĂåŘŐïijŇçŽÿåŕźåŕijåĚěåŔłéĂĆçŤĺäžŐåIJĺåŘĹéĂĆçŽĎåŇĚäÿ■çŽĎæĺąåİŮãĂĆård’åĚűæŸŕåIJĺéąűås ä¿ŃåęĆïijŽ

```
% python3 mypackage/A/spam.py # Relative imports fail
```

åŔęäÿĂæŰźéİćïijŇåęĆæđIJä¡ăä¡£çŤĺPythonçŽĎ-méĂL’éąźæİěæL’ğèąŇåĚĹåL’■çŽĎèĎŽæIJñïijŇçŽÿåŕ ä¿ŃåęĆïijŽ

```
% python3 -m mypackage.A.spam # Relative imports work
```

æŻt’åd’ŽçŽĎåŇĚçŽĎçŽÿåŕźåŕijåĚěçŽĎèČŇæŹŕç§ěèŕE,èŕůçIJŃ PEP 328 .

12.4 10.4 åřĘæĺąåİŮåĹĘåL’šæĹŘåd’Žäÿłæ ŰĞäžű

éŮőécŸ

ä¡ăæČşåřĘäÿĂäÿłæĺąåİŮåĹĘåL’šæĹŘåd’Žäÿłæ ŰĞäžűãĂĆä¡ĘæŸŕä¡ăäÿ■æČşåřĘåĹĘçężçŽĎæŰĞäžűçż

èğčåEşæŰźæąĹ

çĺŃåžŔæĺąåİŮåŔŕäžěéĂŽè£ĞåŔŸæĹŘåŇĚæİěåĹĘåL’šæĹŘåd’ŽäÿłçŃñçńŃçŽĎæŰĞäžűãĂĆèĂČèŹŚäÿ

```
# mymodule.py
class A:
    def spam(self):
        print('A.spam')

class B(A):
    def bar(self):
        print('B.bar')
```

åĄĞèő¿ä¡ăæČşmymodule.pyåĹĘäÿžäÿd’äÿłæŰĞäžűïijŇæŕŔäÿłåőŽäźL’çŽĎäÿĂäÿłçśžãĂĆèęĄåĄŽåĹřè èŕŹè£ŹäÿłçŻőå¡ŢäÿŃïijŇåĹŻåžžäžěäÿŃæŰĞäžűïijŽ

```
mymodule/
    __init__.py
    a.py
    b.py
```

åIJÍa.pyæŰĞäžűäÿ■æŔŠåĚěäžěäÿŃäžčçăĄïijŽ

```
# a.py
class A:
    def spam(self):
        print('A.spam')
```

åIJÍb.pyæŰĞäžűäÿ■æŔŠåĚěäžěäÿŃäžčçăĄïijŽ

```
# b.py
from .a import A
class B(A):
    def bar(self):
        print('B.bar')
```

æIJĂåŘŐïijŇåIJÍ __init__.py äÿ■ïijŇářĘ2äÿłæŰĞäžűçšŸåŘĹåIJÍäÿĂèţůïijŽ

```
# __init__.py
from .a import A
from .b import B
```

åęĆæđIJæŇL'çĚğè£ŹäžŻæ■ěéłd'ïijŇæL'ĂäžğçŤ§çŽĎåŇĚMyModuleářĘä¡IJäÿžäÿĂäÿłå■ŢäÿĂçŽĎéĂż

```
>>> import mymodule
>>> a = mymodule.A()
>>> a.spam()
A.spam
>>> b = mymodule.B()
>>> b.bar()
B.bar
>>>
```

èőÍèőž

åIJÍè£Źäÿłçńăè£ĆäÿŽçŽĎäÿżèęĄéŰőécŸæŸŕäÿĂäÿłèő¿èőąéŰőécŸïijŇäÿ■çőąä¡ăæŸŕåŘęåÿŇæIJŻçŤÍæ

```
from mymodule.a import A
from mymodule.b import B
...
```

è£ŹæăůèČ¡åůěä¡IJïijŇä¡Ęè£ŹèőľçŤÍæĹůæL'£åŔŮæŻť'åd'ŽçŽĎèť§æŃĚïijŇçŤÍæĹůèęĄç§ěéĄŞäÿ■åŘŇ

```
from mymodule import A, B
```

åŕźåŘŐèĂĚèĂŇèÍĂïijŇèőľmoduleæĹŘäÿžäÿĂäÿłåd'ğçŽĎæžŘæŰĞäžűæŸŕæIJĂåÿÿèğĄçŽĎãĂĆä¡Ę
è£ŹæăůåĄŽçŽĎåĚşéŤőæŸŕåĹŻåžžäÿĂäÿłåŇĚçŻőå¡ŢïijŇä¡£çŤÍ __init__.py
æŰĞäžűæİěářĘæŕŔéČÍåĹĘçšŸåŘĹåIJÍäÿĂèţůãĂĆ

å¡ŞäÿĂäÿłæÍąåİŮèćńåĹĘåL'šïijŇä¡äéIJĂèęĄçL'źåĹńæşÍæĎŔäžd'åŔL'åijŢçŤÍçŽĎæŰĞäžűåŘ■ãĂĆäÿ¿äÿ
from .a import A æİěèŐůåŔŰãĂĆ

æŢť äÿłçńäèŁĆéČ¡ä¡£çŤĺåŇĚçŽĎçŻÿåŕźåřijåĚěæİěéĄ£åĚ■åřĘéąűåśĆæĺąåİŮåŘ■çąňçijŰçăĄåĹřæžŘäżč

ä¡IJäÿžè£ŹäÿĂçńäèŁĆçŽĎåżűäijÿïijŇåřĘäżŃçż■åżűè£§åŕijåĚěãĂĆåęĆåŻ¿æL’Äçd’žïijŇ__init__.pyæŰ
èęĄåĄŽåĹřè£ŹäÿĂçĆźïijŇ__init__.pyæIJL’çżĘå¿őçŽĎåŔŸåŇŰïijŽ

```
# __init__.py
def A():
    from .a import A
    return A()

def B():
    from .b import B
    return B()
```

åIJÍè£ŹäÿłçL’ĹæIJñäÿ■ïijŇçśżAåŠŇçśżBèćńæŻ£æ■ćäÿžåIJÍçňňäÿĂæňąèő£éŮőæŮűåŁäè¡¡æL’ĂéIJĂçŽĹ
ä¿ŃåęĆïijŽ

```
>>> import mymodule
>>> a = mymodule.A()
>>> a.spam()
A.spam
>>>
```

åžűè£§åŁäè¡¡çŽĎäÿżèęĄçijžçĆźæŸŕçżğæL’£åŠŇçśżådŃæčĂæ§ěåŔŕèČ¡äijŽäÿ■æŰ■ãĂĆä¡ăåŔŕèČ¡äijŽć

```
if isinstance(x, mymodule.A): # Error
...

if isinstance(x, mymodule.a.A): # Ok
...
```

åžűè£§åŁäè¡¡çŽĎçIJ§åőđä¿Ńå■Ř, èğĄæăĞåĞĘåžŞ multiprocessing/__init__.py
çŽĎæžŘçăĄ.

12.5 10.5 åĹľçŤĺåŚ¡åŘ■çľžéŮťåŕijåĚěçŻőå¡ŢåĹĘæŢčçŽĎäżčçăĄ

éŮőécŸ

ä¡ăåŔŕèČ¡æIJL’åd’ğéĞŔçŽĎäżčçăĄïijŇçŤśäÿ■åŘŇçŽĎäžžæİěåĹĘæŢčåIJřçżt’æŁd’ãĂĆæŕŔäÿłéČĺåĹĘè

èğčåĘşæŰźæąĹ

äżŐæIJñèt’ĺäÿŁèőšïijŇä¡ăèęĄåőŽäźL’äÿĂäÿłéąűçžğPythonåŇĚïijŇä¡IJäÿžäÿĂäÿłåd’ğéŻĘåŘĹåĹĘåijĂç

åIJÍçż§äÿĂäÿ■åŘŇçŽĎçŻőå¡ŢéĞŇçż§äÿĂçŻÿåŘŇçŽĎåŚ¡åŘ■çľžéŮťïijŇä¡ĘæŸŕèęĄåĹăåŐżçŤĺæİěåřH

```
foo-package/
    spam/
        blah.py
```

```
bar-package/
    spam/
        grok.py
```

åIJÍè£Ź2äÿłçŻőå¡ŢéĞŇïijŇéČ¡æIJL’çİĂåĚśåŘŇçŽĎåŚ¡åŘ■çl’žéŮt’spamãĂĆåIJÍäżżä¡ŢäÿĂäÿłçŻőå¡ŢéC

èől’æĹŚäżñçIJŃçIJŃïijŇåęĆæđIJåřĘfoo-packageåŠŇbar-packageéČ¡åŁäåĹřpythonæÍąåİŮèůřå¿ĎåźűåřİèŕŢářijåĚëäijŽåŔŚçŤ§äżĂäźĹ

```
>>> import sys
>>> sys.path.extend(['foo-package', 'bar-package'])
>>> import spam.blah
>>> import spam.grok
>>>
```

äÿd’äÿłäÿ■åŘŇçŽĎåŇĚçŻőå¡ŢèćńåŕĹåźűåĹřäÿĂèţůïijŇä¡ääŔŕäżěářijåĚěspam.blahåŠŇspam.grokïijŇå

èőÍèőž

åIJÍè£ŹéĞŇåůëä¡IJçŽĎæIJžåĹűèćńçğřäÿžâĂIJåŇĚåŚ¡åŘ■çl’žéŮt’âĂİçŽĎäÿĂäÿłçL’źå¿ĄãĂĆäżŐæIJňè

åŇĚåŚ¡åŘ■çl’žéŮt’çŽĎåĚşéŤőæŸŕçąőä£ÍéąűçžğçŻőå¡Ţäÿ■ęšąæIJL’__init__.pyæŰĞäżűæİëä¡IJäÿžåĚśäÿ¿äÿłä¿Ńå■ŘïijŽ

```
>>> import spam
>>> spam.__path__
_NamespacePath(['foo-package/spam', 'bar-package/spam'])
>>>
```

åIJÍåőŽä¡■åŇĚçŽĎå■ŘçżĎäżűæŮűïijŇçŻőå¡Ţ__path__åřĘèćńçŤÍåĹř(ä¿ŃåęĆ, å¡ŞåŕijåĚěspam.grokæĹŰèĂĚspam.blahçŽĎæŮűåĂŹ).

åŇĚåŚ¡åŘ■çl’žéŮt’çŽĎäÿĂäÿłéĞ■èęĄçL’źçĆźæŸŕäżżä¡ŢäžžéČ¡åŔŕäżěçŤÍèĞłåůśçŽĎäżčçăĄæİěæL’l’åś

```
my-package/
    spam/
        custom.py
```

åęĆæđIJä¡ăåřĘä¡ăçŽĎäżčçăĄçŻőå¡ŢåŠŇåĚűäżŰåŇĚäÿĂèţůæůżåŁăåĹřsys.pathïijŇè£ŹåřĘæŮăçijİåIJřå

```
>>> import spam.custom
>>> import spam.grok
>>> import spam.blah
>>>
```

äÿĂäÿłåŇĚæŸŕåŘęèćńä¡IJäÿžäÿĂäÿłåŇĚåŚ¡åŘ■çl’žéŮt’çŽĎäÿżèęĄæŰźæşŢæŸŕæčĂæ§ěåĚű__file__åś

```
>>> spam.__file__
Traceback (most recent call last):
    File "<stdin>", line 1, in <module>
```

```
AttributeError: 'module' object has no attribute '__file__'
>>> spam
<module 'spam' (namespace)>
>>>
```

æŻť'åd'ŽçŽĎåŇĚåŚ¡åŘ■çl'žéŮt'ä£ąæĄŕåŔŕäžěæ§ěçIJŃ PEP 420.

12.6 10.6 éĞ■æŰřåŁäè¡¡æĺąåİŮ

éŮőécŸ

ä¡ăæČşéĞ■æŰřåŁäè¡¡åůšçżŔåŁäè¡¡çŽĎæĺąåİŮïijŇåŻääÿžä¡ăåŕźåĚűæžŘçăĄè£ŻèąŇäžĘä£őæŤźãĂĆ

èğčåĘşæŰźæąĹ

ä¡£çŤĺimp.reload()æİěéĞ■æŰřåŁäè¡¡åĚĹåL'■åŁäè¡¡çŽĎæĺąåİŮãĂĆäÿ¿äÿłä¿Ňå■ŘïijŽ

```
>>> import spam
>>> import imp
>>> imp.reload(spam)
<module 'spam' from './spam.py'>
>>>
```

èőĺèőž

éĞ■æŰřåŁäè¡¡æĺąåİŮåIJĺåijĂåŔŚåŠŇèřČèŕŢè£ĞçÍŃäÿ■åÿÿåÿÿå¿ĹæIJL'çŤĺãĂĆä¡ĘåIJĺçŤ§äžğçŐŕåćČä

reload()æŞęéŹd'äžĘæĺąåİŮåžŢåśĆå■ŮåĚÿçŽĎåĘĚåőźïijŇåźűéĂŽè£ĞéĞ■æŰřæL'ğèąŇæĺąåİŮçŽĎæžŘ

ář¡çőąåęĆæ■d'ïijŇreload()æšąæIJL'æŻť'æŰřåČŔâĂİfrom module import nameâĂİè£ŹæăůäĄçŤĺimportèŕ■åŘěářijåĚěçŽĎåőŽäźL'ãĂĆäÿ¿äÿłä¿Ňå■ŘïijŽ

```
# spam.py
def bar():
    print('bar')

def grok():
    print('grok')
```

çŐřåIJĺåŘŕåŁĺäžd'äžŠåijŔäijŽèŕİïijŽ

```
>>> import spam
>>> from spam import grok
>>> spam.bar()
bar
>>> grok()
```

```
grok
>>>
```

äÿ■éĂĂåĞžPythonä£őæŤźspam.pyçŽĎæžŘçăĄïijŇářĘgrok()åĞ¡æŢřæŤźæĹŘè£ŹæăůïijŽ

```
def grok():
    print('New grok')
```

çŐřåIJĺåŻđåĹřäžď'äžŠåijŔäijŽèŕİïijŇéĞ■æŰřåŁäè¡¡æĺąåİŮïijŇářİèŕŢäÿŃè£ŹäÿłåőđéłŇïijŽ

```
>>> import imp
>>> imp.reload(spam)
<module 'spam' from './spam.py'>
>>> spam.bar()
bar
>>> grok() # Notice old output
grok
>>> spam.grok() # Notice new output
New grok
>>>
```

åIJÍè£Źäÿłä¿Ńå■Řäÿ■ïijŇä¡ăçIJŃåĹřæIJL'2äÿłçL'ĹæIJňçŽĎgrok()åĞ¡æŢřèćńåŁäè¡¡ãĂĆéĂŽåÿÿæİèèŕť'ï

åŻäæ■d'ïijŇåIJÍçŤ§äžğçŐŕáćČäÿ■åŔŕèČ¡éIJĂèęĄéĄ£åĚ■éĞ■æŰřåŁäè¡¡æĺąåİŮãĂĆåIJÍäžď'äžŠçŐŕáćČ

12.7 10.7 è£ŘèąŇçŻőå¡ŢæĹŰåŐŃçijľæŰĞäžű

éŮőécŸ

æĆÍæIJL'äÿĂäÿłåůšæĹŘéŢ£äÿžåŇĚåŘńåď'Žäÿłæ ŰĞäżűçŽĎåžŤçŤÍïijŇåőČåůšè£IJäÿ■åĘ■æŸŕäÿĂäÿłçő

èğčåĘşæŰźæąĹ

åęĆæđIJä¡ăçŽĎåžŤçŤÍçÍŃåžŔåůšçżŔæIJL'åď'Žäÿłæ ŰĞäżűïijŇä¡ăåŔŕäžěæŁŁä¡ăçŽĎåžŤçŤÍçÍŃåžŔæŤ¿
äÿ¿äÿłä¿Ńå■ŘïijŇä¡ăåŔŕäžěåČŔè£ŹæăůåĹŻåžžçŻőå¡Ţïijž

```
myapplication/
    spam.py
    bar.py
    grok.py
    __main__.py
```

åęĆæđIJ__main__.pyå■ŸåIJÍïijŇä¡ăåŔŕäžěçőĂå■ŢåIJřåIJÍéąűçžğçŻőå¡Ţè£ŘèąŇPythonèğčéĞŁåŹÍïijž

```
bash % python3 myapplication
```

èğčéĞŁåŹÍåřĘæL'ğèąŇ__main__.pyæŰĞäżűä¡IJäÿžäÿżçÍŃåžŔãĂĆ

åęĆæđIJä¡ăåřĘä¡ăçŽĎäžčçăĄæL'ŞåŇĚæĹŘzipæŰĞäżűïijŇè£Źçğ■æŁĂæIJŕåŘŇæăůäź§éĂĆçŤÍïijŇäÿ¿ă

```
bash % ls
spam.py bar.py grok.py __main__.py
bash % zip -r myapp.zip *.py
bash % python3 myapp.zip
... output from __main__.py ...
```

èőÍèőž

åĹŻåžžäÿĂäÿłçŻőå¡ŢæĹŰzipæŰĞäżűåźűæůżåŁă__main__.pyæŰĞäżűæİěářĘäÿĂäÿłæŻť åď ğçŽĎPytho

çŤśäžŐçŻőå¡ŢåŠŇzipæŰĞäżűäÿŐæ■čåÿÿæŰĞäżűæIJL’äÿĂçĆźäÿ■åŘŇïijŇä¡ääŔřèČ¡è£ŸéIJĂèęĄáćđå

```
#!/usr/bin/env python3 /usr/local/bin/myapp.zip
```

12.8 10.8 èŕżåŔŰä¡■äžŐåŇĚäÿ■çŽĎæŢřæ■őæŰĞäżű

éŮőécŸ

ä¡ăçŽĎåŇĚäÿ■åŇĚåŘńäžčçăĄéIJĂèęĄåŐżèŕżåŔŰçŽĎæŢřæ■őæŰĞäżűãĂĆä¡ăéIJĂèęĄåř¡åŔřèČ¡åIJřçŢ

èğčåĘşæŰźæąĹ

åĄĞèő¿ä¡ăçŽĎåŇĚäÿ■çŽĎæŰĞäżűçżĎçżĞæĹŘåęĆäÿŃïijŽ

```
mypackage/
    __init__.py
    somedata.dat
    spam.py
```

çŐřåIJĺåĄĞèő¿spam.pyæŰĞäżűéIJĂèęĄèŕżåŔŰsomedata.datæŰĞäżűäÿ■çŽĎåĘĚåőźãĂĆä¡ăåŔřäžčçŢĺà

```
# spam.py
import pkgutil
data = pkgutil.get_data(__package__, 'somedata.dat')
```

çŤśæ■d’äžğçŢ§çŽĎåŔŸéĞŔæŸřåŇĚåŘńèřěæŰĞäżűçŽĎåŐ§ågŃåĘĚåőźçŽĎå■ŮèŁĆå■Ůçňęäÿšã ĂĆ

èőÍèőž

èęĄèŕżåŔŰæŢřæ■őæŰĞäżűïijŇä¡ääŔřèČ¡äijŽåĂ¿åŘŚäžŐçijŰåĘŹä¡£çŢĺåĘĚç¡őçŽĎI/
OåŁ§èČ¡çŽĎäžčçăĄïijŇåęĆopen()ãĂĆä¡ĘæŸřè£Źçğ■æŰźæşŢäź§æIJL’äÿĂäžŻéŮőécŸãĂĆ

éęŰåĚĹïijŇäÿĂäÿłåŇĚářźèğčéĞŁåŹĺçŽĎå¡ŞåL’■åůëä¡IJçŻőå¡ŢåĞääźŐæšąæIJL’æŐğåĹűæİČãĂĆåŻăæ

çňňäžŇïijŇåŇĚéĂŽåÿÿåőL’èčĚä¡IJäÿž.zipæĹŰ.eggæŰĞäżűïijŇè£ŹäžŻæŰĞäżűåźűäÿ■åČŔåIJĺæŰĞäżű

pkgutil.get_data()åĞ¡æŢřæŸŕäÿĂäÿłèŕżåŔŰæŢřæ■őæŰĞäžűçŽĎéńŸçžĝåůěåĚůïijŇäÿ■çŤĺçőąåŇĚæŸŕ

get_data()çŽĎçňňäÿĂäÿłåŔĆæŢřæŸŕåŇĚåŘńåŇĚåŘ■çŽĎå■Ůçňęäÿšã ĂĆä¡ăåŔŕäżěçŻť'æŐëä¡£çŤĺåŇĚ

12.9 10.9 åřĘæŰĞäžűåď'źåŁăåĚěåĹřsys.path

éŮőécŸ

ä¡ăæŮăæşŢåŕijåĚëä¡ăçŽĎPythonäżčçăĄąŻăäÿžåőČæĽ'ĂåIJĺçŽĎçŻőå¡Ţäÿ■åIJĺsys.pathéĞŇãĂĆä¡ăæČş

èğčåĘşæŰźæąĹ

æIJL'äÿd'çğ■åÿÿçŤĺçŽĎæŰźåijŔåřĘæŰřçŻőå¡ŢæůżåŁăåĹřsys.pathãĂĆçňňäÿĂçğ■ïijŇä¡ăåŔŕäżěä¡£çŤĺ

```
bash % env PYTHONPATH=/some/dir:/other/dir python3
Python 3.3.0 (default, Oct 4 2012, 10:17:33)
[GCC 4.2.1 (Apple Inc. build 5666) (dot 3)] on darwin
Type "help", "copyright", "credits" or "license" for more␣
↪information.
>>> import sys
>>> sys.path
['', '/some/dir', '/other/dir', ...]
>>>
```

åIJĺèĞłåőŽäźL'ážŤçŤĺçĺŃåžŔäÿ■ïijŇè£ŹæăůçŽĎçŐŕåćČåŔŸéĞŔåŔŕåIJĺçĺŃåžŔåŘŕåŁĺæŮűèő¿ç¡őæĹŰ

çňňäžŇçğ■æŰźæşŢæŸŕåĹŻåžžäÿĂäÿł.pthæŰĞäżűïijŇåřĘçŻőå¡ŢåĹŮäÿ¿åĞžæÌěïijŇåČŔè£ŹæăůïijŽ

```
# myapplication.pth
/some/dir
/other/dir
```

è£ŹäÿŁ.pthæŰĞäżűéIJĂèęĄæŤ¿åIJĺæ§ŘäÿłPythonçŽĎsite-packagesçŻőå¡ŢïijŇéĂŽåÿÿä¡■äžŐ/usr/local/lib/python3.3/site-packages æĹŰèĂĚ ~/.local/lib/python3.3/sitepackagesãĂĆå¡ŞèğčéĞŁåŹĺåŘŕåŁĺæŮűïijŇ.pthæŰĞäżűéĞŇåĹŮäÿ¿åĞžæÌěçŽĎå■ŸåIJ

èőĺèőž

æŕŤèţůèť źåŁŽåIJŕæĽ¿æŰĞäżűïijŇä¡ăåŔŕèČ¡äijŽåĂ¿åŘŚäžŐåĘŹäÿĂäÿłäžčçăĄæĽŃåŁĺěřČèŁĆsys.pat

```
import sys
sys.path.insert(0, '/some/dir')
sys.path.insert(0, '/other/dir')
```

èŹ¡çĎűè£ŹèČ¡âĂIJåůëä¡IJâĂÌïijŇåőČæŸŕåIJĺåőđèůţäÿ■æđĄäÿžèĎĘåijśïijŇäžŤář¡éĞŔéĄ£åĚ■ä¡£çŤĺã

```
import sys
from os.path import abspath, join, dirname
sys.path.insert(0, join(abspath(dirname(__file__)), 'src'))
```

è£ŹåřĘsrcçŻőå¡Ţæůżå£ăåĹřpathéĞŇïijŇåŠŇæĽğèąŇæŔŠåĚèæ■ěéłd'çŽĎäžčçăĄåIJĺåŘŇäÿĂäÿłçŻőå¡T

site-packagesçŻőå¡ŢæŸŕçňňäÿL'æŰźåŇĚåŠŇæĺąåİŮåőL'èčĚçŽĎçŻőå¡ŢãĂĆåęĆæđIJä¡ăæL'ŃåŁĺåőL'èč
packagesçŻőå¡ŢãĂĆèŹ¡çĎűçŤĺäžŐéĚ■ç¡őpathçŽĎ.pthæŰĞäžűå£ĚéążæŤ¿ç¡őåIJĺsite-
packageséĞŇïijŇä¡ĘåőČéĚ■ç¡őçŽĎèůřå¿ĎåŘŕäžěæŸŕçşżçż§äÿŁäżżä¡Ţä¡ăåÿŇæIJŻçŽĎçŻőå¡ŢãĂĆåŻăæ■d'

12.10 10.10 éĂŽè£Ğå■Ůçňęäÿšå Ř■åŕijåĚěæĺąåİŮ

éŮőécŸ

ä¡ăæČşåŕijåĚěäÿĂäÿłæĺąåİŮïijŇä¡ĘæŸŕæĺąåİŮçŽĎåŘ■å■ŮåIJĺå■ŮçňęäÿšéĞŇãĂĆä¡ăæČşåŕźå■Ůçňęäÿ

èğčåĘşæŰźæąĹ

ä¡£çŤĺimportlib.import_module()åĞ¡æŢřæİěæĽŃåŁĺåŕijåĚěåŘ■å■Ůäÿžå■ŮçňęäÿšçżŹåĞžçŽĎäÿĂäÿłæ

```
>>> import importlib
>>> math = importlib.import_module('math')
>>> math.sin(2)
0.9092974268256817
>>> mod = importlib.import_module('urllib.request')
>>> u = mod.urlopen('http://www.python.org')
>>>
```

import_moduleåŘłæŸŕçőĂå■ŢåIJřæĽğèąŇåŠŇimportçŻÿåŘŇçŽĎæ■ěéłd'ïijŇä¡ĘæŸŕè£ŤåŻđçŤ§æĹŘç

åęĆæđIJä¡ăæ■čåIJĺä¡£çŤĺçŽĎåŇĚïijŇimport_module()äź§åŘŕçŤĺäžŐçŻÿåŕźåŕijåĚěãĂĆä¡ĘæŸŕïijŇä¡äé

```
import importlib
# Same as 'from . import b'
b = importlib.import_module('.b', __package__)
```

èőĺèőž

ä¡£çŤĺimport_module()æĽŃåŁĺåŕijåĚěæĺąåİŮçŽĎéŮőécŸéĂŽåÿÿåĞžçŐřåIJĺäžěæ§Řçğ■æŰźåijŔçijŰå

åIJĺæŮğçŽĎäžčçăĄïijŇæIJL'æŮűä¡ääijŽçIJŃåĹřçŤĺäžŐåŕijåĚěçŽĎåĘĚåžžåĞ¡æŢř__import__()ãĂĆår¡ç
éĂŽåÿÿæŻt'åőźæŸŞä¡£çŤĺãĂĆ

èĞłåőŽäźL'åŕijåĚèè£ĞçÍŃçŽĎénŸçžğåőđä¿ŃèğĄ10.11åřŔèŁĆ

12.11 10.11 éĂŽè£ĞéŠľå■Řè£lJçÍŃåŁăè¡¡æÍąåİŮ

éŮőécŸ

ä¡ăæČşèĞłåőŽäźL'PythonçŽĎimportèŕ■åŔěïijŇä¡£å¿ŮåőČèČ¡äžŐè£IJçÍŃæIJžåŹÍäÿŁéÍćéĂŔæŸŐçŽĎå

èğčåĘşæŰźæąĹ

éęŰåĚĹèęĄæŔŘåĞžæİěçŽĎæŸŕåőL'åĚÍéŮőécŸãĂĆæIJňèŁĆèőÍèőžçŽĎæĂİæČşåęĆæđIJæšąæIJL'äÿĂ
äź§åřśæŸŕèŕť'ïijŇæĹŚäžňçŽĎäÿżèęĄçŻőçŽĎæŸŕæůśåĚěåĹĘæđŘPythonçŽĎimportèŕ■åŔěæIJžåĹűãĂĆ
åęĆæđIJä¡ăçŘĘèğčäžĘæIJňèŁĆåĘĚéČÍåŐ§çŘĘïijŇä¡ăářśèČ¡åd'§äÿžåĚűäżŰäżżä¡ŢçŻőçŽĎèĂŇèĞłåőŽäźL'i
æIJL'äžĘè£ŹäžŻïijŇèől'æĹŚäžňçżğçż■åŘŚåL'■èţřãĂĆ

æIJňèŁĆæäÿå£ČæŸŕèő¿èőąåŕijåĚěèŕ■åŔěçŽĎæL'l'åśŢåŁ§èČ¡ãĂĆæIJL'å¿Ĺåd'Žçğ■æŰźæşŢåŔŕäżěåĄŽ
äÿ■è£ĞäÿžäžĘæijŤçd'žçŽĎæŰźä¿£ïijŇæĹŚäžňåijĂăğŃåĚĹæđĎéĂăäÿŃéİćè£ŹäÿłPythonäžčçăĄçżŞæđĎïijŽ

```
testcode/
    spam.py
    fib.py
    grok/
        __init__.py
        blah.py
```

è£ŹäžŻæŰĞäżűçŽĎåĘĚåőźåźűäÿ■éĞ■èęĄïijŇäÿ■è£ĞæĹŚäžňåIJÍæŕŔäÿłæŰĞäżűäÿ■æŤ¿åĚěäžĘåřŚéĞ
è£Źæăůä¡ăåŔŕäżěæţŃèŕŢåőČäžňåźűæ§ěçIJŃå¡ŞåőČäžňècńåŕijåĚěæŮűçŽĎè¿ŞåĞžãĂĆä¿ŃåęĆïijŽ

```
# spam.py
print("I'm spam")

def hello(name):
    print('Hello %s' % name)

# fib.py
print("I'm fib")

def fib(n):
    if n < 2:
        return 1
    else:
        return fib(n-1) + fib(n-2)

# grok/__init__.py
print("I'm grok.__init__")

# grok/blah.py
print("I'm grok.blah")
```

è£ŹéĞŇçŽĎçŽőçŽĎæŸŕåĚĄèőÿè£ŹäžŻæŰĞäżűä¡IJäÿžæÍąåİŮèćńè£IJçÍŃèő£éŮőãĂĆ
äź§èőÿæIJĂçőĂå■ŢçŽĎæŰźåijŔářśæŸŕårĘåőČäžňåŔŚåÿČåĹřäÿĂäÿłwebæIJ■åŁąåŹÍäÿŁéİćãĂĆåIJÍtestcode

```
bash % cd testcode
bash % python3 -m http.server 15000
Serving HTTP on 0.0.0.0 port 15000 ...
```

æIJ■åŁąåŹĺè£Řèą Ňètůæİěå ŘŐåĘ■åŘŕåŁĺäÿĂäÿłå■ŢçŃňçŽĎPythonèğčéĞŁåŹĺãĂĆçąőä£İä¡ăåŔŕäžěä¡£çŤĺ urllib è ő£éŮőåĹře£IJçĺŃæŰĞäžűãĂĆä¿ŃåęĆïijŽ

```
>>> from urllib.request import urlopen
>>> u = urlopen('http://localhost:15000/fib.py')
>>> data = u.read().decode('utf-8')
>>> print(data)
# fib.py
print("I'm fib")

def fib(n):
    if n < 2:
        return 1
    else:
        return fib(n-1) + fib(n-2)
>>>
```

äžŐè£Źäÿ łæIJ■åŁąåŹĺåŁäè¡¡æžŘäžčçăĄæŸŕæŐěäÿŃæİěæIJňèŁĆçŽĎå§žçąĂãĂĆäÿžäžĘæŻ£äžčæL'ŃåŁĺçŽĎéĂŽè£Ğ urlopen() æİěæŤűéŻĘæžŘæŰĞäžűïijŇæĹŚäžňéĂŽè£ĞèĞłåőŽäźL'importèŕ■åŔěæİěåIJĺåŘŐåŔŕèĞłåŁĺåÿőæĹŚäžňåĄŽåĹřãĂĆ

åŁäè¡¡è£IJçĺŃæĺąåİŮçŽĎçňňäÿĂçğ■æŰźæşŢæŸŕåĹŻåžžäÿĂäÿłæŸ¿çd'žçŽĎåŁäè¡¡åĞ¡æŢřæİěåőŇæĹŘ

```
import imp
import urllib.request
import sys

def load_module(url):
    u = urllib.request.urlopen(url)
    source = u.read().decode('utf-8')
    mod = sys.modules.setdefault(url, imp.new_module(url))
    code = compile(source, url, 'exec')
    mod.__file__ = url
    mod.__package__ = ''
    exec(code, mod.__dict__)
    return mod
```

è£ŹäÿłåĞ¡æŢřäijŽäÿŃè¡¡æžŘäžčçăĄïijŇåźűä¡£çŤĺ compile() åřĘåĚűçijŰèŕŠåĹřäÿĂäÿłäžčçăĄåŕźèśąäÿ■ïijŇ çĎűåŘŐåIJĺäÿĂäÿłæŰřåĹŽåžžçŽĎæĺąåİŮåŕźèśąçŽĎå■ŮåĚÿä

```
>>> fib = load_module('http://localhost:15000/fib.py')
I'm fib
>>> fib.fib(10)
89
>>> spam = load_module('http://localhost:15000/spam.py')
I'm spam
>>> spam.hello('Guido')
```

```
Hello Guido
>>> fib
<module 'http://localhost:15000/fib.py' from 'http://
 ↪localhost:15000/fib.py'>
>>> spam
<module 'http://localhost:15000/spam.py' from 'http://
 ↪localhost:15000/spam.py'>
>>>
```

æ■čåęĆä¡ăæĽĂèğĄïijŇåŕźäžŐçőĂå■ŢçŽĎæĺąåİŮè£ŹäÿłæŸŕèąŇå¿ŮéĂŽçŽĎãĂĆ
äÿ■è£ĞåőČåźűæšąæIJĽåţŇåĚěåĹřéĂŽåÿÿçŽĎimportèŕ■åŔěäÿ■ïijŇåęĆæđIJèęĄæŤŕæŇĄæŻť'énŸçžğçŽĎçż

äÿĂäÿłæŻť'éĚůçŽĎåĄŽæşŢæŸŕåĹŽåżžäÿĂäÿłèĞłåőŽäźĽåŕijåĚěåŹĺãĂĆçňňäÿĂçğ■æŰźæşŢæŸŕåĹŽåż

```
# urlimport.py
import sys
import importlib.abc
import imp
from urllib.request import urlopen
from urllib.error import HTTPError, URLError
from html.parser import HTMLParser

# Debugging
import logging
log = logging.getLogger(__name__)

# Get links from a given URL
def _get_links(url):
    class LinkParser(HTMLParser):
        def handle_starttag(self, tag, attrs):
            if tag == 'a':
                attrs = dict(attrs)
                links.add(attrs.get('href').rstrip('/'))
    links = set()
    try:
        log.debug('Getting links from %s' % url)
        u = urlopen(url)
        parser = LinkParser()
        parser.feed(u.read().decode('utf-8'))
    except Exception as e:
        log.debug('Could not get links. %s', e)
    log.debug('links: %r', links)
    return links

class UrlMetaFinder(importlib.abc.MetaPathFinder):
    def __init__(self, baseurl):
        self._baseurl = baseurl
        self._links = { }
        self._loaders = { baseurl : UrlModuleLoader(baseurl) }

    def find_module(self, fullname, path=None):
```

```
        log.debug('find_module: fullname=%r, path=%r', fullname,␣
↪path)
        if path is None:
            baseurl = self._baseurl
        else:
            if not path[0].startswith(self._baseurl):
                return None
            baseurl = path[0]
        parts = fullname.split('.')
        basename = parts[-1]
        log.debug('find_module: baseurl=%r, basename=%r', baseurl,␣
↪basename)

        # Check link cache
        if basename not in self._links:
            self._links[baseurl] = _get_links(baseurl)

        # Check if it's a package
        if basename in self._links[baseurl]:
            log.debug('find_module: trying package %r', fullname)
            fullurl = self._baseurl + '/' + basename
            # Attempt to load the package (which accesses __init__.
↪py)
            loader = UrlPackageLoader(fullurl)
            try:
                loader.load_module(fullname)
                self._links[fullurl] = _get_links(fullurl)
                self._loaders[fullurl] = UrlModuleLoader(fullurl)
                log.debug('find_module: package %r loaded',␣
↪fullname)
            except ImportError as e:
                log.debug('find_module: package failed. %s', e)
                loader = None
            return loader
        # A normal module
        filename = basename + '.py'
        if filename in self._links[baseurl]:
            log.debug('find_module: module %r found', fullname)
            return self._loaders[baseurl]
        else:
            log.debug('find_module: module %r not found', fullname)
            return None

    def invalidate_caches(self):
        log.debug('invalidating link cache')
        self._links.clear()

# Module Loader for a URL
class UrlModuleLoader(importlib.abc.SourceLoader):
    def __init__(self, baseurl):
```

```
        self._baseurl = baseurl
        self._source_cache = {}

    def module_repr(self, module):
        return '<urlmodule %r from %r>' % (module.__name__, module._
↪_file__)

    # Required method
    def load_module(self, fullname):
        code = self.get_code(fullname)
        mod = sys.modules.setdefault(fullname, imp.new_
↪module(fullname))
        mod.__file__ = self.get_filename(fullname)
        mod.__loader__ = self
        mod.__package__ = fullname.rpartition('.')[0]
        exec(code, mod.__dict__)
        return mod

    # Optional extensions
    def get_code(self, fullname):
        src = self.get_source(fullname)
        return compile(src, self.get_filename(fullname), 'exec')

    def get_data(self, path):
        pass

    def get_filename(self, fullname):
        return self._baseurl + '/' + fullname.split('.')[-1] + '.py'

    def get_source(self, fullname):
        filename = self.get_filename(fullname)
        log.debug('loader: reading %r', filename)
        if filename in self._source_cache:
            log.debug('loader: cached %r', filename)
            return self._source_cache[filename]
        try:
            u = urlopen(filename)
            source = u.read().decode('utf-8')
            log.debug('loader: %r loaded', filename)
            self._source_cache[filename] = source
            return source
        except (HTTPError, URLError) as e:
            log.debug('loader: %r failed. %s', filename, e)
            raise ImportError("Can't load %s" % filename)

    def is_package(self, fullname):
        return False

# Package loader for a URL
class UrlPackageLoader(UrlModuleLoader):
```

```
    def load_module(self, fullname):
        mod = super().load_module(fullname)
        mod.__path__ = [ self._baseurl ]
        mod.__package__ = fullname

    def get_filename(self, fullname):
        return self._baseurl + '/' + '__init__.py'

    def is_package(self, fullname):
        return True

# Utility functions for installing/uninstalling the loader
_installed_meta_cache = { }
def install_meta(address):
    if address not in _installed_meta_cache:
        finder = UrlMetaFinder(address)
        _installed_meta_cache[address] = finder
        sys.meta_path.append(finder)
        log.debug('%r installed on sys.meta_path', finder)

def remove_meta(address):
    if address in _installed_meta_cache:
        finder = _installed_meta_cache.pop(address)
        sys.meta_path.remove(finder)
        log.debug('%r removed from sys.meta_path', finder)
```

äÿŃéÍćæŸŕäÿĂäÿłäžd'äžŠäijŽèŕİïijŇæijŤçd'žäžĘåęĆä¡Ţä¡£çŤĺåL'■éÍćçŽĎäżčçăĄïijŽ

```
>>> # importing currently fails
>>> import fib
Traceback (most recent call last):
File "<stdin>", line 1, in <module>
ImportError: No module named 'fib'
>>> # Load the importer and retry (it works)
>>> import urlimport
>>> urlimport.install_meta('http://localhost:15000')
>>> import fib
I'm fib
>>> import spam
I'm spam
>>> import grok.blah
I'm grok.__init__
I'm grok.blah
>>> grok.blah.__file__
'http://localhost:15000/grok/blah.py'
>>>
```

è£ŹäÿłçL'źæőŁçŽĎæŰźæĄäijŽåőL'èčĔäÿĂäÿłçL'źåĹńçŽĎæ§ěæL'¿åŹÍ

`UrlMetaFinder` åőđä¿ŃïijŇ ä¡IJäÿž `sys.meta_path`

äÿ■æIJĂåŘŐçŽĎåőđä¡ŞãĂĆ å¡ŞæĺąåİŮèćńåŕijåĚěæŮűïijŇäijŽä¿İæ■ő `sys.meta_path`

äÿ■çŽĎæ§ěæL’¿åŹĺáőŽä¡■æĺąåİŮãĂĆ åIJĺè£Źäÿłä¿Ńå■Řäÿ■ïijŇUrlMetaFinder åőđä¿ŃæŸŕæIJĂåŘŐäÿĂäÿłæ§ěæL’¿åŹĺæŰźæąĹïijŇ å¡ŞæĺąåİŮåİJĺäżżä¡ŢäÿĂäÿłæŹőéĂŽåIJřæŰźéČ¡æL’¿äÿ

ä¡IJäÿžåÿÿèğĄçŽĎåőđçŐřæŰźæąĹïijŇUrlMetaFinder çśżåŇĚèčĚåIJĺäÿĂäÿłçŤĺæĹůæŇĞåőŽçŽĎURLäÿŁãĂĆ åIJĺåĘĚéČĺïijŇæ§ěæL’¿åŹléĂŽè£ĞæŁŞåŘŰæŇĞåčåŕijåĚěçŽĎæŮűåĂŹïijŇæĺąåİŮåŘ■äijŽèů§åůšæIJL’çŽĎéŞ¿æŐěä¡IJåŕźæŕŤãĂĆåęĆæđIJæL’¿åĹřäžĘäÿĂäÿłåÑäÿĂäÿłå■ŢçŃñçŽĎ UrlModuleLoader çśżèćńçŤĺæİěäżŐè£IJçÍŃæIJžåŹĺäÿŁåŁãè¡¡æžŘäżčçăĄåźűåĹŻåżžè£ŹéĞŇçijŞå■ŸéŞ¿æŐěçŽĎäÿĂäÿłåŐ§åŽäæŸŕéĄ£åĚ■äÿ■å£ĚèęĄçŽĎHTTPèŕůæśĆéĞ■åd’■åŕijåĚěãĂĆ

èĞłåőŽäźL’åŕijåĚěçŽĎçňňäžÑçğ■æŰźæşŢæŸŕçijŰåĘŹäÿĂäÿłéŠľå■ŘçŻt’æŐěątÑåĚěåĹř sys.path åŔŸéĞŘäÿ■åŐżïijŇ èŕĘåĹńæ§ŘäžŻçŻőå¡ŢåŚ¡åŘ■æĺąåijŔãĂĆ åIJĺ urlimport.py äÿ■æůżåŁääęĆäÿŃçŽĎçśżåŠŇæŤŕæŇĄåĞ¡æŢřijŽ

```
# urlimport.py
# ... include previous code above ...
# Path finder class for a URL
class UrlPathFinder(importlib.abc.PathEntryFinder):
    def __init__(self, baseurl):
        self._links = None
        self._loader = UrlModuleLoader(baseurl)
        self._baseurl = baseurl

    def find_loader(self, fullname):
        log.debug('find_loader: %r', fullname)
        parts = fullname.split('.')
        basename = parts[-1]
        # Check link cache
        if self._links is None:
            self._links = [] # See discussion
            self._links = _get_links(self._baseurl)

        # Check if it's a package
        if basename in self._links:
            log.debug('find_loader: trying package %r', fullname)
            fullurl = self._baseurl + '/' + basename
            # Attempt to load the package (which accesses __init__.
↪py)
            loader = UrlPackageLoader(fullurl)
            try:
                loader.load_module(fullname)
                log.debug('find_loader: package %r loaded',␣
↪fullname)
            except ImportError as e:
                log.debug('find_loader: %r is a namespace package',␣
↪fullname)
                loader = None
            return (loader, [fullurl])

        # A normal module
        filename = basename + '.py'
        if filename in self._links:
```

```
            log.debug('find_loader: module %r found', fullname)
            return (self._loader, [])
        else:
            log.debug('find_loader: module %r not found', fullname)
            return (None, [])

    def invalidate_caches(self):
        log.debug('invalidating link cache')
        self._links = None

# Check path to see if it looks like a URL
_url_path_cache = {}
def handle_url(path):
    if path.startswith(('http://', 'https://')):
        log.debug('Handle path? %s. [Yes]', path)
        if path in _url_path_cache:
            finder = _url_path_cache[path]
        else:
            finder = UrlPathFinder(path)
            _url_path_cache[path] = finder
        return finder
    else:
        log.debug('Handle path? %s. [No]', path)

def install_path_hook():
    sys.path_hooks.append(handle_url)
    sys.path_importer_cache.clear()
    log.debug('Installing handle_url')

def remove_path_hook():
    sys.path_hooks.remove(handle_url)
    sys.path_importer_cache.clear()
    log.debug('Removing handle_url')
```

èęĄä¡£çŤĺè£Źäÿłèůŕå¿Ďæ§ěæL’¿åŹĺïijŇä¡ăåŔłéIJĂèęĄåIJĺ `sys.path` äÿ■åŁăåĚěURLéŞ¿æŐěãĂĆä¿ŃåęĆïijŽ

```
>>> # Initial import fails
>>> import fib
Traceback (most recent call last):
    File "<stdin>", line 1, in <module>
ImportError: No module named 'fib'

>>> # Install the path hook
>>> import urlimport
>>> urlimport.install_path_hook()

>>> # Imports still fail (not on path)
>>> import fib
Traceback (most recent call last):
```

```
    File "<stdin>", line 1, in <module>
ImportError: No module named 'fib'

>>> # Add an entry to sys.path and watch it work
>>> import sys
>>> sys.path.append('http://localhost:15000')
>>> import fib
I'm fib
>>> import grok.blah
I'm grok.__init__
I'm grok.blah
>>> grok.blah.__file__
'http://localhost:15000/grok/blah.py'
>>>
```

åĚşéŤőçĆźåřśæŸŕ `handle_url()` åĞ¡æŢřïijŇåőČèćńæůżåŁääĹřäžĘ `sys.path_hooks` åŔŸéĞŔäÿ■ãĂĆ å¡Ş `sys.path` çŽĎåőđä¡Şèćńåđ'ĎçŘĘæŮűïijŇäijŽèřČçŤĺ `sys.path_hooks` äÿ■çŽĎåĞ¡æŢřãĂĆ åęĆæđIJäżżä¡ŢäÿĂäÿłåĞ¡æŢřè£ŤåŻđäžĘäÿĂäÿłæ§ěæL'¿åŹĺåŕźèśą `sys.path` åőđä¡ŞåŁäè¡¡æĺąåİŮãĂĆ

è£IJçĺŃæĺąåİŮåŁäè¡¡èů§åĚűäżŰçŽĎåŁäè¡¡ä¡£çŤĺæŰźæşŢåĞääźŐæŸŕäÿĂæăůçŽĎãĂĆä¿ŃåęĆïijŽ

```
>>> fib
<urlmodule 'fib' from 'http://localhost:15000/fib.py'>
>>> fib.__name__
'fib'
>>> fib.__file__
'http://localhost:15000/fib.py'
>>> import inspect
>>> print(inspect.getsource(fib))
# fib.py
print("I'm fib")

def fib(n):
    if n < 2:
        return 1
    else:
        return fib(n-1) + fib(n-2)
>>>
```

èőĺèőž

åIJĺèŕęçżĘèőĺèőžäźŃåL'■ïijŇæIJL'çĆźèęĄåijžèřČçŽĎæŸŕïijŇPythonçŽĎæĺąåİŮãĂĄåŇĚåŠŇåŕijåĚěæIJ å■şä¡£çżŔéłŇäÿřåŕŇçŽĎPythonçĺŃåžŔåŠŸäź§å¿ĹåřŚèČ¡çš¿éĂŽåőČäžñãĂĆ æĹŚåIJĺè£ŹéĞŇæŐĺè■ŘäÿĂäžŽåĂijçŽĎåŐżèŕżçŽĎæŰĞæąčåŠŇäźęçś■ïijŇåŇĚæŃň importlib module åŠŇ PEP 302. æŰĞæąčåĘĚåőźåIJĺè£ŹéĞŇäÿ■äijŽèćńéĞ■åd'■æŔŘåĹŕïijŇäÿ■è£ĞæĹŚåIJĺè£Z

éęŰåĚĹïijŇåęĆæđIJä¡ăæČşåĹŽåžžäÿĂäÿłæŰřçŽĎæĺąåİŮåŕźèśąïijŇä¡£çŤĺ `imp.new_module()` åĞ¡æŢřïijŽ

```
>>> import imp
>>> m = imp.new_module('spam')
>>> m
<module 'spam'>
>>> m.__name__
'spam'
>>>
```

æÍąåİŮåŕźèśąéĂŽåÿÿæIJL’äÿĂäžŻæIJ§æIJŻåśđæĂğïijŇåŇĚæŃň `__file__` ïijĹè£ŘèąŇæÍąåİŮåŁäè¡¡èí■åŘěçŽĎæŰĞäžűåŘ■ïijL’ åŠŇ `__package__` (åŇĚåŘ■)ãĂĆ

åĚűæňąïijŇæÍąåİŮäijŽèćńèğčéĞŁåŹÍçijŞå■Ÿèţůæİěã ĂĆæÍąåİŮçijŞå■ŸåŘŕäžěåIJÍå■ŮåĚÿ `sys.modules` äÿ■èćńæL’¿åĹřãĂĆ åŻääÿžæIJL’äžĘè£Źäÿłçij Şå■ŸæIJžåĹűïijŇéĂŽåÿÿåŘŕäžěårĘçijŞå■ŸåŠ

```
>>> import sys
>>> import imp
>>> m = sys.modules.setdefault('spam', imp.new_module('spam'))
>>> m
<module 'spam'>
>>>
```

åęĆæđIJçżŹåőŽæÍąåİŮåůšçżŘå■ŸåIJÍéĆčäźĹåřśäijŽçŻt’æŐèèŐůå¿ŮåůšçżŕèćńåĹŻåżžè£ĞçŽĎæÍąåİŮï

```
>>> import math
>>> m = sys.modules.setdefault('math', imp.new_module('math'))
>>> m
<module 'math' from '/usr/local/lib/python3.3/lib-dynload/math.so'>
>>> m.sin(2)
0.9092974268256817
>>> m.cos(2)
-0.4161468365471424
>>>
```

çŤśäžŐåĹŻåżžæÍąåİŮå¿ĹçőĂå■Ţïij Ňå¿Ĺåőźæ ŸŞçijŰåĘŹçőĂå■ŢåĞ¡æŢřæŕŤåęĆçňňäÿĂéČĺåĹĘçŽĎ `load_module()` åĞ¡æŢřãĂĆ è£ŹäÿłæŰźæąĹçŽĎäÿĂäÿłçijžçĆźæŸŕå¿ĹéŽ¿åď ĎçŘĘåď■æİĆæČĚåĘţæŕŤäÿžäžĘåď ĎçŘĘäÿĂäÿłåŇĚïijŇä¡ãèęĄéĞ■æŰřåőđçŐřæŹőéĂŽimportèí■åŘěçŽĎåžŢåśĆéĂżè¿ŚïijĹæŕŤåęĆæL’ğèąŇéĆčäžŻæŰĞäžűïijŇèő¿ç¡őèůřå¿Ďç■L’ïijL’ãĂĆè£Źäÿłåď ■æİĆæĂğåřśæŸŕäÿžäżĂäźĹæIJĂåě¡çŻt’æŐ

æL’l’åśŢimportèí■åŘěå¿ĹçőĂå■Ţïij Ňä¡ĘæŸŕäijŽæIJL’å¿Ĺåď Žçğżå ŁĺæŞ■ä¡IJãĂĆ æIJĂéńŸåśĆäÿŁïijŇåŕijåĚěæŞ■ä¡IJèćńäÿĂäÿłä¡■äžŐsys.meta_pathåĹŮèąĺäÿ■çŽĎâĂIJåĚČèůřå¿ĎâĂİæ§ěæ åęĆæđIJä¡ãè¿ŞåĞžåőČçŽĎåĂijïijŇäijŽçIJŇåĹřäÿŇéÍćè£ŹæăůïijŽ

```
>>> from pprint import pprint
>>> pprint(sys.meta_path)
[<class '_frozen_importlib.BuiltinImporter'>,
<class '_frozen_importlib.FrozenImporter'>,
<class '_frozen_importlib.PathFinder'>]
>>>
```

å¡ŞæL’ğèąŇäÿĂäÿłèí■åŘěæŕŤåęĆ `import fib` æŮűïijŇèğčéĞŁåŹÍäijŽéĄ■åŐĘsys.mata_pathäÿ■çŽĎèřČçŤÍåőČäžňçŽĎ `find_module()` æŰźæşŢåőŽä¡■æ■čçąőçŽĎæÍąåİŮåŁäè¡¡åŹÍãĂĆ

åŔŕäžěéĂŽè£ĞåőđéłŇæİěçIJŃçIJŃïijŽ

```
>>> class Finder:
...     def find_module(self, fullname, path):
...         print('Looking for', fullname, path)
...         return None
...
>>> import sys
>>> sys.meta_path.insert(0, Finder()) # Insert as first entry
>>> import math
Looking for math None
>>> import types
Looking for types None
>>> import threading
Looking for threading None
Looking for time None
Looking for traceback None
Looking for linecache None
Looking for tokenize None
Looking for token None
>>>
```

æşÍæĎŔçIJŃ `find_module()` æŰźæşŢæŸŕæĂŐæăůåIJÍæŕŔäÿĂäÿłåŕijåĚěåřśèćńèğęåŔŚçŽĎãĂĆè£ŹäÿłæŰźæşŢäÿ■çŽĎpathåŔĆæŢřçŽĎä¡IJçŤÍæŸŕåď˙ĎçŘĘåŇĚãĂĆåď˙ŽäÿłåŇĚèćńåŕijåĚěïijŇåřśæŸŕäÿĂäÿłåŔŕåIJÍåŇĚçŽĎ `__path__` åšđæĂğäÿ■æL'¿åĹřçŽĎèůŕå¿ĎåĹŮèąÍãĂĆ èęĄæL'¿åĹřåŇĚçŽĎå■ŘçżĎäžűåřśèęĄæčĂæ§ěè£ŹäžŻèůŕå¿ĎãĂæŕŤåęĆæşÍæĎŔåŕźäžŐ `xml.etree` åŠŇ `xml.etree.ElementTree` çŽĎèůŕå¿ĎéĚ■ç¡őïijŽ

```
>>> import xml.etree.ElementTree
Looking for xml None
Looking for xml.etree ['/usr/local/lib/python3.3/xml']
Looking for xml.etree.ElementTree ['/usr/local/lib/python3.3/xml/
↪etree']
Looking for warnings None
Looking for contextlib None
Looking for xml.etree.ElementPath ['/usr/local/lib/python3.3/xml/
↪etree']
Looking for _elementtree None
Looking for copy None
Looking for org None
Looking for pyexpat None
Looking for ElementC14N None
>>>
```

åIJÍ `sys.meta_path` äÿŁæ§ěæL'¿åŹÍçŽĎä¡■ç¡őå¿ĹéĞ■èęĄïijŇåřĘåőČäžŐéŸ§åď˙ç䞺åĹřéŸ§år¿ïijŇ

```
>>> del sys.meta_path[0]
>>> sys.meta_path.append(Finder())
>>> import urllib.request
>>> import datetime
```

çŐřåIJĺä¡ăçIJŃäÿ■åĹřäżżä¡Ţè¿ŞåĞžäžĘïijŃåŻääÿžåŕijåĚèècńsys.meta_pathäÿ■çŽĎåĚűäżŰåőđä¡Şåď'Đç
è£ŹæŮűåĂŹïijŃä¡ääŔłæIJL'åIJĺåŕijåĚěäÿ■å■ŸåIJĺæĺąåİŮçŽĎæŮűåĂŹæL'■èČ¡çIJŃåĹřåőČècńèğęåŔŚïijŽ

```
>>> import fib
Looking for fib None
Traceback (most recent call last):
    File "<stdin>", line 1, in <module>
ImportError: No module named 'fib'
>>> import xml.superfast
Looking for xml.superfast ['/usr/local/lib/python3.3/xml']
Traceback (most recent call last):
    File "<stdin>", line 1, in <module>
ImportError: No module named 'xml.superfast'
>>>
```

ä¡ääźŃåL'■åőL'èčĚè£ĞäÿĂäÿłæ■ŢèŐůæIJłç§ěæĺąåİŮçŽĎæ§ěæL'¿åŹĺïijŃè£ŹäÿłæŸŕ
UrlMetaFinder çśżçŽĎåĚşéŤőãĂĆ äÿĂäÿł UrlMetaFinder åőđä¿ŃècńæůżåŁääĹř
sys.meta_path çŽĎæIJńář¿ïijŃä¡IJäÿžæIJĂåŘŐäÿĂäÿłæ§ěæL'¿åŹĺæŰźæąĹãĂĆ
åęĆædIJècńèřůæśĆçŽĎæĺąåİŮåŘ■äÿ■èČ¡åőŽä¡■ïijŃářśäijŽècńè£Źäÿłæ§ěæL'¿åŹĺåď'ĐçŘĘæŐL'ãĂĆ
åď'ĐçŘĘåŃĚçŽĎæŰűåĂŹéIJĂèęĄæşĺæĎŔïijŃåIJĺpathåŔĆæŢřäÿ■æŃĞåőŽçŽĎåĂijéIJĂèęĄècńæčĂæ§ěïijŃ
åęĆædIJäÿ■æŸŕïijŃèřěå■ŘæĺąåİŮå£Ěéąžå¡ŠåśđäžŐåĚűäżŰæ§ěæL'¿åŹĺåźűècńå£¡çŢěæŐL'ãĂĆ

åŕźäžŐåŃĚçŽĎåĚűäżŰåď'ĐçŘĘåŔŕåIJĺ UrlPackageLoader
çśżäÿ■èćńæL'¿åĹřãĂĆ è£Źäÿłçśżäÿ■äijŽåŕijåĚěåŃĚåŘ■ïijŃèĂŃæŸŕåŐžåŁäè¡¡åŕźåžŢçŽĎ
__init__.py æŰĞäżűãĂĆ åőČäź§äijŽèő¿ç¡őæĺąåİŮçŽĎ __path__
åśđæĂğïijŃè£ŹäÿĂæ■ěå¿ĹéĞ■èęĄïijŃ åŻääÿžåIJĺåŁäè¡¡åŃĚçŽĎå■ŘæĺąåİŮæŮűè£ŹäÿłåĂijäijŽècńäijäçżŹå
find_module() èřČçŤĺãĂĆ å§žäžŐèůŕå¿ĐçŽĎåŕijåĚěéŠl'å■ŘæŸŕè£ŹäžŽæĂİæČşçŽĎäÿĂäÿłæL'l'åśŢïijŃ
æĹŚäžňéČ¡ç§ěéĄŞïijŃsys.path æŸŕäÿĂäÿłPythonæ§ěæL'¿æĺąåİŮçŽĎçŻő¡ŢåĹŮèąĺïijŃä¿ŃåęĆïijŽ

```
>>> from pprint import pprint
>>> import sys
>>> pprint(sys.path)
['',
'/usr/local/lib/python33.zip',
'/usr/local/lib/python3.3',
'/usr/local/lib/python3.3/plat-darwin',
'/usr/local/lib/python3.3/lib-dynload',
'/usr/local/lib/...3.3/site-packages']
>>>
```

åIJĺ sys.path äÿ■çŽĎærŔäÿĂäÿłåőđä¡ŞéČ¡äijŽècńéćĺåd'ŰçŽĎçżŚåőŽåĹřäÿĂäÿłæ§ěæL'¿åŹĺårźèśąäÿ
ä¡ääŔŕäžěéĂŽè£Ğæ§ěçIJŃ sys.path_importer_cache
åŐżçIJŃäÿŃè£ŹäžŽæ§ěæL'¿åŹĺïijŽ

```
>>> pprint(sys.path_importer_cache)
{'.': FileFinder('.'),
'/usr/local/lib/python3.3': FileFinder('/usr/local/lib/python3.3'),
'/usr/local/lib/python3.3/': FileFinder('/usr/local/lib/python3.3/
↪'),
'/usr/local/lib/python3.3/collections': FileFinder('...python3.3/
↪collections'),
```

```
'/usr/local/lib/python3.3/encodings': FileFinder('...python3.3/
 ↪encodings'),
'/usr/local/lib/python3.3/lib-dynload': FileFinder('...python3.3/
 ↪lib-dynload'),
'/usr/local/lib/python3.3/plat-darwin': FileFinder('...python3.3/
 ↪plat-darwin'),
'/usr/local/lib/python3.3/site-packages': FileFinder('...python3.3/
 ↪site-packages'),
'/usr/local/lib/python33.zip': None}
>>>
```

sys.path_importer_cache æŕŤ sys.path äijŽæŻť'åď'ğçĆźïijŇ åŻääÿžåőČäijŽäÿžæĽĂæIJĽèćńåŁäè¡¡äżčçăĄçŽĎçŻőå¡Ţèőřå¡ŢåőČäžńçŽĎæ§ěæĽ¿åŹĺãĂĆ è£ŹåŇĚæŃňåŇĚçŽĎå■ŘçŻőå¡ŢïijŇè£ŹäžŽéĂŽåÿÿåIJĺ sys.path äÿ■æŸŕäÿ■å■ŸåIJĺçŽĎãĂĆ

èęĄæĽ'ğèąŇ import fib ïijŇäijŽéąžåžŔæčĂæ§ě sys.path äÿ■çŽĎçŻőå¡ŢãĂĆ åŕźäžŐæŕŔäÿłçŻőå¡ŢïijŇåŘ■çğřâĂIJfibâĂİäijŽèćńäijăçżŹçŻÿåžŤçŽĎ sys.path_importer_cache äÿ■çŽĎæ§ěæĽ¿åŹĺãĂĆ è£ŹäÿłåŔŕäżěèőľä¡ăåĹŻåżžèĞłåůśçŽĎæ§ěæĽ¿åŹĺåźűå

```
>>> class Finder:
... def find_loader(self, name):
...     print('Looking for', name)
...     return (None, [])
...
>>> import sys
>>> # Add a "debug" entry to the importer cache
>>> sys.path_importer_cache['debug'] = Finder()
>>> # Add a "debug" directory to sys.path
>>> sys.path.insert(0, 'debug')
>>> import threading
Looking for threading
Looking for time
Looking for traceback
Looking for linecache
Looking for tokenize
Looking for token
>>>
```

åIJĺè£ŹéĞŇïijŇä¡ăåŔŕäżěäÿžåŘ■å■ŮâĂIJdebugâĂİåĹŻåżžäÿĂäÿłæŰřçŽĎçijŞå■Ÿåőđä¡Şåźűår̨åőČèő¿ sys.path äÿŁçŽĎçňňäÿĂäÿłãĂĆ åIJĺæĽĂæIJĽæŐěäÿŃæİěçŽĎårijåĚěäÿ■ïijŇä¡ääijŽçIJŃåĹřä¡äçŽĎæ§ěä äÿ■è£ĞïijŇçŤśäžŐåőČè£ŤåŻđ (None, [])ïijŇéĆčäźĹåď'ĎçŘĘè£ŻçĺŃäijŽçżğçż■åď'ĎçŘĘäÿŃäÿĂäÿłåőđä¡Şã

sys.path_importer_cache çŽĎä¡£çŤĺèćńäÿĂäÿłå■ŸåĆĺåIJĺ sys.path_hooks äÿ■çŽĎåĞ¡æŢřåĹŮèąĺæŐğåĹűãĂĆ èŕŢèŕŢäÿŃéİćçŽĎä¿Ńå■ŘïijŇåőČäijŽæÿĚéŹď'çijŞå■Ÿåźűçżź sys.path_hooks æůżåŁääÿĂäÿłæŰřçŽĎèůŕå¿ĎæčĂæ§ěåĞ¡æŢř

```
>>> sys.path_importer_cache.clear()
>>> def check_path(path):
...     print('Checking', path)
...     raise ImportError()
```

```
...
>>> sys.path_hooks.insert(0, check_path)
>>> import fib
Checked debug
Checking .
Checking /usr/local/lib/python33.zip
Checking /usr/local/lib/python3.3
Checking /usr/local/lib/python3.3/plat-darwin
Checking /usr/local/lib/python3.3/lib-dynload
Checking /Users/beazley/.local/lib/python3.3/site-packages
Checking /usr/local/lib/python3.3/site-packages
Looking for fib
Traceback (most recent call last):
    File "<stdin>", line 1, in <module>
ImportError: No module named 'fib'
>>>
```

æ■čåęĆä¡ăæĽĂèğĄïijŇcheck_path() åĞ¡æŢřèćńæŕŔäÿł sys.path äÿ■çŽĎåőđä¡ŞěřČçŢĺãĂĆ äÿ■éą¿ïijŇçŢśäžŐæŁŻåĞžäžĘ ImportError åijĆåÿÿïijŇ åŢěéČ¡äÿ■äijŽåŔŚçŢ§äžĘïijĹäžĔäżĎåřĘæčĂæ§ěè¡ňçğżåĹřsys.path_hooksçŽĎäÿŇäÿĂäÿłåĞ¡æŢřïijL'ãĂĆ

ç§ěéĄŞäžĘæĂŐæăůsys.pathæŸŕæĂŐæăůèćńåď'ĎçŘĘçŽĎïijŇä¡ăářśèČ¡æđĎåżžäÿĂäÿłèĞłåőŽäźL'èůŕå¿

```
>>> def check_url(path):
...     if path.startswith('http://'):
...         return Finder()
...     else:
...         raise ImportError()
...
>>> sys.path.append('http://localhost:15000')
>>> sys.path_hooks[0] = check_url
>>> import fib
Looking for fib # Finder output!
Traceback (most recent call last):
    File "<stdin>", line 1, in <module>
ImportError: No module named 'fib'

>>> # Notice installation of Finder in sys.path_importer_cache
>>> sys.path_importer_cache['http://localhost:15000']
<__main__.Finder object at 0x10064c850>
>>>
```

è£Źářśæ ŸŕæIJňèŁĆæIJĂåŘŐéČĺåĹĘçŽĎåĚşéŤőçĆźãĂĆäžŇåőđäÿŁïijŇäÿĂäÿłçŤĺæİěåIJĺsys.pathäÿ■æ
å¡ŞåőČäżňèćńçćřåĹřçŽĎæŮűůåĂŹïijŇäÿĂäÿłæŰřçŽĎ UrlPathFinder åőđä¿ŃèćńåĹŻåžžåźűèćńæŤ¿åĚě sys.path_importer_cache. äźŇåŘŐïijŇæĽĂæIJL'éIJĂèęĄæčĂæ§ě sys.path çŽĎářijåĚèŕ■åŕěéČ¡äijŽä¡£çŤĺä¡ăçŽĎèĞłåőŽäźL'æ§ě

å§žäžŐèůŕå¿ĎářijåĚěçŽĎåŇĚåď'ĎçŘEçĺ■å¿őæIJL'çĆźåď'■æİĆïijŇåźűäÿŤèů§ find_loader() æŰźæşŢè£ŤåŻđåĂijæIJL'åĚşãĂĆ åŕźäžŐçőĂå■ŢæĺąåİŮïijŇfind_loader() è£ŤåŻđäÿĂäÿłåĚČçżĎ(loader, None)ïijŇ åĚűäÿ■çŽĎload-eræŸŕäÿĂäÿłçŤĺäžŐářijåĚěæĺąåİŮçŽĎåŁăè¡¡åŹĺåőđä¿ŃãĂĆ

åŕźäžŐäÿĂäÿłæŹőéĂŽçŽĎåŇĚïijŇfind_loader() è£ŤåŻđäÿĂäÿłåĚČçżĎ(loader, path)ïijŇ åĚűäÿ■çŽĎloaderæŸŕäÿĂäÿłçŤĺäžŐåŕijåĚěåŇĚïijĹåźűæĽğèąŇ__init__.pyïijĽçŽĎåŁãè¡¡åŹĺåőđä¿pathæŸŕäÿĂäÿłäijŽåĹİåğŃåŇŰåŇĚçŽĎ __path__ åśđæĂğçŽĎçŽőå¡ŢåĹŮèąĺãĂĆä¿ŃåęĆïijŇåęĆæđIJå§žçąĂURLæŸŕ http://localhost:15000 åźűäÿŤäÿĂäÿłçŤĺæĹůæĽğèąŇ import grok , éĆčäźĹ find_loader() è£ŤåŻđçŽĎpathåřśäijŽæŸŕ [âĂŸhttp://localhost:15000/grokâĂŹ]

find_loader() è£ŸèęĄèČ¡åď ĎçŘĘäÿĂäÿłåŚ¡åŘ■çľžéŮťåŇĚãĂĆäÿĂäÿłåŚ¡åŘ■çľžéŮťåŇĚäÿ■æIJĽäÿĂäÿłåŘĹæşŢçŽĎåŇĚçŻőå¡ŢåŘ■ïijŇä¡ĘæŸŕäÿ■å■ŸåIJĺ__init__.pyæŰè£ŹæăůçŽĎèŕİïijŇfind_loader() å£ĚéążèŁŤåŻđäÿĂäÿłåĚČçżĎ(None, path)ïijŇ pathæŸŕäÿĂäÿłçŻőå¡ŢåĹŮèąĺïijŇçŤśåőČæİěæđĎåżžåŇĚçŽĎåőŽäźĽæIJĽ__init__.pyæŰĞäžűçŽĎ__path__åŕźäžŐè£Źçğ■æČĚåĘţïijŇåŕijåĚěæIJžåĹűäijŽçżğçż■åĽ■èąŇåŐżæčĂæ§ěsys.pathäÿ■çŽĎçŽőå¡ŢãĂĆåęĆæđIJæĽ¿åĹřäžĘåŚ¡åŘ■çľžéŮťåŇĚïijŇæĽĂæIJĽçŽĎçżŞæđIJèůŕå¿ĎèćńåŁäåĹřäÿĂèţůæİěæđĎåżžæIJĂåĚşäžŐåŚ¡åŘ■çľžéŮťåŇĚçŽĎæŻťåď Žä£qæĄŕèŕůåŔĆèĂČ10.5åřŔèŁĆãĂĆ

æĽĂæIJĽçŽĎåŇĚéČ¡åŇĚåŘńäžĘäÿĂäÿłåĘĚéČĺèůŕå¿Ďèő¿ç¡őïijŇåŔŕäžěåIJĺ__path__åśđæĂğäÿ■çIJŃ

```
>>> import xml.etree.ElementTree
>>> xml.__path__
['/usr/local/lib/python3.3/xml']
>>> xml.etree.__path__
['/usr/local/lib/python3.3/xml/etree']
>>>
```

äźŃåL’■æŔŘåĹřïijŇ__path__çŽĎèő¿ç¡őæŸŕéĂŽè£Ğ find_loader() æŰźæşŢè£ŤåŻđåĂijæŐğåĹűçŽĎãĂĆ äÿ■è£ĞïijŇ__path__æŐëäÿŃæİëäź§ècńsys.path_hooksäÿ■çŽĎåĞ¡æŢåŻăæ■d’ïijŇä¡ĘåŇĚçŽĎå■ŘçżĎäžűècńåŁäè¡¡åŘŐïijŇä¡■äžŐ__path__äÿ■çŽĎåőđä¡ŞäijŽècń handle_url() åĞ¡æŢřæčĂæ§ěãĂĆ è£ŹäijŽářijèĞťæŰřçŽĎ UrlPathFinder åőđä¿ŃècńåĹŽåžžåźűäÿŤècńåŁääĚěåĹř sys.path_importer_cache äÿ■ãĂĆ

è£ŸæIJĽäÿłéŽ¿çĆźářśæŸŕ handle_url() åĞ¡æŢřäžěåŘŁåőČèů§åĘĚéČĺä¡£çŤĺçŽĎ _get_links() åĞ¡æŢřäźŃéŮťçŽĎäžd’äžŠãĂĆ åęĆæđIJä¡äçŽĎæ§ěæĽ¿åŹĺåőđçŐŕéIJĂèęĄä¡£çŤĺåĹřåĚűæIJĽåŘŕèČ¡è£ŹäžŻæĹąåİŮäijŽåIJĺæ§ěæĽ¿åŹĺæŞ■ä¡IJæIJ§éŮť è£ŽèąŇæŻťåď ŽçŽĎářijåĚěãĂĆ åőČåŘŕäžěářijèĞť handle_url() åŠŇåĚűäžŰæ§ěæĽ¿åŹĺéČĺåĹĘéŽůåĚěäÿĂçğ■éĂŠå¡Šå¿łçŐŕçŁűæĂĄãäÿžäžĘèğčéĞŁè£Źçğ■åŘŕèČ¡æĂğïijŇåőđçŐřäÿ■æIJĽäÿĂäÿłècńåĹŽåžžçŽĎæ§ěæĽ¿åŹĺçijŞå■ŸïijĹæŕŘäÿĂåőČåŘŕäžěéĄ£åĚ■åĹŽåžžéĞ■åď■æ§ěæĽ¿åŹĺçŽĎéŮőécŸãĂĆ åŘęåď ŰïijŇäÿŃéİćçŽĎäžčçăĄçĽĞæőţåŘŕäžěçąőä£İæ§ěæĽ¿åŹĺäÿ■äijŽåIJĺåĹİåğŃåŇŰéŞ¿æŐéžĘåŘĹçŽĎ

```
# Check link cache
if self._links is None:
    self._links = [] # See discussion
    self._links = _get_links(self._baseurl)
```

æIJĂåŘŐïijŇæ§ěæĽ¿åŹĺçŽĎ invalidate_caches() æŰźæşŢæŸŕäÿĂäÿłåůěåĚůæŰźæşŢïijŇçŤĺæİěæÿĚçŘĘåĘĚéČĺçijŞå■ŸãĂĆ è£ŹäÿłæŰźæşŢåĘ■çŤĺæĹůèřČçŤĺ importlib.invalidate_caches() çŽĎæŮűåĂŹècńèğęåŔŠãĂĆ åęĆæđIJä¡äæČşèől’URLåŕijåĚèèĂĚéĞ■æŰřèŕžåŘŰéŞ¿æŐěåĹŮèąĺçŽĎèŕİåŘŕä

åŕźæŕŤäÿŃäÿď’çğ■æŰźæąĹïijĹä£őæŤźsys.meta_pathæĹŰä¡£çŤĺäÿĂäÿłèůŕå¿ĎéŠl’å■ŘïijL’ãĂĆ ä¡£çŤĺsys.meta_pathçŽĎåŕijåĚèèĂĚåŘŕäžěæŃL’çĚğèĞłåůśçŽĎéIJĂèęĄèĞłçŤśåď ĎçŘĘæĺąåİŮãĂĆ ä¿ŃåęĆïijŇåőČäžňåŘŕäžěäžŐæŢřæ■őåžŞäÿ■åŕijåĚěæĹŰäžěäÿ■åŘŃäžŐäÿĂèĹňæĺąåİŮ/åŃĚåď ĎçŘĘæŰźåi

è£Źçğ■èĞłçŤśåŘŇæăůæĎŘåŚşçİĂåŕijåĚěèĂĚéIJĂèęĄèĞłåůśè£Żèą ŇåĘĚéČĺçŽĎäÿĂäžŻçőąçŘĘãĂĆ
åŘęåď Űïij Ňå§žäžŐèůŕå¿ĎçŽĎéŠľå■ŘåŘłæŸŕéĂĆçŤĺäžŐåŕźsys.pathçŽĎåď ĎçŘĘãĂĆ
éĂŽè£Ğè£Źçğ■æĽľåśŢåŁäè¡¡çŽĎæĺąåİŮèů§æŹőéĂŽæŰźåijŔåŁäè¡¡çŽĎçĽźæĂğæŸŕäÿĂæăůçŽĎãĂĆ

åęĆæđIJåĹřçŐřåIJĺäÿžæ■ćä¡ăè£ŸæŸŕäÿ■æŸŕå¿ĹæŸŐçŹ¡ïijŇéĆčäźĹåŘŕäžěéĂŽè£ĞåćđåŁääÿĂäžŻæŮ

```
>>> import logging
>>> logging.basicConfig(level=logging.DEBUG)
>>> import urlimport
>>> urlimport.install_path_hook()
DEBUG:urlimport:Installing handle_url
>>> import fib
DEBUG:urlimport:Handle path? /usr/local/lib/python33.zip. [No]
Traceback (most recent call last):
File "<stdin>", line 1, in <module>
ImportError: No module named 'fib'
>>> import sys
>>> sys.path.append('http://localhost:15000')
>>> import fib
DEBUG:urlimport:Handle path? http://localhost:15000. [Yes]
DEBUG:urlimport:Getting links from http://localhost:15000
DEBUG:urlimport:links: {'spam.py', 'fib.py', 'grok'}
DEBUG:urlimport:find_loader: 'fib'
DEBUG:urlimport:find_loader: module 'fib' found
DEBUG:urlimport:loader: reading 'http://localhost:15000/fib.py'
DEBUG:urlimport:loader: 'http://localhost:15000/fib.py' loaded
I'm fib
>>>
```

æIJĂåŘŐïijŇåžžèőőä¡ăèŁśçĆźæŮűéŮt'çIJŃçIJŃ PEP 302 äžěåŘŁimportlibçŽĎæŰĞæąčãĂĆ

12.12 10.12 åŕijåĚěæĺąåİŮçŽĎåŘŇæŮűä£őæŤźæĺąåİŮ

éŮőécŸ

ä¡ăæČşçżŹæ§Řäÿłåůšå■ŸåIJĺæĺąåİŮäÿ■çŽĎåĞ¡æŢřæůżåŁäècĚéěřåŹĺãĂĆ
äÿ■è£ĞïijŇåĽ■æŘŘæŸŕè£ŹäÿłæĺąåİŮåůšçżŔèćńåŕijåĚěåźűäÿŤècńä¡£çŤĺè£ĞãĂĆ

èğčåĘşæŰźæąĹ

è£ŹéĞŇéŮőécŸçŽĎæIJňèťĺåřśæŸŕä¡ăæČşåIJĺæĺąåİŮècńåŁäè¡¡æŮűæĽğèąŇæ§Řäÿłåŀĺä¡IJãĂĆ
åŘŕèČ¡æŸŕä¡ăæČşåIJĺäÿĂäÿłæĺąåİŮècńåŁäè¡¡æŮűèğęåŔŚæ§ŘäÿłåŻđèřČåĞ¡æŢřæİěéĂŽç§ëä¡ããĂĆ

è£ŹäÿłéŮőécŸåŘŕäžëä¡£çŤĺ10.11åřŔèŁĆäÿ■åŘŇæăůçŽĎåŕijåĚěéŠľå■ŘæIJžåĹűæİěåőđçŐřãĂĆäÿŃéİć

```
# postimport.py
import importlib
import sys
```

```
from collections import defaultdict

_post_import_hooks = defaultdict(list)

class PostImportFinder:
    def __init__(self):
        self._skip = set()

    def find_module(self, fullname, path=None):
        if fullname in self._skip:
            return None
        self._skip.add(fullname)
        return PostImportLoader(self)

class PostImportLoader:
    def __init__(self, finder):
        self._finder = finder

    def load_module(self, fullname):
        importlib.import_module(fullname)
        module = sys.modules[fullname]
        for func in _post_import_hooks[fullname]:
            func(module)
        self._finder._skip.remove(fullname)
        return module

def when_imported(fullname):
    def decorate(func):
        if fullname in sys.modules:
            func(sys.modules[fullname])
        else:
            _post_import_hooks[fullname].append(func)
        return func
    return decorate

sys.meta_path.insert(0, PostImportFinder())
```

è£Źæăůïijǹä¡ăářśåŕŕäžěä¡£çŤÍ `when_imported()` èčĚéěřåŹĺäžĘïijǹä¿ǹåęĆïijŽ

```
>>> from postimport import when_imported
>>> @when_imported('threading')
... def warn_threads(mod):
...     print('Threads? Are you crazy?')
...
>>>
>>> import threading
Threads? Are you crazy?
>>>
```

ä¡IJäÿžäÿĂäÿłæŻť'åőđéŹĚçŽĎä¿Ńå■ŕïijǹä¡ăåŕŕèČ¡æČşåIJĺåůšå■ŸåIJĺçŽĎåőŽäźL'äÿŁéİćæůżåŁăèčĚé

```
from functools import wraps
from postimport import when_imported

def logged(func):
    @wraps(func)
    def wrapper(*args, **kwargs):
        print('Calling', func.__name__, args, kwargs)
        return func(*args, **kwargs)
    return wrapper

# Example
@when_imported('math')
def add_logging(mod):
    mod.cos = logged(mod.cos)
    mod.sin = logged(mod.sin)
```

èőÍèőž

æIJňèŁĆæŁĂæIJŕä¿İèţŰäžŐ10.11åřŔèŁĆäÿ■èőšè£řè£ĞçŽĎåŕijåĚéŠľå■ŘïijŇåźűçÍ■ä¡IJä£őæŤźãĂĆ

`@when_imported` èčĚéěřåŹÍçŽĎä¡IJçŤÍæŸŕæşÍåĘŇåIJÍåŕijåĚěæŮűèćńæ£Äæť żçŽĎåď ĎçŘĘåŹÍåĞ¡æ èŕěèčĚéěřåŹÍæčĂæ§ěsys.modulesæİěæ§ěçIJŃæĺąåİŮæŸŕåŘęçIJ§çŽĎåůšçżŔèćńåŁäè¡¡äžĘãĂĆ åęĆæđIJæŸŕçŽĎèŕÍïijŇèřěåď ĎçŘĘåŹÍèćńçńŇå■şèřČçŤÍãĂĆäÿ■çĎűïijŇåď ĎçŘĘåŹÍèćńæůżåŁäåĹř `_post_import_hooks` å■ŮåĚÿäÿ■çŽĎäÿĂäÿłåĹŮèąĺäÿ■åŐżãĂĆ `_post_import_hooks` çŽĎä¡IJçŤÍåřśæŸŕæŤűéŻĘæĽĂæIJĽçŽĎäÿžæŕŔäÿłæĺąåİŮæşÍåĘŇçŽĎåď ĎçŘĘäÿĂäÿłæĺąåİŮåŔŕäžěæşÍåĘŇåď Žäÿłåď ĎçŘĘåŹÍãĂĆ

èęĄèőľ æĺąåİŮåŕijåĚěåŘŐèğęåŔŚæůżåŁäçŽĎåŁĺä¡IJïijŇ`PostImportFinder` çśżèćńèő¿ç¡őäÿžsys.meta_pathçňňäÿĂäÿłåĚČçť ããĂĆ åőČäijŽæ■ŢèŐůæĽĂæIJĽæĺąåİŮåŕijåĚěæŞ■ä¡IJãĂĆ

æIJňèŁĆäÿ■çŽĎ `PostImportFinder` çŽĎä¡IJçŤÍåźűäÿ■æŸŕåŁäè¡¡æĺąåİŮïijŇèĂŇæŸŕèĞłåÿęåŕijåĚ åőđéŹĚçŽĎåŕijåĚèèćńåğŤæť ¿çżŹä¡■äžŐsys.meta_pathäÿ■çŽĎåĚűäžŰæ§ěæĽ¿åŹÍãĂĆ `PostImportLoader` çśżäÿ■çŽĎ `imp.import_module()` åĞ¡æŢřèćńéĂŠå¡ŠçŽĎèřČçŤÍãĂĆ äÿžäžĘéĄ£åĚ■éŹůåĚěæŮăçž£å¿łçŐŕïijŇ`PostImportFinder` ä£ÍæŇĄäžĘäÿĂäÿłæĽĂæIJĽèćńåŁäè¡¡è£ĞçŽĎæĺąåİŮéŻĘåŘĹãĂĆ åęĆæđIJäÿĂäÿłæĺąåİŮåŘ■å■ŸåIJÍåřśäijŽçŻť æŐèèćńå£¡çŢěæŐĽãĂĆ

å¡ŞäÿĂäÿłæĺąåİŮèćń `imp.import_module()` åŁäè¡¡åŘŐïijŇ æĽĂæIJĽåIJÍ_post_import_hooksèćńæşÍåĘŇçŽĎåď ĎçŘĘåŹÍèćńèřČçŤÍïijŇä¡£çŤÍæŰřåŁäè¡¡æĺąåİŮä¡IJäÿžã

æIJĽäÿĂçĆźéIJĂèęĄæşÍæĎŔçŽĎæŸŕæIJňæIJžäÿ■éĂĆçŤÍäžŐéĆčäžŻéĂŽè£Ğ `imp.reload()` èćńæŸ¿åijŔåŁäè¡¡çŽĎæĺąåİŮãĂĆ äź§åŕśæŸŕèŕťïijŇåęĆæđIJä¡ååŁäè¡¡äÿĂäÿłäźŇåĽ■åůšèćńåŁäåŘęåď ŰïijŇèęĄæŸŕä¡ääžŐsys.modulesäÿ■åĹäéŹď æĺąåİŮçĎűåŘŐåĘ■éĞ■æŰřåŕijåĚěïijŇåď ĎçŘĘåŹÍåŔĹä

æŽť åď ŽåĚşäžŐåŕijåĚěåŘŐéŠľå■Řä£ąæĄŕèřůåŔĆèĂČ PEP 369.

12.13 10.13 åőĽèčĚçğĄæIJĽçŽĎåŇĚ

éŮőécŸ

ä¡ăæČşèęĄåőĽèčĚäÿĂäÿłçňňäÿĽæŰźåŇĚïijŇä¡ĘæŸŕæšąæIJĽæİČéŹŘářĘåőČåőĽèčĚåĹřçşżçż§Python
æĹŰèĂĚïijŇä¡ăåŔŕèČ¡æČşèęĄåőĽèčĚäÿĂäÿłä¿ŻèĞłåůśä¡£çŤĺçŽĎåŇĚïijŇèĂŇäÿ■æŸŕçşżçż§äÿŁéİćæĽĂa

èğčåĘşæŰźæąĹ

PythonæIJĽäÿĂäÿłçŤĺæĹůåőĽèčĚçŻőå¡Ţïij ŇéĂŽåÿÿçśżäijijâĂİ~/.local/lib/python3.3/site-packagesâĂİãĂĆ èęĄåijžåĹűåIJĺè£ŹäÿłçŻőå¡Ţäÿ■åőĽèčĚåŇĚïijŇåŔŕä¡£çŤĺåőĽèčĚéĂĽ'éąźâĂIJ–userâĂİãĂ

```
python3 setup.py install --user
```

æĹŰèĂĚ

```
pip install --user packagename
```

åIJĺsys.pathäÿ■çŤĺæĹůçŽĎâĂIJsite-packagesâĂİçŻőå¡Ţä¡■äžŐçşżçż§çŽĎâĂIJsite-packagesâĂİçŻőå¡ŢäźŇåĽ■ãĂĆ åŻăæ■ď'ïijŇä¡ăåőĽèčĚåIJĺéĞŇéİćçŽĎåŇĚářśæŕŤçşżçż§åůšåőĽèčĚçŽĎåŇïijĹář¡çőąåźűäÿ■æĂżæŸŕè£ŹæăûïijŇèęĄåŔŰåĘşäžŐçňňäÿĽæŰźåŇĚçőąçŘĘåŹĺïijŇæŕŤåęĆdistributeæĹŰpi

èőĺèőž

éĂŽåÿÿåŇĚäijŽèćńåőĽèčĚåĹřçşżçż§çŽĎsite-packagesçŻőå¡Ţäÿ■åŐżïijŇèůŕå¿ĎçśżäijijâĂIJ/usr/local/lib/python3.3/site-packagesâĂİãĂĆ äÿ■è£ĞïijŇè£ŹæăůåĄŽéIJĂèęĄæIJĽçőąçŘĘåŚŸæİČéŹŘåźűäÿŤä¡£çŤĺsudoåŚ¡äžd'ãĂĆ åřśçőŮä¡ăæIJĽè£ŹæăůçŽĎæİČéŹŘåŐżæĽ'ğèąŇåŚ¡äžd'ïijŇä¡£çŤĺsudoåŐżåőĽèčĚäÿĂäÿłæŰřçŽĎïijŇåŔŕèČ

åőĽèčĚåŇĚåĹřçŤĺæĹůçŻőå¡Ţäÿ■éĂŽåÿÿæŸŕäÿĂäÿłæIJĽæŢĹçŽĎæŰźæąĹïijŇåőČåĚĄèőÿä¡ăåĹŻåžžä

åŘęåd'ŰïijŇä¡ăè£ŸåŔŕäžěåĹŻåžžäÿĂäÿłèŹŽæŃ§çŐŕåćČïijŇè£ŹäÿłæĹŚäžňåIJĺäÿŇäÿĂèŁĆäijŽèőšåĹřă

12.14 10.14 åĹŻåžžæŰřçŽĎPythonçŐŕåćČ

éŮőécŸ

ä¡ăæČşåĹŻåžžäÿĂäÿłæŰřçŽĎPythonçŐŕåćČïijŇçŤĺæİěåőĽèčĚæĺąåİŮåŠŇåŇĚãĂĆ äÿ■è£ĞïijŇä¡ăäÿ■æČşåőĽèčĚäÿĂäÿłæŰřçŽĎPythonåĚŇéŽĘïijŇäź§äÿ■æČşåŕźçşżçż§PythonçŐŕåćČäžğçŤ§

èğčåĘşæŰźæąĹ

ä¡ăåŔŕäžěä¡£çŤĺ `pyvenv` åŚ¡äžd'åĹŻåžžäÿĂäÿłæŰřçŽĎâĂIJèŹŽæŃ§âĂİçŐŕåćČãĂĆ è£ŹäÿłåŚ¡äžd'èćńåőĽèčĚåIJĺPythonèğčéĞŁåŹĺåŘŇäÿĂçŻőå¡ŢïijŇæĹŰWindowsäÿŁéİćçŽĎScriptsçŻőå¡Ţäÿ

```
bash % pyvenv Spam
bash %
```

äijäçżŹ `pyvenv` åŚ¡äżd'çŽĎåŘ■å■ŮæŸŕåřĘèęĄèćńåĹŻåżžçŽĎçŻőå¡ŢåŘ■ãĂĆå¡Şèćńå
ĹŻåżžåŘŐïijÑS

```
bash % cd Spam
bash % ls
bin include lib pyvenv.cfg
bash %
```

åIJĺbinçŻőå¡Ţäÿ■ïijÑä¡ääijŽæL'¿åĹřäÿĂäÿłåŔŕäżěä¡£çŤĺçŽĎPythonèğčéĞŁåŹĺïijŽ

```
bash % Spam/bin/python3
Python 3.3.0 (default, Oct 6 2012, 15:45:22)
[GCC 4.2.1 (Apple Inc. build 5666) (dot 3)] on darwin
Type "help", "copyright", "credits" or "license" for more␣
↪information.
>>> from pprint import pprint
>>> import sys
>>> pprint(sys.path)
['',
'/usr/local/lib/python33.zip',
'/usr/local/lib/python3.3',
'/usr/local/lib/python3.3/plat-darwin',
'/usr/local/lib/python3.3/lib-dynload',
'/Users/beazley/Spam/lib/python3.3/site-packages']
>>>
```

è£ŹäÿłèğčéĞŁåŹĺçŽĎçL'źçĆźářśæŸŕäżŰçŽĎsite-packagesçŻőå¡Ţèćńèő¿ç¡őäÿžæŰřåĹŻåżžçŽĎçŐŕåćČ
åęĆæđIJä¡ăèęĄåőL'èčĚçňňäÿL'æŰźåŇĚïijÑåőČäžňäijŽèćńåőL'èčĚåIJĺéĆčéĞŇïijŇèĂŇäÿ■æŸŕéĂŽåÿÿçşżçż
packagesçŻőå¡ŢãĂĆ

èőĺèőž

åĹŻåżžèŹŽæŃ§çŐŕåćČéĂŽåÿÿæŸŕäÿžäžĘåőL'èčĚåŠŇçőąçŘĘçňňäÿL'æŰźåŇĚãĂĆ
æ■čåęĆä¡ăåIJĺä¿Ńå■Řäÿ■çIJŃåĹřçŽĎéĆčæăůïijŇsys.path
åŔŸéĞŔåŇĚåŘńæİèèĞłäžŐçşżçż§PythonçŽĎçŻőå¡ŢïijŇ èĂŇ site-
packagesçŻőå¡ŢåůšçżŕèćńéĞ■åőŽä¡■åĹřäÿĂäÿłæŰřçŽĎçŻőå¡ŢãĂĆ

æIJL'äžĘäÿĂäÿłæŰřçŽĎèŹŽæŃ§çŐŕåćČïijÑäÿŃäÿĂæ■ěårśæŸŕåőL'èčĚäÿĂäÿłåŇĚçőąçŘĘåŹĺïijŃærŤå
ä¡ĘåőL'èčĚè£Źæăůç̌ŽĎåůěåĚůåŠŇåŇĚçŽĎæŮűåĂŹïijÑä¡ăéIJĂèęĄçąőä£İä¡ää¡£çŤĺçŽĎæŸŕèŹŽæŃ§çŐŕåćČ
åőČäijŽårĘåŇĚåőL'èčĚåĹřæŰřåĹŻåżžçŽĎsite-packagesçŻőå¡Ţäÿ■åŐžãĂĆ

år¡çőąäÿĂäÿłèŹŽæŃ§çŐŕåćČçIJŃäÿŁåŐżæŸŕPythonåőL'èčĚçŽĎäÿĂäÿłåd'■åĹűïijŇ
äÿ■è£ĞåőČåőđéŹĚäÿŁåŔłåŇĚåŘńäžĘåřŚéĞŔåĞääÿłæŰĞäžűåŠŇäÿĂäžŽçňęåŘůéŞ¿æŐěãĂĆ
æL'ĂæIJL'æăĞåĞĘäžŞåĞ¡æŰĞäžűåŠŇåŘŕæL'ğèąŇèğčéĞŁåŹĺéČ¡æİèèĞłåŐ§æİèçŽĎPythonåőL'èčĚãĂĆ
åŻăæ■d'ïijÑåĹŻåżžè£Źæăůç̌ŽĎçŐŕåćČæŸŕå¿Ĺåőźæ ŸŞçŽĎïijÑåźűäÿŤåĞääźŐäÿ■äijŽæűĹèĂŮæIJžåŹĺèţĎæ

éżŸèőd'æČĚåĘţäÿŃïijŇèŹŽæŃ§çŐŕåćČæŸŕçl'žçŽĎïijÑäÿ■åŇĚåŘńäżżä¡Ţéćİåd'ŰçŽĎçňňäÿL'æŰźåžŞ
åŘŕäżěä¡£çŤĺâĂIJ–system-site-packagesâĂİéĂL'éąźæİèåĹŻåżžèŹŽæŃ§çŐŕåćČïijÑä¿ŃåęĆïijŽ

```
bash % pyvenv --system-site-packages Spam
bash %
```

èů§åď ŽåĚşäžŐ `pyvenv` åŠŇèŹŽæŃ§çŐŕåćČçŽĎä£ąæĄŕåŘŕäžěåŔĆèĂČ PEP 405.

12.15 10.15 åĹĘåŔŚåŇĚ

éŮőécŸ

ä¡ăåůšçżŘçijŰåĘŹäžĘäÿĂäÿłæIJL'çŤĺçŽĎåžŞïijŇæČşářĘåőČåĹĘäžńçżŹåĚűäżŰäžžãĂĆ

èğčåĘşæŰźæąĹ

åęĆæđIJä¡ăæČşåĹĘåŔŚä¡ăçŽĎäżčçăĄïijŇçňňäÿĂäżűäžŃåřśæŸŕçżŹåőČäÿĂäÿłåŤŕäÿĂçŽĎåŘ■å■ŮïijŇä¿ŃåęĆïijŇäÿĂäÿłåĚÿåđŃçŽĎåĞ¡æŢřåžŞåŇĚäijŽçśżäijijäÿŃéİćè£ŹæăůïijŽ

```
projectname/
    README.txt
    Doc/
        documentation.txt
    projectname/
        __init__.py
        foo.py
        bar.py
        utils/
            __init__.py
            spam.py
            grok.py
    examples/
        helloworld.py
        ...
```

èęĄèől'ä¡ăçŽĎåŇĚåŔŕäžěåŔŚåÿČåĞžåŐżïijŇéęŰåĚĹä¡ăèęĄçijŰåĘŹäÿĂäÿł `setup.py` ïijŇçśżäijijäÿŃéİćè£ŹæăůïijŽ

```
# setup.py
from distutils.core import setup

setup(name='projectname',
    version='1.0',
    author='Your Name',
    author_email='you@youraddress.com',
    url='http://www.you.com/projectname',
    packages=['projectname', 'projectname.utils'],
)
```

äÿŃäÿĂæ■ěïijŇåřśæŸŕåĹŻåžžäÿĂäÿł `MANIFEST.in` æŰĞäžűïijŇåĹŮåĞžæL'ĂæIJL'åIJĺä¡ăçŽĎåŇĚäÿ

```
# MANIFEST.in
include *.txt
recursive-include examples *
recursive-include Doc *
```

çąőä£İ `setup.py` åŠŇ `MANIFEST.in` æŰĞäżűæŤ¿åIJĺä¡ăçŽĎåŇĚçŽĎæIJĂéąűçžğçŻőå¡Ţäÿ■ãĂĆ
äÿĂæŮęä¡ăåůšçżŕŕåĄŽäžĘè£ŹäžŻïijŇä¡ăåřśåŕŕäžěåČŕäÿŇéİćè£ŹæăůæL'ğèąŇåŚ¡äžď'æİěåĹŽåžžäÿĂäÿłæžŘ

```
% bash python3 setup.py sdist
```

åőČäijŽåĹŻåžžäÿĂäÿłæŰĞäżűæŕŤåęĆâĂİprojectname-1.0.zipâĂİ æĹŰ
âĂIJprojectname-1.0.tar.gzâĂİ, åĚůä¡Şä¿İètŰäžŐä¡ăçŽĎçşżçż§åźşåŘřãĂĆåęĆæđIJäÿĂåĹĞæ■čåÿÿïijŇ
è£ŹäÿłæŰĞäżűåřśåŕŕäžěåŔŚéĂĄçżŹåĹńäžžä¡£çŤĺæĹŰèĂĚäÿŁäijäèĞş Python Package Index.

èőĺèőž

åŕźäžŐçžŕPythonäżčçăĄïijŇçijŰåEŹäÿĂäÿłæŹőéĂŽçŽĎ `setup.py`
æŰĞäżűéĂŽåÿÿå¿ĹçőĂå■ŢãĂĆ äÿĂäÿłåŔŕèČ¡çŽĎéŮőécŸæŸŕä¡ăå£ĚéąžæL'ŃåŁĺåĹŮåĞžæL'ĂæIJL'æđĎæ
äÿĂäÿłåÿÿèğĄéŤŹèŕŕåřśæŸŕäżĚäžĚåŔłåĹŮåĞžäÿĂäÿłåŇĚçŽĎæIJĂéąűçžğçŻőå¡ŢïijŇå£ŸèőřäžĘåŇĚåŘńåŇ
è£Źäź§æŸŕäÿžäžĂäźĹåIJĺ `setup.py` äÿ■åŕźäžŐåŇĚçŽĎèŕť'æŸŐåŇĚåŘńäžĘåĹŮèąĺ
`packages=['projectname', 'projectname.utils']`

åď'ğéČĺåĹĘPythonçĺŃåžŔåŠŸéČ¡ç§ěéĄŞïijŇæIJL'å¿Ĺåď'ŽçňňäÿL'æŰźåŇĚçőąçŘĘåŹĺä¿ŻéĂL'æŃľ'ïijŇ
æIJL'äžŻæŸŕäÿžäžĘæŻ£äžčæăĞåĞĘåžŞäÿ■çŽĎdistutilsãĂĆæşĺæĎŔåęĆæđIJä¡ää¿ÌètŰè£ŹäžŻåŇĚïijŇ
çŤĺæĹůåŔŕèČ¡äÿ■èČ¡åőL'èčĚä¡ăçŽĎè¡ŕäżűïijŇéŹď'éİđäžŰäžňåůšçżŔäžŃåĚĹåőL'èčĚè£ĞæL'ĂéIJĂèęĄçŽĎå
æ■čåŻäåęĆæ■d'ïijŇä¡ăæŻt'åžŤèřěæŮűåĹżèőřä¡ŔèűŁçőĂå■Ţèűŀåě¡çŽĎéĄŞçŘĘãĂĆ
æIJĂåě¡èől'ä¡ăçŽĎäžčçăĄä¡£çŤĺæăĞåĞĘçŽĎPython 3åőL'èčĚãĂĆ
åęĆæđIJåĚűäžŰåŇĚäź§éIJĂèęĄçŽĎèŕİïijŇåŔŕäžěéĂŽè£ĞäÿĂäÿłåŔŕéĂL'éąźæİěæŤŕæŇĄãĂĆ

åŕźäžŐæűL'åŘŁåĹřCæL'l'åśŢçŽĎäžčçăĄæL'ŞåŇĚäÿŐåĹĘåŔŚåŕśæŻt'åď'■æİĆçĆźäžĘãĂĆ
çňň15çńååŕźåĚşäžŐCæL'l'åśŢçŽĎè£ŹæŰźéİćç§ěèŕĘæIJL'äÿĂäžŻèŕęçżĘèőšèğčïijŇçL'źåĹńæŸŕåIJĺ15.2åřŔè

13 çňňå■ĄäÿĂçńăïijŽç¡ŚçżIJäÿŐWebçijŰçĺŃ

æIJňçńăæŸŕåĚşäžŐåIJĺç¡ŚçżIJåžŤçŤĺåŠŇåĹĘåÿČåijŔåžŤçŤĺäÿ■ä¡£çŤĺçŽĎåŘĎçğ■äÿżécŸãĂĆäÿżécŸ

Contents:

13.1 11.1 ä¡IJäÿžåőćæĹůçńŕäÿŐHTTPælJ■åŁąäžď'äžŠ

éŰőécŸ

ä¡ăéIJĂèęĄéĂŽè£ĞHTTPå■ŔèőőäžěåőćæĹůçńŕçŽĎæŰźåijŔèő£éŰőåď'Žçğ■æIJ■åŁąãĂĆä¿ŃåęĆïijŇäÿ

èğčåĘşæŰźæąĹ

åŕźäžŐçőĂå■ŢçŽĎäžŃæČĚæİěèŕťïijŇéĂŽåÿÿä¡£çŤÍ `urllib.request` æĺąåİŮåřšåď§äžĘãĂĆä¿ŃåęĆïijŇåŘŚéĂĄäÿĂäÿłçőĂå■ŢçŽĎHTTP GETèřůæśĆåĹřè£IJçÍŃçŽĎæIJ■åŁąäÿŁïijŇåŘŕäžěè£ŹæăůåĄŽïijŽ

```
from urllib import request, parse

# Base URL being accessed
url = 'http://httpbin.org/get'

# Dictionary of query parameters (if any)
parms = {
   'name1' : 'value1',
   'name2' : 'value2'
}

# Encode the query string
querystring = parse.urlencode(parms)

# Make a GET request and read the response
u = request.urlopen(url+'?' + querystring)
resp = u.read()
```

åęĆædIJä¡ăéIJĂèęĄä¡£çŤÍPOSTæŰźæşŢåIJÍèřůæśĆäÿżä¡Şäÿ■åŘŚéĂĄæ§ěèŕćåŘĆæŢřïijŇåŘŕäžěåřĘåŘ `urlopen()` åĞ¡æŢřïijŇåřšåČŔè£ŹæăůïijŽ

```
from urllib import request, parse

# Base URL being accessed
url = 'http://httpbin.org/post'

# Dictionary of query parameters (if any)
parms = {
   'name1' : 'value1',
   'name2' : 'value2'
}

# Encode the query string
querystring = parse.urlencode(parms)

# Make a POST request and read the response
u = request.urlopen(url, querystring.encode('ascii'))
resp = u.read()
```

åęĆædIJä¡ăéIJĂèęĄåIJÍåŘŚåĞžçŽĎèřůæśĆäÿ■æŘŘä¿ŻäÿĂäžŻèĞłåőŽäźL'çŽĎHTTPåď't'ïijŇä¿ŃåęĆäŧ `user-agent` å■Ůæőţ,åŘŕäžěåĹŻåžžäÿĂäÿłåŇĚåŘńå■Ůæőţå Ăijç ŽĎå■ŮåĚÿïijŇåźűåĹŻåžžäÿĂäÿłRequestå `urlopen()` ïijŇåęĆäÿŃïijŽ

```
from urllib import request, parse
...
```

```
# Extra headers
headers = {
    'User-agent' : 'none/ofyourbusiness',
    'Spam' : 'Eggs'
}

req = request.Request(url, querystring.encode('ascii'),␣
↪headers=headers)

# Make a request and read the response
u = request.urlopen(req)
resp = u.read()
```

åęĆædIJéIJĂèęĄäžd'äžŠçŽĎæIJ■åŁąæŕŤäÿŁéİćçŽĎä¿Ńå■ŘéČ¡èęĄåd'■æİĆïijŇäź§èőÿåžŤèŕěåŐżçIJŃç
requests åžŞïijĹhttps://pypi.python.org/pypi/requestsïijL'ãĂĆä¿ŃåęĆïijŇäÿŃéİćè£Źäÿłçd'žä¿ŃéĞĞçŤĺreques

```
import requests

# Base URL being accessed
url = 'http://httpbin.org/post'

# Dictionary of query parameters (if any)
parms = {
   'name1' : 'value1',
   'name2' : 'value2'
}

# Extra headers
headers = {
    'User-agent' : 'none/ofyourbusiness',
    'Spam' : 'Eggs'
}

resp = requests.post(url, data=parms, headers=headers)

# Decoded text returned by the request
text = resp.text
```

åĚşäžŐrequestsåžŞïijŇäÿĂäÿłåĂijå¿ŮäÿĂæŔŘçŽĎçL'źæĂğåřśæŸŕåőČèČ¡äžěåd'Žçğ■æŰźåijŔäżŐèŕůa
`resp.text` åÿęçżŹæĹŚäžňçŽĎæŸŕäžěUnicodeèğčçăĄçŽĎåŞ■åžŤæŰĞæIJñãĂĆä¡ĘæŸŕïijŇåęĆædIJåŐżèć
`resp.content` ïijŇářśäijŽå¿ŮåĹřåŐ§ăğŃçŽĎäžŇè£ŻåĹűæŢřæ■őãĂĆåŔęäÿĂæŰźéİćïijŇåęĆædIJèő£éŮć
`resp.json` ïijŇéĆčäźĹářśäijŽå¿ŮåĹřJSONæăijåijŔçŽĎåŞ■åžŤåĘĚåőźãĂĆ

äÿŃéİćè£Źäÿłçd'žä¿ŃåĹl'çŤÍ `requests` åžŞåŘŚèţůäÿĂäÿłHEAD-èŕůæśĆïijŇåźűäžŐåŞ■åžŤäÿ■æŔŘåŘŰåĞžäÿĂäžŻHTTPåd'ť'æŢřæ■őçŽĎå■Ůæőţïij Ž

```
import requests

resp = requests.head('http://www.python.org/index.html')
```

```
status = resp.status_code
last_modified = resp.headers['last-modified']
content_type = resp.headers['content-type']
content_length = resp.headers['content-length']
```

äÿŃéİćæŸŕäÿĂäÿłåĹľçŤĺrequestséĂŽè£Ğå§žæIJňèŏď'èŕĄçŹżå¡ŢPypiçŽĎä¿Ńå■ŘïijŽ

```
import requests

resp = requests.get('http://pypi.python.org/pypi?:action=login',
                    auth=('user','password'))
```

äÿŃéİćæŸŕäÿĂäÿłåĹľçŤĺrequestsåřĘHTTP cookiesäżŐäÿĂäÿłèŕůæśĆäijåéĂŠåĹřåŔęäÿĂäÿłçŽĎä¿Ńå■

```
import requests

# First request
resp1 = requests.get(url)
...

# Second requests with cookies received on first requests
resp2 = requests.get(url, cookies=resp1.cookies)
```

æIJĂåŘŐä¡Ęåźűéİđæ IJĂäÿ■éĞ■èęĄçŽĎäÿĂäÿłä¿Ńå■ŘæŸŕçŤĺrequestsäÿŁäijååĘĚåőźïijŽ

```
import requests
url = 'http://httpbin.org/post'
files = { 'file': ('data.csv', open('data.csv', 'rb')) }

r = requests.post(url, files=files)
```

èőĺèőž

åŕźäžŐçIJ§çŽĎå¿ĹçőĂå■ŢHTTPåőćæĹůçńŕäžčçăĄïijŇçŤĺåĘĚç¡őçŽĎ `urllib` æĺąåİŮéĂŽåÿÿåřśèűşåď§äžĘãĂĆä¡ĘæŸŕïijŇåęĆædIJä¡äèęĄåĄŽçŽĎäÿ■äžĚäžĚåŔłæŸŕçőĂå■ŢçŽĎGETæĹ `requests` åď'ğæŸ¿èžńæL'ŃçŽĎæŮűåĂŹäžĘãĂĆ

ä¿ŃåęĆïijŇåęĆædIJä¡ăåĘşåőŽåİŽæŇĄä¡£çŤĺæăĞåĞĚçŽĎçĺŃéžŔåžŞèĂŇäÿ■èĂČèŹŚåČŔ `requests` è£Źæăůç ŽĎçňňäÿL'æŰźåžŞïijŇéĆčäźĹäź§èőÿåřśäÿ■å¿Ůäÿ■ä¡£çŤĺåžŢåśĆçŽĎ `http.client` æĺąåİŮæİěåőđçŐřèĞłåůśçŽĎäžčçăĄãĂĆærŤæŰźèŕť'ïijŇäÿŃéİćçŽĎäžčçăĄåśŢçď'žäžĘåęĆä

```
from http.client import HTTPConnection
from urllib import parse

c = HTTPConnection('www.python.org', 80)
c.request('HEAD', '/index.html')
resp = c.getresponse()

print('Status', resp.status)
```

```
for name, value in resp.getheaders():
    print(name, value)
```

åŘŇæăůåIJřïijŇåęĆæđIJå£Ěéążçij ŰåĘŹæűL’åŔŁäžčçŘĘãĂĄèőd’èŕĄãĂĄcookiesäżěåŔŁåĚűäżŰäÿĂäžZ
urllib åřśæŸ¿å¿ŮçL’źåĹńåĹńæL’■åŠŇåŢřåŮęãĂĆæŕŤæŰźèŕt’ïijŇäÿŃéİćè£Źäÿłçd’ža¿Ńåőđç ŐřåIJĺPython

```
import urllib.request

auth = urllib.request.HTTPBasicAuthHandler()
auth.add_password('pypi','http://pypi.python.org','username',
 ↪'password')
opener = urllib.request.build_opener(auth)

r = urllib.request.Request('http://pypi.python.org/pypi?
 ↪:action=login')
u = opener.open(r)
resp = u.read()

# From here. You can access more pages using opener
...
```

åİęçŹ¡èŕt’ïijŇæL’ĂæIJL’çŽĎè£ŹäžŻæŞ■ä¡IJåIJĺ requests
åžŞäÿ■éČ¡åŔŸå¿ŮçőĂå■ŢçŽĎåd’ŽãĂĆ

åIJĺåijĂåŔŚè£ĞçĺŃäÿ■æţŃèŕŢHTTPåőćæĹůçńŕäžčçăĄåÿÿåÿÿæŸŕå¿Ĺäžd’äžžæšöäÿğçŽĎïijŇåŻääÿžæL
//httpbin.orgïijL’ãĂĆè£ŹäÿłçńŹçĆźäijŽæŐěæŤůåŘŚåĞžçŽĎèřůæśĆïijŇçĎűåŘŐäžěJSONçŽĎå¡ćåijŔářĘçŻÿ

```
>>> import requests
>>> r = requests.get('http://httpbin.org/get?name=Dave&n=37',
...     headers = { 'User-agent': 'goaway/1.0' })
>>> resp = r.json
>>> resp['headers']
{'User-Agent': 'goaway/1.0', 'Content-Length': '', 'Content-Type': '
 ↪',
'Accept-Encoding': 'gzip, deflate, compress', 'Connection':
'keep-alive', 'Host': 'httpbin.org', 'Accept': '*/*'}
>>> resp['args']
{'name': 'Dave', 'n': '37'}
>>>
```

åIJĺèęĄåŘŇäÿĂäÿłçIJ§æ■čçŽĎçńŹçĆźè£ŻèąŇäžd’äžŠåL’■ïijŇåĚĹåIJĺ httpbin.org
è£ŹæăůçŽĎç¡ŚçńŹäÿŁåĄŽåőđéłŇåÿÿåÿÿæŸŕåŔŕåŘŰçŽĎåŁđæşŢãĂĆård’åĚűæŸŕå¡ŞæĹŚäžňéİćårź3æňąçŹź

år¡çőąæIJňèŁĆæšąæIJL’æűL’åŔŁïijŇ request åžŞè£Ÿårźèőÿåd’ŽénŸçžğçŽĎHTTPåőćæĹůçńŕå■Rèőő
requests æĺąåİŮçŽĎæŰĞæąčïijĹhttp://docs.python-requests.
org)èt’ĺéĞŘå¿ĹénŸïijĹåİęçŹ¡èŕt’æŕŤåIJĺè£Źç§■ç§■çŽĎäÿĂèŁĆçŽĎçŕĞáźĚäÿ■æL’ĂæŔŘä¿ŻçŽĎäżżä¡Ţä£ą

13.2 11.2 åĹŻåžžTCPæIJ■åŁąåŹÍ

éŮőécŸ

ä¡ăæČşåőđçŐřäÿĂäÿłæIJ■åŁąåŹĺïijŇéĂŽè£ĞTCPå■Ŕèőőå ŠŇåőćæĹůçńŕéĂŽä£ąãĂĆ

èğčåĘşæŰźæąĹ

åĹŻåžžäÿĂäÿłTCPæIJ■åŁąåŹÍçŽĎäÿĂäÿłçőĂå■ŢæŰźæşŢæŸŕä¡£çŤÍ `socketserver` åžŞãĂĆä¿ŃåęĆïijŇäÿŃéÍćæŸŕäÿĂäÿłçőĂå■ŢçŽĎåžŤç■ŤæIJ■åŁąåŹÍïijŽ

```
from socketserver import BaseRequestHandler, TCPServer

class EchoHandler(BaseRequestHandler):
    def handle(self):
        print('Got connection from', self.client_address)
        while True:

            msg = self.request.recv(8192)
            if not msg:
                break
            self.request.send(msg)

if __name__ == '__main__':
    serv = TCPServer(('', 20000), EchoHandler)
    serv.serve_forever()
```

åIJÍè£ŹæőţäžčçăĄäÿ■ïijŇä¡ăåőŽäźL'äžĘäÿĂäÿłçL'źæőŁçŽĎåď'ĎçŘĘçśżïijŇåőđçŐřäžĘäÿĂäÿł `handle()` æŰźæşŢïijŇçŤÍæİěäÿžåőćæĹůçńŕè£đæŐěæIJ■åŁąãĂĆ `request` åśđæĂğæŸŕåőćæĹůçńŕsocketïijŇ`client_address` æIJL'åőćæĹůçńŕåIJřåİĂãĂĆ äÿžäžĘæţŃèŕŢè£ŹäÿłæIJ■åŁąåŹÍïijŇè£ŘèąŇåőČåźűæL'ŞåijĂåŔęåď'ŰäÿĂäÿłPythonè£ŻçÍŃè£đæŐěè£Źäÿłæ

```
>>> from socket import socket, AF_INET, SOCK_STREAM
>>> s = socket(AF_INET, SOCK_STREAM)
>>> s.connect(('localhost', 20000))
>>> s.send(b'Hello')
5
>>> s.recv(8192)
b'Hello'
>>>
```

å¿Ĺåď'ŽæŮűåĂŹïijŇåŔŕäžěå¿Ĺåőźæ ŸŞçŽĎåőŽäźL'äÿĂäÿłäÿ■åŘŇçŽĎåď'ĎçŘĘåŹĺãĂĆäÿŃéÍćæŸŕäÿĂ `StreamRequestHandler` å§žçśžåřĘäÿĂäÿłçśżæŰĞäžűæŐěåŔčæŤ¿ç¡őåIJĺåžŢåśĆsocketäÿŁçŽĎä¿Ńå■Ř

```
from socketserver import StreamRequestHandler, TCPServer

class EchoHandler(StreamRequestHandler):
    def handle(self):
        print('Got connection from', self.client_address)
```

```
        # self.rfile is a file-like object for reading
        for line in self.rfile:
            # self.wfile is a file-like object for writing
            self.wfile.write(line)

if __name__ == '__main__':
    serv = TCPServer(('', 20000), EchoHandler)
    serv.serve_forever()
```

èőÍèőž

socketserver åŘŕäžěèőľ æĹŚäžňå¿Ĺåőźæ ŸŞçŽĎåĹŻåžžçőÄå■ŢçŽĎTCPæIJ■åŁąåŹĺãĂĆ ä¡ĘæŸŕïijÑä¡äéIJĂèęĄæşĺæĎŘçŽĎæŸŕïijÑéżŸèőď æČĚåĘţäÿŃè£Źçğ■æIJ■åŁąåŹĺæŸŕå■Ţçž£çĺÑçŽĎïijÑäÿ åęĆæđIJä¡äæČşåď ĎçŘĘåď ŽäÿłåőćæĺůçńŕïijÑåŘŕäžěåĹİåğÑåŇŰäÿĂäÿł ForkingTCPServer æĹŰèĂĚæŸŕ ThreadingTCPServer åŕźèśąãĂĆä¿ŃåęĆïijŽ

```
from socketserver import ThreadingTCPServer


if __name__ == '__main__':
    serv = ThreadingTCPServer(('', 20000), EchoHandler)
    serv.serve_forever()
```

ä¡£çŤĺforkæĹŰçž£çĺÑæIJ■åŁąåŹĺæIJL'äÿłæ¡IJåIJĺéŮőécŸåřśæŸŕåőČäžñäijŽäÿžæŕŘäÿłåőćæĹůçńrè£đæ çŤśäžŐåőćæĹůçńrè£đæŐěæŢřæŸŕæšąæIJL'éŹŘåĹűçŽĎïijÑåŽäæ■đ'äÿĂäÿłæĄűæĎŘçŽĎézŚåőćåŘŕäžěåŘŇ

åęĆæđIJä¡äæŃĚå£Čè£ŹäÿłéŮőécŸïijÑä¡ääŘŕäžěåĹŻåžžäÿĂäÿłécĎåĚĹåĹĘéĚ■åď ğåřŘçŽĎåůěä¡IJçž£ç ä¡ääĚĹåĹŻåžžäÿĂäÿłæŹőéĂŽçŽĎéIđçž£çĺÑæIJ■åŁąåŹĺïijÑçĎűåŘŐåIJĺäÿĂäÿłçž£çĺÑæśääÿ■ä¡£çŤĺ serve_forever() æŰźæşŢæİěåŘŕåŁĺåőČäžñäĆ

```
if __name__ == '__main__':
    from threading import Thread
    NWORKERS = 16
    serv = TCPServer(('', 20000), EchoHandler)
    for n in range(NWORKERS):
        t = Thread(target=serv.serve_forever)
        t.daemon = True
        t.start()
    serv.serve_forever()
```

äÿĂèĹňæİěèőšïijÑäÿĂäÿł TCPServer åIJĺåőđä¿ŃåŇŰçŽĎæŮűåĂŹäijŽçżŚåőŽåźűæ£Äæť żçŽÿåžŤçŽ socket ãĂĆ äÿ■è£ĞïijÑæIJL'æŮűåĂŹä¡äæČşéĂŽè£Ğèő¿ç¡őæ§ŘäžŽéĂL'éąźåŐżèřČæŢť åžŢäÿŃçŽĎ *socket*' ïijÑåŘŕäžěèő¿ç¡őåŔĆæŢř bind_and_activate=False ãĂĆåęĆäÿŃïijŽ

```
if __name__ == '__main__':
    serv = TCPServer(('', 20000), EchoHandler, bind_and_
↪activate=False)
    # Set up various socket options
    serv.socket.setsockopt(socket.SOL_SOCKET, socket.SO_REUSEADDR,␣
↪True)
```

```
    # Bind and activate
    serv.server_bind()
    serv.server_activate()
    serv.serve_forever()
```

äÿŁéÍćçŽĎ `socket` éĂĽ'éąźæŸŕäÿĂäÿłéÍđåÿÿæŹőéĄ■çŽĎéĚ■ç¡őéąźïijŇåőČåĚĄèőÿæIJ■åŁąåŹĺéĞ■æ
çŤśäžŐèęĄèćńçżŔåÿÿä¡£çŤĺåĹřïijŇåőČèćńæŤ¿ç¡őåĹřçśżåŔŸéĞŔäÿ■ïijŇåŔŕäžěçŻť'æŐěåIJÍ
`TCPServer` äÿŁéÍćèő¿ç¡õãĂĆ åIJÍåőđä¿ŃåŇŰæIJ■åŁąåŹĺçŽĎæŮűåĂŹåŐżèő¿ç¡őåőČçŽĎåĂijïijŇåęĆäÿŃ

```
if __name__ == '__main__':
    TCPServer.allow_reuse_address = True
    serv = TCPServer(('', 20000), EchoHandler)
    serv.serve_forever()
```

åIJÍäÿŁéÍćçđ'žä¿Ńäÿ■ïijŇæĹŚäžňæijŤçđ'žäžĘäÿđ'çğ■äÿ■åŘŇçŽĎåđ'ĎçŘĘåŹĺå§žçśżïijĹ
`BaseRequestHandler` åŠŇ `StreamRequestHandler` ïijL'ãĂĆ
`StreamRequestHandler` æŻť'åŁăçĄţæť'żçĆźïijŇèČ¡éĂŽè£Ğèő¿ç¡őåĚűäžŰçŽĎçśżåŔŸéĞŔæÍěæŤŕæŇA

```
import socket

class EchoHandler(StreamRequestHandler):
    # Optional settings (defaults shown)
    timeout = 5                     # Timeout on all socket␣
↪operations
    rbufsize = -1                   # Read buffer size
    wbufsize = 0                    # Write buffer size
    disable_nagle_algorithm = False  # Sets TCP_NODELAY socket␣
↪option
    def handle(self):
        print('Got connection from', self.client_address)
        try:
            for line in self.rfile:
                # self.wfile is a file-like object for writing
                self.wfile.write(line)
        except socket.timeout:
            print('Timed out!')
```

æIJĂåŘŐïijŇè£ŸéIJĂèęĄæşĺæĎŔçŽĎæŸŕåůĺåď'ğéČĺåĹĘPythonçŽĎéńŸåśÇç¡ŚçżIJæĺąåİŮïijĹærŤåęĆI
RPCç■L'ïijL'éČ¡æŸŕåżžçńŇåIJÍ `socketserver` åŁ§èČ¡äźŇäÿŁãĂĆ
äź§åřśæŸŕèŕť'ïijŇçŻť'æŐëä¡£çŤĺ `socket` åžŞæİěåőđçŐřæIJ■åŁąåŹĺäź§åźűäÿ■æŸŕå¿ĹéŽ¿ãĂĆ
äÿŃéÍćæŸŕäÿĂäÿłä¡£çŤĺ `socket` çŻť'æŐěçijŰçÍŃåőđçŐřçŽĎäÿĂäÿłæIJ■åŁąåŹĺçőĂå■Ţä¿Ńå■ŘïijŽ

```
from socket import socket, AF_INET, SOCK_STREAM

def echo_handler(address, client_sock):
    print('Got connection from {}'.format(address))
    while True:
        msg = client_sock.recv(8192)
        if not msg:
            break
```

```
        client_sock.sendall(msg)
    client_sock.close()

def echo_server(address, backlog=5):
    sock = socket(AF_INET, SOCK_STREAM)
    sock.bind(address)
    sock.listen(backlog)
    while True:
        client_sock, client_addr = sock.accept()
        echo_handler(client_addr, client_sock)

if __name__ == '__main__':
    echo_server(('', 20000))
```

13.3 11.3 åĹŻåżžUDPæIJ■åŁąåŹÍ

éŮőécŸ

ä¡ăæČşåőđçŐřäÿĂäÿłå§žäžŐUDPå■Řèőőç ŽĎæIJ■åŁąåŹÍæİěäÿŐåőćæĹůçńŕéĂŽä£ąãĂĆ

èğčåĘşæŰźæąĹ

èů§TCPäÿĂæăůïijŇUDPæIJ■åŁąåŹÍäź§åŘŕäžěéĂŽè£Ğä¡£çŤÍ `socketserver` åžŞå¿Ĺåőźæ ŸŞçŽĎèćńåĹŻåżžãĂĆ ä¿ŃåęĆïijŇäÿŃéİćæ ŸŕäÿĂäÿłçőĂå■ŢçŽĎæŮűéŮťæIJ■åŁąåŹÍïijŽ

```
from socketserver import BaseRequestHandler, UDPServer
import time

class TimeHandler(BaseRequestHandler):
    def handle(self):
        print('Got connection from', self.client_address)
        # Get message and client socket
        msg, sock = self.request
        resp = time.ctime()
        sock.sendto(resp.encode('ascii'), self.client_address)

if __name__ == '__main__':
    serv = UDPServer(('', 20000), TimeHandler)
    serv.serve_forever()
```

èů§äźŃåL’■äÿĂæăůïijŇä¡ăåĚĹåőŽäźL’äÿĂäÿłåőđçŐř `handle()` çL’źæőŁæŰźæşŢçŽĎçśžïijŇäÿžåőćæĹůçńŕè£đæŐěæIJ■åŁąãĂĆ è£ŹäÿłçśżçŽĎ `request` åśđæĂğæŸŕäÿĂäÿłåŇĚåŘńäžĘæŢřæ■őæŁěåŠŇåžŢåśĆsock-etåŕźèśąçŽĎåĚČçżĎãĂĆ`client_address` åŇĚåŘńäžĘåőćæĹůçńŕåIJřåİĂãĂĆ

æĹŚäžňæİěæţŃèŕŢäÿŃè£ŹäÿłæIJ■åŁąåŹÍïijŇéęŰåĚĹè£ŘèąŇåőČïijŇçĎűåŘŐæL’Şåij ÄåŔęåd’ŰäÿĂäÿłI

```
>>> from socket import socket, AF_INET, SOCK_DGRAM
>>> s = socket(AF_INET, SOCK_DGRAM)
>>> s.sendto(b'', ('localhost', 20000))
0
>>> s.recvfrom(8192)
(b'Wed Aug 15 20:35:08 2012', ('127.0.0.1', 20000))
>>>
```

èőÍèőž

äÿĂäÿłåĚÿåđŃçŽĎUDPæIJ■åŁąåŹÍæŐěæŤűåĹřè¿¿çŽĎæŢřæ■őæŁě(æűĹæĄŕ)åŠŇåőćæĹůçńŕåIJřåİĂãĂ
åőČèęĄçżŹåőćæĹůçńŕåŻđåŔŚäÿĂäÿłæŢřæ■őæŁěãĂĆåŕźäžŐæŢřæ■őæŁěçŽĎäijåéĂĄïijŇ
ä¡ăåžŤèŕěä¡£çŤĺsocketçŽĎ `sendto()` åŠŇ `recvfrom()` æŰźæşŢãĂĆ
åř¡çőąäijåçż§çŽĎ `send()` åŠŇ `recv()` äź§åŔŕäžěè¿¿åĹřåŘŇæăůçŽĎæŢĹæđIJïijŇ
ä¡ĘæŸŕåĽ■éİćçŽĎäÿd'äÿłæŰźæşŢåŕźäžŐUDPè£đæŐěèĂŇèÍĂæŻt'æŹőéĄ■ãĂĆ

çŤśäžŐæšąæIJL'åžŢåśĆçŽĎè£đæŐěïijŇUPDæIJ■åŁąåŹÍçŻÿåŕźäžŐTCPæIJ■åŁąåŹÍæİèèőšåőđçŐřętůæİ
äÿ■è£GïijŇUDPåd'l'çŤ§æŸŕäÿ■åŔŕéİăçŽĎïijĹåŻääÿžéĂŽä£ąæšąæIJL'åżžçńŃè£đæŐěïijŇæűĹæĄŕåŔŕèČ¡äÿ
åŻăæ■d'éIJĂèęĄçŤśä¡äèĞłåůśæİěåĘşåőŽèřěæĂŐæăůåd'ĎçŘĘäÿćåd'śæűĹæĄŕçŽĎæČĚåĘţãĂĆè£Źäÿłåůšçżl
äÿ■è£ĞéĂŽåÿÿæİèèŕt'ïijŇåęĆæđIJåŔŕéİăæĂğåŕźäžŐä¡ăçÍŃåžŔå¿ĹéĞ■èęĄïijŇä¡ăéIJĂèęĄåĂ§åŁl'äžŐåžŔåÍ
UDPéĂŽåÿÿèćńçŤĺåIJĺéĆčäžŻåŕźäžŐåŔŕéİăäijàè¿ŞèęĄæśĆäÿ■æŸŕå¿ĹéńŸçŽĎåIJžåŘĹãĂĆä¿ŃåęĆïijŇåIJĺå
æŮăéIJĂè£ŤåŻđæĄćåd'■äÿćåd'śçŽĎæŢřæ■őåŇĚïijĹçÍŃåžŔåŘłéIJĂçőĂå■ŢçŽĎå£¡çŢěáőČåźűçżğçż■åŘŚåĽ

`UDPServer` çśżæŸŕå■Ţçž£çÍŃçŽĎïijŇäź§åřśæŸŕèŕt'äÿĂæňąåŘłèČ¡äÿžäÿĂäÿłåőćæĹůçńŕè£đæŐěæIJ■
åőđéŹĚä¡£çŤĺäÿ■ïijŇè£ŹäÿłæŮăèőžæŸŕåŕźäžŐUDPè£ŸæŸŕTCPéČ¡äÿ■æŸŕäżĂäźĹåd'ğéŮőécŸãĂĆ
åęĆæđIJä¡ăæČşèęĄåźűåŘŚæŞ■ä¡IJïijŇåŔŕäžěåőđä¿ŃåŇŰäÿĂäÿł `ForkingUDPServer`
æĹŰ `ThreadingUDPServer` åŕźèśąïijŽ

```
from socketserver import ThreadingUDPServer

   if __name__ == '__main__':
    serv = ThreadingUDPServer(('',20000), TimeHandler)
    serv.serve_forever()
```

çŻt'æŐěä¡£çŤĺ `socket` æİěåőđçŐřäÿĂäÿłUDPæIJ■åŁąåŹÍäź§äÿ■éŽ¿ïijŇäÿŃéİćæŸŕäÿĂäÿłä¿Ńå■ŘïijŽ

```
from socket import socket, AF_INET, SOCK_DGRAM
import time

def time_server(address):
    sock = socket(AF_INET, SOCK_DGRAM)
    sock.bind(address)
    while True:
        msg, addr = sock.recvfrom(8192)
        print('Got message from', addr)
        resp = time.ctime()
        sock.sendto(resp.encode('ascii'), addr)
```

```
if __name__ == '__main__':
    time_server(('', 20000))
```

13.4 11.4 éÄŽè£ĞCIDRåIJřåİÄçŤ§æĹŘåŕźåžŤçŽĎIPåIJřåİÄéŻĘ

éŮőécŸ

ä¡äæIJL'äÿĂäÿłCIDRç¡ŚçżIJåIJřåİĂæŕŤåęĆâĂIJ123.45.67.89/27âĂİïijŇä¡ăæČşåřĘåĔűè¡ňæ■ćæĹŘåőČa
ïijĹæŕŤåęĆïijŇâĂIJ123.45.67.64âĂİ, âĂIJ123.45.67.65âĂİ, âĂę, âĂIJ123.45.67.95âĂİ)ïijL'

èğčåĘşæŰźæąĹ

åŘŕäżěä¡£çŤÍ `ipaddress` æĺąåİŮå¿ĹåőźæŸŞçŽĎåőđçŐřè£ŹæăůçŽĎèőąçőŮãĂĆä¿ŃåęĆïijŽ

```
>>> import ipaddress
>>> net = ipaddress.ip_network('123.45.67.64/27')
>>> net
IPv4Network('123.45.67.64/27')
>>> for a in net:
...     print(a)
...
123.45.67.64
123.45.67.65
123.45.67.66
123.45.67.67
123.45.67.68
...
123.45.67.95
>>>

>>> net6 = ipaddress.ip_network('12:3456:78:90ab:cd:ef01:23:30/125')
>>> net6
IPv6Network('12:3456:78:90ab:cd:ef01:23:30/125')
>>> for a in net6:
...     print(a)
...
12:3456:78:90ab:cd:ef01:23:30
12:3456:78:90ab:cd:ef01:23:31
12:3456:78:90ab:cd:ef01:23:32
12:3456:78:90ab:cd:ef01:23:33
12:3456:78:90ab:cd:ef01:23:34
12:3456:78:90ab:cd:ef01:23:35
12:3456:78:90ab:cd:ef01:23:36
12:3456:78:90ab:cd:ef01:23:37
>>>
```

`Network` äź§åĚĄèőÿåČŔæŢřçżĎäÿĂæăůçŽĎçť'ćåijŢåŔŰåĂijïijŇä¿ŃåęĆïijŽ

```
>>> net.num_addresses
32
>>> net[0]

IPv4Address('123.45.67.64')
>>> net[1]
IPv4Address('123.45.67.65')
>>> net[-1]
IPv4Address('123.45.67.95')
>>> net[-2]
IPv4Address('123.45.67.94')
>>>
```

åŔęåď'ŰïijŇä¡ăè£ŸåŔŕäžěæL'ğèąŇç¡ŚçżIJæĹŘåŚŸæčĂæ§ěäźŃçśżçŽĎæŞ■ä¡IJïijŽ

```
>>> a = ipaddress.ip_address('123.45.67.69')
>>> a in net
True
>>> b = ipaddress.ip_address('123.45.67.123')
>>> b in net
False
>>>
```

äÿĂäÿłIPåIJřåİĂåŠŇç¡ŚçżIJåIJřåİĂèČ¡éĂŽè£ĞäÿĂäÿłIPæŐěåŔčæİěæŇĞåőŽïijŇä¿ŃåęĆïijŽ

```
>>> inet = ipaddress.ip_interface('123.45.67.73/27')
>>> inet.network
IPv4Network('123.45.67.64/27')
>>> inet.ip
IPv4Address('123.45.67.73')
>>>
```

èőÍèőž

ipaddress æÍąåİŮæIJL'å¿Ĺåď'ŽçśżåŔŕäžěèąÍçď'žIPåIJřåİĂãĂĄç¡ŚçżIJåŠŇæŐěåŔčãĂĆ
å¡Şä¡ăéIJĂèęĄæŞ■ä¡IJç¡ŚçżIJåIJřåİĂïijĹæŕŤåęĆèğčædŘãĂĄæL'Şå■řãĂĄéłŇèŕĄç■L'ïijL'çŽĎæŮűåĂŹäijŽå

èęĄæşÍæĎŔçŽĎæŸŕïijŇipaddress æÍąåİŮèů§åĚűäžŰäÿĂäžŽåŠŇç¡ŚçżIJçŽÿåĚşçŽĎæÍąåİŮæŕŤåęĆ
socket åžŞäžď'éŻĘå¿ĹåřŚãĂĆ æL'ĂäžěïijŇä¡ääÿ■èČ¡ä¡£çŤÍ IPv4Address
çŽĎåőđä¿ŃæİěäžčæŻ£äÿĂäÿłåIJřåİĂå■ŮçňęäÿšïijŇä¡ăéęŰåĚĹå¿ŮæŸ¿åijŔçŽĎä¡£çŤÍ
str() è¡ňæ■ćåőČãĂĆä¿ŃåęĆïijŽ

```
>>> a = ipaddress.ip_address('127.0.0.1')
>>> from socket import socket, AF_INET, SOCK_STREAM
>>> s = socket(AF_INET, SOCK_STREAM)
>>> s.connect((a, 8080))
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: Can't convert 'IPv4Address' object to str implicitly
```

```
>>> s.connect((str(a), 8080))
>>>
```

æŻť'åď'ŽçŻÿåĚşåĘĚåőźïijŇèŕůåŔĆèĂČ An Introduction to the ipaddress Module

13.5 11.5 åĹŻåżžäÿĂäÿłçőÅå■ŢçŽĎRESTæŐěåŔč

éŮőécŸ

ä¡ăæČşä¡£çŤĺäÿĂäÿłçőÅå■ŢçŽĎRESTæŐěåŔčéĂŽè£Ğç¡ŚçżIJè£IJçÍŃæŐğåĹűæĹŰèő£éŮőä¡ăçŽĎåžŤ

èğčåĘşæŰźæąĹ

æđĎåżžäÿĂäÿłRESTéčŐæăijçŽĎæŐěåŔčæIJĂçőÅå■ŢçŽĎæŰźæşŢæŸŕåĹŻåżžäÿĂäÿłå§žäžŐWSGIæă 3333ïijL'çŽĎå¿ĹářŔçŽĎåžŞïijŇäÿŃéİćæŸŕäÿĂäÿłä¿Ńå■ŘïijŽ

```
# resty.py

import cgi

def notfound_404(environ, start_response):
    start_response('404 Not Found', [ ('Content-type', 'text/plain
↪') ])
    return [b'Not Found']

class PathDispatcher:
    def __init__(self):
        self.pathmap = { }

    def __call__(self, environ, start_response):
        path = environ['PATH_INFO']
        params = cgi.FieldStorage(environ['wsgi.input'],
                                  environ=environ)
        method = environ['REQUEST_METHOD'].lower()
        environ['params'] = { key: params.getvalue(key) for key in␣
↪params }
        handler = self.pathmap.get((method,path), notfound_404)
        return handler(environ, start_response)

    def register(self, method, path, function):
        self.pathmap[method.lower(), path] = function
        return function
```

äÿžäžĘä¡£çŤĺè£ŹäÿłèřČåžęåŹĺïijÑä¡ääŔłéIJÄèęAçijŰåĘŹäÿ■åŘŇçŽĎåď'ĎçŘĘåŹĺïijÑářšåČŔäÿŃéİćè£

```
import time

_hello_resp = '''\
```

```
<html>
  <head>
     <title>Hello {name}</title>
   </head>
   <body>
     <h1>Hello {name}!</h1>
   </body>
</html>'''

def hello_world(environ, start_response):
    start_response('200 OK', [ ('Content-type','text/html')])
    params = environ['params']
    resp = _hello_resp.format(name=params.get('name'))
    yield resp.encode('utf-8')

_localtime_resp = '''\
<?xml version="1.0"?>
<time>
  <year>{t.tm_year}</year>
  <month>{t.tm_mon}</month>
  <day>{t.tm_mday}</day>
  <hour>{t.tm_hour}</hour>
  <minute>{t.tm_min}</minute>
  <second>{t.tm_sec}</second>
</time>'''

def localtime(environ, start_response):
    start_response('200 OK', [ ('Content-type', 'application/xml')␣
↪])
    resp = _localtime_resp.format(t=time.localtime())
    yield resp.encode('utf-8')

if __name__ == '__main__':
    from resty import PathDispatcher
    from wsgiref.simple_server import make_server

    # Create the dispatcher and register functions
    dispatcher = PathDispatcher()
    dispatcher.register('GET', '/hello', hello_world)
    dispatcher.register('GET', '/localtime', localtime)

    # Launch a basic server
    httpd = make_server('', 8080, dispatcher)
    print('Serving on port 8080...')
    httpd.serve_forever()
```

èęĄæţŃèŕŢäÿŃè£ŹäÿłæIJ■åŁąåŹĺïijŇä¡ăåŔŕäžěä¡£çŤĺäÿĂäÿłæţŔèğĹåŹĺæĹŰ `urllib` åŠŇåőČäžďäžŠãĂĆä¿ŃåęĆïijŽ

```
>>> u = urlopen('http://localhost:8080/hello?name=Guido')
>>> print(u.read().decode('utf-8'))
<html>
  <head>
     <title>Hello Guido</title>
   </head>
   <body>
     <h1>Hello Guido!</h1>
   </body>
</html>

>>> u = urlopen('http://localhost:8080/localtime')
>>> print(u.read().decode('utf-8'))
<?xml version="1.0"?>
<time>
  <year>2012</year>
  <month>11</month>
  <day>24</day>
  <hour>14</hour>
  <minute>49</minute>
  <second>17</second>
</time>
>>>
```

èőÍèőž

åIJÍçijŰåĘŹRESTæŐěåŔčæŮűïijŇéĂŽåÿÿéČ¡æŸŕæIJ■åŁąäžŐæŹőéĂŽçŽĎHTTPèŕůæśĆãĂĆä¡ĘæŸŕè
è£ŹäžŻæŢřæ■őäžěåŘĎçğ■æăĞåĞĘæăijåijŔçijŰçăĄïijŇæŕŤåęĆXMLãĂĄJSONæĹŰCSVãĂĆ
åř¡çőąçÍŃåžŔçIJŃäÿŁåŐžå¿ĹçőĂå■ŢïijŇä¡ĘæŸŕäžěè£Źçğ■æŰźåijŔæŔŘä¿ŻçŽĎAPIåŕźäžŐå¿Ĺåď'ŽåžŤçŤÍç

ä¿ŃåęĆïijŇéŢ£æIJ§è£ŘèąŇçŽĎçÍŃåžŔåŔŕěČ¡äijŽä¡£çŤÍäÿĂäÿłREST
APIæÌěåőđçŐřçŻŚæŐğæĹŰèŕŁæŰ■ãĂĆ åď'ğæŢřæ■őåžŤçŤÍçÍŃåžŔåŔŕäžěä¡£çŤÍRESTæÌěæđĎåžžäÿĂäÿłæ
RESTè£ŸèČ¡çŤÍæÌěæŐğåĹűçąňäžűěő¿åď'ĞæŕŤåęĆæIJžåŹÍäžžãĂĄäijăæĎ$åŹÍãĂĄåůěåŐĆæĹŰçĄŕæşąãĂĆ
æŻť'éĞ■èęĄçŽĎæŸŕïijŇREST APIåůšçżŔèćńåď'ğéĞŘåőćæĹůçńŕçijŰçÍŃçŐŕåćČæĽ'ĂæŤŕæŇĄïijŇæŕŤåęĆ-
Javascript, Android, iOSç■L'ãĂĆ åŽăæ■d'ïijŇåĹl'çŤÍè£Źçğ■æŐěåŘčåŔŕäžěèől'ä¡ăåijĂåŘŠåĞžæŻť'åŁăåď'■æ

äÿžäžĘåőđçŐřäÿĂäÿłçőĂå■ŢçŽĎRESTæŐěåŘčïijŇä¡ăåŔłéIJÀèől'ä¡ăçŽĎçÍŃåžŔäžčçăĄæżąèűşPython
WSGIèćńæăĞåĞĘåžŞæŤŕæŇĄïijŇåŘŇæŰűäź§èćńçżÌåď'ğéČĺåĹEçňňäÿĽ'æŰźwebæąĘæđűæŤŕæŇĄãĂĆ
åŽăæ■d'ïijŇåęĆæđIJä¡ăçŽĎäžčçăĄéĄţå¿łè£ŹäÿłæăĞåĞĘïijŇåIJĺåŘŐéÍćçŽĎä¡£çŤÍè£ĞçÍŃäÿ■åřśäijŽæŻť'åŁ

åIJÍWSGIäÿ■ïijŇä¡ăåŔŕäžěåČŔäÿŃéÍćè£ŹæăůçžęåőŽçŽĎæŰźåijŔäžěäÿĂäÿłåŔŕèŕČçŤÍåŕźèśąå¡ćåijŔæÍ

```
import cgi

def wsgi_app(environ, start_response):
    pass
```

environ åśđæĂğæŸŕäÿĂäÿłå■ŮåĚÿïijŇåŇĚåŘńäžĘäžŐwebæIJ■åŁąåŹĺåęĆA-
pache[åŔĆèĂČInternet RFC 3875]æŔŘä¿ŽçŽĎCGIæŐěåŘčäÿ■èŐůåŔŰçŽĎåĂijăĂĆ
èęĄåřĘè£ŹäžŻäÿ■åŘŇçŽĎåĂijæŔŘåŔŰåĞžæÌěïijŇä¡ăåŔŕäžěåČŔè£ŹäźĹè£ŹæăůåĘŹïijŽ

```
def wsgi_app(environ, start_response):
    method = environ['REQUEST_METHOD']
    path = environ['PATH_INFO']
    # Parse the query parameters
    params = cgi.FieldStorage(environ['wsgi.input'],␣
↪environ=environ)
```

æĹŚäżňåśŢçď˙žäžĘäÿĂäžŻåÿÿèğĄçŽĎåĂijãĂĆenviron['REQUEST_METHOD'] äžčèąĺèŕůæśĆçśżåđŃåęĆGETãĂĄPOSTãĂĄHEADç■Ľ˙ãĂĆ environ['PATH_INFO'] èąĺçď˙žèćńèŕůæśĆèţĎæžŘçŽĎèůŕå¿ĎãĂĆ èřČçŢĺ cgi.FieldStorage() åŔŕäžëäżŐèŕůæśĆäÿ■æŔŘåŔŰæ§ěèŕćåŔĆæŢřåźűåřĘåőČäżňæŤ¿åĚëäÿĂäÿłçśżå■ŮåĚÿåŕźèśąäÿ■äžëä¿£åŘŐ

start_response åŔĆæŢřæŸŕäÿĂäÿłäÿžäžĘåĹİåğŃåŇŰäÿĂäÿłèŕůæśĆåŕźèśąèĂŇå£Ěéążèćńèř˙ÇçŢĺ çňňäÿĂäÿłåŔĆæŢřæŸŕè£ŤåŻđçŽĎHTTPçŁűæĂĄåĂijïijŇçňňäžŇäÿłåŔĆæŢřæŸŕäÿĂäÿł(åŘ■,åĂij)åĚČçżĎ

```
def wsgi_app(environ, start_response):
    pass
    start_response('200 OK', [('Content-type', 'text/plain')])
```

äÿžäžĘè£ŤåŻđæŢřæ■őïijŇäÿĂäÿłWSGIçĺŃåžŔå£Ěéążè£ŤåŻđäÿĂäÿłå■ŮèŁĆå■ŮçňęäÿšåžŔåĹŮãĂĆåĚ

```
def wsgi_app(environ, start_response):
    pass
    start_response('200 OK', [('Content-type', 'text/plain')])
    resp = []
    resp.append(b'Hello World\n')
    resp.append(b'Goodbye!\n')
    return resp
```

æĹŰèĂĚïijŇä¡ăè£ŸåŔŕäžëä¡£çŤĺ yield ïijŽ

```
def wsgi_app(environ, start_response):
    pass
    start_response('200 OK', [('Content-type', 'text/plain')])
    yield b'Hello World\n'
    yield b'Goodbye!\n'
```

è£ŹéĞŇèęĄåijžèřČçŽĎäÿĂçĆźæŸŕæIJĂåŘŐè£ŤåŻđçŽĎå£ĚéążæŸŕå■ŮèŁĆå■Ůçňęäÿšã ĂĆåęĆæđIJè£ å¡ŞçĎűïijŇåźűæšąæIJL'èęĄæśĆä¡ăè£ŤåŻđçŽĎäÿĂåőŽæŸŕæŰĞæIJñïijŇä¡ăåŔŕäžëå¿Ĺè¡żæİ¿çŽĎçijŰåĘŹäÿ

år¡çőąWSGIçĺŃåžŔéĂŽåÿÿèćńåőŽäźL'æĹŘäÿĂäÿłåĞ¡æŢŕïijŇäÿ■è£Ğä¡ăäź§åŔŕäžëä¡£çŤĺçśżåőđä¿ŃæĺÇ __call__() æŰźæşŢãĂĆä¿ŃåęĆïijŽ

```
class WSGIApplication:
    def __init__(self):
        ...
    def __call__(self, environ, start_response)
       ...
```

æĹŚäżňåůšçżŔåIJĺäÿŁéİćä¡£çŤĺè£Źçğ■æŁĂæIJŕåĹŻåžž PathDispatcher çśżãĂĆ è£ŹäÿłåĹĘåŘŠåŹĺäžĚäžĚåŘłæŸŕçőąçŘĘäÿĂäÿłå■ŮåĚÿïijŇårĘ(æŰźæşŢ,èůŕå¿Ď)åŕźæŸăåŕĎåĹråď˙ĎçŘĘåŹĺ

å¡Şäÿ ĂäÿłèŕůæśĆåĹŕæİěæŮűïijŇåőČçŽĎæŰźæşŢåŠŇèůŕå¿ĎèćńæŔŘåŔŰåĞžæİěïijŇçĎűåŔŐèćńåĹĘåŔŚåĹ
åŔęåď ŰïijŇäżżä¡Ţæ§ěèŕćåŔŸéĞŔäijŽèćńèğčæđŘåŔŐæŢ¿åĹŕäÿĂäÿłå■ŮåĚÿäÿ■ïijŇäżě
environ['params'] å¡ćåijŔå■ŸåĆĺãĂĆ åŔŐéİćè£Źäÿłæ■ěéłď åď łäÿÿèğĄïijŇæĹ Ăäżěåżžèőőä¡ăåİJåĹĘ
ä¡£çŤĺåĹĘåŔŚåŹĺçŽĎæŰűåĂŹïijŇä¡ăåŔłéIJĂçőĂå■ŢçŽĎåĹŻåżžäÿĂäÿłåőđä¿ŃïijŇçĎűåŔŐéĂŽè£ĞåőČæ
çijŰåĘŹè£ŹäžŻåĞ¡æŢřåžŤèŕěèűĚçžğçőĂå■ŢäžĘïijŇåŔłèęĄä¡ăéĄţå¿ł
start_response() åĞ¡æŢřçŽĎçijŰåĘŹèğĎåĹŹïijŇåźűäÿŤæIJĂåŔŐè£ŤåŻđå■ŮèŁĆå■Ůçňęäÿšå■şåŔŕ

å¡ŞçijŰåĘŹè£Źçğ■åĞ¡æŢřçŽĎæŮűåĂŹè£ŸéIJĂæşĺæĐŔçŽĎäÿĂçĆźåřśæŸŕåŕźäžŐå■Ůçňęäÿšæİąæİ£ç
æšąäžžæĐ£æĐŔåĘŹéĆčçğ■åĹŕåď ĎæůůåŘĹçİĂ print() åĞ¡æŢř ãĂĄXM-
LåŠŇåď ğéĞŔæäijåijŔåŃŰæŞ■ä¡IJçŽĎäżčçăĄãĂĆ æĹŚäžňäÿŁéİćä¡£çŤĺäžĘäÿĽåijŢåŔůåŃĚåŔńçŽĎéćĎåĚ
è£Źçğ■æŰźåijŔçŽĎåŔŕäžěèőľ æĹŚäžňå¿ĹåőźæŸşçŽĎåIJĺäžěåŔŐä£őæŤźè¿ŞåĞžæäijåijŔ(åŔłéIJĂèęĄä£őæ

æIJĂåŔŐïijŇä¡£çŤĺWSGIè£ŸæIJĽäÿĂäÿłå¿ĹéĞ■èęĄçŽĎéČĺåĹĘåřśæŸŕæšąæIJĽäżĂäźĹåIJřæŰźæŸŕé
åŽăäÿžæăĞåĞĘåŕźäžŐæIJ■åŁąåŹĺåŠŇæąĘæđűæŸŕäÿ■çńŃçŽĎïijŇä¡ăåŔŕäžěåřĘä¡ăçŽĎçĺŃåžŔæŢ¿åĚěäżżä
æĹŚäžňä¡£çŤĺäÿŃéİćçŽĎäżčçăĄæţŃèŕŢæţŃèŕŢæIJňèĹĆäżčçăĄïijŽ

```
if __name__ == '__main__':
    from wsgiref.simple_server import make_server

    # Create the dispatcher and register functions
    dispatcher = PathDispatcher()
    pass

    # Launch a basic server
    httpd = make_server('', 8080, dispatcher)
    print('Serving on port 8080...')
    httpd.serve_forever()
```

äÿŁéİćäżčçăĄåĹŻåżžäžĘäÿĂäÿłçőĂå■ŢçŽĎæIJ■åŁąåŹĺïijŇçĎűåŔŐä¡ăåřśåŔŕäžěæİěæţŃèŕŢäÿŃä¡ăçŽ
æIJĂåŔŐïijŇå¡Şä¡ăåĞĘåď Ğè£ŻäÿĂæ■ěæĹ ľ åśŢä¡ăçŽĎçĺŃåžŔçŽĎæŮűåĂŹïijŇä¡ăåŔŕäžěä£őæŤźè£Źäÿłäż

WSGIæIJňèžńæŸŕäÿĂäÿłå¿ĹåřŔçŽĎæăĞåĞĘãĂĆåŻăæ■ďåőČåźűæšąæIJĽæŘŘä¿ŻäÿĂäžŻéńŸçžğçŽĎ
è£ŹäžŻä¡äèĞłåůśåőđçŐřèţůæİěäź§äÿ■éŽ¿ãĂĆäÿ■è£ĞåęĆæđIJä¡ăæČşèęĄæŻť åď ŽçŽĎæŤŕæŇĄïijŇåŔŕäžěè
WebOb æĹŰèĂĚ Paste

13.6 11.6 éĂŽè£ĞXML-RPCåőđçŐřçőĂå■ŢçŽĎè£IJçĺŃèřČçŤĺ

éŮőéćŸ

ä¡ăæČşæĽ¿åĹŕäÿĂäÿłçőĂå■ŢçŽĎæŰźåijŔåŐżæĽğèąŇè£ŘèąŇåIJĺè£IJçĺŃæIJžåŹĺäÿŁéİćçŽĎPythonçĺ

èğčåĘşæŰźæąĹ

åőđçŐřäÿĂäÿłè£IJçĺŃæŰźæşŢèřČçŤĺçŽĎæIJĂçőĂå■ŢæŰźåijŔæŸŕä¡£çŤĺXML-
RPCãĂĆäÿŃéİćæĹŚäžňæijŤçď žäÿĂäÿŃäÿĂäÿłåőđçŐřäžĘéŤő-
åĂijå■ŸåĆĺåŁ§èČ¡çŽĎçőĂå■ŢæIJ■åŁąåŹĺïijŽ

```
from xmlrpc.server import SimpleXMLRPCServer

class KeyValueServer:
    _rpc_methods_ = ['get', 'set', 'delete', 'exists', 'keys']
    def __init__(self, address):
        self._data = {}
        self._serv = SimpleXMLRPCServer(address, allow_none=True)
        for name in self._rpc_methods_:
            self._serv.register_function(getattr(self, name))

    def get(self, name):
        return self._data[name]

    def set(self, name, value):
        self._data[name] = value

    def delete(self, name):
        del self._data[name]

    def exists(self, name):
        return name in self._data

    def keys(self):
        return list(self._data)

    def serve_forever(self):
        self._serv.serve_forever()

# Example
if __name__ == '__main__':
    kvserv = KeyValueServer(('', 15000))
    kvserv.serve_forever()
```

äÿŃéÌćæĹŚäżñäżŐäÿĂäÿłåőćæĹůçńŕæIJžåŹĺäÿŁéÌćæÌěèõ£éŮőæIJ■åŁąåŹĺïijŽ

```
>>> from xmlrpc.client import ServerProxy
>>> s = ServerProxy('http://localhost:15000', allow_none=True)
>>> s.set('foo', 'bar')
>>> s.set('spam', [1, 2, 3])
>>> s.keys()
['spam', 'foo']
>>> s.get('foo')
'bar'
>>> s.get('spam')
[1, 2, 3]
>>> s.delete('spam')
>>> s.exists('spam')
False
>>>
```

èőÍèőž

XML-RPC åŘŕäžěèőľ æĹŠäžňå¿Ĺåőźæ˙ŞçŽĎæđĎéĂääÿĂäÿłçőĂå■ŢçŽĎè£IJçÍŃèřČçŤÍæIJ■åŁąãĂĆä¡éĂŽè£ĞåőČçŽĎæŰźæşŢ `register_function()` æĺěæşĺåĘŇåĞ¡æŢřijŇçĎűåŘŐä¡£çŤÍæŰźæşŢ `serve_forever()` åŘŕåŁĺåőČãĂĆ åIJÍäÿŁéĺćæĹŠäžňářĘè£ŹäžŻæ■ěéłď˙æŤ¿åIJÍäÿĂèţůåĘŹåĹřäÿĂäÿłçśż

```
from xmlrpc.server import SimpleXMLRPCServer
def add(x,y):
    return x+y

serv = SimpleXMLRPCServer(('', 15000))
serv.register_function(add)
serv.serve_forever()
```

XML-RPCæŽť éIJšåĞžæĺěçŽĎåĞ¡æŢřåŘłèČ¡éĂĆçŤÍäžŐéČÍåĹĘæŢřæ■őçśżåđŃïijŇærŤåęĆå■Ůçňęäÿš
åŕźäžŐåĚűäžŰçśżåđŃářšå¿ŮéIJĂèęĄåĄŽäžŻéćİåď ŰçŽĎåŁ§èŕ¿äžĘãĂĆ
ä¿ŃåęĆïijŇåęĆæđIJä¡æčÇşéĂŽè£Ğ XML-RPC äijäéĂŠäÿĂäÿłářźèšąåőđä¿ŃïijŇåőđéŹĚäÿŁåŘłæIJL'äžŰçŽĎ

```
>>> class Point:
...     def __init__(self, x, y):
...             self.x = x
...             self.y = y
...
>>> p = Point(2, 3)
>>> s.set('foo', p)
>>> s.get('foo')
{'x': 2, 'y': 3}
>>>
```

çśżäijijçŽĎïijŇářźäžŐäžŇè£ŻåĹűæŢřæ■őçŽĎåď ĎçŘĘäź§èů§ä¡äæČşèšąçŽĎäÿ■åď łäÿĂæåůïijŽ

```
>>> s.set('foo', b'Hello World')
>>> s.get('foo')
<xmlrpc.client.Binary object at 0x10131d410>

>>> _.data
b'Hello World'
>>>
```

äÿĂèĹňæİěèőšïijŇä¡ääÿ■åžŤèŕěářĘ XML-RPC æIJ■åŁąäżěåĚňåĚśAPIçŽĎæŰźåijŔæŽť éIJšåĞžæİěãĂĆ
åŕźäžŐè£ŹçğæČĚåĘţïijŇéĂŽåÿÿåĹĘåÿČåijŔåžŤçŤÍçÍŃåžŔäijŽæŸŕäÿĂäÿłæŽť åě¡çŽĎéĂL'æŃ'ãĂĆ

XML-RPCçŽĎäÿĂäÿłçijžçĆźæŸŕåőČçŽĎæĂğèČ¡ãĂĆ`SimpleXMLRPCServer` çŽĎåőđçŐřæŸŕå■Ţçž£çÍŃçŽĎïijŇ æL'Ăäżěåőčäÿ■éĂĆåŘĹäžŐåď ğåđŃçÍŃåžŔïijŇår¡çőąæĹŠäžňåIJÍ11.2ařł
åŘęåď ŰïijŇçŤśäžŐ XML-RPC åřĘæL'ĂæIJL'æŢřæ■őéČ¡åžŔåĹŮåŇŰäÿžXMLæäijåijŔïijŇæL'ĂäżěåőčäijŽ
ä¡ĘæŸŕåőČäź§æIJL'äijŸçĆźïijŇè£ŹçğæŰźåijŔçŽĎçijŰçăĄåŘŕäżěèćńçżÍåď ğéČÍåĹĘåĚűäžŰçijŰçÍŃèŕ■èÍĂ
éĂŽè£Ğä¡£çŤÍè£ŹçğæŰźåijŔïijŇåĚűäžŰèŕ■èÍĂçŽĎåőćæĹůçńŕçÍŃåžŔéČ¡èČ¡èő£éŮőä¡ăçŽĎæIJ■åŁąãĂĆ

èŹ¡çĎűXML-RPCæIJL'å¿Ĺåď ŽçijžçĆźïijŇä¡ĘæŸŕåęĆæđIJä¡äéIJĂèęĄå£ńéĂ§æđĎåžžäÿĂäÿłçőĂå■Ţè£
æIJL'æŮűåĂŹïijŇçőĂå■ŢçŽĎæŰźæąĹářšåůšçżŔèűşåď §äžĘãĂĆ

13.7 11.7 åIJÍäÿ■åŘŇçŽĎPythonèğčéĞŁåŹÍäźŃéŮťäžďäžŠ

éŮőécŸ

ä¡ăåIJÍäÿ■åŘŇçŽĎæIJžåŹÍäÿŁéİćè£ŘèąŇçİĂåď'ŽäÿłPythonèğčéĞŁåŹÍåőđä¿ŃïijŇåźűåÿŇæIJŻèČ¡åď'§å

èğčåĘşæŰźæąĹ

éĂŽè£Ğä¡£çŤÍ `multiprocessing.connection` æÍąåİŮåŔŕäžěå¿ĹåőźæŸŞçŽĎåőđçŐřèğčéĞŁåŹÍ
äÿŃéİćæŸŕäÿĂäÿłçőĂå■ŢçŽĎåžŤç■ŤæIJ■åŁąåŹÍä¿Ńå■ŘïijŽ

```
from multiprocessing.connection import Listener
import traceback

def echo_client(conn):
    try:
        while True:
            msg = conn.recv()
            conn.send(msg)
    except EOFError:
        print('Connection closed')

def echo_server(address, authkey):
    serv = Listener(address, authkey=authkey)
    while True:
        try:
            client = serv.accept()

            echo_client(client)
        except Exception:
            traceback.print_exc()

echo_server(('', 25000), authkey=b'peekaboo')
```

çĎűåŘŐåőćæĹůçńŕè£đæŐěæIJ■åŁąåŹÍåźűåŔŠéĂĄæűĹæĄŕçŽĎçőĂå■Ţçď'žä¿ŃïijŽ

```
>>> from multiprocessing.connection import Client
>>> c = Client(('localhost', 25000), authkey=b'peekaboo')
>>> c.send('hello')
>>> c.recv()
'hello'
>>> c.send(42)
>>> c.recv()
42
>>> c.send([1, 2, 3, 4, 5])
>>> c.recv()
[1, 2, 3, 4, 5]
>>>
```

èů§åžŢåśĆsocketäÿ■åŘŇçŽĎæŸŕïijŇæŕŔäÿłæűĹæĄŕäijŽåőŇæŢť'ä£Ìå■ŸïijĹæŕŔäÿĂäÿłéĂŽè£Ğsend()
åŘęåď'ŰïijŇæĽ'ĂæIJL'åŕźèśąäijŽéĂŽè£ĞpickleåžŔåĹŮåŇŰãĂĆåŻãæ■ď'ïijŇäżżä¡ŢåĚijåőźpickleçŽĎåŕźèśą

èőÍèőž

çŽőåL'■æIJL'å¿Ĺåď'ŽçŤÍæÌěåőđçŐřåŘĎçğ■æűĹæĄŕäijàè¿ŞçŽĎåŇĚåŠŇåĞ¡æŢřåžŞïijŇæŕŤåęĆZeroMQ
ä¡ãè£ŸæIJL'åŘęåď'ŰäÿĂçğ■éĂĽ'æŃľ'åŕśæŸŕèĞłåůśåIJĺåžŢåśĆsocketå§žçąĂäźŇäÿŁæÌěåőđçŐřäÿĂäÿłæűĹæ
ä¡ĘæŸŕä¡ăæČşèęĄçőĂå■ŢäÿĂçĆźçŽĎæŰźæąĹïijŇéĆčäźĹè£ŹæŮůåĂŹ
multiprocessing.connection åŕśæť¿äÿŁçŤÍåIJžäžĘãĂĆ
äžĚäžĚä¡£çŤÍäÿĂäžŽçőĂå■ŢçŽĎèŕ■åŘěå■şåŔŕåőđçŐřåď'Žäÿłèğčéğ̆ŁåŹĺäźŇéŮť'çŽĎæűĹæĄŕéĂŽä£ąãĂĆ

åęĆæđIJä¡ăçŽĎèğčéğ̆ŁåŹĺè£ŘèąŇåIJÍåŘŇäÿĂåŘřæIJžåŹĺäÿŁéİćïijŇéĆčäźĹä¡ăåŔŕäžěä¡£çŤÍåŘęåď'ŰçŽ
èęĄæČşä¡£çŤÍUNIXå§§åěŮæŐěå■ŮæÌěåĹŽåžžäÿĂäÿłè£đæŐěïijŇåŘłéIJĂçőĂå■ŢçŽĎårĘåIJřåİĂæŤźåĘźäÿ

```
s = Listener('/tmp/myconn', authkey=b'peekaboo')
```

èęĄæČşä¡£çŤÍWindowsåŚ¡åŘ■çőąéĄŞæÌěåĹŽåžžè£đæŐěïijŇåŘłéIJĂåČŔäÿŇéİćè£ŹæăůäĄ£çŤÍäÿĂäÿła

```
s = Listener(r'\\.\pipe\myconn', authkey=b'peekaboo')
```

äÿĂäÿłéĂŽçŤÍåĞĘåĹŹæŸŕïijŇä¡ăäÿ■èęĄä¡£çŤÍ multiprocessing
æÌěåőđçŐřäÿĂäÿłåŕźåď'ŰçŽĎåĚňåĚśæIJ■åŁąãĂĆ Client() åŠŇ Listener()
äÿ■çŽĎ authkey åŔĆæŢřçŤÍæÌěèőď'èŕĄåŔŚèţůè£đæŐěçŽĎçżĹçńŕçŤÍæĹůãĂĆ
åęĆæđIJåŕĘéŠěäÿ■åŕźäijŽäžğçŤ§äÿĂäÿłåijĆåÿÿãĂĆæ■ď'åď'ŰïijŇèŕěæĺąåIÙæIJĂéĂĆåŘĹçŤÍæÌěåžžçńŇéŢ£
ä¿ŇåęĆïijŇäÿď'äÿłèğčéğ̆ŁåŹĺäźŇéŮť'åŘŕåŁĺåŘŐåŕśåijĂäğŇåžžçńŇè£đæŐěåźűåIJĺåď'ĎçŘĘæ§ŘäÿłéŮőécŸ

åęĆæđIJä¡ăéIJĂèęĄåŕźåžŢåśĆè£đæŐěåĄŽæŽť'åď'ŽçŽĎæŐğåĹűïijŇæŕŤåęĆéIJĂèęĄæŤŕæŇĄèűĚæŮűã
ä¡ăæIJĂåě¡ä¡£çŤÍåŘęåď'ŰçŽĎåžŞæĹŰèĂĚæŸŕåIJĺéńŸåśĆsocketäÿŁæÌěåőđçŐřè£ŹäžŽçL'źæĂğãĂĆ

13.8 11.8 åőđçŐřè£IJçÍŇæŰźæşŢèřČçŤÍ

éŮőécŸ

ä¡ăæČşåIJÍäÿĂäÿłæűĹæĄŕäijàè¿ŞåśĆåęĆ sockets ãĂĄmultiprocessing
connections æĹŰ ZeroMQ çŽĎå§žçąĂäźŇäÿŁåőđçŐřäÿĂäÿłçőĂå■ŢçŽĎè£IJçÍŇè£ĞçÍŇèřČçŤÍïijĹRPC

èğčåĘşæŰźæąĹ

åřĘåĞ¡æŢřèřůæśĆãĂĄåŘĆæŢřåŠŇè£ŤåŻđåĂijä¡£çŤÍpickleçijŰçăĄåŘŐïijŇåIJÍäÿ■åŘŇçŽĎèğčéğ̆ŁåŹ
äÿŇéİćæŸŕäÿĂäÿłçőĂå■ŢçŽĎPRCåď'ĎçŘĘåŹÍïijŇåŘŕäžěèćńæŢť'åŘĹåĹřäÿĂäÿłæIJ■åŁąåŹÍäÿ■åŐžïijŽ

```
# rpcserver.py

import pickle
class RPCHandler:
    def __init__(self):
        self._functions = { }
```

```
    def register_function(self, func):
        self._functions[func.__name__] = func

    def handle_connection(self, connection):
        try:
            while True:
                # Receive a message
                func_name, args, kwargs = pickle.loads(connection.
↪recv())
                # Run the RPC and send a response
                try:
                    r = self._functions[func_name](*args,**kwargs)
                    connection.send(pickle.dumps(r))
                except Exception as e:
                    connection.send(pickle.dumps(e))
        except EOFError:
            pass
```

èęĄä¡£çŤĺè£Źäÿłåđ'ĎçŘĘåŹĺïijŇä¡ăéIJĂèęĄåřĘåőČåŁăåĚěåĹřäÿĂäÿłæűĹæĄŕæIJ■åŁąåŹĺäÿ■ãĂĆä¡ăæä¡ĘæŸŕä¡£çŤĺ multiprocessing åžŞæŸŕæIJĂçőĂå■ŢçŽĎãĂĆäÿŃéİćæŸŕäÿĂäÿłR-PCæIJ■åŁąåŹĺä¿Ńå■ŘïijŽ

```
from multiprocessing.connection import Listener
from threading import Thread

def rpc_server(handler, address, authkey):
    sock = Listener(address, authkey=authkey)
    while True:
        client = sock.accept()
        t = Thread(target=handler.handle_connection, args=(client,))
        t.daemon = True
        t.start()

# Some remote functions
def add(x, y):
    return x + y

def sub(x, y):
    return x - y

# Register with a handler
handler = RPCHandler()
handler.register_function(add)
handler.register_function(sub)

# Run the server
rpc_server(handler, ('localhost', 17000), authkey=b'peekaboo')
```

äÿžäžĘäżŐäÿĂäÿłè£IJçĺŃåőćæĹůçńŕèő£éŮőæIJ■åŁąåŹĺïijŇä¡ăéIJĂèęĄåĹŻåżžäÿĂäÿłåŕźåžŢçŽĎçŢĺæİ

```
import pickle

class RPCProxy:
    def __init__(self, connection):
        self._connection = connection
    def __getattr__(self, name):
        def do_rpc(*args, **kwargs):
            self._connection.send(pickle.dumps((name, args,␣
↪kwargs)))
            result = pickle.loads(self._connection.recv())
            if isinstance(result, Exception):
                raise result
            return result
        return do_rpc
```

èęĄä¡£çŤĺè£ŹäÿłäžčçŘĘçśżïijŇä¡äéIJĂèęĄåřĘåĚűåŇĚèčĚåĹřäÿĂäÿłæIJ■åŁąåŹĺçŽĎè£đæŐěäÿŁéİćïijŇ

```
>>> from multiprocessing.connection import Client
>>> c = Client(('localhost', 17000), authkey=b'peekaboo')
>>> proxy = RPCProxy(c)
>>> proxy.add(2, 3)

5
>>> proxy.sub(2, 3)
-1
>>> proxy.sub([1, 2], 4)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  File "rpcserver.py", line 37, in do_rpc
    raise result
TypeError: unsupported operand type(s) for -: 'list' and 'int'
>>>
```

èęĄæşĺæĎŘçŽĎæŸŕå¿Ĺåd'ŽæűĹæĄŕåśĆïijĹæŕŤåęĆ `multiprocessing` ïijL'åůšçżŘä¡£çŤĺpickleåžŘåĹŮåŇŰäžĘæŢřæ■őãĂĆ åęĆæđIJæŸŕè£ŹæăůçŽĎèŕİïijŇåŕź `pickle.dumps()` åŠŇ `pickle.loads()` çŽĎèřČçŤĺèęĄåŐżæŐL'ãĂĆ

èőĺèőž

`RPCHandler` åŠŇ `RPCProxy` çŽĎå§žæIJňæĂİèůŕæŸŕå¿ĹæŕŤè¿ČçőĂå■ŢçŽĎãĂĆ åęĆæđIJäÿĂäÿłåőćæĹůçńŕæČşèęĄèřČçŤĺäÿĂäÿłè£IJçíŇåĞ¡æŢřïijŇæŕŤåęĆ `foo(1, 2, z=3)` ,äžčçŘĘçśżåĹŻåžžäÿĂäÿłåŇĚåŘńäžĘåĞ¡æŢřåŘ■åŠŇåŔĆæŢřçŽĎåĚČçżĎ `('foo', (1, 2), {'z': 3})` ãĂĆ è£ŹäÿłåĚČçżĎèćńpickleåžŘåĹŮåŇŰåŘŐéĂŽè£Ğç¡ŚçżIJè£đæŐěåŔŚçŢ§åČ è£ŹäÿĂæ■ěåIJĺ `RPCProxy` çŽĎ `__getattr__()` æŰźæşŢè£ŤåŻđçŽĎ `do_rpc()` éŮ■åŇĚäÿ■åőŇæĹŘãĂĆ æIJ■åŁąåŹĺæŐěæŤűåŘŐéĂŽè£ĞpickleåŘ■åžŘåĹŮåŇŰæűĹæĄŕïijŇæ§ěæL'¿åĞ¡æ æL'ğèąŇçżŞæđIJ(æĹŰåijĆåÿÿ)èćńpickleåžŘåĹŮåŇŰåŘŐè£ŤåŻđåŔŚéĂĄçżŹåőćæĹůçńŕãĂĆæĹŚäžňçŽĎåő `multiprocessing` è£ŻèąŇéĂŽä£ąãĂĆ äÿ■è£ĞïijŇè£Źçğ■æŰźåijŔåŕäžěéĂĆçŤĺäžŐåĚűäžŰäžžä¡ŢæűĹ äžĚäžĚåŔłéIJĂèęĄåřĘè£đæŐěåŕźèśąæ■ćæĹŘåŘĹéĂĆçŽĎZeroMQçŽĎsocketåŕźèśąå■şåŔŕãĂĆ

çŤśäžŐåžŢåśĆéIJÄèęĄä¿İèţŰpickleïijŇéĆčäźĹåőL’åĚĺéŮőécŸåřśéIJÄèęĄèĂČèŹŚäžĘ
ïijĹåŽääÿžäÿĂäÿłèĄłæŸŐçŽĎéżŠåőćåŔŕäžěåĹŽåžžçL’źåőŽçŽĎæűĹæĄŕïijŇèČ¡åd’§èőľäżżæĎŔåĞ¡æŢřéĂŽ
åŽäæ■d’ä¡äæřÿè£IJäÿ■èęĄåĚĄèőÿæİěèĞłäÿ■ä£ąäżżæĹŰæIJłèőd’èŕĄçŽĎåőćæĹůçńŕçŽĎRPCãĂĆçL’źåĹńæ
è£Źçğ■åŔłèČ¡åIJĺåĘĚéČĺèćńä¡£çŤĺïijŇä¡■äžŐéŸšçĄńáćŹåŘŐéĺćåźűäÿŤäÿ■èęĄåŕźåd’ŰæŽť éIJšãĂĆ

ä¡IJäÿžpickleçŽĎæŻ£äżčïijŇä¡äáź§èőÿåŔŕäžěèĂČèŹŚä¡£çŤĺJSONãĂĄXMLæĹŰäÿĂäžŻåĚűäžŰçŽĎçi
ä¿ŇåęĆïijŇæIJñæIJžåőđä¿ŇåŔŕäžěå¿Ĺåőźæ ŸŞçŽĎæŤźåĘŹæĹŘJSONçijŰçăĄæŰźæąĹãĂĆè£ŸéIJÄèęĄåřĘ
`pickle.loads()` åŠŇ `pickle.dumps()` æŻ£æ■ćæĹŘ `json.loads()` åŠŇ `json.dumps()` å■şåŔŕïijŽ

```
# jsonrpcserver.py
import json

class RPCHandler:
    def __init__(self):
        self._functions = { }

    def register_function(self, func):
        self._functions[func.__name__] = func

    def handle_connection(self, connection):
        try:
            while True:
                # Receive a message
                func_name, args, kwargs = json.loads(connection.
↪recv())
                # Run the RPC and send a response
                try:
                    r = self._functions[func_name](*args,**kwargs)
                    connection.send(json.dumps(r))
                except Exception as e:
                    connection.send(json.dumps(str(e)))
        except EOFError:
             pass

# jsonrpcclient.py
import json

class RPCProxy:
    def __init__(self, connection):
        self._connection = connection
    def __getattr__(self, name):
        def do_rpc(*args, **kwargs):
            self._connection.send(json.dumps((name, args, kwargs)))
            result = json.loads(self._connection.recv())
            return result
        return do_rpc
```

åőđçŐřRPCçŽĎäÿĂäÿłæŕŤè¿Čåd’■æİĆçŽĎéŮőécŸæŸŕåęĆä¡ŢåŐžåd’ĎçŘĘåijĆåÿÿãĂĆèĞşåřŚïijŇå¡Ş
åŽäæ■d’ïijŇè£ŤåŽđçżŹåőćæĹůçńŕçŽĎåijĆåÿÿæL’Ăäžčèą́ĺçŽĎåŘńäźL’åŕśèęĄåě¡åě¡èő¿ëőąäžĘãĂĆ
åęĆæđIJä¡ää¡£çŤĺpickleïijŇåijĆåÿÿåŕźèśąåőđä¿ŇåIJĺåőćæĹůçńŕèČ¡èćńåŔ■åžŘåĹŮåŇŰåźűæŁŽåĞžãĂĆåęĆ

äÿ■è£ĜèĞşåřŚïijŇä¡ăåžŤèŕěåIJĺåŞ■åžŤäÿ■è£ŤåŻđåijĆåÿÿå■Ůçňęäÿšã ĂĆæĹŚäžňåIJĺJSONçŽĎä¿Ńå■Řäÿ■å

åŕźäžŐåĚűäżŰçŽĎRPCåőđçŐřä¿Ńå■ŘïijŇæĹŚæŐĺè■Řä¡ăçIJŃçIJŃåIJĺXML-RPCäÿ■ä¡£çŤĺçŽĎ `SimpleXMLRPCServer` åŠŇ `ServerProxy` çŽĎåőđçŐřïijŇ äźş§åřśæŸŕ11.6åřŔèŁĆäÿ■çŽĎåĘĚåőźãĂĆ

13.9 11.9 çőĂå■ŢçŽĎåőćæĹůçńŕèŏđ'èŕĄ

éŮőécŸ

ä¡ăæČşåIJĺåĹĘåÿČåijŔçşżçż§äÿ■åőđçŐřäÿĂäÿłçŏĂå■ŢçŽĎåőćæĹůçńŕè£đæŐěèŏđ'èŕĄåŁ§èČ¡ïijŇåŔĹä

èğčåĘşæŰźæąĹ

åŔŕäžěåĹl'çŤĺ `hmac` æĺąåİŮåőđçŐřäÿĂäÿłè£đæŐěæŔąæL'ŃïijŇäžŐèĂŇåőđçŐřäÿĂäÿłçŏĂå■ŢèĂŇénŸ

```
import hmac
import os

def client_authenticate(connection, secret_key):
    '''
    Authenticate client to a remote service.
    connection represents a network connection.
    secret_key is a key known only to both client/server.
    '''
    message = connection.recv(32)
    hash = hmac.new(secret_key, message)
    digest = hash.digest()
    connection.send(digest)

def server_authenticate(connection, secret_key):
    '''
    Request client authentication.
    '''
    message = os.urandom(32)
    connection.send(message)
    hash = hmac.new(secret_key, message)
    digest = hash.digest()
    response = connection.recv(len(digest))
    return hmac.compare_digest(digest,response)
```

å§žæIJňåŐ§çŘĘæŸŕå¡Şè£đæŐěåžžçńŇåŘŐïijŇæIJ■åŁąåŹĺçżŹåőćæĹůçńŕåŔŚéĂĄäÿĂäÿłéŽŔæIJžçŽĎ `os.urandom()` è£ŤåŻđåĂijïijL'ãĂĆ åőćæĹůçńŕåŠŇæIJ■åŁąåŹĺåŘŇæŮűåĹl'çŤĺh-macåŠŇäÿĂäÿłåŔŁæIJL'åŔŇæŰźç§ěéĄŞçŽĎåŕĘéŠěæİèèőąçőŮåĞžäÿĂäÿłåŁăåŕĘåŞĹåÿŇåĂijãĂĆçĎűåŘŐåæIJ■åŁąåŹĺéĂŽè£ĞæŕŤè¿Čè£ŹäÿłåĂijåŠŇèĞłåůśèőąçőŮçŽĎæŸŕåŘęäÿĂèĞt'æİěåĘşåőŽæŐěåŔŮæĹŰæŃŠ `hmac.compare_digest()` åĞ¡æŢřãĂĆ ä¡£çŤĺè£ŹäÿłåĞ¡æŢřåŔŕäžěéĄ£åĚ■éĄ■åĹřæŮűéŮt'åĹĘæđŘæŤäÿžäžĘä¡£çŤĺè£ŹäžŽåĞ¡æŢřïijŇä¡ăéIJĂèęĄåřĘåőČéŽĘæĹŘåĹřåůšæIJL'çŽĎç¡ŚçżIJæĹŰæűĹæĄŕäžčçăĄäÿ■

```
from socket import socket, AF_INET, SOCK_STREAM

secret_key = b'peekaboo'
def echo_handler(client_sock):
    if not server_authenticate(client_sock, secret_key):
        client_sock.close()
        return
    while True:

        msg = client_sock.recv(8192)
        if not msg:
            break
        client_sock.sendall(msg)

def echo_server(address):
    s = socket(AF_INET, SOCK_STREAM)
    s.bind(address)
    s.listen(5)
    while True:
        c,a = s.accept()
        echo_handler(c)

echo_server(('', 18000))
```

Within a client, you would do this:

```
from socket import socket, AF_INET, SOCK_STREAM

secret_key = b'peekaboo'

s = socket(AF_INET, SOCK_STREAM)
s.connect(('localhost', 18000))
client_authenticate(s, secret_key)
s.send(b'Hello World')
resp = s.recv(1024)
```

èőÍèőž

hmac èőd'èŕĄçŽĎäÿĂäÿłåÿÿèğĄä¡£çŤĺåIJžæŹŕæŸŕåĘĚéČĺæűĹæĄŕéĂŽä£ąçşżçż§åŠŇè£ŻçÍŃéŮť'éĂŽ
ä¿ŃåęĆĭijŇåęĆædIJä¡ăçijŰåĘŹçŽĎçşżçż§æűĽ'åŔŁåĹŕäÿĂäÿłéŻĘç¿d'äÿ■åd'Žäÿłåd'ĎçŘĘåŹĺäźŃéŮť'çŽĎéĂ
ä¡ăåŔŕäžěä¡£çŤĺæIJňèŁĆæŰźæąĹæİěçąőä£İåŔłæIJL'èćńåĚĄèőÿçŽĎè£ŻçÍŃäźŃéŮť'æL'■èČ¡å¡ijæ■d'éĂŽä£ą
äžŃåőđäÿŁïijŇå§žäžŐ hmac çŽĎèőd'èŕĄèćń multiprocessing
æĺąåİŮä¡£çŤĺæİěåőđçŐřå■Řè£ZçÍŃçŻť'æŐěçŽĎéĂŽä£ąãĂĆ

è£ŸæIJL'äÿĂçĆźéIJĂèęĄåijžèřČçŽĎæŸŕè£đæŐěèőd'èŕĄåŠŇåŁăárĘæŸŕäÿd'çăĄäžŃãĂĆ
èőd'èŕĄæĹŘåŁ§äźŃåŘŐçŽĎéĂŽä£ąæűĹæĄŕæŸŕäžěæŸŐæŰĞå¡ćåijŔåŘŚéĂĄçŽĎïijŇäżżä¡Ţäžžåŕłèę Ą æČ

hmacèőd'èŕĄçőŮæşŢå§žäžŐåŞĹåÿŇåĞ¡æŢřåęĆMD5åŠŇSHA-
1ïijŇåĚşäžŐè£ŹäÿłåIJĺIETF RFC 2104äÿ■æIJL'èŕęçżĘäżŃçż■ãĂĆ

13.10 11.10 åIJÍç¡ŚçżIJæIJ■åŁąäÿ■åŁååĚěSSL

éŮőécŸ

ä¡ăæČşåőđçŐřäÿĂäÿłå§žäžŐsocketsçŽĎç¡ŚçżIJæIJ■åŁąïijŇåőćæĹůçńřåŠŇæIJ■åŁąåŹĺéĂŽè£ĞSSLå■Ř

èğčåĘşæŰźæąĹ

ssl æĺąåİŮèČ¡äÿžåžŢåśĆsocketè£đæŐěæůżåŁăSSLçŽĎæŤŕæŇĄãĂĆ ssl.wrap_socket() åĞ¡æŢřæŐěåŘŮäÿĂäÿłåůšå■ŸåIJÍçŽĎsocketä¡IJäÿžåŘĆæŢřåźűä¡£çŤÍSSLåśĆæİěåŇĚèč ä¿ŇåęĆïijŇäÿŇéİćæŸŕäÿĂäÿłçőĂå■ŢçŽĎåžŤç■ŤæIJ■åŁąåŹĺïijŇèČ¡åIJÍæIJ■åŁąåŹÍçńřäÿžæĽĂæIJĽåőćæĹ

```
from socket import socket, AF_INET, SOCK_STREAM
import ssl

KEYFILE = 'server_key.pem'   # Private key of the server
CERTFILE = 'server_cert.pem' # Server certificate (given to client)

def echo_client(s):
    while True:
        data = s.recv(8192)
        if data == b'':
            break
        s.send(data)
    s.close()
    print('Connection closed')

def echo_server(address):
    s = socket(AF_INET, SOCK_STREAM)
    s.bind(address)
    s.listen(1)

    # Wrap with an SSL layer requiring client certs
    s_ssl = ssl.wrap_socket(s,
                            keyfile=KEYFILE,
                            certfile=CERTFILE,
                            server_side=True
                            )
    # Wait for connections
    while True:
        try:
            c,a = s_ssl.accept()
            print('Got connection', c, a)
            echo_client(c)
        except Exception as e:
            print('{}: {}'.format(e.__class__.__name__, e))

echo_server(('', 20000))
```

äÿŃéÌćæĹŚäžňæijŤçd’žäÿĂäÿłåőćæĹůçńŕè£đæŐěæIJ■åŁąåŹĺçŽĎäžd’äžŠä¿Ńå■ŘãĂĆåőćæĹůçńŕäijŽèŕ

```
>>> from socket import socket, AF_INET, SOCK_STREAM
>>> import ssl
>>> s = socket(AF_INET, SOCK_STREAM)
>>> s_ssl = ssl.wrap_socket(s,
                cert_reqs=ssl.CERT_REQUIRED,
                ca_certs = 'server_cert.pem')
>>> s_ssl.connect(('localhost', 20000))
>>> s_ssl.send(b'Hello World?')
12
>>> s_ssl.recv(8192)
b'Hello World?'
>>>
```

è£Źçğ■çŻt’æŐěåd’ĎçŘĘåžŢåśĆsocketæŰźåijŔæIJL’äÿłéŮőécŸåřśæŸřåőČäÿ■èČ¡å¿Ĺåě¡çŽĎèů§æăĞåČ
ä¿ŃåęĆïijÑçżÍåd’ğéČĺåĹĘæIJ■åŁąåŹĺäžčçăĄïijĹHTTPãĂĄXML-
RPCç■L’ïijL’åőđéŹĚäÿŁæŸřå§žäžŐ socketserver åžŞçŽĎãĂĆ
åőćæĹůçńŕäžčçăĄåIJĺäÿĂäÿłè¿ČéńŸåśĆäÿŁåőđçŐřãĂĆæĹŚäžňéIJĂèęĄåŔęåd’ŰäÿĂçğ■çĺ■å¿őäÿ■åŘŇçŽĎ

éęŰåĚĹïijÑåŕźäžŐæIJ■åŁąåŹĺèĂŇèĺĂïijÑåŔŕäžěéĂŽè£ĞåČŔäÿŃéÌćè£Źæăůä¡£çŤĺäÿĂäÿłmixinçśžæÌě

```
import ssl

class SSLMixin:
'''
Mixin class that adds support for SSL to existing servers based
on the socketserver module.
'''
def __init__(self, *args,
             keyfile=None, certfile=None, ca_certs=None,
             cert_reqs=ssl.CERT_NONE,
             **kwargs):
    self._keyfile = keyfile
    self._certfile = certfile
    self._ca_certs = ca_certs
    self._cert_reqs = cert_reqs
    super().__init__(*args, **kwargs)

def get_request(self):
    client, addr = super().get_request()
    client_ssl = ssl.wrap_socket(client,
                                 keyfile = self._keyfile,
                                 certfile = self._certfile,
                                 ca_certs = self._ca_certs,
                                 cert_reqs = self._cert_reqs,
                                 server_side = True)
    return client_ssl, addr
```

äÿžäžĘä¡£çŤĺè£ŹäÿłmixinçśžïijÑä¡ăåŔŕäžěåřĘåőČèů§åĚűäžŰæIJ■åŁąåŹĺçśžæůůåŘĹãĂĆä¿ŃåęĆïijÑäÿ
RPCæIJ■åŁąåŹĺä¿Ńå■ŘïijŽ

```
# XML-RPC server with SSL

from xmlrpc.server import SimpleXMLRPCServer

class SSLSimpleXMLRPCServer(SSLMixin, SimpleXMLRPCServer):
    pass

Here's the XML-RPC server from Recipe 11.6 modified only slightly␣
↪to use SSL:

import ssl
from xmlrpc.server import SimpleXMLRPCServer
from sslmixin import SSLMixin

class SSLSimpleXMLRPCServer(SSLMixin, SimpleXMLRPCServer):
    pass

class KeyValueServer:
    _rpc_methods_ = ['get', 'set', 'delete', 'exists', 'keys']
    def __init__(self, *args, **kwargs):
        self._data = {}
        self._serv = SSLSimpleXMLRPCServer(*args, allow_none=True,␣
↪**kwargs)
        for name in self._rpc_methods_:
            self._serv.register_function(getattr(self, name))

    def get(self, name):
        return self._data[name]

    def set(self, name, value):
        self._data[name] = value

    def delete(self, name):
        del self._data[name]

    def exists(self, name):
        return name in self._data

    def keys(self):
        return list(self._data)

    def serve_forever(self):
        self._serv.serve_forever()

if __name__ == '__main__':
    KEYFILE='server_key.pem'     # Private key of the server
    CERTFILE='server_cert.pem'   # Server certificate
    kvserv = KeyValueServer(('', 15000),
                            keyfile=KEYFILE,
                            certfile=CERTFILE)
```

```
    kvserv.serve_forever()
```

ä¡£çŤÍè£ŹäÿłæIJ■åŁąåŹÍæŮűïijŇä¡ăåŔŕäžěä¡£çŤÍæŹőéĂŽçŽĎ `xmlrpc.client` æÍąåİŮæİěè£đæŐěåőČãĂĆ åŔŀéIJĂèęĄåIJÍURLäÿ■æŇĞåőŽ `https:` å■şåŔŕïijŇä¿ŃåęĆïijŽ

```
>>> from xmlrpc.client import ServerProxy
>>> s = ServerProxy('https://localhost:15000', allow_none=True)
>>> s.set('foo','bar')
>>> s.set('spam', [1, 2, 3])
>>> s.keys()
['spam', 'foo']
>>> s.get('foo')
'bar'
>>> s.get('spam')
[1, 2, 3]
>>> s.delete('spam')
>>> s.exists('spam')
False
>>>
```

åŕźäžŐSSLåőćæĹůçńŕæİěèőšäÿĂäÿłæŕŤè¿Čåd’■æİĆçŽĎéŮőécŸæŸŕåęCä¡Ţçąőèőd’æIJ■åŁąåŹÍèŕĄäźęäÿ■åźÿçŽĎæŸŕïijŇæŽĆæŮűę£ŸæšąæIJL’äÿĂäÿłæăĞåĞĘæŰźæşŢæİěèğčåĘşè£ŹäÿłéŮőécŸïijŇéIJĂèęĄèĞłäÿ■è£ĞïijŇäÿŃéİćçżŹåĞžäÿĂäÿłä¿Ńå■ŘïijŇçŤÍæİěåžžçńŃäÿĂäÿłåőL’åĚÍçŽĎXML-RPCè£đæŐěæİěçąőèőd’æIJ■åŁąåŹÍèŕĄäźęïijŽ

```
from xmlrpc.client import SafeTransport, ServerProxy
import ssl

class VerifyCertSafeTransport(SafeTransport):
    def __init__(self, cafile, certfile=None, keyfile=None):
        SafeTransport.__init__(self)
        self._ssl_context = ssl.SSLContext(ssl.PROTOCOL_TLSv1)
        self._ssl_context.load_verify_locations(cafile)
        if certfile:
            self._ssl_context.load_cert_chain(certfile, keyfile)
        self._ssl_context.verify_mode = ssl.CERT_REQUIRED

    def make_connection(self, host):
        # Items in the passed dictionary are passed as keyword
        # arguments to the http.client.HTTPSConnection()␣
↪constructor.
        # The context argument allows an ssl.SSLContext instance to
        # be passed with information about the SSL configuration
        s = super().make_connection((host, {'context': self._ssl_
↪context}))

        return s

# Create the client proxy
s = ServerProxy('https://localhost:15000',
```

```
                transport=VerifyCertSafeTransport('server_cert.pem
↪'),
                allow_none=True)
```

æIJ■åŁąåŹÍåřĘèŕĄäźęåŔŠéĂĄçżŹåőćæĹůçńŕïijŇåőćæĹůçńŕæİěçąőèőd'åőČçŽĎåŘĹæşŢæĂğãĂĆè£ŹçğåęĆæđIJæIJ■åŁąåŹÍæČşèęĄçąőèőd'åőćæĹůçńŕïijŇåŔŕäžěåřĘæIJ■åŁąåŹÍåŘŕåŁÍäžčçăĄä£őæŤźåęĆäÿŃïijŽ

```
if __name__ == '__main__':
    KEYFILE='server_key.pem'    # Private key of the server
    CERTFILE='server_cert.pem' # Server certificate
    CA_CERTS='client_cert.pem' # Certificates of accepted clients

    kvserv = KeyValueServer(('', 15000),
                            keyfile=KEYFILE,
                            certfile=CERTFILE,
                            ca_certs=CA_CERTS,
                            cert_reqs=ssl.CERT_REQUIRED,
                            )
    kvserv.serve_forever()
```

äÿžäžĘèől'XML-RPCåőćæĹůçńŕåŔŠéĂĄèŕĄäźęïijŇä£őæŤź ServerProxy çŽĎåĹİåğŃåŇŰäžčçăĄåęĆäÿŃïijŽ

```
# Create the client proxy
s = ServerProxy('https://localhost:15000',
                transport=VerifyCertSafeTransport('server_cert.pem',
                                                  'client_cert.pem',
                                                  'client_key.pem'),
                allow_none=True)
```

èőÍèőž

èŕŢçİĂåŐżè£ŘèąŇæIJňèŁĆçŽĎäžčçăĄèČ¡æţŃèŕŢä¡ăçŽĎçşżçż§éĚ■ç¡őèČ¡åŁŻåŠŇçŘĘèğčSSLãĂĆ åŔŕèČ¡æIJĂåd'ğçŽĎæŇŠæĹŸæŸŕåęĆä¡ŢäÿĂæ■ěæ■ěçŽĎèŐůåŘŰåĹİåğŃéĚ■ç¡őkeyãĂĄèŕĄäźęåŠŇåĚűäžŰ

æĹŚèğčéĞŁäÿŇåĹřåžŢéIJĂèęĄåŢëïijŇærŔäÿĂäÿłSSLè£đæŐěçŽĹçńŕäÿĂèĹňéČ¡äijŽæIJL'äÿĂäÿłçğĄé è£ŹäÿłèŕĄäźęåŇĚåŘńäžĘåĚňéŠěåźűåIJÍæŕŔäÿĂæňąè£đæŐěçŽĎæŮűåĂŹéČ¡äijŽåŘŚéĂĄçżŹåŕźæŰźãĂĆ åŕźäžŐåĚňåĚśæIJ■åŁąåŹÍïijŇåőČäžňçŽĎèŕĄäźęéĂŽåÿÿæŸŕèćńæİČåÍĄèŕĄäźęæIJžædĎæŕŤåęĆVerisignãĂA äÿžäžĘçąőèőd'æIJ■åŁąåŹÍç■¿åŘ■ïijŇåőćæĹůçńŕåŻđä£Ìå■ŸäÿĂäż¡åŇĚåŘńäžĘä£ąäżżæŐĹæİČæIJžædĎçŽĎ ä¿ŃåęĆïijŇwebæţŔèğĹåŹÍä£Ìå■ŸäžĘäÿżèęĄçŽĎèőd'èŕĄæIJžædĎçŽĎèŕĄäźęïijŇåźűä¡£çŤÍåőČæİěäÿżæŕŔä åŕźæIJňåřŔèŁĆçd'žä¿ŃèĂŇèÍĂïijŇåŘłæŸŕäÿžäžĘæţŃèŕŢïijŇæĹŠäžňåŘŕäžěåĹŻåżżèĞłç■¿åŘ■çŽĎèŕĄäźęïij

bash % openssl req -new -x509 -days 365 -nodes -out server_cert.pem
-keyout server_key.pem

Generating a 1024 bit RSA private key âĂęâĂęâĂęâĂęâĂęâĂęâĂęâĂęâĂęâĂęâĂęâĂęâĂęâĂęâĂęâĂę++++++
âĂę++++++

writing new private key to âĂŸserver_key.pemâĂŹ

You are about to be asked to enter information that will be incorporated into your certificate request. What you are about to enter is what is called a Distinguished Name or a DN. There are quite a few fields but you can leave some blank For some fields there will be a default value, If you enter âĂŸ.âĂŹ, the field will be left blank.

Country Name (2 letter code) [AU]:US State or Province Name (full name) [Some-State]:Illinois Locality Name (eg, city) []:Chicago Organization Name (eg, company) [Internet Widgits Pty Ltd]:Dabeaz, LLC Organizational Unit Name (eg, section) []: Common Name (eg, YOUR name) []:localhost Email Address []: bash %

åIJĺåĹŻåżžèŕĄäźęçŽĎæŮűåĂŹïijŇåŘĎäÿłåĂijçŽĎèő¿åőŽåŔŕäżěæŸŕäżżæĎŔçŽĎïijŇä¡ĘæŸŕâĂİComm
NameâĂIJçŽĎåĂijéĂŽåÿÿèęĄåŇĚåŘńæIJ■åŁąåŹĺçŽĎDNSäÿżæIJżåŘ■ãĂĆ
åęĆæđIJä¡ääŔłæŸŕåIJĺæIJñæIJżæţŃèŕŢïijŇéĆčäźĹåřśä¡£çŤĺâĂİlocalhostâĂIJïijŇåŘęåĹŹä¡£çŤĺæIJ■åŁąåŹĺç

âĂŤ–BEGIN RSA PRIVATE KEYâĂŤ– MIICXQIBAAK-
BgQCZrCNLoEyAKF+f9UNcFaz5Osa6jf7qkbUl8si5xQrY3ZYC7juu
nL1dZLn/VbEFIITaUOgvBtPv1qUWTJGwga62VSG1oFE0ODIx3g2Nh4sRf+rySsx2
L4442nx0z4O5vJQ7k6eRNHAZUUnCL50+YvjyLyt7ryLSjSuKhCcJsbZgPwIDAQAB
AoGAB5evrr7eyL4160tM5rHTeATlaLY3UBOe5Z8XN8Z6gLiB/ucSX9AysviVD/6F
3oD6z2aL8jbeJc1vHqjt0dC2dwwm32vVl8mRdyoAsQpWmiqXrkvP4Bsl04VpBeHw
Qt8xNSW9SFhceL3LEvw9M8i9MV39viih1ILyH8OuHdvJyFECQQDLEjl2d2ppxND9
PoLqVFAirDfX2JnLTdWbc+M11a9Jdn3hKF8TcxfEnFVs5Gav1MusicY5KB0ylYPb
YbTvqKc7AkEAwbnRBO2VYEZsJZp2X0IZqP9ovWokkpYx+PE4+c6MySDgaMcigL7v
WDIHJG1CHudD09GbqENasDzyb2HAIW4CzQJBAKDdkv+xoW6gJx42Auc2WzTcUHCA
eXR/+BLpPrhKykzbvOQ8YvS5W764SUO1u1LWs3G+wnRMvrRvlMCZKgggBjkCQQCG
Jewto2+a+WkOKQXrNNScCDE5aPTmZQc5waCYq4UmCZQcOjkUOiN3ST1U5iuxRqfb
V/yX6fw0qh+fLWtkOs/JAkA+okMSxZwqRtfgOFGBfwQ8/iKrnizeanTQ3L6scFXI
CHZXdJ3XQ6qUmNxNn7iJ7S/LDawo1QfWkCfD9FYoxBlg âĂŤ–END RSA
PRIVATE KEYâĂŤ–

æIJ■åŁąåŹĺèŕĄäźęæŰĞäżűserver_cert.pemåĘĚåőźçśżäijijäÿŃéİćè£Źæăůïijž

âĂŤ–BEGIN CERTIFICATEâĂŤ– MIIC+DCCAmGgAwIBAgIJAPMd+vi45js3MA0GCSqGSIb3DQEI
BAYTAlVTMREwDwYDVQQIEwhJbGxpbm9pczEQMA4GA1UEBxMHQ2hpY2FnbzEUMBIG
A1UEChMLRGFiZWF6LCBMTEMxEjAQBgNVBAMTCWxvY2FsaG9zdDAeFw0xMzAxMTEx
ODQyMjdaFw0xNDAxMTExODQyMjdaMFwxCzAJBgNVBAYTAlVTMREwDwYDVQQIEwhJ
bGxpbm9pczEQMA4GA1UEBxMHQ2hpY2FnbzEUMBIGA1UEChMLRGFiZWF6LCBMTEMx
EjAQBgNVBAMTCWxvY2FsaG9zdDCBnzANBgkqhkiG9w0BAQEFAAOBjQAwgYkCgYEA
mawjS6BMgChfn/VDXBWs+TrGuo3+6pG1JfLIucUK2N2WAu47rpy9XWS5/1WxBSCE
2lDoLwbT79alFkyRsIGutlUhtaBRNDgyMd4NjYeLEX/q8krMdi+OONp8dM+DubyU

O5OnkTRwGVFJwi+dPmL48i8re68i0o0rioQnCbG2YD8CAwEAAaOBwTCBvjAdBgNV
HQ4EFgQUrtoLHHgXiDZTr26NMmgKJLJLFtIwgY4GA1UdIwSBhjCBg4AUrtoLHHgX
iDZTr26NMmgKJLJLFtKhYKReMFwxCzAJBgNVBAYTAlVTMREwDwYDVQQIEwhJbGxp
bm9pczEQMA4GA1UEBxMHQ2hpY2FnbzEUMBIGA1UEChMLRGFiZWF6LCBMTEMxEjAQ
BgNVBAMTCWxvY2FsaG9zdIIJAPMd+vi45js3MAwGA1UdEwQFMAMBAf8wDQYJKoZI
hvcNAQEFBQADgYEAFci+dqvMG4xF8UTnbGVvZJPIzJDRee6Nbt6AHQo9pOdAIMAu

WsGCplSOaDNdKKzl+b2UT2Zp3AIW4Qd51bouSNnR4M/gnr9ZD1ZctFd3jS+C5XRp
D3vvcW5lAnCCC80P6rXy7d7hTeFu5EYKtRGXNvVNd/06NALGDflrrOwxF3Y=
âĂŤ–END CERTIFICATEâĂŤ–

åIJÍæIJ■åŁąåŹÍçńŕäžčçăĄäÿ■ïijŇçğĄéŠěåŠŇèŕĄäźęæŰĞäžűäijŽèćńäijąçżŹSSLçŻÿåĚşçŽĎåŇĚèčĚåĞ¡
çğĄéŠěåžŤèŕěåIJÍä‡Ìå■ŸåIJÍæIJ■åŁąåŹÍäÿ■ïijŇåźűåŁääžěåőL’åĚÍä‡ÌæŁď ãĂĆ

åIJÍåőćæĹůçńŕäžčçăĄäÿ■ïijŇéIJĂèęĄä‡Ìå■ŸäÿĂäÿłåŘĹæşŢèŕĄäźęæŐĹæİČæŰĞäžűæİěçąőèőď’æIJ■åŁ
åęĆæđIJä¡ăæšąæIJL’è£ŹäÿłæŰĞäžűïijŇä¡ăåŔŕäżěåIJÍåőćæĹůçńŕåď’■åĹűäÿĂäż¡æIJ■åŁąåŹÍçŽĎèŕĄäźęåźűä¡
è£đæŐěåžžçńŇåŘŐïijŇæIJ■åŁąåŹÍäijŽæŔŘä¿ŻåőČçŽĎèŕĄäźęïijŇçĎűåŘŐä¡ăåřśèČ¡ä¡£çŤÍåůšçżŔä£Ìå■ŸçŽ

æIJ■åŁąåŹÍäź§èČ¡éĂL’æŃl’æŸŕåŘęèęĄçąőèőď’åőćæĹůçńŕçŽĎèžńäż¡ãĂĆåęĆæđIJèęĄè£Źæăůå
æIJ■åŁąåŹÍäź§éIJĂèęĄä‡Ìå■ŸäÿĂäÿłèćńä£ąäżżèŕĄäźęæŐĹæİČæŰĞäžűæİěçąőèőď’åőćæĹůçńŕèŕĄäźęãĂĆ

åęĆæđIJä¡ăèęĄåIJÍçIJ§åőđçŐŕåćČäÿ■äÿžä¡ăçŽĎç¡ŚçżIJæIJ■åŁąåŁääÿŁSSLçŽĎæŤŕæŇĄïijŇè£ŹåŕŔèŁ
ä¡ăè£ŸåžŤèŕěåŔĆèĂČåĚűäżŰçŽĎæŰĞæąčïijŇåĄŽåě¡èŁśèť źäÿ■åřŚæŮűéŮť’æİèæţŃèŕŢåőČæ■čåÿÿåůěä¡IJ
^_^

13.11 11.11 è£ŽçÍŃéŮť’äijăéĂŠSocketæŰĞäžűæŔŘè£řçňę

éŮőécŸ

ä¡ăæIJL’åď’ŽäÿłpythonèğčéĞŁåŹÍè£ŽçÍŃåIJÍåŘŇæŮűè£ŘèąŇïijŇä¡ăæČşåřĘæ§Řäÿłæ L’ŞåijĂçŽĎæŰĞä
ærŤåęĆïijŇåĄĞèő¿æIJL’äÿłæIJ■åŁąåŹÍè£ŽçÍŃçŻÿåžŤè£đæŐěèŕůæśĆïijŇä¡ĘæŸŕåőđéŹĚçŽĎçŻÿåžŤéĂżè¿Ş

èğčåĘşæŰźæąĹ

äÿžäžĘåIJÍåď’Žäÿłè£ŽçÍŃäÿ■äijăéĂŠæŰĞäžűæŔŘè£řçňęïijŇä¡ăéęŰåĚĹéIJĂèęĄåřĘåőČäžňè£đæŐěåĹřă
èĂŇåIJÍwindowsäÿŁéİćä¡ăéIJĂèęĄä¡£çŤÍåŚ¡åŘ■çőąéĄŞãĂĆäÿ■è£Ğä¡ăæŮăéIJĂçIJ§çŽĎéIJĂèęĄåŐżæŞ■ä¡
éĂŽåÿÿä¡£çŤÍ `multiprocessing` æĹąåİŮæİěåĹŻåżžè£ŹæăůçŽĎè£đæŐěäijŽæŻť’åőźæŸŞäÿĂäžŽãĂĆ

äÿĂæŮęäÿĂäÿłè£đæŐěèćńåĹŻåżžïijŇä¡ăåŔŕäžěä¡£çŤÍ `multiprocessing.reduction` äÿ■çŽĎ `send_handle()` åŠŇ `recv_handle()` åĞ¡æŢřåIJÍäÿ■åŘŇçŽĎåď’ĎçŘĘåŹÍçŻť’æŐěäijăéĂŠæŰĞäžűæŔŘè£řçňęãĂĆ
äÿŃéIćçŽĎä¿Ńå■ŘæijŤçď’žäžĘæIJĂå§žæIJňçŽĎçŤÍæşŢïijŽ

```
import multiprocessing
from multiprocessing.reduction import recv_handle, send_handle
import socket

def worker(in_p, out_p):
    out_p.close()
    while True:
        fd = recv_handle(in_p)
        print('CHILD: GOT FD', fd)
        with socket.socket(socket.AF_INET, socket.SOCK_STREAM,␣
↪fileno=fd) as s:
            while True:
                msg = s.recv(1024)
```

```
                if not msg:
                    break
                print('CHILD: RECV {!r}'.format(msg))
                s.send(msg)

def server(address, in_p, out_p, worker_pid):
    in_p.close()
    s = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
    s.setsockopt(socket.SOL_SOCKET, socket.SO_REUSEADDR, True)
    s.bind(address)
    s.listen(1)
    while True:
        client, addr = s.accept()
        print('SERVER: Got connection from', addr)
        send_handle(out_p, client.fileno(), worker_pid)
        client.close()

if __name__ == '__main__':
    c1, c2 = multiprocessing.Pipe()
    worker_p = multiprocessing.Process(target=worker, args=(c1,c2))
    worker_p.start()

    server_p = multiprocessing.Process(target=server,
                   args=(('', 15000), c1, c2, worker_p.pid))
    server_p.start()

    c1.close()
    c2.close()
```

åIJÍè£Źäÿłä¿Ńå■Řäÿ■ïijÑäÿd'äÿłè£ŻçÍÑèćńåĹŻåžžåźűéĂŽè£ĞäÿĂäÿł multiprocessing çőąéĄŞè£đæŐěèţůæİěãĂĆ æIJ■åŁąåŹÍè£ŻçÍÑæL'ŞåijĂäÿĂäÿłsocketåźűç■L'å¿ĚåőćæĹ åůěä¡IJè£ŻçÍÑäžĚäżĚä¡£çŤÍ recv_handle() åIJÍçőąéĄŞäÿŁéİćç■L'å¿ĚæŐěæŤűäÿĂäÿłæŰĞäżűæŔŔè£řçňęéĂŽè£Ğ å¡ŞæIJ■åŁąåŹÍæŐěæŤűåĹřäÿĂäÿłè£đæŐëïijÑåőČåřĘäžğçŤ§çŽĎsocketæŰĞäżűæŔŔè£řçňęéĂŽè£Ğ send_handle() äijäéĂŠçżŹåůěä¡IJè£ŻçÍÑãĂĆ åůěä¡IJè£ŻçÍÑæŐěæŤűåĹřsocketåŘŐåŘŠåőćæĹůçńřåŻđå

åęĆæđIJä¡ăä¡£çŤÍTelnetæĹŰçśżäijijåůěåĚůè£đæŐěåĹřæIJ■åŁąåŹÍïijÑäÿŃéİćæŸřäÿĂäÿłæijŤçd'ža¿Ńå■

```
bash % python3 passfd.py SERVER: Got connection from (âĂŸ127.0.0.1âĂŹ,
55543) CHILD: GOT FD 7 CHILD: RECV bâĂŹHellornâĂŹ CHILD: RECV
bâĂŹWorldrnâĂŹ
```

æ■d'ä¿ŃæIJĂéĞ■èęĄçŽĎéČÍåĹĘæŸřæIJ■åŁąåŹÍæŐěæŤűåĹřçŽĎåőćæĹůçńřsocketåőđéŹĚäÿŁèćńåŘęå æIJ■åŁąåŹÍäżĚäżĚåŘłæŸřářĘåĚűè¡ňæL'ŃåźűåĕşéŮ■æ■d'è£đæŐěïijÑçĎűåŘŐç■L'å¿ĚäÿŃäÿĂäÿłè£đæŐěãĂ

èőÍèőž

åŕźäžŐåd'ğéČÍåĹĘçÍÑåžŘåŚŸæİèèőšåIJÍäÿ■åŘÑè£ŻçÍÑäźŃéŮt'äijäéĂŠæŰĞäżűæŔŔè£řçňęåě¡åČŔæša ä¡ĘæŸřïijÑæIJL'æŮűåĂŹåőČæŸřædĎåżžäÿĂäÿłåŘŕæL'l'åśŢçşżçž§çŽĎå¿ĹæIJL'çŤÍçŽĎåůěåĚůãĂĆä¿ŃåęĆ ä¡ăåŘŕäžěæIJL'åd'ŽäÿłpythonèğčéĞŁåŹÍåőđä¿ŃïijÑářĘæŰĞäżűæŔŔè£řçňęäijäéĂŠçżŹåĚűåőČèğčéĞŁåŹÍæ

send_handle() åŠŇ recv_handle() åĞ¡æŢřåŔłèČ¡åd'§çŤĺäžŐ multiprocessing è£đæŐěãĂĆ ä¡£çŤĺåőČäžňæİěäžčæŻ£çőąéĄŞçŽĎä¡£çŤĺïijĹåŔĆèĂČ11.7èŁĆïijL'ïijŇä¿ŇåęĆïijŇä¡ăåŔŕäżěèől'æIJ■åŁąåŹĺåŠŇåůěä¡IJèĂĚåŘĎèĞłäžěå■ŢçŃňçŽĎçĺŃåžŔæİěåŘŕåŁĺãĂĆäÿŃéĺćæŸ

```
# servermp.py
from multiprocessing.connection import Listener
from multiprocessing.reduction import send_handle
import socket

def server(work_address, port):
    # Wait for the worker to connect
    work_serv = Listener(work_address, authkey=b'peekaboo')
    worker = work_serv.accept()
    worker_pid = worker.recv()

    # Now run a TCP/IP server and send clients to worker
    s = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
    s.setsockopt(socket.SOL_SOCKET, socket.SO_REUSEADDR, True)
    s.bind(('', port))
    s.listen(1)
    while True:
        client, addr = s.accept()
        print('SERVER: Got connection from', addr)

        send_handle(worker, client.fileno(), worker_pid)
        client.close()

if __name__ == '__main__':
    import sys
    if len(sys.argv) != 3:
        print('Usage: server.py server_address port', file=sys.
↪stderr)
        raise SystemExit(1)

    server(sys.argv[1], int(sys.argv[2]))
```

è£ŘèąŇè£ŹäÿłæIJ■åŁąåŹĺïijŇåŔłéIJĂèęĄæĽğèąŇ *python3 servermp.py /tmp/servconn 15000* ïijŇäÿŃéĺćæŸŕçŻÿåžŤçŽĎåůěä¡IJèĂĚäžčçăĄïijŽ

```
# workermp.py

from multiprocessing.connection import Client
from multiprocessing.reduction import recv_handle
import os
from socket import socket, AF_INET, SOCK_STREAM

def worker(server_address):
    serv = Client(server_address, authkey=b'peekaboo')
    serv.send(os.getpid())
    while True:
        fd = recv_handle(serv)
```

```
        print('WORKER: GOT FD', fd)
        with socket(AF_INET, SOCK_STREAM, fileno=fd) as client:
            while True:
                msg = client.recv(1024)
                if not msg:
                    break
                print('WORKER: RECV {!r}'.format(msg))
                client.send(msg)

if __name__ == '__main__':
    import sys
    if len(sys.argv) != 2:
        print('Usage: worker.py server_address', file=sys.stderr)
        raise SystemExit(1)

    worker(sys.argv[1])
```

èęĄè£ŘèąŇåůěä¡IJèĂĚïijŇæL'ğèąŇæL'ğèąŇåŚ¡äžď *python3 workermp.py /tmp/servconn* . æŢĹædIJèů§ä¡£çŤĺPipe()ä¿Ńå■ŘæŸŕåőŇåĚĺäÿĂæăůçŽĎãĂĆ æŰĞäżűæŔŔè£řçňęçŽĎäijăéĂŠäijŽæűL'åŔŁåĹřUNIXå§§åěŮæŐěå■ŮçŽĎåĹŻåžžåŠŇåěŮæŐěå■ŮçŽĎ `sendmsg()` æŰźæşŢãĂĆ äÿ■è£Ğè£ŹçğæŁĂæIJŕåźűäÿ■åÿÿèğĄïijŇäÿŃéİćæŸŕä¡£çŤĺåěŮæŐěå■ŮæİěäijăéĂŠäijŽæűL'åŔŁåĹřUNIXå§§åěŮæŐěå■ŮçŽĎ

```
# server.py
import socket

import struct

def send_fd(sock, fd):
    '''
    Send a single file descriptor.
    '''
    sock.sendmsg([b'x'],
                 [(socket.SOL_SOCKET, socket.SCM_RIGHTS, struct.
↪pack('i', fd))])
    ack = sock.recv(2)
    assert ack == b'OK'

def server(work_address, port):
    # Wait for the worker to connect
    work_serv = socket.socket(socket.AF_UNIX, socket.SOCK_STREAM)
    work_serv.bind(work_address)
    work_serv.listen(1)
    worker, addr = work_serv.accept()

    # Now run a TCP/IP server and send clients to worker
    s = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
    s.setsockopt(socket.SOL_SOCKET, socket.SO_REUSEADDR, True)
    s.bind(('',port))
    s.listen(1)
    while True:
```

```
        client, addr = s.accept()
        print('SERVER: Got connection from', addr)
        send_fd(worker, client.fileno())
        client.close()

if __name__ == '__main__':
    import sys
    if len(sys.argv) != 3:
        print('Usage: server.py server_address port', file=sys.
↪stderr)
        raise SystemExit(1)

    server(sys.argv[1], int(sys.argv[2]))
```

äÿŃéİćæŸŕä¡£çŤĺåěŮæŐěå■ŮçŽĎåůëä¡IJèĂĚåőđçŐřijŽ

```
# worker.py
import socket
import struct

def recv_fd(sock):
    '''
    Receive a single file descriptor
    '''
    msg, ancdata, flags, addr = sock.recvmsg(1,
                                     socket.CMSG_LEN(struct.
↪calcsize('i')))

    cmsg_level, cmsg_type, cmsg_data = ancdata[0]
    assert cmsg_level == socket.SOL_SOCKET and cmsg_type == socket.
↪SCM_RIGHTS
    sock.sendall(b'OK')

    return struct.unpack('i', cmsg_data)[0]

def worker(server_address):
    serv = socket.socket(socket.AF_UNIX, socket.SOCK_STREAM)
    serv.connect(server_address)
    while True:
        fd = recv_fd(serv)
        print('WORKER: GOT FD', fd)
        with socket.socket(socket.AF_INET, socket.SOCK_STREAM,␣
↪fileno=fd) as client:
            while True:
                msg = client.recv(1024)
                if not msg:
                    break
                print('WORKER: RECV {!r}'.format(msg))
                client.send(msg)
```

```
if __name__ == '__main__':
    import sys
    if len(sys.argv) != 2:
        print('Usage: worker.py server_address', file=sys.stderr)
        raise SystemExit(1)

    worker(sys.argv[1])
```

åęĆædIJä¡ăæČşåIJÍä¡ăçŽĎçÍŃåžŔäÿ■äijăéĂŠæŰĞäžűæŔŔè£řçňęïijŇåżžèőőä¡ååŔĆéŸĚåĚűäžŰäÿĂäžŽ
æŕŤåęĆ `Unix Network Programming by W. Richard Stevens (Prentice Hall, 1990)`. åIJÍWindowsäÿŁäijăéĂŠæŰĞäžűæŔŔè£řçňęèů§UnixæŸŕäÿ■äÿĂæăůçŽĎïijŇåżžèőőä¡ăçăŤ `multiprocessing.reduction` äÿ■çŽĎæžŘäžčçăĄçIJŃçIJŃåĚűåůëä¡IJåŐ§çŘĘãĂĆ

13.12 11.12 çŘĘèğčäžŃäžűéľśåŁÍçŽĎIO

éŮőécŸ

ä¡ăåžŤèŕěåůšçżŔåŘňè£Ğå§žäžŐäžŃäžűéľśåŁÍæĹŰåijĆæ■ěI/OçŽĎåŇĚïijŇä¡ĘæŸŕä¡ăè£Ÿäÿ■èČ¡åőŇåŘ
æĹŰèĂĚæŸŕåęĆædIJä¡£çŤĺåőČçŽĎèŕÍäijŽåŕźä¡ăçŽĎçÍŃåžŔäžğçŤ§äżĂäźĹå¡śåŞ■ãĂĆ

èğčåĘşæŰźæąĹ

äžŃäžűéľśåŁÍI/OæIJňèťÍäÿŁæİěèőšåřśæŸŕåřĘå§žæIJňI/OæŞ■ä¡IJïijĹæŕŤåęĆèŕżåŠŇåĘŹïijL'è¡ňåŇŰäÿž
ä¿ŃåęĆïijŇå¡ŞæŢřæ■őåIJÍæ§ŘäÿłsocketäÿŁèćńæŐěåŔŮåŘŐïijŇåőČäijŽè¡ňæ■ćæĹŘäÿĂäÿł
`receive` äžŃäžűïijŇçĎűåŘŐèćńä¡ăåőŽäźL'çŽĎåŻđèřČæŰźæşŢæĹŰåĞ¡æŢřæİěåď'ĎçŘĘãĂĆ
ä¡IJäÿžäÿĂäÿłåŔŕèČ¡çŽĎèţůåğŇçĆźïijŇäÿĂäÿłäžŃäžűéľśåŁÍçŽĎæąĘæđůåŔŕèČ¡äijŽäžěäÿĂäÿłåőđçŐřäžĘä

```
class EventHandler:
    def fileno(self):
        'Return the associated file descriptor'
        raise NotImplemented('must implement')

    def wants_to_receive(self):
        'Return True if receiving is allowed'
        return False

    def handle_receive(self):
        'Perform the receive operation'
        pass

    def wants_to_send(self):
        'Return True if sending is requested'
        return False

    def handle_send(self):
        'Send outgoing data'
        pass
```

è£Źäÿłçśżç ŽĎåőđä¿Ńä¡IJäÿžæŔŠäžűèćńæŤ¿åĚěçśżäijijäÿŃéIćè£Źæăůç ŽĎäžŃäžűå¿łçŐŕäÿ■ïijŽ

```
import select

def event_loop(handlers):
    while True:
        wants_recv = [h for h in handlers if h.wants_to_receive()]
        wants_send = [h for h in handlers if h.wants_to_send()]
        can_recv, can_send, _ = select.select(wants_recv, wants_
↪send, [])
        for h in can_recv:
            h.handle_receive()
        for h in can_send:
            h.handle_send()
```

äžŃäžűå¿łçŐŕçŽĎåĚşéŤőéČĺåĹĘæŸŕ `select()` èřČçŤĺïijŇåőČäijŽäÿ■æŰ■è¡őèŕćæŰĞäžűæŔŔè£řçňę åIJĺèřČçŤĺ `select()` äźŃåĽ■ïijŇæŮűéŮť å¿łçŐŕäijŽèŕćéŮőæĽĂæIJĽçŽĎåď ĎçŘĘåŹĺæÌěåĘşåőŽåŞłäÿĂä çĎűåŘŐåőČåřĘçżŞæđIJåĹŮèąĺæŔŘä¿ŻçżŹ `select()` ãĂĆçĎűåŘŐ `select()` è£ŤåŻđåĞĘåď ĞæŐěåŘŮæĹŰåŔŚéĂĄçŽĎåŕźèśąçżĎæĹŘçŽĎåĹŮèąĺãĂĆ çĎűåŘŐçŻÿåžŤçŽĎ `handle_receive()` æĹŰ `handle_send()` æŰźæşŢèćńèğęåŔŚãĂĆ

çijŰåĘŹåžŤçŤĺçÍŃåžŔçŽĎæŮűåĂŹïijŇ`EventHandler` çŽĎåőđä¿ŃäijŽèćńåĹŻåžžãĂĆä¿ŃåęĆïijŇäÿŃéIćæŸŕäÿď äÿłçőĂå■ŢçŽĎå§žäžŐUDPç¡ŚçżIJæIJ■åŁąçŽĎåd

```
import socket
import time

class UDPServer(EventHandler):
    def __init__(self, address):
        self.sock = socket.socket(socket.AF_INET, socket.SOCK_DGRAM)
        self.sock.bind(address)

    def fileno(self):
        return self.sock.fileno()

    def wants_to_receive(self):
        return True

class UDPTimeServer(UDPServer):
    def handle_receive(self):
        msg, addr = self.sock.recvfrom(1)
        self.sock.sendto(time.ctime().encode('ascii'), addr)

class UDPEchoServer(UDPServer):
    def handle_receive(self):
        msg, addr = self.sock.recvfrom(8192)
        self.sock.sendto(msg, addr)

if __name__ == '__main__':
    handlers = [ UDPTimeServer(('',14000)), UDPEchoServer(('',
↪15000))  ]
```

```
    event_loop(handlers)
```

æţŃèŕŢè£Źæőţäžčçă Ąïij ŃèŕŢçİĂäžŐåŔęåď Űäÿ Ăäÿł Pythonèğčé ĞŁåŹÍè£đæŐěåőČïijŽ

```
>>> from socket import *
>>> s = socket(AF_INET, SOCK_DGRAM)
>>> s.sendto(b'',('localhost',14000))
0
>>> s.recvfrom(128)
(b'Tue Sep 18 14:29:23 2012', ('127.0.0.1', 14000))
>>> s.sendto(b'Hello',('localhost',15000))
5
>>> s.recvfrom(128)
(b'Hello', ('127.0.0.1', 15000))
>>>
```

åőđçŐřäÿ Ăäÿł TCP æIJ■åŁąåŹÍäijŽæŻťåŁååď■æİĆäÿ ĂçĆźïijŃåŻääÿžæŕŔäÿ ĂäÿłåőćæĹůçńŕéČ¡èęĄåĹİäÿ ŃéİćæŸŕäÿ Ăäÿł TCP åžŤç■ŤåőćæĹůçńŕä¿Ńå■ŘïijŽ

```
class TCPServer(EventHandler):
    def __init__(self, address, client_handler, handler_list):
        self.sock = socket.socket(socket.AF_INET, socket.SOCK_
↪STREAM)
        self.sock.setsockopt(socket.SOL_SOCKET, socket.SO_REUSEADDR,
↪ True)
        self.sock.bind(address)
        self.sock.listen(1)
        self.client_handler = client_handler
        self.handler_list = handler_list

    def fileno(self):
        return self.sock.fileno()

    def wants_to_receive(self):
        return True

    def handle_receive(self):
        client, addr = self.sock.accept()
        # Add the client to the event loop's handler list
        self.handler_list.append(self.client_handler(client, self.
↪handler_list))

class TCPClient(EventHandler):
    def __init__(self, sock, handler_list):
        self.sock = sock
        self.handler_list = handler_list
        self.outgoing = bytearray()

    def fileno(self):
        return self.sock.fileno()
```

```
    def close(self):
        self.sock.close()
        # Remove myself from the event loop's handler list
        self.handler_list.remove(self)

    def wants_to_send(self):
        return True if self.outgoing else False

    def handle_send(self):
        nsent = self.sock.send(self.outgoing)
        self.outgoing = self.outgoing[nsent:]

class TCPEchoClient(TCPClient):
    def wants_to_receive(self):
        return True

    def handle_receive(self):
        data = self.sock.recv(8192)
        if not data:
            self.close()
        else:
            self.outgoing.extend(data)

if __name__ == '__main__':
    handlers = []
    handlers.append(TCPServer(('',16000), TCPEchoClient, handlers))
    event_loop(handlers)
```

TCPä¿Ńå■ŘçŽĎåĚşéŤőçĆźæŸŕäżŐåď'ĎçŘĘåŹĺäÿ■åĹŮèąĺåćđåŁäåŠŇåĹăéŹď'åőćæĹůçńŕçŽĎæŞ■ä¡IJã
åŕźæŕŔäÿĂäÿłè£đæŐěïijŇäÿĂäÿłæŰřçŽĎåď'ĎçŘĘåŹĺèćńåĹŻåžžåźůåŁäåĹřåĹŮèąĺäÿ■ãĂĆå¡Şè£đæŐěèćńåĚ
åęĆæđIJä¡äè£ŘèąŇçĺŃåžŘåźűèŕŢçİĂçŤĺTelnetæĹŰçśžäijijåůěåĚůè£đæŐěïijŇåőČäijŽářĘä¡äåŔŚéĂĄçŽĎæű

èőĺèőž

åőđéŹĚäÿŁæĽ'ĂæIJĽçŽĎäžŃäžűél'śåŁĺæąĘæđűåŐ§çŘĘèů§äÿŁéİćçŽĎä¿Ńå■ŘçŻÿåůőæŮäåĞããĂĆåőđ
ä¡ĘæŸŕåIJĺæIJĂæăÿå£ČçŽĎéČĺåĹĘïijŇéČ¡äijŽæIJĽäÿĂäÿłè¡őèŕćçŽĎå¿łçŐŕæİěæčĂæ§ěæť'żåŁĺsocketïijŇåz

äžŃäžűél'śåŁĺI/OçŽĎäÿĂäÿłåŔŕèČ¡åě¡åď'ĎæŸŕåőČèČ¡åď'ĎçŘĘéİđåÿÿåď'ğçŽĎåźűåŔŚè£đæŐěïijŇèĂŇ
äź§åřśæŸŕèŕť'ïijŇselect() èřČçŤĺïijĹæĹŰåĚűäžŰç■L'æŢĹçŽĎïijL'èČ¡çŻŚåŘňåď'ğéĞŘçŽĎsocketåźűåŞ■
åIJĺå¿łçŐŕäÿ■äÿĂæňąåď'ĎçŘĘäÿĂäÿłäžŃäžűïijŇåźűäÿ■éIJĂèęĄåĚűäžŰçŽĎåźűåŔŚæIJžåĹűãĂĆ

äžŃäžűél'śåŁĺI/OçŽĎçijžçĆźæŸŕæšąæIJL'çIJ§æ■čçŽĎåŘŇæ■ěæIJžåĹűãĂĆ
åęĆæđIJäżżä¡ŢäžŃäžűåď'ĎçŘĘåŹĺæŰźæşŢéŸżåąđæĹŰæL'ğèąŇäÿĂäÿłèĂŮæŮűèőąçőŮïijŇåőČäijŽéŸżåąđa
èřČçŤĺéĆčäžŻåźűäÿ■æŸŕäžŃäžűél'śåŁĺéčŐæăijçŽĎåžŞåĞ¡æŢřäź§äijŽæIJL'éŮőécŸïijŇåŘŇæăůèęĄæŸŕæ§I

åŕźäžŐéŸżåąđæĹŰèĂŮæŮűèőąçőŮçŽĎéŮőécŸåŔŕäżěéĂŽè£ĞåřĘäžŃäžűåŔŚéĂĄäÿłåĚűäžŰå■ŢçŃňç
äÿ■è£ĞïijŇåIJĺäžŃäžűå¿łçŐŕäÿ■åijŢåĚěåď'Žçž£çĺŃåŠŇåď'Žè£ŻçĺŃæŸŕæŕŤè¿ČæčŸæL'ŃçŽĎïijŇ
äÿŃéİćçŽĎä¿Ńå■ŘæijŤçď'žäžĘåęĆä¡Ţä¡£çŤĺ concurrent.futures
æĹąåİŮæİěåőđçŐŕïijŽ

```
from concurrent.futures import ThreadPoolExecutor
import os

class ThreadPoolHandler(EventHandler):
    def __init__(self, nworkers):
        if os.name == 'posix':
            self.signal_done_sock, self.done_sock = socket.
↪socketpair()
        else:
            server = socket.socket(socket.AF_INET, socket.SOCK_
↪STREAM)
            server.bind(('127.0.0.1', 0))
            server.listen(1)
            self.signal_done_sock = socket.socket(socket.AF_INET,
                                                  socket.SOCK_
↪STREAM)
            self.signal_done_sock.connect(server.getsockname())
            self.done_sock, _ = server.accept()
            server.close()

        self.pending = []
        self.pool = ThreadPoolExecutor(nworkers)

    def fileno(self):
        return self.done_sock.fileno()

    # Callback that executes when the thread is done
    def _complete(self, callback, r):

        self.pending.append((callback, r.result()))
        self.signal_done_sock.send(b'x')

    # Run a function in a thread pool
    def run(self, func, args=(), kwargs={},*,callback):
        r = self.pool.submit(func, *args, **kwargs)
        r.add_done_callback(lambda r: self._complete(callback, r))

    def wants_to_receive(self):
        return True

    # Run callback functions of completed work
    def handle_receive(self):
        # Invoke all pending callback functions
        for callback, result in self.pending:
            callback(result)
            self.done_sock.recv(1)
        self.pending = []
```

åIJÍäžčçăĄäÿ■ïijŇrun() æŰźæşŢèćńçŤĺæİěářĘåůëä¡IJæŔŘäžd'çżŹåŻđèřČåĞ¡æŢřæśäïijŇåd'ĎçŘĘåőŇ
åőđéŹĚåůëä¡IJèćńæŔŘäžd'çżŹ ThreadPoolExecutor åőđä¿ŃãĂĆ

äÿ■è£ĞäÿĂäÿłéŽ¿çĆźæŸŕå■ŔèřČèőąçőŮçżŞæđIJåŠŇäžŃäžűå¿łçŐŕïijŇäÿžäžĘèğčåĘşåőČïijŇæĹŚäžňåĹŻåż
å¡Şçž£çĺŃæśäåőŇæĹŘåůëä¡IJåŘŐïijŇåőČäijŽæL'ğèąŇçśžäÿ■çŽĎ `_complete()`
æŰźæşŢãĂĆ è£ŹäÿłæŰźæşŢåĘ■æ§ŘäÿłsocketäÿŁåĘŹåĚëå■ŮèŁĆäźŃåL'■äijŽèőšæŇĆèţůçŽĎåŻđèřČåĞ¡æŢ
`fileno()` æŰźæşŢè£ŤåŻđåŔęåđ'ŰçŽĎéĆčäÿłsocketãĂĆ åŻäæ■đ'ïijŇè£Źäÿłå■ŮèŁĆèćńåĘŹåĚěæŮűïijŇå
çĎůåŘŐ `handle_receive()` æŰźæşŢèćńæ£Äæť'žåźűäÿžæL'ĂæIJL'äźŃåL'■æŔŘäžđ'çŽĎåůëä¡IJæL'ğèąŇ
åİęçŹ¡èőšïijŇèřť'äžĘè£ŹäźĹåđ'Žè£đæĹŚèĞłåůśéČ¡æŹŢäžĘãĂĆ
äÿŃéIćæŸŕäÿĂäÿłçőÄå■ŢçŽĎæIJ■åŁąåŹĺïijŇæijŤçđ'žäžĘåęĆä¡Ţä¡£çŤĺçž£çĺŃæśäæİěåőđçŐřèĂŮæŮűçŽĎè

```
# A really bad Fibonacci implementation
def fib(n):
    if n < 2:
        return 1
    else:
        return fib(n - 1) + fib(n - 2)

class UDPFibServer(UDPServer):
    def handle_receive(self):
        msg, addr = self.sock.recvfrom(128)
        n = int(msg)
        pool.run(fib, (n,), callback=lambda r: self.respond(r,␣
↪addr))

    def respond(self, result, addr):
        self.sock.sendto(str(result).encode('ascii'), addr)

if __name__ == '__main__':
    pool = ThreadPoolHandler(16)
    handlers = [ pool, UDPFibServer(('',16000))]
    event_loop(handlers)
```

è£ŘèąŇè£ŹäÿłæIJ■åŁąåŹĺïijŇçĎůåŘŐèřŢçİĂçŤĺåĚűåőČPythonçĺŃåžŔæİěæţŃèřŢåőČïijŽ

```
from socket import *
sock = socket(AF_INET, SOCK_DGRAM)
for x in range(40):
    sock.sendto(str(x).encode('ascii'), ('localhost', 16000))
    resp = sock.recvfrom(8192)
    print(resp[0])
```

ä¡ăåžŤèřèèČ¡åIJĺäÿ■åŘŇçłŮåŔčäÿ■éĞ■åđ'■çŽĎæL'ğèąŇè£ŹäÿłçĺŃåžŔïijŇåźűäÿŤäÿ■äijŽå¡śåŞ■åĹřåĚű

åůšçżŔéŸĚèřżåőŇäžĘè£ŹäÿĂářŔèŁĆïijŇéĆčäźĹä¡ăåžŤèřëä¡£çŤĺè£ŹéĞŇçŽĎäžčçăĄåŘŮïij§äź§èőÿäÿ■
äÿ■è£ĞïijŇåęĆæđIJä¡ăçŘĘèğčäžĘå§žæIJňåŐ§çŘĘïijŇä¡ăářśèČ¡çŘĘèğčè£ŹäžŻæĄĘæđűæL'Ää¡£çŤĺçŽĎæăÿ
ä¡IJäÿžářźåŻđèřČåĞ¡æŢřçijŰçĺŃçŽĎæŻ£äžčïijŇäžŇäžűéľśåŁĺçijŰçăĄæIJL'æŮűåĂŹäijŽä¡£çŤĺåĹřå■ŔçĺŃï

13.13 11.13 åŔŠéĂĄäÿŐæŐěæŤűåď'ğåđŃæŢřçżĎ

éŮőécŸ

ä¡ăèęĄéĂŽè£Ğç¡ŠçżIJè£đæŐěåŔŠéĂĄåŠŇæŐěåŔÙè£đçż■æŢřæ■őçŽĎåď'ğåđŃæŢřçżĎïijŇåźűår¡éĞŔ

èğčåĘşæŰźæąĹ

äÿŃéİćçŽĎåĞ¡æŢřåĹľçŤĺ memoryviews æİěåŔŚéĂĄåŠŇæŐěåŔŮåď˙ğæŢřçżĎïijŽ

```
# zerocopy.py

def send_from(arr, dest):
    view = memoryview(arr).cast('B')
    while len(view):
        nsent = dest.send(view)
        view = view[nsent:]

def recv_into(arr, source):
    view = memoryview(arr).cast('B')
    while len(view):
        nrecv = source.recv_into(view)
        view = view[nrecv:]
```

äÿžäžĘæţŃèŕŢçÍŃåžŔïijŇéęŰåĚĹåĹŻåžžäÿĂäÿłéĂŽè£Ğsocketè£đæŐěçŽĎæIJ■åŁąåŹĺåŠŇåőćæĹůçńŕç

```
>>> from socket import *
>>> s = socket(AF_INET, SOCK_STREAM)
>>> s.bind(('', 25000))
>>> s.listen(1)
>>> c,a = s.accept()
>>>
```

åIJÍåőćæĹůçńŕïijĹåŔęåď˙ŰäÿĂäÿłèğčéĞŁåŹĺäÿ■ïijL˙ïijŽ

```
>>> from socket import *
>>> c = socket(AF_INET, SOCK_STREAM)
>>> c.connect(('localhost', 25000))
>>>
```

æIJňèŁĆçŽĎçŻőæăĞæŸŕä¡ăèČ¡éĂŽè£Ğè£đæŐěäijăè¿ŞäÿĂäÿłèűĚåď˙ğæŢřçżĎãĂĆè£ŹçğæČĚåĘţçŽĎ
array æĺąåİŮæĹŰ numpy æĺąåİŮæİěåĹŻåžžæŢřçżĎïijŽ

```
# Server
>>> import numpy
>>> a = numpy.arange(0.0, 50000000.0)
>>> send_from(a, c)
>>>

# Client
>>> import numpy
>>> a = numpy.zeros(shape=50000000, dtype=float)
>>> a[0:10]
array([ 0.,  0.,  0.,  0.,  0.,  0.,  0.,  0.,  0.,  0.])
>>> recv_into(a, c)
>>> a[0:10]
array([ 0.,  1.,  2.,  3.,  4.,  5.,  6.,  7.,  8.,  9.])
```

```
>>>
```

èőÍèőž

åIJÍæŢřæ■őåŕĘéŻĘåđŃåĹĘåÿČåijŔèőąçőŮåŠŇåźşèąŇèőąçőŮçÍŃåžŔäÿ■ïijŇèĞłåůśåĘŹçÍŃåžŔæÍěåőđç
äÿ■è£ĞïijŇèęĄæŸŕä¡ăçąőåőđæČşè£Źæăůå ĄŽïijŇä¡ăåŔŕèČ¡éIJĂèęĄåŕĘä¡ăçŽĎæŢřæ■őè¡ñæ■ćæĹŘåŐ§ågŃ
ä¡ăåŔŕèČ¡è£ŸéIJĂèęĄåŕĘæŢřæ■őåĹĞåL'šæĹŘåd'Žäÿłå İŮïijŇåŻăäÿžåd'ğéČÍåĹĘåŠŇç¡ŚçżIJçŻÿåĚşçŽĎåĞ¡

äÿĂçğ■æŰźæşŢæŸŕä¡£çŤÍæ§Řçğ■æIJžåĹűåžŘåĹŮåŇŰæŢřæ■őâĂŤâĂŤåŔŕèČ¡åřĘåĚűè¡ñæ■ćæĹŘäÿĂ
äÿ■è£ĞïijŇè£ŹæăůæIJĂçżĹäijŽåĹŻåžžæŢřæ■őçŽĎäÿĂäÿłåd'■åĹűãĂĆ
åřśçőŮä¡ăåŘłæŸŕéŽűçćÕçŽĎåĄŽè£ŹäžŻïijŇä¡ăçŽĎäžčçăĄæIJĂçżĹè£ŸæŸŕäijŽæIJL'åd'ğéĞŘçŽĎåřŘåđŃå

æIJňèŁĆéĂŽè£Ğä¡£çŤÍåĘĚå■ŸèğĘåŻ¿åśŢçd'žäžĘäÿĂäžŻé■ŤæşŢæŞ■ä¡IJãĂĆ
æIJňèt'ÍäÿŀïijŇäÿĂäÿłåĘĚå■ŸèğĘåŻ¿åřśæŸŕäÿĂäÿłåůšå■ŸåIJÍæŢřçżĎçŽĎèęĘçŽŰåśĆãĂĆäÿ■äžĚäžĚæŸŕé
åĘĚå■ŸèğĘåŻ¿è£ŸèČ¡äžěäÿ■åŘŇçŽĎæŰźåijŔè¡ñæ■ćæĹŘäÿ■åŘŇçśžåđŃæÍěèąÍçŐřæŢřæ■őãĂĆ
è£Źäÿłåřśæ ŸŕäÿŃéÍćè£Źäÿłèŕ■åŔěçŽĎçŽőçŽĎïijŽ

```
view = memoryview(arr).cast('B')
```

åőČæŐěåŔŮäÿĂäÿłæŢřçżĎ arråźűåřĘåĚűè¡ñæ■ćäÿžäÿĂäÿłæŮăçňęåŔůå■ŮèŁĆçŽĎåĘĚå■ŸèğĘåŻ¿ãĂĆ
æŕŤåęĆ `socket.send()` æĹŰ `send.recv_into()` ãĂĆ
åIJÍåĘĚéČÍïijŇè£ŹäžŻæŰźæşŢèČ¡åd'§çŻt'æŐěæŞ■ä¡IJè£ŹäÿłåĘĚå■ŸåŇžå§§ãĂĆä¿ŃåęĆïijŇ`sock.send()` çŻt'æŐěäžŐåĘĚå■ŸäÿåŔŠçŤ§æŢřæ■őèĂŇäÿ■éIJĂèęĄåd'■åĹűãĂĆ `send.recv_into()` ä¡£çŤÍè£ŹäÿłåĘĚå■ŸåŇžå§§ä¡IJäÿžæŐěåŔŮæŞ■ä¡IJçŽĎè¿ŞåĚěçijŞåĘšåŇžãĂĆ

åL'l'äÿŃçŽĎäÿĂäÿłéŽ¿çĆźåřśæŸŕsocketåĞ¡æŢřåŔŕèČ¡åŔłæŞ■ä¡IJéČÍåĹĘæŢřæ■õãĂĆ
éĂŽåÿÿæÍěěőšïijŇæĹŚäžňå¿Ůä¡£çŤÍå¿Ĺåd'Žäÿ■åŘŇçŽĎ `send()` åŠŇ `recv_into()`
æÍěäijåè¿ŞæŢt'äÿłæŢřçżĎãĂĆ äÿ■çŤÍæŃĚå£ČïijŇæŕŔæňąæŞ■ä¡IJåŘŐïijŇèğĘåŻ¿äijŽéĂŽè£ĞåŔŚéĂĄæĹŰ
æŰřçŽĎèğĘåŻ¿åŘŇæăůäź§æŸŕåĘĚå■ŸèęĘçŽŰåśĆãĂĆåŽăæ■d'ïijŇè£ŸæŸŕæšąæIJL'äžżä¡ŢçŽĎåd'■åĹűæŞ

è£ŹéĞŇæIJL'äÿłéŮőécŸåřśæŸŕæŐěåŔŮèĂĚå£ĚéążäžŇåĚĹç§ěéĄŞæIJL'åd'ŽåřŚæŢřæ■őèęĄècńåŔŚéĂ
äžěä¿£åőĆèČ¡écĎåĹĘéĚ■äÿĂäÿłæŢřçżĎæĹŮèĂĚçąőä£ÌåőĆèČ¡åřĘæŐěåŔŮçŽĎæŢřæ■őæŤ¿åĚěäÿĂäÿłåůš
åęĆæđIJæšąåŁđæşŢç§ěéĄŞçŽĎèŕÍïijŇåŔŚéĂĄèĂĚåřśå¿ŮåĚĹåřĘæŢřæ■őåd'ğåřŔåŔŚéĂĄè£ĞæÌěïijŇçĎűå

14 çňňå■ĄäžŇçńăïijŽåźűåŔŚçijŰçÍŃ

åŕźäžŐåźűåŔŚçijŰçÍŃ, PythonæIJL'åd'Žçğ■éŢ£æIJ§æŤŕæŇĄçŽĎæŰźæşŢ,
åŃĚæŃňåd'Žçž£çÍŃ, èřČçŤÍå■Řè£ŻçÍŃ, äžěåŔŁåŘĎçğ■åŘĎæăůçŽĎåĚşäžŐçŤ§æĹŘåŹĺåĞ¡æŢřçŽĎæŁĂåů
è£ŹäÿĂçńäåřĘäijŽçżŹåĞžåźűåŔŚçijŰçÍŃåŘĎçğ■æŰźéÍćçŽĎæŁĂåůğ,
åŃĚæŃňéĂŽçŤÍçŽĎåd'Žçž£çÍŃæŁĂæIJŕäžěåŔŁåźűèąŇèőąçőŮçŽĎåőđçŐřæŰźæşŢ.

åČŔçżŔéłŇäÿřárŇçŽĎçÍŃåžŔåŚŸæL'Ăç§ěéĄŞçŽĎéĆčæăů,
åd'ğåőűæŃĚå£Čåźűåŕ§çŽĎçÍŃåžŔæIJL'æ¡IJåIJÍçŽĎå■śéŹl'. åŽăæ■d',
æIJňçńăçŽĎäÿżèęĄçŽőæăĞäźŃäÿĂæŸŕçżŹåĞžæŻt'åŁăåŔŕä£ąèţŰåŠŇæŸŞèŘČèŕŢçŽĎäžčçăĄ.

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14.1 12.1 åŘŕåŁĺäÿŐåĄIJæ■ćçž£çĺŃ

éŮőécŸ

ä¡ăèęĄäÿžéIJĂèęĄåźűåŔŚæL'ğèąŇçŽĎäžčçăĄåĹŻåžž/éŤĂæŕĄçž£çĺŃ

èğčåĘşæŰźæąĹ

threading åžŞåŔŕäżěåIJĺå■ŢçŃňçŽĎçž£çĺŃäÿ■æL'ğèąŇäżżä¡ŢçŽĎåIJĺ Python äÿ■åŔŕäżěèřČçŤĺçŽĎåŕźèśąãĂĆä¡ăåŔŕäżěåĹŻåžžäÿĂäÿł Thread åŕźèśąåźűåřĘä¡ăèęĄæL'ğèąŇçŽĎåŕźèśąäžě target åŔĆæŢřçŽĎå¡ćåijŔæŔŘä¿ŻçžŹèŕěåŕźèśąãĂĆ äÿŃéIćæŸŕäÿĂäÿłçőĂå■ŢçŽĎä¿Ńå■ŘïijŽ

```
# Code to execute in an independent thread
import time
def countdown(n):
    while n > 0:
        print('T-minus', n)
        n -= 1
        time.sleep(5)

# Create and launch a thread
from threading import Thread
t = Thread(target=countdown, args=(10,))
t.start()
```

å¡Şä¡ăåĹŻåžžåě¡äÿĂäÿłçž£çĺŃåŕźèśąåŘŐïijŇèŕěåŕźèśąåźűäÿ■äijŽçńŃå■şæL'ğèąŇïijŇéŹd'éIđä¡ăèřČçŤĺä start() æŰźæşŢïijĹå¡Şä¡ăèřČçŤĺ start() æŰźæşŢæŮűïijŇåőČäijŽèřČçŤĺä¡ăäijăéĂŠè£ŻæIěçŽĎåĞ¡æŢ POSIX çž£çĺŃæĹŰèĂĚäÿĂäÿł Windows çž£çĺŃïijL'ïijŇè£ŹäžŽçž£çĺŃåřĘçŤśæŞ■ä¡IJçşżçż§æIěåĚĺæIČçőąçĹ

```
if t.is_alive():
    print('Still running')
else:
    print('Completed')
```

ä¡ăäź§åŔŕäżěåřĘäÿĂäÿłçž£çĺŃåŁăåĚěåĹřå¡ŞåL'■çž£çĺŃïijŇåźűç■L'å¿ĚåőČçżĹæ■ćïijŽ

```
t.join()
```

PythonèğčéĞŁåŹĺçŻt'åĹřæL'ĂæIJL'çž£çĺŃéČ¡çżĹæ■ćåL'■äż■ä‡ÍæŇĄè£ŘèąÑãĂĆåŕźäžŐéIJĂèęĄéŢ£æ ä¿ŃåęĆïijŽ

```
t = Thread(target=countdown, args=(10,), daemon=True)
t.start()
```

åŘŐåŔřçž£çĺŃæŮăæŞç■L'å¿ĚïijŇäÿ■è£ĞïijŇè£ŹäžŽçž£çĺŃäijŽåIJĺäÿżçž£çĺŃçżĹæ■ćæŮűèĞłåŁĺéŤĂ éŹd'äžĘåęĆäÿŁæL'Ăçd'žçŽĎäÿd'äÿłæŞ■ä¡IJïijŇåźűæšąæIJL'åd'łåd'ŽåŔŕäžěåŕźçž£çĺŃåĄŽçŽĎäžŃæČĚãĂĆ

```
class CountdownTask:
    def __init__(self):
        self._running = True

    def terminate(self):
        self._running = False

    def run(self, n):
        while self._running and n > 0:
            print('T-minus', n)
            n -= 1
            time.sleep(5)

c = CountdownTask()
t = Thread(target=c.run, args=(10,))
t.start()
c.terminate() # Signal termination
t.join()      # Wait for actual termination (if needed)
```

åęĆædIJçž£çÍŃæL'ğèąŇäÿĂäžŻåČŔI/Oè£Źæăůç ŽĎéŸżåąđæŞ■ä¡IJïijŇéĆčäźĹéĂŽè£Ğè¡őèŕćæİěçżĹæ■ä¿Ńå■ŘåęĆäÿŃïijŽ

```
class IOTask:
    def terminate(self):
        self._running = False

    def run(self, sock):
        # sock is a socket
        sock.settimeout(5)         # Set timeout period
        while self._running:
            # Perform a blocking I/O operation w/ timeout
            try:
                data = sock.recv(8192)
                break
            except socket.timeout:
                continue
            # Continued processing
            ...
        # Terminated
        return
```

èőÍèőž

çŤśäžŐåĚĺåśĂèğčéĞŁéŤĄïijĹGILïijL'çŽĎåŐ§åŻăïijŇPython çŽĎçž£çÍŃèćńéŹŘåĹűåĹřåŘŇäÿĂæŮűåĹżåŔĺåĚĄèőÿäÿĂäÿłçž£çÍŃæL'ğèąŇè£ŹæăůäÿĂäÿłæL'ğèąŇæĺąåđŇçŽĎçž£çÍŃæŻť éĂĆçŤĺäžŐåď ĎçŘĘI/OåŠŇåĚűäżŮéIJĂèęĄåźűåŔŚæL'ğèąŇçŽĎéŸżåąđæŞ■ä¡IJïijĹærŤåęĆ

æIJL'æŮűä¡ăäijŽçIJŃåĹřäÿŃè¿źè£Źçğ■éĂŽè£ĞçżğæL'£ `Thread` çśżæİěåőđçŐřçŽĎçž£çÍŃïijŽ

```
from threading import Thread

class CountdownThread(Thread):
    def __init__(self, n):
        super().__init__()
        self.n = 0
    def run(self):
        while self.n > 0:

            print('T-minus', self.n)
            self.n -= 1
            time.sleep(5)

c = CountdownThread(5)
c.start()
```

åř¡çőąè£Źæăůäź§åŔŕäžěåůěä¡IJïijŇä¡Ęè£Źä¡£å¿Ůä¡ăçŽĎäžčçăĄä¿ÌètŰäžŐ threading åžŞïijŇæĽ˘Ăäžěä¡ăçŽĎè£ŹäžŻäžčçăĄåŔŕèČ¡åIJÍçž£çÍŃäÿŁäÿŇæŰĞäÿ■ä¡£çŤÍãĂĆäÿŁæŰĞæ threading åžŞæŮăåĚşçŽĎïijŇè£Źæăůåŕśä¡£å¿Ůè£ŹäžŻäžčçăĄåŔŕäžěèćńçŤÍåIJÍåĚűäžŰçŽĎäÿŁäÿŇæŰĞ multiprocessing æÍąåİŮåIJÍäÿĂäÿłå■ŢçŃňçŽĎè£ŽçÍŃäÿ■æĽ˘ğèąŇä¡ăçŽĎäžčçăĄïijŽ

```
import multiprocessing
c = CountdownTask(5)
p = multiprocessing.Process(target=c.run)
p.start()
```

åĘ■æňąéĞ■çŤşïijŇè£Źæőţäžčçă Ą äžĚéĂĆçŤÍäžŐ CountdownTask çśżæŸŕäžěçŃňçńŇäžŐåőđéŹĚçŽĎåźűåŔŚæĽ˘Ńæőţïij Ĺåd’Žçž£çÍŃãĂĄåd’Žè£ŽçÍŃç■Ľ˘ç■Ľ˘ïijĽ˘åőđçŐřçŽĎæ

14.2 12.2 åĹd’æŰ■çž£çÍŃæŸŕåŘęåůšçżŔåŘŕåŁÍ

éŮőécŸ

ä¡ăåůšçżŔåŘŕåŁÍäžĘäÿĂäÿłçž£çÍŃïijŇä¡ĘæŸŕä¡ăæČşç§ěéĄŞåőČæŸŕäÿ■æŸŕçIJ§çŽĎåůšçżŔåijĂäğŃè£

èğčåĘşæŰźæąĹ

çž£çÍŃçŽĎäÿĂäÿłåĚşéŤőçĽ˘źæĂğæŸŕæŕŔäÿłçž£çÍŃéČ¡æŸŕçŃňçńŃè£ŘèąŇäÿŤçŁűæĂĄäÿ■åŔŕécĎæţ threading åžŞäÿ■çŽĎ Event åŕźèśąãĂĆ Event åŕźèśąåŇĚåŘńäÿĂäÿłåŔŕçŤśçž£çÍŃèő¿ç¡őçŽĎä£ąåŔůæ åŕźèśąäÿ■çŽĎä£ąåŔůæăĞå£Ůèćńèő¿ç¡őäÿžåĄĞãĂĆåęĆæđIJæIJL’çž£çÍŃç■Ľ˘å¿ĚäÿĂäÿł event åŕźèśąïijŇèĂŇè£Źäÿł event åŕźèśąçŽĎæăĞå£ŮäÿžåĄĞïijŇéĆčäźĹè£ŹäÿłçŽ£çÍŃåřĘäijŽèćńäÿĂçŻť’éŸź event åŕźèśąçŽĎä£ąåŔůæăĞå£Ůèő¿ç¡őäÿžçIJ§ïijŇåőČåřĘåŤd’éĘŠæĽ˘ĂæIJL’ç■Ľ˘å¿Ěè£Źäÿł event åŕźèśąçŽĎçž£çÍŃãĂĆåęĆæđIJäÿĂäÿłçž£çÍŃç■Ľ˘å¿ĚäÿĂäÿłåůšçżŔèćńèő¿ç¡őäÿžçIJ§çŽĎ event åŕźèśąïijŇéĆčäźĹåőČåřĘå£¡çŢèè£ŹäÿłäžŃäžűïijŇçžğçż■æĽ˘ğèąŇäĂĆ äÿŃè¿źçŽĎäžčçăĄåśŢçd’žäžĘåęĆä¡Ţä¡£çŤÍ Event æÌèå■ŔèřČçž£çÍŃçŽĎåŘŕåŁÍïijŽ

```
from threading import Thread, Event
import time

# Code to execute in an independent thread
def countdown(n, started_evt):
    print('countdown starting')
    started_evt.set()
    while n > 0:
        print('T-minus', n)
        n -= 1
        time.sleep(5)

# Create the event object that will be used to signal startup
started_evt = Event()

# Launch the thread and pass the startup event
print('Launching countdown')
t = Thread(target=countdown, args=(10,started_evt))
t.start()

# Wait for the thread to start
started_evt.wait()
print('countdown is running')
```

å¡Şä¡äæL'ğèąŇè£ŹæőţäžčçăĄïijŇâĂIJcountdown is runningâĂİ æĂżæŸŕæŸ¿çd'žåIJÍ âĂIJcountdown startingâĂİ äźŇåŘŐæŸ¿çd'žãĂĆè£ŹæŸŕçŤśäžŐä¡£çŤÍ event æİěå■ŔèřČçž£çÍŃïijŇä¡£å¿Ůäÿżçž£çÍŃèęĄç■L'åĹř `countdown()` åĞ¡æŢřè¿ŞåĞžåŘŕåŁÍä£qæĄŕåŘŐïijŇæL'■èČ¡çżğçż■æL'ğèąŇãĂĆ

èőÍèőž

event åŕźèśąæIJĂåě¡å■Ţæňąä¡£çŤÍïijŇåřśæŸŕèŕt'ïijŇä¡ăåĹŻåžžäÿĂäÿł event åŕźèśąïijŇèőľæ§Řäÿł£çÍŃç■L'å¿Ěè£ŹäÿłåŕźèśąïijŇäÿĂæŮęè£Źäÿłåŕźèśąèćńèő¿ç¡őäÿžçIJ§ïijŇä¡ăåřśåžŤèŕě `clear()` æŰźæşŢæİěéĞ■ç¡ő event åŕźèśąïijŇä¡ĘæŸŕå¿ĹéŽ¿çąőä£ĺåőL'åĚĺåIJřæÿĚçŘĘ event åŕźèśąåźűåŕźåőČéĞ■æŰřèţŃåĂijãĂĆå¿ĹåŘŕèČ¡äijŽåŘŚçŤ§éŤŹè£ĞäžŃäžűãĂĄæ■żéŤĄæĹŰèĂĚåĚűä event åŕźèśąçŽĎäžčçăĄäijŽåIJÍçž£çÍŃåĘ■æňąç■L'å¿Ěè£ŹäÿŁ event åŕźèśąäźŃåL'■æL'ğèąŇïijL'ãĂĆåęĆæđIJäÿĂäÿłçž£çÍŃéIJĂèęĄäÿ■åĄIJåIJřéĞ■åd'■ä¡£çŤÍ event åŕźèśąïijŇä¡ăæIJĂåě¡ä¡£çŤÍ `Condition` åŕźèśąæİěäžčæŽ£ãĂĆäÿŃéİćçŽĎäžčçăĄä¡£çŤÍ `Condition` åŕźèśąåődçŐřäžĘäÿĂäÿłåŚÍæIJ§åőŽæŮűåŹÍïijŇærŔå¡ŞåőŽæŮűåŹÍèűĚæŮűçŽĎæŮűåĂŹïijŇål

```
import threading
import time

class PeriodicTimer:
    def __init__(self, interval):
        self._interval = interval
        self._flag = 0
        self._cv = threading.Condition()
```

```
    def start(self):
        t = threading.Thread(target=self.run)
        t.daemon = True

        t.start()

    def run(self):
        '''
        Run the timer and notify waiting threads after each interval
        '''
        while True:
            time.sleep(self._interval)
            with self._cv:
                self._flag ^= 1
                self._cv.notify_all()

    def wait_for_tick(self):
        '''
        Wait for the next tick of the timer
        '''
        with self._cv:
            last_flag = self._flag
            while last_flag == self._flag:
                self._cv.wait()

# Example use of the timer
ptimer = PeriodicTimer(5)
ptimer.start()

# Two threads that synchronize on the timer
def countdown(nticks):
    while nticks > 0:
        ptimer.wait_for_tick()
        print('T-minus', nticks)
        nticks -= 1

def countup(last):
    n = 0
    while n < last:
        ptimer.wait_for_tick()
        print('Counting', n)
        n += 1

threading.Thread(target=countdown, args=(10,)).start()
threading.Thread(target=countup, args=(5,)).start()
```

eventåŕźèśąçŽĎäÿĂäÿłéĞ■èęĄçĽźçĆźæŸŕå¡ŞåőČèćńèő¿ç¡őäÿžçIJ§æŮűäijŽåŤd'éĘŠæĽ'ĂæIJĽç■Ľ'å¿Ě
`Condition` åŕźèśąæİěæŻ£äżčãĂĆèĂČèŹŚäÿĂäÿŃè£Źæőţä¡£çŤĺä£ąåŔůéĞŔåőđçŐřçŽĎäżčçăĄijŽ

```
# Worker thread
def worker(n, sema):
    # Wait to be signaled
    sema.acquire()

    # Do some work
    print('Working', n)

# Create some threads
sema = threading.Semaphore(0)
nworkers = 10
for n in range(nworkers):
    t = threading.Thread(target=worker, args=(n, sema,))
    t.start()
```

è£Řèą Ňäÿ Łè¿źçŽĎäžčçă Ąåř Ęäij ŽåŘřåŁÍäÿ Ăäÿłçž£çÍŃæśäïij Ňä¡Ęæ ŸřáźűæšąæIJL'äżĂäźĹäžŃæČĚåŔŚ

```
>>> sema.release()
Working 0
>>> sema.release()
Working 1
>>>
```

çijŰåĘŹæűL'åŔŁåĹřåd'ğéĞŔçŽĎçž£çÍŃéŮt'åŘŇæ■ěéŮőécŸçŽĎäžčçăĄäijŽèől'ä¡ăçŮŻäÿ■æňšçŤ§ãĂĆ

14.3 12.3 çž£çÍŃéŮť'éĂŽä£ą

éŮőécŸ

ä¡ăçŽĎçÍŃåžŔäÿ■æIJL'åd'Žäyłçž£çÍŃïijŇä¡ăéIJĂèęĄåIJÍè£ŹäžŻçž£çÍŃäźŃéŮt'åőL'åĚÍåIJřäžd'æ■ćä£ąa

èğčåĘşæŰźæąĹ

äżŐäÿĂäÿłçž£çÍŃåŘŚåŔęäÿĂäÿłçž£çÍŃåŘŚéĂĄæŢřæ■őæIJĂåőL'åĚÍçŽĎæŰźåijŔåŔřèČ¡åřśæŸřä¡£çŤÍ

queue åžŞäÿ■çŽĎéŸ§åĹŮäžEãĂĆåĹŻåžžäÿĂäÿłèćńåd'Žäÿłçž£çÍŃåĚśäžńçŽĎ
Queue åŕźèśąïijŇè£ŹäžŻçž£çÍŃéĂŽè£Ğä¡£çŤÍ put() åŠŇ get()
æŞ■ä¡IJæÌěåŘŚéŸ§åĹŮäÿ■æůżåŁăæĹŰèĂĚåĹăéŹd'åĚČçt'ăãĂĆ ä¿ŃåęĆïijŽ

```
from queue import Queue
from threading import Thread

# A thread that produces data
def producer(out_q):
    while True:
        # Produce some data
        ...
        out_q.put(data)
```

```
# A thread that consumes data
def consumer(in_q):
    while True:
# Get some data
        data = in_q.get()
        # Process the data
        ...

# Create the shared queue and launch both threads
q = Queue()
t1 = Thread(target=consumer, args=(q,))
t2 = Thread(target=producer, args=(q,))
t1.start()
t2.start()
```

Queue åŕźèśąåůšçżŔåŇĚåŘńäžĘå£ĚèęĄçŽĎéŤĄïijŇæĽ Ăäžëä¡ăåŔŕäžěéĂŽè£ĞåőČåIJĺåď Žäÿłçž£çíŇé
å¡Şä¡£çŤĺéŸ§åĹŮæŮűïijŇå■ŔèřČçŤ§äžğèĂĚåŠŇæűĹèť źèĂĚçŽĎåĚşéŮ■éŮőécŸåŔŕèČ¡äijŽæIJL äÿĂäžŹé

```
from queue import Queue
from threading import Thread

# Object that signals shutdown
_sentinel = object()

# A thread that produces data
def producer(out_q):
    while running:
        # Produce some data
        ...
        out_q.put(data)

    # Put the sentinel on the queue to indicate completion
    out_q.put(_sentinel)

# A thread that consumes data
def consumer(in_q):
    while True:
        # Get some data
        data = in_q.get()

        # Check for termination
        if data is _sentinel:
            in_q.put(_sentinel)
            break

        # Process the data
        ...
```

æIJñä¿Ńäÿ■æIJL äÿĂäÿłçL źæőŁçŽĎåIJřæŰźïijŽæűĹèť źèĂĚåIJĺèŕžåĹřè£ŹäÿłçL źæőŁåĂijäźŃåŘŐçńŃ

åř¡çőąéŸ§åĹŮæŸŕæIJĂåÿÿèğĄçŽĎçž£çÍŃéŮťéĂŽä£ąæIJžåĹűïijŇä¡ĘæŸŕäż■çĎűåŔŕäżěèĞłåůśéĂŽè£ĞåĹŽ
Condition åŔŸéĞŔæİěåŇĚèčËä¡ăçŽĎæŢřæ■őçżŞæđĎãĂĆäÿŃè¿źè£Źäÿłä¿Ňå■ŘæijŤçď žäžĘåęĆä¡ŢåĹŻ

```
import heapq
import threading

class PriorityQueue:
    def __init__(self):
        self._queue = []
        self._count = 0
        self._cv = threading.Condition()
    def put(self, item, priority):
        with self._cv:
            heapq.heappush(self._queue, (-priority, self._count,␣
↪item))
            self._count += 1
            self._cv.notify()

    def get(self):
        with self._cv:
            while len(self._queue) == 0:
                self._cv.wait()
            return heapq.heappop(self._queue)[-1]
```

ä¡£çŤĺéŸ§åĹŮæİěè£ŻèąŇçž£çÍŃéŮťéĂŽä£ąæŸŕäÿŕäÿłå■ŢåŘŚãĂĄäÿ■çąőåőŽçŽĎè£ĞçÍŃãĂĆéĂŽåÿ
task_done() åŠŇ join() ïijŽ

```
from queue import Queue
from threading import Thread

# A thread that produces data
def producer(out_q):
    while running:
        # Produce some data
        ...
        out_q.put(data)

# A thread that consumes data
def consumer(in_q):
    while True:
        # Get some data
        data = in_q.get()

        # Process the data
        ...
        # Indicate completion
        in_q.task_done()

# Create the shared queue and launch both threads
q = Queue()
t1 = Thread(target=consumer, args=(q,))
```

```
t2 = Thread(target=producer, args=(q,))
t1.start()
t2.start()

# Wait for all produced items to be consumed
q.join()
```

åęĆædIJäÿĂäÿłçž£çÍŃéIJĂèęĄåIJÍäÿĂäÿłâĂIJæűĹèť źèĂĚâĂİçž£çÍŃåď ĎçŘĘåőŇçĽźåőŽçŽĎæŢřæ■ő
Event æŤ¿åĹřäÿĂèţůä¡£çŤĺïijŇè£ŹæăůâĂIJçŤ§ăžğèĂĚâĂİåřśåŔŕäżěéĂŽè£Ğè£ŹäÿłEventåŕźèśąæİěçŻŚæţ

```
from queue import Queue
from threading import Thread, Event

# A thread that produces data
def producer(out_q):
    while running:
        # Produce some data
        ...
        # Make an (data, event) pair and hand it to the consumer
        evt = Event()
        out_q.put((data, evt))
        ...
        # Wait for the consumer to process the item
        evt.wait()

# A thread that consumes data
def consumer(in_q):
    while True:
        # Get some data
        data, evt = in_q.get()
        # Process the data
        ...
        # Indicate completion
        evt.set()
```

èőÍèőž

å§žäžŐçőĂå■ŢéŸ§åĹŮçijŰåĘŹåď Žçž£çÍŃçÍŃåžŔåIJÍåď ŽæŢřæČĚåĘţäÿŃæŸŕäÿĂäÿłæŕŤè¿ČæŸŐæŹž
ä¡£çŤÍçž£çÍŃéŸ§åĹŮæIJL äÿĂäÿłèęĄæşÍæĎŔçŽĎéŮőécŸæŸŕijŇåŘŠéŸ§åĹŮäÿ■æůžåŁăæŢřæ■őéąźæŮűå

```
from queue import Queue
from threading import Thread
import copy

# A thread that produces data
def producer(out_q):
    while True:
        # Produce some data
        ...
```

```
        out_q.put(copy.deepcopy(data))

# A thread that consumes data
def consumer(in_q):
    while True:
        # Get some data
        data = in_q.get()
        # Process the data
        ...
```

Queue åŕźèśąæŔŘä¿ŻäÿĂäžŻåIJĺå¡ŞåĽ■äÿŁäÿŃæŰĞå¿ĹæIJĽçŤĺçŽĎéŹĎåŁăçĽźæĂğãĂĆæŕŤåęĆåIJ
Queue åŕźèśąæŮűæŔŘä¿ŻåŔŕéĂĽçŽĎ size åŔĆæŢřæİěéŹŘåĹűåŔŕäžěæůżåŁäåĹřéŸ§åĹŮäÿ■çŽĎåĚČçť ă
âĂIJæűĹèť źâĂİçŽĎéĂ§åžęå£ńïijŇéĆčäźĹä¡£çŤĺåŽžåőŽåď ğåřŔçŽĎéŸ§åĹŮåřśåŔŕäžěåIJĺéŸ§åĹŮåůšæżąçŽ
get() åŠŇ put() æŰźæşŢéČ¡æŤŕæŇĄéÍđéŸżàąđæŰźåijŔåŠŇèő¿åőŽèűĚæŮűïijŇä¿ŃåęĆïijŽ

```
import queue
q = queue.Queue()

try:
    data = q.get(block=False)
except queue.Empty:
    ...

try:
    q.put(item, block=False)
except queue.Full:
    ...

try:
    data = q.get(timeout=5.0)
except queue.Empty:
    ...
```

è£ŹäžŻæŞ■ä¡IJéČ¡åŔŕäžěçŤĺæİěéĄ£åĚ■å¡ŞæĽğèąŇæ§ŘäžŻçĽźåőŽéŸ§åĹŮæŞ■ä¡IJæŮűåŔŠçŤ§æŮăé
put() æŰźæşŢåŠŇäÿĂäÿłåŽžåőŽåď ğåřŔçŽĎéŸ§åĹŮäÿĂèţůä¡£çŤĺïijŇè£ŹæăůåˇŞéŸ§åĹŮåůšæżąæŮűåřśà

```
def producer(q):
    ...
    try:
        q.put(item, block=False)
    except queue.Full:
        log.warning('queued item %r discarded!', item)
```

åęĆæđIJä¡ăèŕŢåŻ¿èőľæűĹèť źèĂĚçž£çĺŃåIJĺæĽğèąŇåČŔ q.get()
è£ŹæăůçŽĎæŞ■ä¡IJæŮűïijŇèűĚæŮűèĞłåŁĺçžĹæ■ćäžěä¿£æčĂæ§ěçźĹæ■ćæăĞå£ŮïijŇä¡ăåžŤèŕěä¡£çŤĺ
q.get() çŽĎåŔŕéĂĽåŔĆæŢř timeout ïijŇåęĆäÿŃïijŽ

```
_running = True

def consumer(q):
```

```
    while _running:
        try:
            item = q.get(timeout=5.0)
            # Process item
            ...
        except queue.Empty:
            pass
```

æIJĂåŘŐïijŇæIJĽ `q.qsize()` ïijŇ `q.full()` ïijŇ `q.empty()` ç■Ľåőđç ŤÍæŰźæşŢåŔŕäžěèŐůåŔŰäÿĂäÿłéŸ§åĹŮçŽĎå¡ŞåĽ■åđ'ğářŔåŠŇçŁűæĂĄãĆä¡ĘèęĄæşÍæĎŔïijŇè `empty()` åĹđ'æŰ■åĞžè£ŹäÿłéŸ§åĹŮäÿžçľžïijŇä¡ĘåŘŇæŮűåŔęåđ'ŰäÿĂäÿłçž£çÍŃåŔŕèČ¡åůšçżŘåŘŚè£Źä

14.4 12.4 çżŹåĚşéŤőéČÍåĹĘåŁäéŤĄ

éŮőécŸ

ä¡ăéIJĂèęĄåŕźåđ'Žçž£çÍŃçÍŃåžŔäÿ■çŽĎäÿt'çŢŇåŇžåŁäéŤĄäżěéĄ£åĚ■çńđäžĽ'æİąäžűãĂĆ

èğčåĘşæŰźæąĹ

èęĄåIJÍåđ'Žçž£çÍŃçÍŃåžŔäÿ■åőĽ'åĚÍä¡£çŤÍåŔŕåŔŸåŕźèśąïijŇä¡ăéIJĂèęĄä¡£çŤÍ threading åžŞäÿ■çŽĎ `Lock` åŕźèśąïijŇåřśåČŔäÿŃè¿źè£ŹäÿłäżŃå■Řè£ŹæăůïijŽ

```
import threading

class SharedCounter:
    '''
    A counter object that can be shared by multiple threads.
    '''
    def __init__(self, initial_value = 0):
        self._value = initial_value
        self._value_lock = threading.Lock()

    def incr(self,delta=1):
        '''
        Increment the counter with locking
        '''
        with self._value_lock:
             self._value += delta

    def decr(self,delta=1):
        '''
        Decrement the counter with locking
        '''
        with self._value_lock:
             self._value -= delta
```

Lock åŕźèśąåŠŇ with èŕ■åŔěåİŮäÿĂèţůä¡£çŤĺåŔŕäžěä£İèŕĄäžŠæŰěæL’ğèąŇïijŇåřśæŸŕæŕŔæňąåŔłæI
with èŕ■åŔěåŇĚåŘńçŽĎäžčçăĄåİŮãĂĆwith èŕ■åŔëäijŽåIJĺè£Źäÿłäžčçă Ą åİŮæL’ğèąŇåL’■èĞłåŁĺèŐůåŔŰéŤ

èőĺèőž

çž£çĺŃèřČåžęæIJňèť’ĺäÿŁæŸŕäÿ■çąőåőŽçŽĎïijŇåŻäæ■d’ïijŇåIJĺåd’Žçž£çĺŃçĺŃåžŔäÿ■éŤŹèŕŕåIJŕä¡£çŤ
åIJĺäÿĂäžŻâĂIJèĂĄçŽĎâĂİ Python äžčçăĄäÿ■ïijŇæŸ¿åijŔèŐůåŔŰåŠŇéĞŁæŤ¿éŤĄæŸŕå¿Ĺåÿÿèğ Ą çŽĎãĂ

```
import threading

class SharedCounter:
    '''
    A counter object that can be shared by multiple threads.
    '''
    def __init__(self, initial_value = 0):
        self._value = initial_value
        self._value_lock = threading.Lock()

    def incr(self,delta=1):
        '''
        Increment the counter with locking
        '''
        self._value_lock.acquire()
        self._value += delta
        self._value_lock.release()

    def decr(self,delta=1):
        '''
        Decrement the counter with locking
        '''
        self._value_lock.acquire()
        self._value -= delta
        self._value_lock.release()
```

çŻÿæŕŤäžŐè£Źçğ■æŸ¿åijŔèřČçŤĺçŽĎæŰźæşŢïijŇwith èŕ■åŔëæŻť’åŁääijŸéŻĚïijŇäź§æŻť’äÿ■åőźæŸŞ
release() æŰźæşŢæĹŰèĂĚçĺŃåžŔåIJĺèŐůå¿ŮéŤĄäźŃåŘŐäžğçŤ§åijĆåÿÿè£Źäÿd’çğ■æČĚåĘţïijĹä¡£çŤĺ
with èŕ■åŔëåŔŕäžěä£İèŕĄåIJĺè£Źäÿd’çğ■æČĚåĘţäÿŃäż■èČ¡æ■čçąőéĞŁæŤ¿éŤĄïijL’ãĂĆ
äÿžäžĘéA£åĚ■åĞžçŐřæ■żéŤĄçŽĎæČĚåĘţïijŇä¡£çŤĺéŤĄæIJžåĹűçŽĎçĺŃåžŔåžŤèŕěèő¿åőŽäÿžæŕŔäÿłçž£çĺ
åIJĺ threading åžŞäÿ■è£ŸæŔŘä¿ŻäžĘåĚűäžŰçŽĎåŘŇæ■ěåŐ§èŕ■ïijŇæŕŤåęĆ RLock
åŠŇ Semaphore åŕźèśąãĂĆä¡ĘæŸŕæäźæ■őäžěå¿ĂçżŔéłŇïijŇè£ŹäžŻåŐ§èŕ■æŸŕçŤĺäžŐäÿĂäžŻçL’źæőŁçŽ
RLock ïijĹåŔŕéĞ■åĚěéŤĄïijL’åŔŕäžěèćńåŘŇäÿĂäÿłçž£çĺŃåd’Žæňąè ŐůåŔŰïijŇäÿżèęĄçŤĺæÌěåőđçŐřå§žäžŐ
SharedCounter çśżïijŽ

```
import threading

class SharedCounter:
    '''
    A counter object that can be shared by multiple threads.
    '''
    _lock = threading.RLock()
```

```
    def __init__(self, initial_value = 0):
        self._value = initial_value

    def incr(self,delta=1):
        '''
        Increment the counter with locking
        '''
        with SharedCounter._lock:
            self._value += delta

    def decr(self,delta=1):
        '''
        Decrement the counter with locking
        '''
        with SharedCounter._lock:
             self.incr(-delta)
```

åIJÍäÿŁè¿źè£ŹäÿłäïŃå■ŘäÿïijŇæšąæIJL’åŕźæŕŔäÿĂäÿłåőđä¿Ńäÿ■çŽĎåŔŕåŔŸåŕźèśąåŁăéŤĄïijŇåŔŰè
decr æŰźæşĢãĂĆ è£ŹçğåőđçŐřæŰźåijŔçŽĎäÿĂäÿłçL’źçĆźæŸŕïijŇæŮăèőžè£ŹäÿłçśżæIJL’åd’ŽåřŠäÿłåőđä¿
ä£ąåŔůéĞŔåŕźèśąæŸŕäÿĂäÿłåżžçńŇåIJÍåĚśäžńèőąæĢřåŹÍå§žçąĂäÿŁçŽĎåŘŇæ■ěåŐ§èŕ■ãĂĆåęĆæđIJèőąæĢ
èŕ■åŔěåřĘèőąæĢřåŹÍåĞŔ1ïijŇçž£çÍŃèćńåĚĄèőÿæL’ğèąŇãĂĆwith
èŕ■åŔěæL’ğèąŇçżŞæİ§åŘŐïijŇèőąæĢřåŹÍåŁăïijŚãĂĆåęĆæđIJèőąæĢřåŹÍäÿž0ïijŇçž£çÍŃåřĘèćńéŸżåąđïijŇçŽ

```
from threading import Semaphore
import urllib.request

# At most, five threads allowed to run at once
_fetch_url_sema = Semaphore(5)

def fetch_url(url):
    with _fetch_url_sema:
        return urllib.request.urlopen(url)
```

åęĆæđIJä¡ăåŕźçž£çÍŃåŘŇæ■ěåŐ§èŕ■çŽĎåžĢåśĆçŘĘèőžåŠŇåőđçŐřæĎ§åĚť’èűčïijŇåŔŕäżěåŔĆèĂČæŞ

14.5 12.5 éŸšæ■ćæ■żéŤĄçŽĎåŁăéŤĄæIJžåĹű

éŮőécŸ

ä¡ăæ■čåIJÍåĘŹäÿĂäÿłåd’Žçž£çÍŃçÍŃåžŔïijŇåĚűäÿ■çž£çÍŃéIJĂèęĄäÿĂæňąèŐůåŔŰåd’ŽäÿłéŤĄïijŇæ■d

èğčåĘşæŰźæąĹ

åIJÍåd’Žçž£çÍŃçÍŃåžŔäÿ■ïijŇæ■żéŤĄéŮőécŸå¿Ĺåd’ğäÿĂéČÍåĹĘæŸŕçŤšäžŐçž£çÍŃåŘŇæŮűèŐůåŔŰå
æŮűåĂŹåŔŚçŤ§éŸżåąđïijŇéĆčäźĹè£Źäÿłçž£çÍŃåřšåŔŕèČ¡éŸżåąđåĚűäżŰçž£çÍŃçŽĎæL’ğèąŇïijŇäżŐèĂŇå
èğčåĘşæ■żéŤĄéŮőécŸçŽĎäÿĂçğ■æŰźæąĹæŸŕäÿžçÍŃåžŔäÿ■çŽĎæŕŔäÿĂäÿłéŤĄåĹĘéĚ■äÿĂäÿłåŤŕäÿĂçŽ
æŸŕéİđåÿÿåőźæŸŞåőđçŐřçŽĎïijŇçd’žä¿ŃåęĆäÿŃïijŽ

```
import threading
from contextlib import contextmanager

# Thread-local state to stored information on locks already acquired
_local = threading.local()

@contextmanager
def acquire(*locks):
    # Sort locks by object identifier
    locks = sorted(locks, key=lambda x: id(x))

    # Make sure lock order of previously acquired locks is not␣
↪violated
    acquired = getattr(_local,'acquired',[])
    if acquired and max(id(lock) for lock in acquired) >=␣
↪id(locks[0]):
        raise RuntimeError('Lock Order Violation')

    # Acquire all of the locks
    acquired.extend(locks)
    _local.acquired = acquired

    try:
        for lock in locks:
            lock.acquire()
        yield
    finally:
        # Release locks in reverse order of acquisition
        for lock in reversed(locks):
            lock.release()
        del acquired[-len(locks):]
```

åęĆä¡Ţä¡£çŤĺè£Źäÿłäÿ£äÿŃæŰĞçőąçŘĘåŹĺåŚćïij§ä¡ääŔŕäžěæŇL’çĚğæ■čåÿÿéĂŤå¿ĎåĹŻåžžäÿĂäÿłéŤ
acquire() åĞ¡æŢřæİěçŤşèřůéŤĄïijŇ çd’žä¿ŃåęĆäÿŃïijŽ

```
import threading
x_lock = threading.Lock()
y_lock = threading.Lock()

def thread_1():
    while True:
        with acquire(x_lock, y_lock):
            print('Thread-1')

def thread_2():
    while True:
        with acquire(y_lock, x_lock):
            print('Thread-2')

t1 = threading.Thread(target=thread_1)
```

```
t1.daemon = True
t1.start()

t2 = threading.Thread(target=thread_2)
t2.daemon = True
t2.start()
```

åęĆædIJä¡ăæL'ğèąŇè£Źæőţäžčçă Ąïij Ňä¡ăäijŽåŔŚçŐřåőČå■şä¡£åIJĺäÿ■åŘŇçŽĎåĞ¡æŢřäÿ■äžěäÿ■åŘŇç
åĚűåĚşéŤőåIJĺäžŐïijŇåIJĺçňňäÿĂæőţäžčçăĄäÿ■ïijŇæĹŚäžňářźè£ŹäžŽéŤĄè£ŻèąŇäžĘæŐŠåžŔãĆéĂŽè£Ğ
åęĆædIJæIJL'åď'Žäÿł `acquire()` æŞ■ä¡IJèćńåţŇåěŮèřČçŤĺïijŇåŔŕäžěéĂŽè£Ğçž£çĺŃæIJňåIJřå■ŸåĆĺïijĹT
åĄĞèő¿ä¡ăçŽĎäžčçăĄæŸŕè£ŹæăůåĘŹçŽĎïijŽ

```
import threading
x_lock = threading.Lock()
y_lock = threading.Lock()

def thread_1():

    while True:
        with acquire(x_lock):
            with acquire(y_lock):
                print('Thread-1')

def thread_2():
    while True:
        with acquire(y_lock):
            with acquire(x_lock):
                print('Thread-2')

t1 = threading.Thread(target=thread_1)
t1.daemon = True
t1.start()

t2 = threading.Thread(target=thread_2)
t2.daemon = True
t2.start()
```

åęĆædIJä¡äè£ŘèąŇè£ŹäÿłçL'ĹæIJňçŽĎäžčçăĄïijŇå£ĚåőŽäijŽæIJL'äÿĂäÿłçž£çĺŃåŔŚçŢ§åť'ľæžČïijŇåi

```
Exception in thread Thread-1:
Traceback (most recent call last):
  File "/usr/local/lib/python3.3/threading.py", line 639, in _
↪bootstrap_inner
    self.run()
  File "/usr/local/lib/python3.3/threading.py", line 596, in run
    self._target(*self._args, **self._kwargs)
  File "deadlock.py", line 49, in thread_1
    with acquire(y_lock):
  File "/usr/local/lib/python3.3/contextlib.py", line 48, in __
↪enter__
```

```
    return next(self.gen)
  File "deadlock.py", line 15, in acquire
    raise RuntimeError("Lock Order Violation")
RuntimeError: Lock Order Violation
>>>
```

åŔŠçŤ§åťľæžČçŽĎåŐ§åŻäåIJĺäžŐïijŇæŕŔäÿłçž£çĺŃéČ¡èőřå¡ŢçİĂèĞłåůšåůšçżŔèŐůåŔŰåĹřçŽĎéŤĄã
acquire()　　åĞ¡æŢřäijŽæčĂæ§ěäźŃåĽ■åůšçżŔèŐůåŔŰçŽĎéŤĄåĹÙèąĺïijŇ
çŤšäžŐéŤĄæŸŕæŇĽçĚğå■ĞåžŔæŐŠåĹÙèŐůåŔŰçŽĎïijŇæĽĂäžěåĞ¡æŢřäijŽèőďäÿžäźŃåĽ■åůšèŐůåŔŰç

èőĺèőž

æ■żéŤĄæŸŕæŕŔäÿĂäÿłåď'Žçž£çĺŃçĺŃåžŔéČ¡äijŽéİcäÿť'çŽĎäÿĂäÿłéŮőécŸïijĹåřśåČŔåőČæŸŕæŕŔäÿĂ
çž£çĺŃåŔłèČ¡åŘŇæŮűä£ĺæŇĄäÿĂäÿłéŤĄïijŇè£ŹæăůçĺŃåžŔåřśäÿ■äijŽècńæ■żéŤĄéŮőécŸæĽĂåŻřæĽřãĂĆ

æ■żéŤĄçŽĎæčĂæţŃäÿŐæĄćåď'■æŸŕäÿĂäÿłåĞăäźŐæšąæIJL'äijŸéŽĚçŽĎèğčåĘşæŰźæąĹçŽĎæL'ľåśŢ
è£ŘèąŇçŽĎæŮűåĂŹäijŽæŕŔéŽŤäÿĂæőţæŮűéŮť'éĞ■ç¡őèőąæŢřåŹĺïijŇåIJĺæšąæIJL'åŘŠçŤ§æ■żéŤĄçŽĎæČ
èűĚæŮűïijŇè£ŹæŮűçĺŃåžŔäijŽéĂŽè£ĞéĞ■åŘŕèĞłèžńæĄćåď'■åĹřæ■čåÿÿçŁűæĂĄãĂĆ

éĄ£åĚ■æ■żéŤĄæŸŕåŖęåď'ŰäÿĂçğ■èğčåĘşæ■żéŤĄéŮőécŸçŽĎæŰźåijŔïijŇåIJĺè£ŽçĺŃèŐůåŔŰéŤĄçŽ
æ■żéŤĄçŁűæĂĄãĂĆèŕĄæŸŐářśçŢŹçżŹèŕżèĂĚä¡IJäÿžçżČäźääžĘãĂĆéĄ£åĚ■æ■żéŤĄçŽĎäÿżèęĄæĂİæČşa
æ■żéŤĄçŽĎäÿĂäÿłå£ĚèęĄæİąäžűïijŇäžŐèĂŇéĄ£åĚ■çĺŃåžŔè£ŻåĚěæ■żéŤĄçŁűæĂĄãĂĆ

äÿŃéİcäżěäÿĂäÿłåĚşäžŐçž£çĺŃæ■żéŤĄçŽĎçżŔåĚÿéŮőécŸïijŽâĂIJåŞšå■ęåőűåřśéď'ŘéŮőécŸâĂİïijŇä
éİcåĽ■æIJL'äÿĂçćŮéě■åŠŇäÿĂåŔłç■ůå■ŘãĂĆåIJĺè£ŹéĞŇæŕŔäÿłåŞšå■ęåőűåŔŕäžěçIJŃåĄŽæŸŕäÿĂäÿłçŃı
æĂİèĂČãĂĄåŘČéě■äÿĽçğ■çŁűæĂĄäÿ■çŽĎäÿĂäÿłãĂĆéIJĂèęĄæşĺæĎŔçŽĎæŸŕïijŇæŕŔäÿłåŞšå■ęåőűåŘČ
éĆčäźĹäžŮäžňäžŤäÿłéČ¡åŘłèČ¡æŃ£çİĂäÿĂåŘłç■ůå■ŘåİŘåIJĺéĆčåĎ£ïijŇçŽť'åĹřéě£æ■žãĂĆæ■ď'æŮűäžŮä
äÿŃéİcæŸŕäÿĂäÿłçőĂå■ŢçŽĎä¡£çŤĺæ■żéŤĄéĄ£åĚ■æIJžåĹûèğčåĘşâĂIJåŞšå■ęåőűåřśéď'ŘéŮőécŸâĂİçŽĎå

```
import threading

# The philosopher thread
def philosopher(left, right):
    while True:
        with acquire(left,right):
             print(threading.currentThread(), 'eating')

# The chopsticks (represented by locks)
NSTICKS = 5
chopsticks = [threading.Lock() for n in range(NSTICKS)]

# Create all of the philosophers
for n in range(NSTICKS):
    t = threading.Thread(target=philosopher,
                         args=(chopsticks[n],chopsticks[(n+1) %␣
↪NSTICKS]))
    t.start()
```

æIJĂåŘŐïijŇèęĄçL'źåĹńæşĺæĎŔåĹřïijŇäÿžäžĘéĄ£åĚ■æ■żéŤĄïijŇæL'ĂæIJL'çŽĎåŁäéŤĄæŞ■ä¡IJå£Ěé
acquire()　　åĞ¡æŢřãĂĆåęĆæđIJäżčçăĄäÿ■çŽĎæ§ŘéČĺåĹĘçżŢè£Ğacquire

åĞ¡æŢřçŻťæŐěçŤşèřůéŤĄïijŇéĆčäźĹæŢťäÿłæ■żéŤĄéĄ£åĚ■æIJžåĹűářšäÿ■ètůä¡IJçŤĺäžEãĂĆ

14.6 12.6 ä£ìå■Ÿçž£çÍÑçŽĎçŁűæĂĄä£qæĄŕ

éŮőécŸ

ä¡ăéIJĂèęĄä£Ìå■Ÿæ■čåIJÍè£ŘèąÑçž£çÍÑçŽĎçŁűæĂĄïijÑè£ŹäÿłçŁűæĂĄåŕźäžŐåĚűäżŰçŽĎçž£çÍÑæŸ

èğčåĘşæŰźæąĹ

æIJL'æŮűåIJÍåď'Žçž£çÍÑçijŰçÍÑäÿ■ïijÑä¡ăéIJĂèęĄåŘłä£Ìå■Ÿå¡ŞåL'■è£ŘèąÑçž£çÍÑçŽĎçŁűæĂĄãĂĆ
èęĄè£ŹäźĹåĄŽïijÑåŘŕä¡£çŤÍ `thread.local()` åĹŻåžžäÿĂäÿłæIJňåIJřçž£çÍÑå■ŸåĆÍåŕźèśąãĂĆ
åŕźè£ŹäÿłåŕźèśąçŽĎåśđæĂğçŽĎä£Ìå■ŸåŠÑèŕźåŘŰæŞ■ä¡IJéČ¡åŘłäijŽåŕźæL'ğèąÑçž£çÍÑåŘŕèğĄïijÑèĂÑåĚ

ä¡IJäÿžä¡£çŤÍæIJňåIJřå■ŸåĆÍçŽĎäÿĂäÿłæIJL'èűčçŽĎåőđéŹĚä¿Ńå■ŘïijÑ
èĂČèŹŚåIJÍ8.3åŕŘèŁĆåőŽäźL'è£ĞçŽĎ `LazyConnection` äÿŁäÿŃæŰĞçőąçŘĘåŹÍçśżãĂĆ
äÿŃéÍćæĹŚäžñåŕźåőČè£ŻèąÑäÿĂäžŻåŕŘçŽĎä£őæŤźä¡£å¿ŮåőČåŘŕäžěéĂĆçŤĺäžŐåď'Žçž£çÍŃïijŽ

```
from socket import socket, AF_INET, SOCK_STREAM
import threading

class LazyConnection:
    def __init__(self, address, family=AF_INET, type=SOCK_STREAM):
        self.address = address
        self.family = AF_INET
        self.type = SOCK_STREAM
        self.local = threading.local()

    def __enter__(self):
        if hasattr(self.local, 'sock'):
            raise RuntimeError('Already connected')
        self.local.sock = socket(self.family, self.type)
        self.local.sock.connect(self.address)
        return self.local.sock

    def __exit__(self, exc_ty, exc_val, tb):
        self.local.sock.close()
        del self.local.sock
```

äžčçăĄäÿ■ïijÑèĞłåůśèğĆår§åŕźäžŐ `self.local` åśđæĂğçŽĎä¡£çŤÍãĂĆ
åőČèćńåĹİåğŃåŇŰår¿äÿĂäÿł `threading.local()` åőđä¿ŃãĂĆ
åĚűäžŰæŰźæşŢæŞ■ä¡IJèćńå■ŸåĆÍäÿž `self.local.sock` çŽĎåěŮæŐěå■ŮåŕźèśąãĂĆ
æIJL'äžĘè£ŹäžŻåŕśåŘŕäžěåIJÍåď'Žçž£çÍÑäÿ■åőL'åĚÍçŽĎä¡£çŤÍ `LazyConnection`
åőđä¿ŃäžĘãĂĆä¿ŃåęĆïijŽ

```
from functools import partial
def test(conn):
    with conn as s:
```

```
        s.send(b'GET /index.html HTTP/1.0\r\n')
        s.send(b'Host: www.python.org\r\n')

        s.send(b'\r\n')
        resp = b''.join(iter(partial(s.recv, 8192), b''))

    print('Got {} bytes'.format(len(resp)))

if __name__ == '__main__':
    conn = LazyConnection(('www.python.org', 80))

    t1 = threading.Thread(target=test, args=(conn,))
    t2 = threading.Thread(target=test, args=(conn,))
    t1.start()
    t2.start()
    t1.join()
    t2.join()
```

åőČäźŃæĽĂäžěèąŇå¿ŮéĂŽçŽĎåŐ§åŽäæŸŕæŕŔäÿłçž£çÍŃäijŽåĹŽåžžäÿĂäÿłèĞłåůśäÿŞåśđçŽĎåěŮæŐ
åŻäæ■d'ïijŇå¡Şäÿ■åŘŇçŽĎçž£çÍŃæĽ'ğèąŇåěŮæŐěå■ŮæŞ■ä¡IJæŮűïijŇçŤśäžŐæŞ■ä¡IJçŽĎæŸŕäÿ■åŘŇçŽ

èőÍèőž

åIJÍåď'ğéČÍåĹEçÍŃåžŔäÿ■åĹŽåžžåŠŇæŞ■ä¡IJçž£çÍŃçL'źåőŽçŁűæĂĄåźűäÿ■äijŽæIJL'äžĂäźĹéŮőécŸãĹ
äÿ■è£ĞïijŇå¡ŞåĞžäžEéŮőécŸçŽĎæŮűåĂŹïijŇéĂŽåÿÿæŸŕåŽääÿžæ§Řäÿłåŕźèśąèćńåď'Žäÿłçž£çÍŃä¡£çŤÍåĹ
æŕŤåęĆäÿĂäÿłåěŮæŐěå■ŮæĹŰæŰĞäžűãĂĆä¡ääÿ■èČ¡èől'æL'ĂæIJL'çž£çÍŃèt'ąçŇőäÿĂäÿłå■ŢçŃňåŕźèśąïijĺ
åŽääÿžåď'Žäÿłçž£çÍŃåŘŇæŮűèŕžåŠŇåĘŹçŽĎæŮűåĂŹäijŽäžğçŤ§æůůäźśãĂĆ
æIJňåIJřçž£çÍŃå■ŸåĆÍéĂŽè£Ğèől'è£ŹäžŽètĎæžŘåŔłèČ¡åIJÍècńä¡£çŤÍçŽĎçž£çÍŃäÿ■åŔŕèğĄæİèèğčåĘşè£Ź

æIJňèŁĆäÿ■ïijŇä¡£çŤÍ `thread.local()` åŔŕäžěèől' `LazyConnection` çśżæŤŕæŇĄäÿĂäÿłçž£çÍŃäÿĂäÿłè£đæŐěïijŇ
èĂŇäÿ■æŸŕåŕźäžŐæL'ĂæIJL'çŽĎè£ŻçÍŃéČ¡åŔłæIJL'äÿĂäÿłè£đæŐěãĂĆ

åĚűåŐ§çŘEæŸŕïijŇæŕŔäÿł `threading.local()` åődä¿ŃäÿžæŕŔäÿłçž£çÍŃçżt'æŁd'çİĂäÿĂäÿłå■Ţç
æL'ĂæIJL'æŹőéĂŽåődä¿ŃæŞ■ä¡IJæŕŤåęĆèŐůåŔŰãĂĄä£őæŤźåŠŇåĹăéŹd'åĂijäžĚäžĚæŞ■ä¡IJè£Źäÿłå■Ůå
æŕŔäÿłçž£çÍŃä¡£çŤÍäÿĂäÿłçŃňçńŇçŽĎå■ŮåĚÿåŕśåŔŕäžěä£İèŕĄæŢřæ■őçŽĎéŽŤçęžäžĘãĂĆ

14.7 12.7 åĹŽåžžäÿĂäÿłçž£çÍŃæśă

éŮőécŸ

ä¡ăåĹŽåžžäÿĂäÿłåůěä¡IJèĂĚçž£çÍŃæśăïijŇçŤÍæİěçŻÿåžŤåőćæĹůçńŕèŕůæśĆæĹŰæL'ğèąŇåĚűäžŰçŽĎå

èğčåĘşæŰźæąĹ

`concurrent.futures` åĞ¡æŢřåžŞæIJL'äÿĂäÿł `ThreadPoolExecutor` çśżåŔŕäžěèćńçŤÍæİěåőŇæĹŘè£ŹäÿłäžžåŁąãĂĆ äÿŃéİćæŸŕäÿĂäÿłçőĂå■ŢçŽĎTCPæIJ■åŁąåŹĺijŇä¡£çŤÍäžE

```
from socket import AF_INET, SOCK_STREAM, socket
from concurrent.futures import ThreadPoolExecutor

def echo_client(sock, client_addr):
    '''
    Handle a client connection
    '''
    print('Got connection from', client_addr)
    while True:
        msg = sock.recv(65536)
        if not msg:
            break
        sock.sendall(msg)
    print('Client closed connection')
    sock.close()

def echo_server(addr):
    pool = ThreadPoolExecutor(128)
    sock = socket(AF_INET, SOCK_STREAM)
    sock.bind(addr)
    sock.listen(5)
    while True:
        client_sock, client_addr = sock.accept()
        pool.submit(echo_client, client_sock, client_addr)

echo_server(('',15000))
```

åęĆædIJä¡ăæČşæL’ŃåŁĺåĹŻåżžä¡ăèĞłåůśçŽĎçž£çĺŃæśäïijŇ
éĂŽåÿÿåŘŕäžěä¡£çŤĺäÿĂäÿłQueueæİěè¡żæİ¿åőđçŐřãĂĆäÿŃéİćæŸŕäÿĂäÿłçĺ■å¿őäÿ■åŘŇä¡ĘæŸŕæL’ŃåŁĺåő

```
from socket import socket, AF_INET, SOCK_STREAM
from threading import Thread
from queue import Queue

def echo_client(q):
    '''
    Handle a client connection
    '''
    sock, client_addr = q.get()
    print('Got connection from', client_addr)
    while True:
        msg = sock.recv(65536)
        if not msg:
            break
        sock.sendall(msg)
    print('Client closed connection')

    sock.close()

def echo_server(addr, nworkers):
```

```
    # Launch the client workers
    q = Queue()
    for n in range(nworkers):
        t = Thread(target=echo_client, args=(q,))
        t.daemon = True
        t.start()

    # Run the server
    sock = socket(AF_INET, SOCK_STREAM)
    sock.bind(addr)
    sock.listen(5)
    while True:
        client_sock, client_addr = sock.accept()
        q.put((client_sock, client_addr))

echo_server(('',15000), 128)
```

ä¡£çŤÍ `ThreadPoolExecutor` çŻÿåŕźäžŐæL'ŃåŁÍåőđçŐřçŽĎäÿĂäÿłåě¡åď'ĎåIJÍäžŐåőČä¡£å¿Ů äżżåŁąæŔŘäžd'èĂĚæŻt'æŰźä¿£çŽĎäżŐèćńèřČçŤÍåĞ¡æŢřäÿ■èŐůåŔŰè£ŤåŻđåĂijãĂĆä¿ŃåęĆïijŇä¡ăåŔŕèČ

```
from concurrent.futures import ThreadPoolExecutor
import urllib.request

def fetch_url(url):
    u = urllib.request.urlopen(url)
    data = u.read()
    return data

pool = ThreadPoolExecutor(10)
# Submit work to the pool
a = pool.submit(fetch_url, 'http://www.python.org')
b = pool.submit(fetch_url, 'http://www.pypy.org')

# Get the results back
x = a.result()
y = b.result()
```

ä¿Ńå■Řäÿ■è£ŤåŻđçŽĎhandleåŕźèśąäijŽåÿőä¡ăåď'ĎçŘĘæL'ĂæIJL'çŽĎéŸżåąđäÿŐå■Řä¡IJïijŇçĎűåŘŐä çL'źåĹńçŽĎïijŇ`a.result()` æŞ■ä¡IJäijŽéŸżåąđè£ŻçÍÑçŻt'åĹřåŕźåžŤçŽĎåĞ¡æŢřæL'ğèąŇåőŇæĹŘåźűè£Ť

èőÍèőž

éĂŽåÿÿæÌěèőšïijŇä¡ăåžŤèŕěéĄ£åĚ■çijŰåĘŹçž£çÍÑæŢřéĞŘåŔŕäžěæŮäéŹŘåĹűåćđéŢ£çŽĎçÍÑåžŘãĂĆ

```
from threading import Thread
from socket import socket, AF_INET, SOCK_STREAM

def echo_client(sock, client_addr):
    '''
```

```
    Handle a client connection
    '''
    print('Got connection from', client_addr)
    while True:
        msg = sock.recv(65536)
        if not msg:
            break
        sock.sendall(msg)
    print('Client closed connection')
    sock.close()

def echo_server(addr, nworkers):
    # Run the server
    sock = socket(AF_INET, SOCK_STREAM)
    sock.bind(addr)
    sock.listen(5)
    while True:
        client_sock, client_addr = sock.accept()
        t = Thread(target=echo_client, args=(client_sock, client_
↪addr))
        t.daemon = True
        t.start()

echo_server(('',15000))
```

åř¡çőąè£ŹäÿłäźšåŘŕäžěåůěä¡IJïijŇ ä¡ĘæŸŕåőČäÿ■èČ¡æŁţå¿ąæIJL’äžžèŕŢåŻ¿éĂŽè£ĞåĹŻåžžåď ğéĞŔçž
éĂŽè£Ğä¡£çŤĺécĎåĚĹåĹİåğŇåŇŰçŽĎçž£çĺŃæśäïijŇä¡ååŘŕäžěèő¿ç¡őåŘŇæŮűè£ŘèąŇçž£çĺŃçŽĎäÿŁéŹŘa

ä¡ăåŘŕèČ¡äijŽåĚşå£ČåĹŻåžžåď ğéĞŔçž£çĺŃäijŽæIJL’äžĂäźĹåŘŐæđIJãĂĆ
çŐřäžčæŞ■ä¡IJçşżç§åŘŕäžěå¿Ĺè¡żæİ¿çŽĎåĹŻåžžåĞää■Čäÿłçž£çĺŃçŽĎçž£çĺŃæśãäĂĆ
çŤŽèĞşïijŇåŘŇæŮűåĞää■Čäÿłçž£çĺŃç■L’å¿Ěåůěä¡IJåźűäÿ■äijŽåŕźåĚűäžŰäžčçăĄäžğçŤ§æĂğèČ¡å¡śåŞ■ãĂ
å¡ŞçĎűäžĘïijŇåęĆæđIJæL’ĂæIJL’çž£çĺŃåŘŇæŮűèćńåŤd’éĘŠåźűçńŇå■şåIJĺCPUäÿŁæL’ğèąŇïijŇéĆčåřśäÿ■
éĂŽåÿÿïijŇä¡ääžŤèŕěåŘłåIJĺI/Oåď ĎçŘĘçŻÿåĚşäžčçăĄäÿ■ä¡£çŤĺçž£çĺŃæśãäĂĆ

åĹŻåžžåď ğçŽĎçž£çĺŃæśăçŽĎäÿĂäÿłåŘŕèČ¡éIJĂèęĄåĚşæşĺçŽĎéŮőécŸæŸŕåĘĚå■ŸçŽĎä¡£çŤĺãĂĆ
ä¿ŇåęĆïijŇåęĆæđIJä¡ääIJĺOS Xçşżç§äÿŁéİćåĹŻåžž2000äÿłçž£çĺŃïijŇçşżç§æŸ¿çd’žPythonè£ŻçĺŃä¡£çŤĺã
äÿ■è£Ğïij Ňè£ŹäÿłèőąçőŮéĂŽåÿÿæŸŕæIJL’èŕŕåůőçŽĎãĂĆå¡ŞåĹŻåžžäÿĂäÿłçž£çĺŃæŮűïijŇæŞ■ä¡IJçşżç§äij
æŤ¿ç¡őçž£çĺŃçŽĎæL’ğèąŇæĂĹïijĹéĂŽåÿÿæŸŕ8MBåď ğåřŘïijL’ãĂĆä¡ĘæŸŕè£ŹäÿłåĘĚå■ŸåŘłæIJL’äÿĂåřŔ
åŻăæ■d’ïijŇPythonè£ŻçĺŃä¡£çŤĺåĹřçŽĎçIJ§åőđåĘĚå■ŸåĚűåőđå¿ĹåřŔ
ïijĹæŕŤåęĆïijŇåŕźäžŐ2000äÿłçž£çĺŃæİèèőšïijŇåŘłä¡£çŤĺåĹřäžĘ70MBçŽĎçIJ§åőđåĘĚå■ŸïijŇèĂŇäÿ■æŸŕ
åęĆæđIJä¡ăæŃĚå£ČèŹŽæŃ§åĘĚå■Ÿåď ğåřŘïijŇåŘŕäžěä¡£çŤĺ threading.
stack_size() åĞ¡æŢřæİěéŹ■ä¡ŐåőČãĂĆä¿ŃåęĆïijŽ

```
import threading
threading.stack_size(65536)
```

åęĆæđIJä¡ääŁääÿŁè£ŹæIąèŕ■åŘěåźűåĘ■æňąè£ŘèąŇåL’■éİćçŽĎåĹŻåžž2000äÿłçž£çĺŃèŕŢéłŇïijŇ
ä¡ăäijŽåŔŚçŐřPythonè£ŻçĺŃåŘłä¡£çŤĺåĹřäžĘåď ğæęĆ210MBçŽĎèŹŽæŃ§åĘĚå■ŸïijŇèĂŇçIJ§åőđåĘĚå■Ÿ
æşĺæĎŘçž£çĺŃæĂĹåď ğåřŘå£ĚéąžèĞşåřŠäÿž32768å■ŮèŁĆïijŇéĂŽåÿÿæŸŕçşżç§åĘĚå■Ÿéąţåď ğåřŘïijĹ409

14.8 12.8 çőÄå■ŢçŽĎåźűèąŇçijŰçíŃ

éŮőécŸ

ä¡ăæIJL'äÿłçÍŃåžŔèęĄæL'ğèąŇCPUåŕĘéŻĘåđŃåůěä¡IJïijŇä¡ăæČşèől'äżŰåĹl'çŤĺåd'ŽæäÿCPUçŽĎäijŸå

èğčåĘşæŰźæąĹ

concurrent.futures åžŞæŔŘä¿ŻäžĘäÿĂäÿł ProcessPoolExecutor çśżïijŇ åŔŕèćńçŤĺæÌěåIJĺäÿĂäÿłå■ŢçŃňçŽĎPythonèğčéĞŁåŹĺäÿ■æL'ğèąŇèőąçőŮåŕĘéŻĘåđŃçŽĎäżżåŁąãĂĆ äÿ■è£ĞïijŇèęĄä¡£çŤĺåőČïijŇä¡ăéęŰåĚĹèęĄæIJL'äÿĂäžŻèőąçőŮåŕĘéŻĘåđŃçŽĎäżżåŁąãĂĆ æĹŚäžňéĂŽè£ĞäÿĂäÿłçőÄå■ŢèĂŇåőđéŹĚçŽĎä¿Ńå■ŘæÌěæijŤçd'žåőČãĂĆåĄĞåőŽä¡ăæIJL'äÿłApache webæIJ■åŁąåŹĺæŮěå£ŮçŻőå¡ŢçŽĎgzipåŐŃçijl'åŇĚïijŽ

```
logs/
   20120701.log.gz
   20120702.log.gz
   20120703.log.gz
   20120704.log.gz
   20120705.log.gz
   20120706.log.gz
   ...
```

è£ŻäÿĂæ■ěåĄĞèő¿æŕŔäÿłæŮěå£ŮæŰĞäžűåĘĚåőźçśżäijijäÿŃéÍćè£Źæăůïijž

```
124.115.6.12 - - [10/Jul/2012:00:18:50 -0500] "GET /robots.txt ..."␣
↪200 71
210.212.209.67 - - [10/Jul/2012:00:18:51 -0500] "GET /ply/ ..." 200␣
↪11875
210.212.209.67 - - [10/Jul/2012:00:18:51 -0500] "GET /favicon.ico ..
↪." 404 369
61.135.216.105 - - [10/Jul/2012:00:20:04 -0500] "GET /blog/atom.xml␣
↪..." 304 -
...
```

äÿŃéÍćæŸŕäÿĂäÿłèĎŽæIJñïijŇåIJÍè£ŹäžŻæŮěå£ŮæŰĞäžűäÿ■æ§ěæL'¿åĞžæL'ĂæIJL'èő£éŮőè£Ğrobot

```
# findrobots.py

import gzip
import io
import glob

def find_robots(filename):
    '''
    Find all of the hosts that access robots.txt in a single log␣
↪file
    '''
    robots = set()
```

```
    with gzip.open(filename) as f:
        for line in io.TextIOWrapper(f,encoding='ascii'):
            fields = line.split()
            if fields[6] == '/robots.txt':
                robots.add(fields[0])
    return robots

def find_all_robots(logdir):
    '''
    Find all hosts across and entire sequence of files
    '''
    files = glob.glob(logdir+'/*.log.gz')
    all_robots = set()
    for robots in map(find_robots, files):
        all_robots.update(robots)
    return all_robots

if __name__ == '__main__':
    robots = find_all_robots('logs')
    for ipaddr in robots:
        print(ipaddr)
```

åL’■éÍćçŽĎçÍŃåžŘä¡£çŤÍäžĘéĂŽåÿÿçŽĎmap-reduceéčŐæäijæİěçijŰåĘŹãĂĆ åĞ¡æŢř `find_robots()` åIJÍäÿĂäÿłæŰĞäżűåŘ■éŻĘåŘĹäÿŁåĄŽmapæŞ■ä¡IJïijŇåźűåřĘçżŞæđIJæśĞæĂżäÿžäÿĂääź§åřśæŸŕ `find_all_robots()` åĞ¡æŢřäÿ■çŽĎ `all_robots` éŻĘåŘĹãĂĆçŐřåIJÍïijŇåĄĞèő¿ä¡ăæČşèęĄä£őæŤźè£ŹäÿłçÍŃåžŘèőľåőČä¡£çŤÍåd’ŽæăÿCPUãĂĆå¿ĹçőĂå■ŢâĂŤâĂŤåŘłéIJĂèęĄåřĘmap()æŞ■ä¡IJæŻ£æ■ćäÿžäÿĂäÿł `concurrent.futures` åžŞäÿ■çŤ§æĹŘçŽĎçśżäijijæŞ■ä¡IJå■şåŘŕãĂĆäÿŃéÍćæŸŕäÿĂäÿłçőĂå■Ţä£őæŤźçL’ĹæIJñïijŽ

```
# findrobots.py

import gzip
import io
import glob
from concurrent import futures

def find_robots(filename):
    '''
    Find all of the hosts that access robots.txt in a single log␣
 ↪file

    '''
    robots = set()
    with gzip.open(filename) as f:
        for line in io.TextIOWrapper(f,encoding='ascii'):
            fields = line.split()
            if fields[6] == '/robots.txt':
                robots.add(fields[0])
    return robots
```

```
def find_all_robots(logdir):
    '''
    Find all hosts across and entire sequence of files
    '''
    files = glob.glob(logdir+'/*.log.gz')
    all_robots = set()
    with futures.ProcessPoolExecutor() as pool:
        for robots in pool.map(find_robots, files):
            all_robots.update(robots)
    return all_robots

if __name__ == '__main__':
    robots = find_all_robots('logs')
    for ipaddr in robots:
        print(ipaddr)
```

éĂŽè£Ğè£Źäÿłä£őæŤźåŘŐïijŇè£ŘèąŇè£ŹäÿłèĎŽæIJňäžğçŤ§åŘŇæăůçŽĎçżŞæđIJïijŇä¡ĘæŸŕåIJÍåŻŻ
åőđéŹĚçŽĎæĂğèČ¡äijŸåŇŰæŢĹæđIJæăźæ■ő䡚çŽĎæIJžåŹÍCPUæŢřéĞŔçŽĎäÿ■åŘŇèĂŇäÿ■åŘŇãĂĆ

èőÍèőž

ProcessPoolExecutor çŽĎåĚÿåđŃçŤÍæşŢåęĆäÿŃïijŽ

```
from concurrent.futures import ProcessPoolExecutor

with ProcessPoolExecutor() as pool:
    ...
    do work in parallel using pool
    ...
```

åĚűåŐ§çŘĘæŸŕïijŇäÿĂäÿł ProcessPoolExecutor
åĹŻåžžNäÿłçŃňçńŃçŽĎPythonèğčéĞŁåŹÍïijŇ NæŸŕçşżçż§äÿŁéİćåŔŕçŤÍCPUçŽĎäÿłæŢřãĂĆä¡ååŔŕäżěéĂŽ
ProcessPoolExecutor(N) æİëä£őæŤź åď ĎçŘĘåŹÍæŢřéĞŔãĂĆè£Źäÿłåď ĎçŘĘæśääijŽäÿĂçŻť è£Řèą
çĎűåŘŐåď ĎçŘĘæśäèćńåĚşéŮ■ãĂĆäÿ■è£ĞïijŇçÍŃåžŔäijŽäÿĂçŻť ç■L’å¿ĚçŻť åĹřæL’ĂæIJL’æŔŘäžď çŽĎå

èćńæŔŘäžď åĹřæśääÿ■çŽĎåůěä¡IJå£ĚéążèćńåőŽäźL’äÿžäÿĂäÿłåĞ¡æŢřãĂĆæIJL’äÿď çğ■æŰźæşŢåŐżæ
åęĆæđIJä¡ăæČşèőľäÿĂäÿłåĹŮèąÍæŐÍåŕijæĹŰäÿĂäÿł map()
æŞ■ä¡IJåźűèąŇæL’ğèąŇçŽĎèŕİïijŇåŔŕä¡£çŤÍ pool.map() :

```
# A function that performs a lot of work
def work(x):
    ...
    return result

# Nonparallel code
results = map(work, data)

# Parallel implementation
```

```
with ProcessPoolExecutor() as pool:
    results = pool.map(work, data)
```

åŘęåď ŰïijŇä¡ååŘŕäžěä¡£çŤÍ `pool.submit()` æÌěæL'ŃåŁÍçŽĎæŘŘäžď'å■Ţäÿłäżžå Łąïij Ž

```
# Some function
def work(x):
    ...
    return result

with ProcessPoolExecutor() as pool:
    ...
    # Example of submitting work to the pool
    future_result = pool.submit(work, arg)

    # Obtaining the result (blocks until done)
    r = future_result.result()
    ...
```

åęĆæđIJä¡ăæL'ŃåŁÍæŘŘäžď'äÿĂäÿłäżžåŁąïijŇçżŞæđIJæŸŕäÿĂäÿł Future åőđä¿ŃãĂĆ èęĄèŐůåŘŰæIJĂçżÍçżŞæđIJïijŇä¡ăéIJĂèęĄěŕĈçŤÍåőČçŽĎ result() æŰźæşŢãĂĆ åőČäijŽéŸżåąđè£ŽçÍŃçŻť'åÍřçżŞæđIJèćńè£ŤåŻđæÌěãĂĆ

åęĆæđIJäÿ■æČşéŸżåąđïijŇä¡ăè£ŸåŘŕäžěä¡£çŤÍäÿĂäÿłåŻđěřČåĞ¡æŢřïijŇä¿ŃåęĆïijŽ

```
def when_done(r):
    print('Got:', r.result())

with ProcessPoolExecutor() as pool:
     future_result = pool.submit(work, arg)
     future_result.add_done_callback(when_done)
```

åŽđèřČåĞ¡æŢřæŐěåŘŮäÿĂäÿł Future åőđä¿ŃïijŇèćńçŤÍæÌěèŐůåŘŰæIJĂçźÍçŽĎçżŞæđIJïijÍærŤåęĆ åř¡çőąåď'ĎçŘĘæśăå¿Łåőźæ ŸŞä¡£çŤÍïijŇåIJÍèő¿èőąåď'ğçÍŃåžŔçŽĎæŮűåĂŹè£ŸæŸŕæIJL'å¿Łåď'ŽéIJĂèęĄæ

- è£Źçğ■ázűèąŇåď'ĎçŘĘæŁĂæIJŕåŘłéĂĆçŤÍäžŐéĆčäžŻåŘŕäžěèćńåĹĘèğčäÿžäžŠçŻÿçŃňçńŃéČÍåĹĘçŽ
- èćńæŘŘäžď'çŽĎäżżåŁąå£Ěéążæ ŸŕçőĂå■ŢåĞ¡æŢřå¡ćåijŔãĂĆåŕźäžŐæŰźæşŢãĂĄéŮ■åŇĚåŠŇåĚűäżŮ
- åĞ¡æŢřåŔĆæŢřåŠŇè£ŤåŻđåĂijå£ĚéążåijåőźpickleïijŇåŻääÿžèęĄä¡£çŤÍåĹřè£ŻçÍŃéŮť'çŽĎéĂŽä£ąï
- èćńæŘŘäžď'çŽĎäżżåŁąåĞ¡æŢřäÿ■åžŤä£ÌçŢŹçŁűæĂĄæĹŰæIJL'åL'ŕä¡IJçŤÍãĂĆéŹď'äžĘæL'Şå■řæŮěå

  äÿĂæŮęåŘŕåŁÍä¡ääÿ■èČ¡æŐğåĹűå■Řè£ŻçÍŃçŽĎäżżä¡Ţèą Ñäÿžïij ŇåŽæ■d'æIJĂåě¡ä£ÌæŇĄçőĂå■ŢåŠ
- åIJÍUnixäÿŁè£ŻçÍŃæśăéĂŽè£ĞěŘĈçŤÍ `fork()` çşżçż§èřČçŤÍèćńåĹŽåžžïijŇ

åőČäijŽåĚŃéŽĘPythonèğčéĞŁåŹÍïijŇåŇĚæŃňforkæŮűçŽĎæL'ĂæIJL'çÍŃåžŘçŁűæĂĄãĂĆ èĂŇåIJÍWindowsäÿŁïijŇåĚŃéŽĘèğčéĞŁåŹÍæŮűäÿ■äijŽåĚŃéŽĘçŁűæĂĄãĂĆ åőđéŹĚçŽĎ-forkæŞ■ä¡IJäijŽåIJÍçňňäÿĂæňąèřČçŤÍ `pool.map()` æĹŰ `pool.submit()` åŘŐåŘŚçŤ§ãĂĆ

- å¡Şä¡ăæůůåŘĹä¡£çŤÍè£ŻçÍŃæśăåŠŇåď'Žçž£çÍŃçŽĎæŮűåŹèęĄçL'źåĹńářŘå£ČãĂĆ

ä¡ăåžŤèŕěåIJĺåĹŻåžžäžžä¡Ţçž£çĺŃäźŃåL’■åĚĹåĹŻåžžåźűæ£Äæť’žè£ŻçĺŃæśăïijĹæŕŤåęĆåIJĺçĺŃåžŔåŘŕ

14.9 12.9 PythonçŽĎåĚĺåśĂéŤĄéŮőécŸ

éŮőécŸ

ä¡ăåůšçżŔåŘňèŕť’è£ĞåĚĺåśĂèğčéĞŁåŹĺéŤĄGILïijŇæŃĚå£ČåőČäijŽå¡śåŞ■åĹřåď’Žçž£çĺŃçĺŃåžŔçŽĎæ

èğčåĘşæŰźæąĹ

åř¡çőąPythonåőŇåĚĺæŤŕæŇĄåď’Žçž£çĺŃçijŰçĺŃïijŇ ä¡ĘæŸŕèğčéĞŁåŹĺçŽĎCèŕ■èĺĂåőđçŐŕéČĺåĹĘåIJĺ
åőđéŹĚäÿŁïijŇèğčéĞŁåŹĺèćńäÿĂäÿłåĚĺåśĂèğčéĞŁåŹĺéŤĄä£ÌæŁď’çİĂïijŇåőČçąőä£Ìäžžä¡ŢæŮűåĂŹéČ¡åŔł
GILæIJĂåď’ğçŽĎéŰőécŸåřśæŸŕPythonçŽĎåď’Žçž£çĺŃçĺŃåžŔåźűäÿ■èČ¡åĹl’çŤĺåď’ŽæäÿCPUçŽĎäijŸåŁ£
ïijĹæŕŤåęĆäÿĂäÿłä¡£çŤĺäžĘåď’Žäÿłçž£çĺŃçŽĎèőąçőŮåŕĘéŻĘåđŃçĺŃåžŔåŘłäijŽåIJĺäÿĂäÿłå■ŢCPUäÿŁéĺć

åIJĺèőĺèőžæŹőéĂŽçŽĎGILäźŃåL’■ïijŇæIJL’äÿĂçĆźèęĄåijžěřČçŽĎæŸŕGILåŘłäijŽå¡śåŞ■åĹřéĆčäžŽäÿ
åęĆæđIJä¡ăçŽĎçĺŃåžŔåď’ğéČĺåĹĘåŘłäijŽæűL’åŘŁåĹřI/OïijŇæŕŤåęĆç¡ŚçżIJäžď’äžŠïijŇéĆčäźĹä¡£çŤĺåď’Žç
åŻääÿžåőČäžňåď’ğéČĺåĹĘæŮűéŮťéČ¡åIJĺç■L’å¿ĚãĂĆåőđéŹĚäÿŁïijŇä¡ăåőŇåĚĺåŔŕäžěæŤ¿å£ČçŽĎåĹŻåžžå
çŐŕäžčæŞ■ä¡IJçşżçż§è£ŘèąŇè£ŹäźĹåď’Žçž£çĺŃæšąæIJL’äžžä¡ŢåŐŃåŁŻïijŇæšąåŢěåŘŕæŃĚå£ČçŽĎãĂĆ

èĂŇåŕźäžŐä¿İèţŰCPUçŽĎçĺŃåžŔïijŇä¡ăéIJĂèęĄåijĐæÿĚæěŽæL’ğèąŇçŽĎèőąçőŮçŽĎçL’źçĆźãĂĆ
ä¿ŃåęĆïijŇäijŸåŇŰåžŢåśĆçőŮæşŢèęĄæŕŤä¡£çŤĺåď’Žçž£çĺŃè£ŘèąŇå£ńå¿Ůåď’ŽãĂĆ
çśżäijijçŽĎïijŇçŤśäžŐPythonæŸŕèğčéĞŁæL’ğèąŇçŽĎïijŇåęĆæđIJä¡ăåřĘéČčäžŽæĂğèČ¡çŞűécĹäžčçăĄçğżå
éĂ§åžęäź§äijŽæŔŘå■ĞçŽĎå¿Ĺå£ńãĂĆåęĆæđIJä¡ăèęĄæŞ■ä¡IJæŢŕçżĎïijŇéĆčäźĹä¡£çŤĺNumPyè£ŹæăůçŽĎ
æIJĂåŘŐïijŇä¡ăè£ŸåŔŕäžěèĂČèŹŠäÿŇåĚűäžŮåŔŕéĂL’ăődçŐŕæŰźæąĹïijŇæŕŤåęĆPyPyïijŇăőČéĂŽè£ĞäÿA
ïijĹäÿ■è£ĞåIJĺåĘŹè£ŹæIJňäźęçŽĎæŮűåĂŹåőČè£Ÿäÿ■èČ¡æŤŕæŇĄPython 3ïijL’ãĂĆ

è£ŸæIJL’äÿĂçĆźèęĄæşĺæĐŔçŽĎæŸŕïijŇçž£çĺŃäÿ■æŸŕäÿŞéŮĺçŤĺæİěäijŸåŇŰæĂğèČ¡çŽĎãĂĆ
äÿĂäÿłCPUä¿İèţŰåđŃçĺŃåžŔåŘŕèČ¡äijŽä¡£çŤĺçž£çĺŃæİěçőąçŘEäÿĂäÿłåŻ¿å¡ćçŤĺæĹůçŢŇéİćãĂĄäÿĂäÿłç
è£ŹæŮűåĂŹïijŇGILäijŽäžğçŤ§äÿĂäžŻéŮőécŸïijŇåŽääÿžåęĆæđIJäÿĂäÿłçž£çĺŃéŢ£æIJ§æŇĄæIJL’GILçŽĐ
äžŃåődäÿŁïijŇäÿĂäÿłåĘŹçŽĎäÿ■åě¡çŽĎCèŕ■èĺĂæL’l’åśŢäijŽåŕijèĞt’è£ŹäÿłéŮőécŸæŻt’åŁääÿěéĞ■ïijŇ
åř¡çőąäžčçăĄçŽĎèőąçőŮéČĺåĹĘäijŽæŕŤäźŃåL’■è£ŘèąŇçŽĎæŻt’å£ńäžŽãĂĆ

èŕť’äžĘè£ŹäźĹåď’ŽïijŇçŐŕåIJĺæČşèŕť’çŽĎæŸŕæĹŚäžňæIJL’äÿd’çğ■ç■ŰçŢěæİèèğčåĘşGILçŽĎçijžçĆźãĂ
éęŰåĚĹïijŇåęĆæđIJä¡ăåőŇåĚĺåůěä¡IJäžŐPythonçŐŕåćČäÿ■ïijŇä¡ăåŘŕäžěä¡£çŤĺ
`multiprocessing` æĺąåİŮæİěåĹŻåžžäÿĂäÿłè£ŽçĺŃæśăïijŇ
åźűåČŔå■ŔåŘŇåď’ĎçŘĘåŹĺäÿĂæăůçŽĎä¡£çŤĺåőČãĂĆä¿ŃåęĆïijŇåĄĞåęĆä¡ăæIJL’åęĆäÿŃçŽĎçž£çĺŃäžčç

```
# Performs a large calculation (CPU bound)
def some_work(args):
    ...
    return result

# A thread that calls the above function
def some_thread():
    while True:
        ...
        r = some_work(args)
    ...
```

ä£őæŤźäžčçăĄïijŇä¡£çŤĺè£ŻçÍŃæśăïijŽ

```
# Processing pool (see below for initiazation)
pool = None

# Performs a large calculation (CPU bound)
def some_work(args):
    ...
    return result

# A thread that calls the above function
def some_thread():
    while True:
        ...
        r = pool.apply(some_work, (args))
        ...

# Initiaze the pool
if __name__ == '__main__':
    import multiprocessing
    pool = multiprocessing.Pool()
```

è£ŹäýłéĂŽè£Ğä¡£çŤĺäÿĂäýłæŁĂåůğåĽ'çŤĺè£ŻçÍŃæśăèğčåĘşäžĘGILçŽĎéŮőécŸãĂĆ
å¡ŞäÿĂäýłçž£çÍŃæČşèçĄæĽ'ğèąŇCPUåŕĘéŻĘåđŃåůěä¡IJæŮűïijŇäijŽåřĘäżżåŁąåŔŞçżŹè£ŻçÍŃæśăãĂĆ
çĎűåŘŐè£ŻçÍŃæśăäijŽåIJĺåŔęåď'ŰäÿĂäýłè£ŻçÍŃäÿ■åŘŕåŁĺäÿĂäýłå■ŢçŃňçŽĎPythonèğčéĞŁåŹĺæİěåůěä¡I
å¡Şçž£çÍŃç■Ľ'å¿ĚçżŞæđIJçŽĎæŮűåĂŹäijŽéĞŁæŤ¿GILãĂĆ åźűäÿŤïijŇçŤśäžŐèőąçőŮäżżåŁąåIJĺå■ŢçŃňèğ
åIJĺäÿĂäýłåď'Žæäÿçşżçž§äýŁéİćïijŇä¡ääijŽåŔŞçŐřè£ŹäýłæŁĂæIJŕåŔŕäžěèőľ'ä¡ăå¿Ĺåě¡çŽĎåĹ'çŤĺåď'ŽCPU

åŘęåď'ŰäÿĂäýłèğčåĘşGILçŽĎç■ŰçŢěæŸŕä¡£çŤĺCæĽ'ľ'åśŢçijŰçÍŃæŁĂæIJŕãĂĆ
äÿżèęĄæĂİæČşæŸŕåřĘèőąçőŮåŕĘéŻĘąđŃäżżåŁąè¡ňçğżçżŹCïijŇèů§PythonçŃňçńŃïijŇåIJĺåůěä¡IJçŽĎæŮűş
è£ŹåŘŕäžěéĂŽè£ĞåIJĺCäžčçăĄäÿ■æŔŠåĚëäÿŃéİćè£ŹæăůçŽĎçĽźæőŁåőŔæİěåőŃæĹŘïijŽ

```
#include "Python.h"
...

PyObject *pyfunc(PyObject *self, PyObject *args) {
   ...
   Py_BEGIN_ALLOW_THREADS
   // Threaded C code
   ...
   Py_END_ALLOW_THREADS
   ...
}
```

åęĆæđIJä¡ăä¡£çŤĺåĚűäžŰåůěåĚůèő£éŰőCèŕ■èÍĂïijŇæŕŤåęĆåŕźäžŐCythonçŽĎctypesåžŞïijŇä¡ăäÿ■éIJĂ
ä¿ŃåęĆïijŇctypesåIJĺèřČçŤĺCæŮűäijŽèĞłåŁĺéĞŁæŤ¿GILãĂĆ

èőÍèőž

èőÿåď ŽçÍŃåžŔåŚŸåIJÍéÌćåŕźçž£çÍŃæĂğèČ¡éŮőéćŸçŽĎæŮűåĂŹïijŇél ňäÿŁåřśäijŽæĂłç¡ŁGILïijŇäžĂ
åĚűåőđè£Źæăůå■Řåď łäÿ■åŐŽéĄŞäź§åď łåď ľ çIJ§äžĘçĆźãĂĆ
ä¡IJäÿžäÿĂäÿłçIJ§åőđçŽĎä¿Ńå■ŘïijŇåIJÍåď Žçž£çÍŃçŽĎç¡ŚçżIJçijŰçÍŃäÿ■çěđçğŸçŽĎ
stalls åŔŕèČ¡æŸŕåŽääÿžåĚűäžŰåŐ§åŽäæŕŤåęĆäÿĂäÿłDNSæ§ěæL’¿åžűæŮűïijŇèĂŇèů§GILæŕńæŮăåĚş
æIJĂåŘŐä¡ăçIJ§çŽĎéIJĂèęĄåĚĹåŐżæŘđæĞĆä¡ăçŽĎäžčçăĄæŸŕåŘęçIJ§çŽĎèćńGILå¡śåŞ■åĹřãĂĆ
åŘŇæŮűè£ŸèęĄæŸŐçŹ¡GILåď ğéČĺåĹĘéČ¡åžŤèŕěåŔłåĚşæşÍCPUçŽĎåď ĎçŘĘèĂŇäÿ■æŸŕI/O.

åęĆæđIJä¡ăåĞĘåď Ğä¡£çŤÍäÿĂäÿłåď ĎçŘĘåŹÍæśăïijŇæşÍæĎŔçŽĎæŸŕè£Źæăůå ĄŽæűL’åŔŁåĹřæŢřæ■ć
èćńæL’ğèąŇçŽĎæŞ■ä¡IJéIJĂèęĄæŤ¿åIJÍäÿĂäÿłéĂŽè£Ğdefèŕ■åŘěåőŽäźL’çŽĎPythonåĞ¡æŢřäÿ■ïijŇäÿ■èČ¡
åźűäÿŤåĞ¡æŢřåŔĆæŢřåŠŇè£ŤåŻđåĂijå£ĚéążèęĄåĚijåőźpickleãĂĆ
åŘŇæăůïijŇèęĄæL’ğèąŇçŽĎäżżåŁąéĞŘå£Ěéążèűşåď §åď ğäżěäijèèąéćĺåď ŰçŽĎéĂŽä£ąåijĂéŤĂãĂĆ

åŘęåď ŰäÿĂäÿłéŽ¿çĆźæŸŕå¡Şæůůåŕĺä¡£çŤÍçž£çÍŃåŠŇè£ŻçÍŃæśăçŽĎæŮűåĂŹäijŽèőľä¡ăå¿Ĺåď ť’çŰï
åęĆæđIJä¡ăèęĄåŘŇæŮűä¡£çŤÍäÿd’èĂĚïijŇæIJĂåě¡åIJÍçÍŃäžŘåŘŕåŁÍæŰűïijŇåĹŻåżžäżżä¡Ţçž£çÍŃäźŃåL’■å
çĎűåŘŐçž£çÍŃä¡£çŤÍåŘŇæăůçŽĎè£ŻçÍŃæśăæİèè£ŻèąŇåőĆäżnçŽĎèőąçőŮåŕĘéŻĘđŃåůëä¡IJãĂĆ

CæL’l’åśŢæIJĂéĞ■èęĄçŽĎçL’źå¿ĄæŸŕåőĆäżnåŠŇPythonèğčéĞŁåŹÍæŸŕä£ÍæŇĄçŃnçńŃçŽĎãĂĆ
äź§åřśæŸŕèŕť’ïijŇåęĆæđIJä¡ăåĞĘåď ĞåřĘPythonäÿ■çŽĎäżżåŁąåĹĘéĚ■åĹřCäÿ■åŐżæL’ğèąŇïijŇ
ä¡ăéIJĂèęĄçąőä£ÍCäżčçăĄçŽĎæŞ■ä¡IJèů§Pythonä£ÍæŇĄçŃnçńŃïijŇ
è£Źåřśæ ĎŔåŚşçÍĂäÿ■èęĄä¡£çŤÍPythonæŢřæ■őçżŞæđĎäżěåŔŁäÿ■èęĄěřČçŤÍPythonçŽĎC
APIãĂĆ åŘęåď ŰäÿĂäÿłåřśæŸŕä¡ăèęĄçąőä£ÍCæL’l’åśŢæL’ĂåĄŽçŽĎåůěä¡IJæŸŕèűşåď §çŽĎïijŇåĂijå¿Ůä¡ăè
äź§åřśæŸŕèŕť’CæL’l’åśŢæŃĚèt’§ètůäžĘåď ğéĞŘçŽĎèőąçőŮäżżåŁąïijŇèĂŇäÿ■æŸŕåřŚæŢřåĞăäÿłèőąçőŮãĂĆ

è£ŹäžŻèğčåĘşGILçŽĎæŰźæąĹåźűäÿ■èČ¡éĂĆçŤÍäžŐæL’ĂæIJL’éŮőéćŸãĂĆ
ä¿ŃåęĆïijŇæ§ŘäžŻçśżåđŃçŽĎåžŤçŤÍçÍŃåžŘåęĆæđIJèćńåĹĘèğčäÿžåď Žäÿłè£ŻçÍŃåď ĎçŘĘçŽĎèŕĺåźűäÿ■è
äź§äÿ■èČ¡åřĘåőĆçŽĎéČĺåĹĘäžčçăĄæŤźæĹŘCèŕ■èÍĂæL’ğèąŇãĂĆ
åŕźäžŐè£ŹäžŻåžŤçŤÍçÍŃåžŘïijŇä¡ăåřśèęĄèĞłåůśéIJĂæśĆèğčåĘşæŰźæąĹäžĘ
ïijĹæŕŤåęĆåď Žè£ŻçÍŃèő£éŮőåĚśäžńåĘĚå■ŸåŇžïijŇåď Žèğčæđ ŘåŹÍè£ŘèąŇäžŐåŘŇäÿĂäÿłè£ŻçÍŃç■L’ïijL
æĹŰèĂĚïijŇä¡ăè£ŸåŔŕäżěèĂČèŹŠäÿŃåĚűäžŰçŽĎèğčéĞŁåŹÍåőđçŐřïijŇæŕŤåęĆPyPyãĂĆ

äžĘèğčæŻť’åď ŽåĚşäžŐåIJÍCæL’l’åśŢäÿ■éĞŁæŤ¿GILïijŇèŕůåŔĆèĂČ15.7åŠŇ15.10åŕŘèŁĆãĂĆ

14.10 12.10 åőŽäźĽäÿĂäÿłActoräżżåŁą

éŮőéćŸ

ä¡ăæČşåőŽäźL’èů§actoræĺąåijŔäÿ■çśżäijijâĂIJactorsâĂİèğŠèL’šçŽĎäżżåŁą

èğčåĘşæŰźæąĹ

actoræĺąåijŔæŸŕäÿĂçğ■æIJĂåŔď èĂĄçŽĎäź§æŸŕæIJĂçőĂå■ŢçŽĎåźűèąŇåŠŇåĹĘåÿČåijŔèőąçőŮèğčä
äžŃåőđäÿŁïijŇåőČåď ľçŤ§çŽĎçőĂå■ŢæĂğæŸŕåőČąęĆæ■ď’åŘŮæńćè£ŐçŽĎéĞ■èęĄåŐ§åŽääźŃäÿĂãĂĆ
çőĂå■ŢæİèèőšïijŇäÿĂäÿłactoråřśæŸŕäÿĂäÿłåźűåŘŚæL’ğèąŇçŽĎäżżåŁąïijŇåŘłæŸŕçőĂå■ŢçŽĎæL’ğèąŇåŘ
åŞ■åžŤè£ŹäžŻæűĹæĄŕæŮűïijŇåőČåŔŕèČ¡è£ŸäijŽçżŹåĚűäžŰactoråŘŚéĂĄæŽť’è£ŽäÿĂæ■ěçŽĎæűĹæĄŕãĂ
actoräźŃéŮť’çŽĎéĂŽä£ąæŸŕå■ŢåŘŚåŠŇåijĆæ■ěçŽĎãĂĆåŽăæ■ď’ïijŇæűĹæĄŕåŘŚéĂĄèĂĚäÿ■ç§ěéĄŞæűĹ
äź§äÿ■äijŽæŐěæŤűåĹřäÿĂäÿłæűĹæĄŕåůšècńåď ĎçŘĘçŽĎåŽđåžŤæĹŰéĂŽç§ěãĂĆ

çżŞåŘĹä¡£çŤĺäÿĂäÿłçž£çĺŃåŠŇäÿĂäÿłéŸ§åĹŮåŔŕäżěå¿Ĺåőźæ ŸŞçŽĎåőŽäźĽ’actorïijŇä¿ŃåęĆïijŽ

```
from queue import Queue
from threading import Thread, Event

# Sentinel used for shutdown
class ActorExit(Exception):
    pass

class Actor:
    def __init__(self):
        self._mailbox = Queue()

    def send(self, msg):
        '''
        Send a message to the actor
        '''
        self._mailbox.put(msg)

    def recv(self):
        '''
        Receive an incoming message
        '''
        msg = self._mailbox.get()
        if msg is ActorExit:
            raise ActorExit()
        return msg

    def close(self):
        '''
        Close the actor, thus shutting it down
        '''
        self.send(ActorExit)

    def start(self):
        '''
        Start concurrent execution
        '''
        self._terminated = Event()
        t = Thread(target=self._bootstrap)

        t.daemon = True
        t.start()

    def _bootstrap(self):
        try:
            self.run()
        except ActorExit:
            pass
        finally:
            self._terminated.set()
```

```
    def join(self):
        self._terminated.wait()

    def run(self):
        '''
        Run method to be implemented by the user
        '''
        while True:
            msg = self.recv()

# Sample ActorTask
class PrintActor(Actor):
    def run(self):
        while True:
            msg = self.recv()
            print('Got:', msg)

# Sample use
p = PrintActor()
p.start()
p.send('Hello')
p.send('World')
p.close()
p.join()
```

è£Źäÿłä¿Ńå■Řäÿ■ïijŇä¡ää¡£çŤĺactoråőđä¿ŃçŽĎ send() æŰźæşŢåŔŠéĂĄæúĹæĄŕçżŹåőČäžňãĂĆ åĚűæIJžåĹűæŸŕïijŇè£ŹäÿłæŰźæşŢäijŽářĘæúĹæĄŕæŤ¿åĚěäÿĂäÿçĎűåŘŐářĘåĚűè¡ňäžd'çżŹåd'ĎçŘĘèćńæŐěåŔŮæűĹæĄŕçŽĎäÿĂäÿłåĘĚéČĺçž£çĺŃãĂĆ close() æŰźæşŢéĂŽè£ĞåIJĺéŸ§åĹŮäÿ■æŤ¿åĚěäÿĂäÿłçL'źæőŁçŽĎđąŞĺåĚţåĂijïijĹActorExitïijL'æİěåĚşéŰçŤĺæĹůåŔŕäžěéĂŽè£Ğçżğæl'£ActoråźűåőŽäźL'åőđçŐřèĞłåůšåd'ĎçŘĘéĂżè¿Śrun()æŰźæşŢæİěåőŽäźL'æŰřActorExit åijĆåÿÿçŽĎä¡£çŤĺåřśæŸŕçŤĺæĹůèĞłåőŽäźL'äžčçăĄåŔŕäžěåIJĺéIJĂèęĄçŽĎæŮűåĂŹæİěæ■ŢèĆïijĹåijĆåÿÿèćńget()æŰźæşŢæŁŻåĞžåźűäijäæŠ■åĞžåŐżïijL'ãĂĆ

åęĆædIJä¡ăæŤ¿åő¡åŕźäžŐåŘŇæ■ěåŠŇåijĆæ■ěæűĹæĄŕåŔŠéĂĄçŽĎèęĄæśĆïijŇ çśżactoråŕźèśąè£ŸåŔŕäžěéĂŽè£ĞçŤ§æĹŘåŹĺæİěçőĂåŇŰåőŽäźL'ãĂĆä¿ŃåęĆïijŽ

```
def print_actor():
    while True:

        try:
            msg = yield       # Get a message
            print('Got:', msg)
        except GeneratorExit:
            print('Actor terminating')

# Sample use
p = print_actor()
next(p)      # Advance to the yield (ready to receive)
p.send('Hello')
```

```
p.send('World')
p.close()
```

èőÍèőž

actoræÍąåijŘçŽĎé■ĚåŁŻåřśåIJÍäžŐåőČçŽĎçőÄå■ŢæĂğãĂĆ åőđéŹĚäÿŁïijÑè£ŹéĞÑäżĚäżĚåŔłæIJL’äÿĂäÿłæăÿå£ČæŞ■ä¡IJ send() . çŤŽèĞşïijÑåŕźäžŐåIJÍå§žäžŐactorçşżçż§äÿ■çŽĎâĂIJæűĹæĄŕâĂİçŽĎæşŻåŇŰæęĆå£ţåŔŕäżěåůšåd’Žçğ■æŰ ä¿ŇåęĆïijÑä¡ăåŔŕäżěäżěåĚČçżĎå¡ćåijŔäijăéĂŠæăĞç■¿æűĹæĄïijÑèől’actoræL’ğèąÑäÿ■åŘŇçŽĎæŞ■ä¡IJïij

```
class TaggedActor(Actor):
    def run(self):
        while True:
            tag, *payload = self.recv()
            getattr(self,'do_'+tag)(*payload)

    # Methods correponding to different message tags
    def do_A(self, x):
        print('Running A', x)

    def do_B(self, x, y):
        print('Running B', x, y)

# Example
a = TaggedActor()
a.start()
a.send(('A', 1))       # Invokes do_A(1)
a.send(('B', 2, 3))    # Invokes do_B(2,3)
```

ä¡IJäÿžåŘęåd’ŰäÿĂäÿłä¿Ńå■ŘïijÑäÿŃéÍćçŽĎactoråĚĄèőÿåIJÍäÿĂäÿłåůěä¡IJèĂĚäÿ■è£ŘèąÑäżżæĎŘçŽ åźűäÿŤéĂŽè£ĞäÿĂäÿłçL’źæőŁçŽĎResultåŕźèśąè£ŤåŻđçżŞæđIJïijŽ

```
from threading import Event
class Result:
    def __init__(self):
        self._evt = Event()
        self._result = None

    def set_result(self, value):
        self._result = value

        self._evt.set()

    def result(self):
        self._evt.wait()
        return self._result

class Worker(Actor):
    def submit(self, func, *args, **kwargs):
```

```
        r = Result()
        self.send((func, args, kwargs, r))
        return r

    def run(self):
        while True:
            func, args, kwargs, r = self.recv()
            r.set_result(func(*args, **kwargs))

# Example use
worker = Worker()
worker.start()
r = worker.submit(pow, 2, 3)
print(r.result())
```

æIJĂåŘŐïijÑâĂIJåŔŠéĂĄâĂİäÿĂäÿłäżżåŁąæűĹæĄŕçŽĎæęĆå£ţåŔŕäżěèćńæL'ľåśŢåĹřåď'Žè£ŻçÍÑçŤŽ
ä¿ÑåęĆïijÑäÿĂäÿłçśżactorårźŕèśąçŽĎ `send()` æŰźæşŢåŔŕäżěèćńçijŰçÍÑèőľ'åőČèČ¡åIJĺäÿĂäÿłåëŮæŐëå■Ů
æĹŰéĂŽè£Ğæ§ŘäžŽæűĹæĄŕäÿ■éŮt'äżűïijĹæŕŤåęĆAMQPãĂĄZMQç■L'ïijL'æİěåŔŠéĂĄãĂĆ

14.11 12.11 åőđçŐřæűĹæĄŕåŔŠåÿČ/èőćéŸĚæĺąåđŃ

éŮőécŸ

ä¡ăæIJL'äÿĂäÿłå§žäžŐçž£çÍÑéĂŽä£ąçŽĎçÍÑåžŔïijÑæČşèőľ'åőČäžňåőđçŐřåŔŠåÿČ/èőćéŸĚæĺąåijŔçŽİ

èğčåĘşæŰźæąĹ

èęĄåőđçŐřåŔŠåÿČ/èőćéŸĚçŽĎæűĹæĄŕéĂŽä£ąæĺąåijŔïijŇ
ä¡ăéĂŽåÿÿèęĄåijŢåĚěäÿĂäÿłå■ŢçÑňçŽĎâĂIJäžđ'æ■ćæIJžâĂİæĹŰâĂIJç¡ŚåĚşâĂİåŕźèśąä¡IJäÿžæL'ĂæIJL'æ
äź§åřśæŸŕèŕt'ïijÑäÿ■çŽt'æŐěåřĘæűĹæĄŕäżŐäÿĂäÿłäżżåŁąåŔŠéĂĄåĹřåŘęäÿĂäÿłïijÑèĂŇæŸŕåřĘåĚűåŔŠé
çĎűåŘŐçŤśäžđ'æ■ćæIJžåřĘåőČåŔŠéĂĄçźŹäÿĂäÿłæĹŰåđ'ŽäÿłèćńåĕşèĄŤäżżåŁąãĂĆäÿÑéİćæŸŕäÿĂäÿłéİđ

```
from collections import defaultdict

class Exchange:
    def __init__(self):
        self._subscribers = set()

    def attach(self, task):
        self._subscribers.add(task)

    def detach(self, task):
        self._subscribers.remove(task)

    def send(self, msg):
        for subscriber in self._subscribers:
            subscriber.send(msg)
```

```
# Dictionary of all created exchanges
_exchanges = defaultdict(Exchange)

# Return the Exchange instance associated with a given name
def get_exchange(name):
    return _exchanges[name]
```

äÿĂäÿłäžď æ■ćæIJžåřśæŸŕäÿĂäÿłæŹőéĂŽåŕźèśąïijŇèť §èť čçžť æŁď äÿĂäÿłæť żèůČçŽĎèőćéŸĚèĂĚéŻł
æŕŔäÿłäžď æ■ćæIJžéĂŽè£ĞäÿĂäÿłåŘ■çğřåőŽä¡■ïijŇget_exchange()
éĂŽè£ĞçżŹåőŽäÿĂäÿłåŘ■çğřè£ŤåŻđçŻÿåžŤçŽĎ `Exchange` åőđä¿ŃãĂĆ

äÿŃéİćæŸŕäÿĂäÿłçőĂå■Ţä¿Ńå■ŘïijŇæijŤçď žäžĘåęĆä¡Ţä¡£çŤĺäÿĂäÿłäžď æ■ćæIJžïijŽ

```
# Example of a task.  Any object with a send() method

class Task:
    ...
    def send(self, msg):
        ...

task_a = Task()
task_b = Task()

# Example of getting an exchange
exc = get_exchange('name')

# Examples of subscribing tasks to it
exc.attach(task_a)
exc.attach(task_b)

# Example of sending messages
exc.send('msg1')
exc.send('msg2')

# Example of unsubscribing
exc.detach(task_a)
exc.detach(task_b)
```

åř¡çőąåŕźäžŐè£ŹäÿłéŮőécŸæIJL’å¿Ĺåď ŽçŽĎåŔŸçğ■ïijŇäÿ■è£ĞäÿĞåŔŸäÿ■çężåĚűåőŮãĂĆ
æűĹæĄŕäijŽècńåŔŠéĂĄçżŹäÿĂäÿłäžď æ■ćæIJžïijŇçĎűåŘŐäžď æ■ćæIJžäijŽåřĘåőČäžňåŔŠéĂĄçżŹècńçżŠå

èőĺèőž

éĂŽè£ĞéŸ§åĹŮåŔŠéĂĄæűĹæĄçŽĎäżżåŁąæĹŰçž£çĺÑçŽĎæĺąåijŔå¿Ĺåőźæ ŸŞècńåőđçŐřåźűäÿŤäź§
äÿ■è£ĞïijŇä¡£çŤĺåŔŠåÿČ/èőćéŸĚæĺąåijŔçŽĎåě¡åď ĎæŻť åŁäæŸŐæŸ¿ãĂĆ

éęŰåĚĹïijŇä¡£çŤĺäÿĂäÿłäžď æ■ćæIJžåŔŕäżěçőĂåŇŰåď ğéČĺåĹĘæűL’åŔŁåĹřçž£çĺÑéĂŽä£ąçŽĎåůěä¡I
æŮäéIJĂåŐżåĘŹéĂŽè£Ğåď Žè£ŻçĺÑæĺąåİŮæİěæŞ■ä¡IJåď Žäÿłçž£çĺÑïijŇä¡ääŔłéIJĂèęĄä¡£çŤĺè£Źäÿłäžď æ

æ§Řçğ■çÍŇåžęäÿŁïijŇè£Źäÿłářśèů§æŮěå£ŮæÍąåİŮçŽĎåůěä¡IJåŐ§çŘęçśżäijijãĂĆ
åőđéŹĚäÿŁïijŇåőČåŘŕäżěè¡żæİ¿çŽĎèğčèĂęçÍŇåžŔäÿ■åď'ŽäÿłäżżåŀąãĂĆ

åĚűæňąïijŇäžď'æ■ćæIJžåź£æŠ■æűĹæĄŕçżŹåď'Žäÿłèőćé ŸĚèĂĚçŽĎèČ¡åŁŻåÿęæİěäžĘäÿĂäÿłåĚÍæŰřçŽ
ä¿ŇåęĆïijŇä¡ăåŘŕäżěä¡£çŤÍåď'Žäżżåŀąçşżçż§ãĂĄåź£æŠ■æĹŰæĽĞåĞžãĂĆ
ä¡ăè£ŸåŘŕäżěéĂŽè£ĞäżěæŹőéĂŽèőćé ŸĚèĂĚèžńäż¡çżŚåőŽæİěædĎåżžèřČèŕŢåŠŇèŕŁæŰ■åůěåĚůãĂĆ
ä¿ŇåęĆïijŇäÿŇéİćæŸŕäÿĂäÿłçőĂå■ŢçŽĎèŕŁæŰ■çśżïijŇåŘŕäżěæŸ¿çď'žèćńåŔŚéĂĄçŽĎæűĹæĄŕïijŽ

```
class DisplayMessages:
    def __init__(self):
        self.count = 0
    def send(self, msg):
        self.count += 1
        print('msg[{}]: {!r}'.format(self.count, msg))

exc = get_exchange('name')
d = DisplayMessages()
exc.attach(d)
```

æIJĂåŘŐïijŇèŕěåőđçŐŕçŽĎäÿĂäÿłéĞ■èęĄçL'źçĆźæŸŕåőČèČ¡åĚijåőźåď'Žäÿłâ ĂIJtask-likeâĂİåŕźèśąãĂĆ ä¿ŇåęĆïijŇæűĹæĄŕæŐěåŘŮèĂĚåŘŕäżěæŸŕactorïijĹ12.10åřŔèŁĆäżŃçż■ïijL'ãĂĄå■ŔçÍŇ `send()` æŰźæşŢçŽĎäÿIJèě£ãĂĆ

åĚşäžŐäžď'æ■ćæIJžçŽĎäÿĂäÿłåŘŕèČ¡éŮőécŸæŸŕåŕźäžŐèőćé ŸĚèĂĚçŽĎæ■čçąőçżŚåőŽåŠŇèğčçżŚãĂ
äÿžäžĘæ■čçąőçŽĎçőąçŘĘèţĎæžŘïijŇæŕŘäÿĂäÿłçżŚåőŽçŽĎèőćé ŸĚèĂĚå£ĚéążæIJĂçżĹèęĄèğčçżŚãĂĆ
åIJĺäżčçăĄäÿ■éĂŽåÿÿäijŽæŸŕåČŔäÿŃéİćè£ŹæăůçŽĎæĺąåijŔïijŽ

```
exc = get_exchange('name')
exc.attach(some_task)
try:
    ...
finally:
    exc.detach(some_task)
```

æ§Řçğ■æĎŘäźL'äÿŁïijŇè£Źäÿłåŝ Ňä¡£çŤÍæŰĞäżűãĂĄéŤĄåŠŇçśżäijijåŕźèśąå¿ĹåČŔãĂĆ
éĂŽåÿÿå¿Ĺåőźæ ŸŞäijŽå£ŸèőřæIJĂåŘŐçŽĎ `detach()` æ■ěéłď'ãĂĆ
äÿžäžĘçőĂåŇŰè£ŹäÿłïijŇä¡ăåŘŕäżěèĂČèŹŚä¡£çŤÍäÿŁäÿŃæŰĞçőąçŘĘåŹĺå■ŔèőőãĂĆ
ä¿ŇåęĆïijŇåIJĺäžď'æ■ćæIJžåŕźèśąäÿŁåćđåŁääÿĂäÿł `subscribe()` æŰźæşŢïijŇåęĆäÿŃïijŽ

```
from contextlib import contextmanager
from collections import defaultdict

class Exchange:
    def __init__(self):
        self._subscribers = set()

    def attach(self, task):
        self._subscribers.add(task)

    def detach(self, task):
```

```
        self._subscribers.remove(task)

    @contextmanager
    def subscribe(self, *tasks):
        for task in tasks:
            self.attach(task)
        try:
            yield
        finally:
            for task in tasks:
                self.detach(task)

    def send(self, msg):
        for subscriber in self._subscribers:
            subscriber.send(msg)

# Dictionary of all created exchanges
_exchanges = defaultdict(Exchange)

# Return the Exchange instance associated with a given name
def get_exchange(name):
    return _exchanges[name]

# Example of using the subscribe() method
exc = get_exchange('name')
with exc.subscribe(task_a, task_b):
     ...
     exc.send('msg1')
     exc.send('msg2')
     ...

# task_a and task_b detached here
```

æIJĂåŘŐè£ŸåžŤèŕěæşĺæĎŘçŽĎæŸŕåĚşäžŐäžďæ■ćæIJžçŽĎæĂİæČşæIJL'å¿Ĺåď'Žçğ■çŽĎæL'l'åśŢåőđä¿ŃåęĆïijŇäžď'æ■ćæIJžåŘŕäżěåőđçŐřäÿĂæŢt'äÿłæűĹæĄŕéĂŽéĄŞéŻĘåŘĹæĹŰæŔŘä¿Żäžď'æ■ćæIJžåŘ■çğäžď'æ■ćæIJžè£ŸåŘŕäżěèćńæL'l'åśŢåĹřåĹĘåÿČåijŔèőąçőŮçĺŃåžŔäÿ■ïijĹæŕŤåęĆïijŇářĘæűĹæĄŕèůŕçŤśåĹřäj

14.12 12.12 ä¡£çŤĺçŤ§æĹŘåŹĺäžčæŻ£çž£çĺŃ

éŮőécŸ

ä¡ăæČşä¡£çŤĺçŤ§æĹŘåŹĺïijĹå■ŔçĺŃïijL'æŻ£äžčçşżçż§çž£çĺŃæİěåőđçŐřåźűåŔŚãĂĆè£ŹäÿłæIJL'æŮűåF

èğčåĘşæŰźæąĹ

èęĄä¡£çŤĺçŤ§æĹŘåŹĺåőđçŐřèĞłåůśçŽĎåźűåŔŚïijŇä¡ăéęŰåĚĹèęĄářźçŤ§æĹŘåŹĺåĞ¡æŢřåŠŇ `yield` èŕ■åŘěæIJL'æůśåĹżçŘĘèğčãĂĆ `yield` èŕ■åŘěäijŽèőľäÿĂäÿłçŤ§æĹŘåŹĺæŇĆèţůåőČçŽĎæL'ğèąŇïi

åřĘçŤ§æĹŘåŹĺå¡ŞåĄŽæ§Řçğ■âĂIJäżżåŁąâĂİåźűä¡£çŤĺäżżåŁąå■Ŕä¡IJåĹĞæ■ćæİěæŻ£æ■ćåőČäžňçŽĎæĽğ
èęĄæijŤçď žè£Źçğ■æĂİæČşïijŇèĂČèŹŚäÿŃéİćäÿď äÿłä¡£çŤĺçőĂå■ŢçŽĎ yield
èŕ■åŔěçŽĎçŤ§æĹŘåŹĺåĞ¡æŢřïijŽ

```
# Two simple generator functions
def countdown(n):
    while n > 0:
        print('T-minus', n)
        yield
        n -= 1
    print('Blastoff!')

def countup(n):
    x = 0
    while x < n:
        print('Counting up', x)
        yield
        x += 1
```

è£ŹäžŻåĞ¡æŢřåIJĺåĘĕéČĺä¡£çŤĺyieldèŕ■åŔěïijŇäÿŃéİćæŸŕäÿĂäÿłåőđçŐřäžEçőĂå■ŢäżżåŁąèřČåžęåŹĺ

```
from collections import deque

class TaskScheduler:
    def __init__(self):
        self._task_queue = deque()

    def new_task(self, task):
        '''
        Admit a newly started task to the scheduler

        '''
        self._task_queue.append(task)

    def run(self):
        '''
        Run until there are no more tasks
        '''
        while self._task_queue:
            task = self._task_queue.popleft()
            try:
                # Run until the next yield statement
                next(task)
                self._task_queue.append(task)
            except StopIteration:
                # Generator is no longer executing
                pass

# Example use
sched = TaskScheduler()
sched.new_task(countdown(10))
```

```
sched.new_task(countdown(5))
sched.new_task(countup(15))
sched.run()
```

`TaskScheduler` çśżåIJÍäÿĂäÿłå¿łçŐŕäÿ■è£ŘèąÑçŤ§æĹŘåŹĺéŻĘåŘĹâĂŤâĂŤæŕŔäÿłéČ¡è£ŘèąÑèå£ŘèąÑè£ŹäÿłäżŃå■ŘïijÑè¿ŞåĞžåęĆäÿŃïijŽ

```
T-minus 10
T-minus 5
Counting up 0
T-minus 9
T-minus 4
Counting up 1
T-minus 8
T-minus 3
Counting up 2
T-minus 7
T-minus 2
...
```

åĹřæ■d'äÿžæ■ćïijÑæĹŚäżñåðđéŹĚäÿŁåůšçżŔåőđçŐřäžĘäÿĂäÿłâĂIJæŞ■ä¡IJçşżçż§âĂİçŽĎæIJĂåřŔæăÿçŤ§æĹŘåŹĺåĞ¡æŢřåřśæŸŕèőd'äÿžïijÑèĂŇyieldèŕ■åŔěæŸŕäżżåŁąæŇĆèţůçŽĎä£ąåŔůãĂĆèřČåžęåŹĺå¿łçŐŕæčĂæ§ěäżżåŁąåĹŮèąÍçŻt'åĹřæšąæIJL'äżżåŁąèęĄæL'ğèąÑäÿžæ■ćãĂĆ

åőđéŹĚäÿŁïijÑä¡ăåŔŕèČ¡æČşèęĄä¡£çŤÍçŤ§æĹŘåŹĺæİěåőđçŐřçőĂå■ŢçŽĎåźűåŔŚãĂĆéĆčäźĹïijÑåIJÍåőđçŐřactoræĹŰç¡ŚçżIJæIJ■åŁąåŹÍçŽĎæŮűåĂŹä¡ăåŔŕäžěä¡£çŤÍçŤ§æĹŘåŹĺæİěæŻ£äżčçž£ç

äÿŃéİćçŽĎäżčçăĄæijŤçd'žäžĘä¡£çŤÍçŤ§æĹŘåŹĺæİěåőđçŐřäÿĂäÿłäÿ■ä¿ÌèţŰçž£çÍŃçŽĎactorïijŽ

```
from collections import deque

class ActorScheduler:
    def __init__(self):
        self._actors = { }          # Mapping of names to actors
        self._msg_queue = deque()   # Message queue

    def new_actor(self, name, actor):
        '''
        Admit a newly started actor to the scheduler and give it a␣
↪name
        '''
        self._msg_queue.append((actor,None))
        self._actors[name] = actor

    def send(self, name, msg):
        '''
        Send a message to a named actor
        '''
        actor = self._actors.get(name)
        if actor:
            self._msg_queue.append((actor,msg))
```

```
    def run(self):
        '''
        Run as long as there are pending messages.
        '''
        while self._msg_queue:
            actor, msg = self._msg_queue.popleft()
            try:
                 actor.send(msg)
            except StopIteration:
                 pass

# Example use
if __name__ == '__main__':
    def printer():
        while True:
            msg = yield
            print('Got:', msg)

    def counter(sched):
        while True:
            # Receive the current count
            n = yield
            if n == 0:
                break
            # Send to the printer task
            sched.send('printer', n)
            # Send the next count to the counter task (recursive)

            sched.send('counter', n-1)

    sched = ActorScheduler()
    # Create the initial actors
    sched.new_actor('printer', printer())
    sched.new_actor('counter', counter(sched))

    # Send an initial message to the counter to initiate
    sched.send('counter', 10000)
    sched.run()
```

åőŇåĚĺåijĎæĞĆè£ŹæőţäżčçăĄéIJĂèęĄæŻťæůśåĚěçŽĎå■ęäźăïijŇä¡ĘæŸŕåĚşéŤőçĆźåIJĺäžŐæŤűéŻĘæ
æIJňèťÍäÿŁïijŇèřČåžęåŹĺåIJÍæIJL'éIJĂèęĄåŔŠéĂĄçŽĎæűĹæĄŕæŮűäijŽäÿĂçŻťè£ŘèąŇçİĂãĂĆ
èőąæŢřçŤ§æĹŘåŹĺäijŽçżŹèĞłåůśåŔŠéĂĄæűĹæĄŕåźűåIJĺäÿĂäÿłéĂŠå¡Šå¿łçŐŕäÿ■çżŞæİ§ãĂĆ

äÿŃéİćæŸŕäÿĂäÿłæŻťåŁăéńŸçžğçŽĎä¿Ńå■ŘïijŇæijŤçď žäžĘä¡£çŤĺçŤ§æĹŘåŹĺæİěåőđçŐŕäÿĂäÿłåźűå

```
from collections import deque
from select import select

# This class represents a generic yield event in the scheduler
class YieldEvent:
```

```
    def handle_yield(self, sched, task):
        pass
    def handle_resume(self, sched, task):
        pass

# Task Scheduler
class Scheduler:
    def __init__(self):
        self._numtasks = 0        # Total num of tasks
        self._ready = deque()     # Tasks ready to run
        self._read_waiting = {}   # Tasks waiting to read
        self._write_waiting = {} # Tasks waiting to write

    # Poll for I/O events and restart waiting tasks
    def _iopoll(self):
        rset,wset,eset = select(self._read_waiting,
                                self._write_waiting,[])
        for r in rset:
            evt, task = self._read_waiting.pop(r)
            evt.handle_resume(self, task)
        for w in wset:
            evt, task = self._write_waiting.pop(w)
            evt.handle_resume(self, task)

    def new(self,task):
        '''
        Add a newly started task to the scheduler
        '''

        self._ready.append((task, None))
        self._numtasks += 1

    def add_ready(self, task, msg=None):
        '''
        Append an already started task to the ready queue.
        msg is what to send into the task when it resumes.
        '''
        self._ready.append((task, msg))

    # Add a task to the reading set
    def _read_wait(self, fileno, evt, task):
        self._read_waiting[fileno] = (evt, task)

    # Add a task to the write set
    def _write_wait(self, fileno, evt, task):
        self._write_waiting[fileno] = (evt, task)

    def run(self):
        '''
        Run the task scheduler until there are no tasks
```

```
        '''
        while self._numtasks:
             if not self._ready:
                  self._iopoll()
             task, msg = self._ready.popleft()
             try:
                 # Run the coroutine to the next yield
                 r = task.send(msg)
                 if isinstance(r, YieldEvent):
                     r.handle_yield(self, task)
                 else:
                     raise RuntimeError('unrecognized yield event')
             except StopIteration:
                 self._numtasks -= 1

# Example implementation of coroutine-based socket I/O
class ReadSocket(YieldEvent):
    def __init__(self, sock, nbytes):
        self.sock = sock
        self.nbytes = nbytes
    def handle_yield(self, sched, task):
        sched._read_wait(self.sock.fileno(), self, task)
    def handle_resume(self, sched, task):
        data = self.sock.recv(self.nbytes)
        sched.add_ready(task, data)

class WriteSocket(YieldEvent):
    def __init__(self, sock, data):
        self.sock = sock
        self.data = data
    def handle_yield(self, sched, task):

        sched._write_wait(self.sock.fileno(), self, task)
    def handle_resume(self, sched, task):
        nsent = self.sock.send(self.data)
        sched.add_ready(task, nsent)

class AcceptSocket(YieldEvent):
    def __init__(self, sock):
        self.sock = sock
    def handle_yield(self, sched, task):
        sched._read_wait(self.sock.fileno(), self, task)
    def handle_resume(self, sched, task):
        r = self.sock.accept()
        sched.add_ready(task, r)

# Wrapper around a socket object for use with yield
class Socket(object):
    def __init__(self, sock):
        self._sock = sock
```

```
    def recv(self, maxbytes):
        return ReadSocket(self._sock, maxbytes)
    def send(self, data):
        return WriteSocket(self._sock, data)
    def accept(self):
        return AcceptSocket(self._sock)
    def __getattr__(self, name):
        return getattr(self._sock, name)

if __name__ == '__main__':
    from socket import socket, AF_INET, SOCK_STREAM
    import time

    # Example of a function involving generators.  This should
    # be called using line = yield from readline(sock)
    def readline(sock):
        chars = []
        while True:
            c = yield sock.recv(1)
            if not c:
                break
            chars.append(c)
            if c == b'\n':
                break
        return b''.join(chars)

    # Echo server using generators
    class EchoServer:
        def __init__(self,addr,sched):
            self.sched = sched
            sched.new(self.server_loop(addr))

        def server_loop(self,addr):
            s = Socket(socket(AF_INET,SOCK_STREAM))

            s.bind(addr)
            s.listen(5)
            while True:
                c,a = yield s.accept()
                print('Got connection from ', a)
                self.sched.new(self.client_handler(Socket(c)))

        def client_handler(self,client):
            while True:
                line = yield from readline(client)
                if not line:
                    break
                line = b'GOT:' + line
                while line:
                    nsent = yield client.send(line)
```

```
                    line = line[nsent:]
            client.close()
            print('Client closed')

    sched = Scheduler()
    EchoServer(('',16000),sched)
    sched.run()
```

è£ŹæőţäžčçăæIJL'çĆźåď■æİĆãĂĆäÿ■è£ĞïijŇåőČåőđçŐřäžĘäÿĂäÿłářŔåđŃçŽĎæŞ■ä¡IJçşžçż§ãĂĆ
æIJL'äÿĂäÿłářšçżłçŽĎäżżåŁąéŸ§åĹŮïijŇåźűäÿŤè£ŸæIJL'åŻăI/OäijŚçIJăçŽĎäżżåŁąç■L'å¿ĚåŇžå§§ãĂĆ
è£ŸæIJL'å¿Ĺåď'ŽèřČåžęåŹÍèť§èť čåIJÍářšçżłéŸ§åĹŮåŠŇI/Oç■L'å¿ĚåŇžå§§äźŃéŮť'çğżåŁÍäżżåŁąãĂĆ

èőÍèőž

åIJÍæđĎåżžå§žäžŐçŤ§æĹŘåŹÍçŽĎåźűåŔŚæąĘæđűæŮűïijŇéĂŽåÿÿäijŽä¡£çŤÍæŻť'åÿÿèğĄçŽĎyieldå¡ćå

```
def some_generator():
    ...
    result = yield data
    ...
```

ä¡£çŤÍè£Źçğ■å¡ćåijŔçŽĎyieldèŕ■åŔěçŽĎåĞ¡æŢřéĂŽåÿÿèćńçğřäÿžâĂIJå■ŔçÍŃâĂİãĂĆ
éĂŽè£ĞèřČåžęåŹÍïijŇyieldèŕ■åŔěåIJÍäÿĂäÿłå¿łçŐŕäÿ■èćńåď'ĎçŘĘïijŇåęĆäÿŃïijŽ

```
f = some_generator()

# Initial result. Is None to start since nothing has been computed
result = None
while True:
    try:
        data = f.send(result)
        result = ... do some calculation ...
    except StopIteration:
        break
```

è£ŹéĞŇçŽĎéĂżè¿ŚçÍ■å¿őæIJL'çĆźåď'■æİĆãĂĆäÿ■è£ĞïijŇèćńäijăçżŹ
`send()` çŽĎåĂijåőŽäźL'äžĘåIJÍyieldèŕ■åŔěéĘŠæİěæŮűçŽĎè£ŤåŻđåĂijãĂĆ
åŻăæ■d'ïijŇåęĆæđIJäÿĂäÿłyieldåĞĘåď'ĞåIJÍářźäźŃåL'■yield-
æŢřæ■őçŽĎåŻđåžŤäÿ■è£ŤåŻđçżŞæđIJæŮűïijŇäijŽåIJÍäÿŃäÿĂæňą `send()`
æŞ■ä¡IJè£ŤåŻđãĂĆ åęĆæđIJäÿĂäÿłçŤ§æĹŘåŹÍåĞ¡æŢřåĹŽåijĂåğŃè£ŘèąŇïijŇåŔŚéĂĄäÿĂäÿłNoneåĂijäij

éŹd'äžĘåŔŚéĂĄåĂijåd'ŰïijŇè£ŸåŔřäžěåIJÍäÿĂäÿłçŤ§æĹŘåŹÍäÿŁéİćæL'ğèąŇäÿĂäÿł
`close()` æŰźæşŢãĂĆ åőČäijŽářijèĞť'åIJÍæL'ğèąŇyieldèŕ■åŔěæŮűæŁŽåĞžäÿĂäÿł
`GeneratorExit` åijĆåÿÿïijŇäżŐèĂŇçžĹæ■ćæL'ğèąŇãĂĆ
åęĆæđIJè£ŻäÿĂæ■ěèő¿èőąïijŇäÿĂäÿłçŤ§æĹŘåŹÍåŔřäžěæ■ŢèŐůè£ŹäÿłåijĆåÿÿåźűæL'ğèąŇæÿĚçŘĘæŞ■ä¡I
åŘŇæăůè£ŸåŔřäžěä¡£çŤÍçŤ§æĹŘåŹÍçŽĎ `throw()` æŰźæşŢåIJÍyield-
èŕ■åŔěæL'ğèąŇæŮűçŤ§æĹŘäÿĂäÿłäżżæĎŔçŽĎæL'ğèąŇæŇĞäžd'ãĂĆ
äÿĂäÿłäżżåŁąěřČåžęåŹÍåŔřåĹl'çŤÍåőČæİěåIJÍè£ŘèąŇçŽĎçŤ§æĹŘåŹÍäÿ■åď'ĎçŘĘéŤŹèŕřãĂĆ

æIJĂåŘŐäÿĂäÿłä¿Ńå■Řäÿ■ä¡£çŤĺçŽĎ `yield from` èŕ■åŔěèćńçŤĺæİěåőđçŐřå■ŔçĺŃïijŇåŔŕäžěèćńåĚ
æIJňèťĺäÿŁåřśæŸŕåřĘæŐğåĹűæİČéĂŔæŸŐçŽĎäijåè¿ŞçżŹæŰřçŽĎåĞ¡æŢřãĂĆ
äÿ■åČŔæŹőéĂŽçŽĎçŤ§æĹŘåŹĺïijŇäÿĂäÿłä¡£çŤĺ `yield from`
èćńèřČçŤĺçŽĎåĞ¡æŢřåŔŕäžěè£ŤåŻđäÿĂäÿłä¡IJäÿž `yield from`
èŕ■åŔěçżŞæđIJçŽĎåĂijãĂĆ åĚşäžŐ `yield from` çŽĎæŻťåď̌Žä£ąæĄŕåŔŕäžěåIJĺ PEP
380 äÿ■æĽ¿åĹřãĂĆ

æIJĂåŘŐïijŇåęĆæđIJä¡£çŤĺçŤ§æĹŘåŹĺçijŰçĺŃïijŇèęĄæŔŘéĘšä¡ăçŽĎæŸŕåőČè£ŸæŸŕæIJĽå¿Łåď̌Žç
çĽźåĹńæŸŕïijŇä¡ăå¿Ůäÿ■åĹřäžżä¡Ţçž£çĺŃåŔŕäžěæŔŘä¿ŻçŽĎåě¡åď̌ĎãĂĆä¿ŃåęĆïijŇåęĆæđIJä¡ăæĽğèąŇĆ
åőČäijŽåřĘæŢťäÿłäżżåŁąæŇĆèţůç§ěéĄŞæŞ■ä¡IJåőŇæĹŘãĂĆäÿžäžĘèğčåĘşè£ŹäÿłéŮőécŸïijŇ
ä¡ăåŔłèČ¡éĂĽæŇĺ̌åřĘæŞ■ä¡IJåğŤæť¿çżŹåŘęåď̌ŰäÿĂäÿłåŔŕäžěçŇñçńŇè£ŘèąŇçŽĎçž£çĺŃæĹŰè£ŻçĺŃãĂ
åŔęåď̌ŰäÿĂäÿłéŹŘåĹűæŸŕåď̌ğéČĺåĹĘPythonåžŞåźűäÿ■èČ¡å¿Łåě¡çŽĎåĚijåőźå§žäžŐçŤ§æĹŘåŹĺçŽĎçž£çĺ
åęĆæđIJä¡ăéĂĽæŇĺ̌è£ŹäÿłæŰźæąĹïijŇä¡ăäijŽåŔŚçŐŕä¡ăéIJĂèęĄèĞłåůśæŤźåĘŹå¿Łåď̌ŽæăĞåĞĘåžŞåĞ¡æ
ä¡IJäÿžæIJňèŁĆæŔŘåĹřçŽĎå■ŔçĺŃåŠŇçŻÿåĚşæŁĂæIJŕçŽĎäÿĂäÿłå§žçąĂèČŇæŹřïijŇåŔŕäžěæ§ěçIJŃ
PEP 342 åŠŇ âĂIJå■ŔçĺŃåŠŇåźűåŔŚçŽĎäÿĂéŮĺæIJĽèűčèŕ¿çĺŃâĂİ

PEP 3156 åŘŇæăůæIJĽäÿĂäÿłåĚşäžŐä¡£çŤĺå■ŔçĺŃçŽĎåijĆæ■ěI/OæĺąåđŃãĂĆ
çĽźåĹńçŽĎïijŇä¡ăäÿ■åŔŕèČ¡èĞłåůśåŐžåőđçŐřäÿĂäÿłåžŢåśĆçŽĎå■ŔçĺŃèřČåžęåŹĺãĂĆ
äÿ■è£ĞïijŇåĚşäžŐå■ŔçĺŃçŽĎæĂİæČşæŸŕå¿Łåď̌ŽæţĄèąŇåžŞçŽĎå§žçąĂïijŇ åŇĚæŃň
gevent, greenlet, Stackless Python äžěåŔŁåĚűäžŰçśžäijijåůěçĺŃãĂĆ

14.13 12.13 åď̌Žäÿłçž£çĺŃéŸ§åĹŮè¡őèŕć

éŮőécŸ

ä¡ăæIJĽäÿĂäÿłçž£çĺŃéŸ§åĹŮéŻĘåŘĹïijŇæČşäÿžåĹřæİěçŽĎåĚČçť̌ăè¡őèŕćåőČäžňïijŇ
åŕśèů§ä¡ăäÿžäÿĂäÿłåőćæĹůçńŕèŕůæśĆåŐżè¡őèŕćäÿĂäÿłç¡ŞçżIJè£đæŐěéŻĘåŘĹçŽĎæŰźåijŔäÿĂæăůãĂĆ

èğčåĘşæŰźæąĹ

åŕźäžŐè¡őèŕćéŮőécŸçŽĎäÿĂäÿłåÿÿèğĄèğčåĘşæŰźæąĹäÿ■æIJĽäÿłå¿ĹåřŚæIJĽäžžç§ěéĄŞçŽĎæŁĂåů
æIJňèťĺäÿŁèőšåĚűæĂİæČşåŕśæŸŕïijŽåŕźäžŐæŕŔäÿłä¡ăæČşèęĄè¡őèŕćçŽĎéŸ§åĽŮïijŇä¡ăåĹŻåžžäÿĂåŕźè£đæ
çĎűåŘŐä¡ăåIJĺåĚűäÿ■äÿĂäÿłåěŮæŐěå■ŮäŸŁéĺćçijŰåĘŹäžčçăĄæĺěæăĞèŕĘå■ŸåIJĺçŽĎæŢřæ■őïijŇ
åŔęåď̌ŰäÿĂäÿłåěŮæŐěå■Ùèćńäijăçžź `select()` æĹŰçśžäijijçŽĎäÿĂäÿłè¡őèŕćæŢřæ■őåĹřè¿¿çŽĎåĞ¡æŢř

```
import queue
import socket
import os

class PollableQueue(queue.Queue):
    def __init__(self):
        super().__init__()
        # Create a pair of connected sockets
        if os.name == 'posix':
            self._putsocket, self._getsocket = socket.socketpair()
        else:
            # Compatibility on non-POSIX systems
            server = socket.socket(socket.AF_INET, socket.SOCK_
↪STREAM)
```

```
            server.bind(('127.0.0.1', 0))
            server.listen(1)
            self._putsocket = socket.socket(socket.AF_INET, socket.
↪SOCK_STREAM)
            self._putsocket.connect(server.getsockname())
            self._getsocket, _ = server.accept()
            server.close()

    def fileno(self):
        return self._getsocket.fileno()

    def put(self, item):
        super().put(item)
        self._putsocket.send(b'x')

    def get(self):
        self._getsocket.recv(1)
        return super().get()
```

åIJÍè£ŹäÿłäžčçăĄäÿ■ïijŇäÿĂäÿłæŰřçŽĎ Queue åőđä¿ŃçśžåđŃèćńåőŽäźL'ïijŇåžŢåśĆæŸŕäÿĂäÿłèćńè£
åIJÍUnixæIJžåŹÍäÿŁçŽĎ socketpair() åĞ¡æŢřèČ¡è¡żæİ¿çŽĎåĹŻåžžè£ŹæăůçŽĎåěÛæŐěå■ŮãĂĆ
åIJÍWindowsäÿŁéİćïijŇä¡åå£Ěéążä¡£çŤĺçśżäijijäžčçăĄæİěæĺąæŃ§åőČãĂĆ
çĎűåŘŐåőŽäźL'æŹőéĂŽçŽĎ get() åŠŇ put() æŰźæşŢåIJÍè£ŹäžŻåěÛæŐěå■ŮäÿŁéİćæİěæL'ğèąŇI/OæŞ
put() æŰźæşŢåE■åřĘæŢřæ■őæŤ¿åĚěéŸ§åĹŮåŘŐäijŽåĘŹäÿĂäÿłå■Ţå■ÛèŁĆåĹřæ§Řäÿłåě ÛæŐěå■Ůäÿ■å
èĂŇ get() æŰźæşŢåIJÍäžŐéŸ§åĹŮäÿ■çğżéŹd'äÿĂäÿłåĚČçt'ăæŮűäijŽäžŐåŔęåd'ŰäÿĂäÿłåěÛæŐěå■Ůäÿ■

fileno() æŰźæşŢä¡£çŤÍäÿĂäÿłåĞ¡æŢřærŤåęĆ select() æİèèől'è£ŹäÿłéŸ§åĹŮåŔŕäžěèćńè¡őèŕćãĂĆ åőČäžĚäžĚåŘłæŸŕæŽt'éIJšäžĘåžŢåśĆèćń get() åĞ¡æŢřä¡£çŤÍåĹřçŽĎsocketçŽĎæŰĞäžűæŔŔè£řçňęèĂŇåůšãĂĆ

äÿŃéİćæŸŕäÿĂäÿłä¿Ńå■ŘïijŇåőŽäźL'äžĘäÿĂäÿłäÿžåĹřæİěçŽĎåĚČçt'äçŻŚæŐğåd'ŽäÿłéŸ§åĹŮçŽĎæű

```
import select
import threading

def consumer(queues):
    '''
    Consumer that reads data on multiple queues simultaneously
    '''
    while True:
        can_read, _, _ = select.select(queues,[],[])
        for r in can_read:
            item = r.get()
            print('Got:', item)

q1 = PollableQueue()
q2 = PollableQueue()
q3 = PollableQueue()
t = threading.Thread(target=consumer, args=([q1,q2,q3],))
t.daemon = True
t.start()
```

```
# Feed data to the queues
q1.put(1)
q2.put(10)
q3.put('hello')
q2.put(15)
...
```

åęĆæđIJä¡ăèŕŢçİÄè£ŘèąŇåőČïijŇä¡ăäijŽåŔŠçŐřè£ŹäÿłæűĹèť źèĂĚäijŽæŐěåŔŮåĹřæL’ĂæIJL’çŽĎèćń

èőĺèőž

åŕźäžŐè¡őèŕćéİđçśżæŰĞäżűåŕźèśąïijŇæŕŤåęĆéŸ§åĹŮéĂŽåÿÿéČ¡æŸŕæŕŤè¿ČæčŸæL’ŃçŽĎéŮőécŸãĂ
ä¿ŇåęĆïijŇåęĆæđIJä¡ăäÿ■ä¡£çŤĺäÿŁéİćçŽĎåěŮæŐěå■ŮæŁĂæIJŕïijŇ
ä¡ăåŤŕäÿĂçŽĎéĂL’æŃl’åřśæŸŕçijŰåĘŹäžčçăĄæİěå¿łçŐŕéĄ■åŐĘè£ŹäžŻéŸ§åĹŮåźűä¡£çŤĺäÿĂäÿłåőŽæŮűå

```
import time
def consumer(queues):
    while True:
        for q in queues:
            if not q.empty():
                item = q.get()
                print('Got:', item)

        # Sleep briefly to avoid 100% CPU
        time.sleep(0.01)
```

è£ŹæăůåĄŽåĚűåőđäÿ■åŘĹçŘĘïijŇè£ŸäijŽåijŢåĚěåĚűäžŰçŽĎæĂğèČ¡éŮőécŸãĂĆ
ä¿ŇåęĆïijŇåęĆæđIJæŰřçŽĎæŢřæ■őèćńåŁăåĚěåĹřäÿĂäÿłéŸ§åĹŮäÿ■ïijŇèĞşåřŚèęĄèŁś10æńçğŠæL’■èČ¡è
åęĆæđIJä¡ăäźŃåL’■çŽĎè¡őèŕćè£ŸèęĄåŐżè¡őèŕćåĚűäžŰåŕźèśąïijŇæŕŤåęĆç¡ŚçżIJåěŮæŐěå■ŮéĆčè£ŸäijŽæ
ä¿ŇåęĆïijŇåęĆæđIJä¡ăæČşåŘŇæŮűè¡őèŕćåěŮæŐěå■ŮåŠŇéŸ§åĹŰïijŇä¡ăåŔŕèČ¡èęĄåČŔäÿŃéİćè£Źæăůä¡£

```
import select

def event_loop(sockets, queues):
    while True:
        # polling with a timeout
        can_read, _, _ = select.select(sockets, [], [], 0.01)
        for r in can_read:
            handle_read(r)
        for q in queues:
            if not q.empty():
                item = q.get()
                print('Got:', item)
```

è£ŹäÿłæŰźæąĹéĂŽè£ĞåřĘéŸ§åĹŮåŠŇåěŮæŐěå■Ůç■L’åŘŇåŕźå¿ĚæİěèğčåĘşäžĘåd’ğéČĺåĹĘçŽĎéŮőe
äÿĂäÿłå■ŢçŃňçŽĎ `select()` èřČçŤĺåŔŕèćńåŘŇæŮűçŤĺæİěè¡őèŕćĂĆ
ä¡£çŤĺèűĚæŮűæĹŮåĚűäžŰå§žäžŐæŮűéŮt’çŽĎæIJžåĹűæİěæL’ğèąŇåŠĺæIJ§æĂğæčĂæ§ěåźűæšąæIJL’å£Ěèę

çŤŽèĞşïijŇåęĆæđIJæŢřæ■őèćńåŁääĚěåĹřäÿĂäÿłéŸ§åĹŮïijŇæűĹèť źèĂĚåĞääźŐåŔŕäżěåőđæŮűçŽĎèćńéĂ
ář¡çőąäijŽæIJL'äÿĂçĆźçĆźåžŢåśĆçŽĎI/Oæ■§èĂŮïijŇä¡£çŤĺåőČéĂŽåÿÿäijŽèŐůå¿ŮæŻť'åě¡çŽĎåŞ■åžŤæŮ

14.14 12.14 åIJÍUnixçşżçż§äÿŁéİćåŘŕåŁĺåőĹæŁd'è£ŻçÍŃ

éŮőécŸ

ä¡ăæČşçijŰåĘŹäÿĂäÿłä¡IJäÿžäÿĂäÿłåIJÍUnixæĹŰçśżUnixçşżçż§äÿŁéİćè£ŘèąŇçŽĎåőĹæŁd'è£ŻçÍŃè£

èğčåĘşæŰźæąĹ

åĹŻåżžäÿĂäÿłæ■čçąőçŽĎåőĹæŁd'è£ŻçÍŃéIJĂèęĄäÿĂäÿłçš¿çąőçŽĎçşżçż§èřČçŤĺåžŔåĹŮäżěåŔŁåŕźäž
äÿŃéİćçŽĎäžčçăĄåśŢçd'žäžĘæĂŐæăůåőŽäźĽäÿĂäÿłåőĹæŁd'è£ŻçÍŃïijŇåŔŕäżěåŘŕåŁĺåŘŐå¿Ĺåőźæ ŸŞçŽĎ

```
#!/usr/bin/env python3
# daemon.py

import os
import sys

import atexit
import signal

def daemonize(pidfile, *, stdin='/dev/null',
                          stdout='/dev/null',
                          stderr='/dev/null'):

    if os.path.exists(pidfile):
        raise RuntimeError('Already running')

    # First fork (detaches from parent)
    try:
        if os.fork() > 0:
            raise SystemExit(0)    # Parent exit
    except OSError as e:
        raise RuntimeError('fork #1 failed.')

    os.chdir('/')
    os.umask(0)
    os.setsid()
    # Second fork (relinquish session leadership)
    try:
        if os.fork() > 0:
            raise SystemExit(0)
    except OSError as e:
        raise RuntimeError('fork #2 failed.')

    # Flush I/O buffers
```

```
    sys.stdout.flush()
    sys.stderr.flush()

    # Replace file descriptors for stdin, stdout, and stderr
    with open(stdin, 'rb', 0) as f:
        os.dup2(f.fileno(), sys.stdin.fileno())
    with open(stdout, 'ab', 0) as f:
        os.dup2(f.fileno(), sys.stdout.fileno())
    with open(stderr, 'ab', 0) as f:
        os.dup2(f.fileno(), sys.stderr.fileno())

    # Write the PID file
    with open(pidfile,'w') as f:
        print(os.getpid(),file=f)

    # Arrange to have the PID file removed on exit/signal
    atexit.register(lambda: os.remove(pidfile))

    # Signal handler for termination (required)
    def sigterm_handler(signo, frame):
        raise SystemExit(1)

    signal.signal(signal.SIGTERM, sigterm_handler)

def main():
    import time
    sys.stdout.write('Daemon started with pid {}\n'.format(os.
↪getpid()))
    while True:
        sys.stdout.write('Daemon Alive! {}\n'.format(time.ctime()))
        time.sleep(10)

if __name__ == '__main__':
    PIDFILE = '/tmp/daemon.pid'

    if len(sys.argv) != 2:
        print('Usage: {} [start|stop]'.format(sys.argv[0]),␣
↪file=sys.stderr)
        raise SystemExit(1)

    if sys.argv[1] == 'start':
        try:
            daemonize(PIDFILE,
                      stdout='/tmp/daemon.log',
                      stderr='/tmp/dameon.log')
        except RuntimeError as e:
            print(e, file=sys.stderr)
            raise SystemExit(1)

        main()
```

```
    elif sys.argv[1] == 'stop':
        if os.path.exists(PIDFILE):
            with open(PIDFILE) as f:
                os.kill(int(f.read()), signal.SIGTERM)
        else:
            print('Not running', file=sys.stderr)
            raise SystemExit(1)

    else:
        print('Unknown command {!r}'.format(sys.argv[1]), file=sys.
↪stderr)
        raise SystemExit(1)
```

èęĄåŘŕåŁĺè£ŹäÿłåőĹæŁd'è£ŻçĺŃïijŇçŤĺæĹůéIJĂèęĄä¡£çŤĺąęĆäÿŃçŽĎåŠ¡äžd'ïijŽ

```
bash % daemon.py start
bash % cat /tmp/daemon.pid
2882
bash % tail -f /tmp/daemon.log
Daemon started with pid 2882
Daemon Alive! Fri Oct 12 13:45:37 2012
Daemon Alive! Fri Oct 12 13:45:47 2012
...
```

åőĹæŁd'è£ŻçĺŃåŘŕäžěåőŇåĚĺåIJĺåŘŐåŘřè£ŘèąŇïijŇåŻäæ■d'è£ŹäÿłåŠ¡äžd'äijŽçńŇå■şè£ŤåŻđãĂĆ
äÿ■è£ĞïijŇä¡ăåŘŕäžěåČŘäÿŁéİćéĆčæăůæ§ěçIJŃäÿŐåőĆçŻÿåĚşçŽĎpidæŰĞäžűåŠŇæŮěå£ŮãĂĆèęĄåĄIJæ

```
bash % daemon.py stop
bash %
```

èőĺèőž

æIJňèŁĆåőŽäźL'äžĘäÿĂäÿłåĞ¡æŢř `daemonize()` ïijŇåIJĺçĺŃåžŘåŘŕåŁĺæŮűèćńèřČçŤĺä¡£å¿ŮçĺŃåžŘ
`daemonize()` åĞ¡æŢřåŘłæŐěåŘŮåĚşéŤőå■ŮåŘĆæŢřïijŇè£ŹæăůçŽĎèŕĺåŘŕéĂL'åŘĆæŢřåIJĺèćńä¡£çŤĺæŮ
åőČäijŽåijžåĹűçŤĺæĹůåČŘäÿŃéİćè£ŹæăůäĄ£çŤĺåőČïijŽ

```
daemonize('daemon.pid',
          stdin='/dev/null,
          stdout='/tmp/daemon.log',
          stderr='/tmp/daemon.log')
```

èĂŇäÿ■æŸŕåČŘäÿŃéİćè£ŹæăůåŘńçşŁäÿ■æÿĚçŽĎèřČçŤĺïijŽ

```
# Illegal. Must use keyword arguments
daemonize('daemon.pid',
          '/dev/null', '/tmp/daemon.log','/tmp/daemon.log')
```

åĹŻåžžäÿĂäÿłåőĹæŁd'è£ŻçĺŃçŽĎæ■ěéłd'çIJŃäÿŁåŐżäÿ■æŸŕå¿ĹæŸŞæĞĆïijŇä¡ĘæŸŕåd'ğä¡ŞæĂİæČ

éęŰåĚĹïijŇäÿĂäÿłåőĹæŁď'è£ŻçÍŃå£Ěéążèę Ąäż ŐçĹűè£ŻçÍŃäÿ■èĎśçężãĂĆ è£ŹæŸŕçŤś
`os.fork()` æŞ■ä¡IJæİěåőŇæĹŘçŽĎïijŇåźűçńŃå■şèćńçĹűè£ŻçÍŃçżĹæ■ćãĂĆ

åIJÍå■Řè£ŻçÍŃåŔŸæĹŘå■ď'åĎ£åŘŐïijŇèřČçŤÍ `os.setsid()`
åĹŻåżžäžĘäÿĂäÿłåĚÍæŰřçŽĎè£ŻçÍŃäijŻèŕİïijŇåźűèő¿ç¡őå■Řè£ŻçÍŃäÿžéęŰéćĘãĂĆ
åőČäijŽèő¿ç¡őè£Źäÿłå■Řè£ŻçÍŃäÿžæŰřçŽĎè£ŻçÍŃçżĎçŽĎéęŰéćĘïijŇåźűçąőä£İäÿ■äijŽåĘ■æIJL'æŐğåĹűç
åęĆæđIJè£ŹäžŻåŘňäÿŁåŐžåď'łé■Ťåźżïij ŇåŻääÿžåőČéIJĂèęĄåřĘåőĹæŁď'è£ŻçÍŃåŘŇçżĹçńŕåĹĘçęžåijĂåźű
èřČçŤÍ `os.chdir()` åŠŇ `os.umask(0)` æŤźåŔŸäžĘå¡ŞåL'■åůëä¡IJçŽőå¡Ţåźűé Ğ■ç¡őæŰĞäżűæİČéŹŘæ
ä£őæŤźçŽőå¡ŢéĂŽåÿÿæŸŕäÿłåě¡äÿżæĎŔïijŇåŻääÿžè£Źæăůå Ŕŕäžëä¡£å¿ŮåőČäÿ■åĘ■åůëä¡IJåIJÍècńåŘŕåŁÍæ

åŘęåď'ŰäÿĂäÿłèřČçŤÍ `os.fork()` åIJÍè£ŹéĞŇæŻť'åŁăçěđçğŸçĆźãĂĆ
è£ŹäÿĂæ■ëä¡£å¿ŮåőĹæŁď'è£ŻçÍŃåď'śåŐżäžĘèŐůåŔŰæŰřçŽĎæŐğåĹűçżĹçńŕçŽĎèČ¡åŁŻåźűäÿŤèőľåőČæ
ïijĹæIJňèť'ĺäÿŁïijŇèŕědaemonæŤ¿åijČäžĘåőČçŽĎäijŽèŕİéęŰéćĘä¡Öä¡■ïijŇåŻäæ■ď'åĘ■äź§æšąæIJL'æİČéŹŘ
ář¡çőąä¡ääŔŕäžěå£¡çŢèè£ŹäÿĂæ■ěïijŇä¡ĘæŸŕæIJĂåě¡äÿ■èęĄè£ŹäźĹåĄŽãĂĆ

äÿĂæŮęåőĹæŁď'è£ŻçÍŃècńæ■čçąőçŽĎåĹĘçężïijŇåőČäijŽéĞ■æŰřåĹİåğŃåŇŰæăĞåĞĘI/OæţĄæŇĞåĚ
è£ŹäÿĂéČĺåĹĘæIJL'çĆźéŽ¿æĞĆãĂĆèů§æăĞåĞĘI/OæţĄçŻÿåĚşçŽĎæŰĞäżűåŕźèšąçŽĎäijŢçŤĺåIJÍèğčéĞŁå
ïijĹsys.stdout, sys.__stdout__ç■L'ïijL'ãĂĆ äžĚäžĚçőĂå■ŢçŽĎåĚşéŮ■
`sys.stdout` åźűéĞ■æŰřæŇĞåőŽåőČæŸŕèąŇäÿ■éĂŽçŽĎïijŇ
åŽääÿžæšąåŁđæşŢç§ěéĄŞåőČæŸŕåŘęåĚÍéČĺéČ¡æŸŕçŤÍçŽĎæŸŕ `sys.stdout` ãĂĆ
è£ŹéĞŇïijŇæĹŚäžňæL'ŞäijĂäžĘäÿĂäÿłå■ŢçŃňçŽĎæŰĞäżűåŕźèšąïijŇåźűěřČçŤÍ `os.`
`dup2()` ïijŇ çŤĺåőČæİěäžčæŻ£èćń `sys.stdout` ä¡£çŤÍçŽĎæŰĞäżűæŔŘè£řçňęãĂĆ
è£Źæăůïij Ň`sys.stdout` ä¡£çŤÍçŽĎåŐ§åğŃæŰĞäżűäijŽèćńåĚşéŮ■åźűçŤśæŰřçŽĎæİèæŻ£æ■ćãĂĆ
è£ŸèęĄäijžěřČçŽĎæŸŕäżżä¡ŢçŤĺäžŐæŰĞäżűçijŰçăĄæĹŰæŰĞæIJňåď'ĎçŘĘçŽĎæăĞåĞĘI/OæţĄè£ŸäijŽä

åőĹæŁď'è£ŻçÍŃçŽĎäÿĂäÿłéĂŽåÿÿåődèůţæŸŕåIJÍäÿĂäÿłæŰĞäżűäÿ■åĘŹåĚëè£ŻçÍŃIDïijŇåŔŕäžěèćńåĚ
`daemonize()` åĞ¡æŢřçŽĎæIJĂåŘŐéČĺåĹĘåĘŹäžĘè£ŹäÿłæŰĞäżűïijŇä¡ĘæŸŕåIJÍçÍŃäžŘçžĹæ■ćæŮűåĹăe
`atexit.register()` åĞ¡æŢřæşĺåĘŇäžĘäÿĂäÿłåĞ¡æŢřåIJÍPythonèğčéĞŁåŹÍçžĹæ■ćæŮűæL'ğèąŇãĂĆ
äÿĂäÿłåŕźäžŐSIGTERMçŽĎä£ąåŘůåď'ĎçŘĘåŹÍçŽĎåőŽäźL'åŘŇæăůéIJĂèęĄèćńäijŸéŻĚçŽĎåĚşéŮ■ãĂĆ
ä£ąåŘůåď'ĎçŘĘåŹÍçőĂå■ŢçŽĎæŁŻåĞžäžĘ `SystemExit()` åijĆåÿÿãĂĆ
æĹŰèőÿè£ŹäÿĂæ■ěçIJŇäÿŁåŐżæšąå£ĚèęĄïijŇä¡ĘæŸŕæšąæIJL'åőČïijŇ
çžĹæ■ćä£ąåŘůäijŽä¡£å¿ŮäÿĂæL'ğèąŇ `atexit.register()`
æşĺåĘŇçŽĎæÿĚçŘĘæŞ■ä¡IJçŽĎæŰůåĂŹåřśæİĂæŐL'äžĘèğčéĞŁåŹÍçãĂĆ
äÿĂäÿłæİĂæŐL'è£ŻçÍŃçŽĎä¿Ńå■Řäžčçă ĄåŔŕäžěåIJÍçÍŃäžŘæIJĂåŘŐçŽĎ `stop`
åŚ¡äžď'çŽĎæŞ■ä¡IJäÿ■çIJŇåĹřãĂĆ

æŻť'åď'ŽåĚşäžŐçijŰåĘŹåőĹæŁď'è£ŻçÍŃçŽĎä£ąæĄŕåŔŕäžěæ§ěçIJŃãĂŁUNIX
çŐŕåćČéńŸçžğçijŰçÍŃãĂŃ, çňňäžŇçL'Ĺ by W. Richard
Stevens and Stephen A. Rago (Addison-Wesley, 2005)ãĂĆ
ář¡çőąåőČæŸŕåĚşæşĺäÿŐCèŕ■èÍĂçijŰçÍŃïijŇä¡ĘæŸŕæL'ĂæIJL'çŽĎåĘĚåőźĆ¡éĂĆçŤÍäžŐPythonïijŇ
åŽääÿžæL'ĂæIJL'éIJĂèęĄçŽĎPOSIXåĞ¡æŢřéČ¡åŔŕäžěåIJÍæăĞåĞĘåžŞäÿ■æL'¿åĹřãĂĆ

15 çňňå■ĄäÿL'çńäïijŽèĎŽæIJňçijŰçÍŃäÿŐçşżçż§çőąçŘĘ

èőÿåď'Žäžžä¡£çŤÍPythonä¡IJäÿžäÿĂäÿłshellèĎŽæIJňçŽĎæŻ£äžčïijŇçŤÍæİěåőđçŐŕåÿÿçŤÍçşżçż§äżżåĹą

Contents:

15.1 13.1 éĂŽè£ĞéĞ■åőŽåŘŚ/çőąéĄŞ/æŰĞäžűæŐěåŔŮè¿ŞåĚě

éŮőécŸ

ä¡ăåÿŇæIJŻä¡ăçŽĎèĎŽæIJňæŐěåŔŮäżżä¡ŢçŤĺæĹůèőd'äÿžæIJĂçőĂå■ŢçŽĎè¿ŞåĚěæŰźåijŔãĂĆåŇĚæ
éĞ■åőŽåŘŚæŰĞäžűåĹřèŕěèĎŽæIJňïijŇæĹŰåIJĺåŚ¡äžd'èąŇäÿ■äijăéĂŠäÿĂäÿłæŰĞäžűåŘ■æĹŰæŰĞäžűåŘ■

èğčåĘşæŰźæąĹ

PythonåĘĚç¡őçŽĎ `fileinput` æĺąåİŮèől'è£ŹäÿłåŔŸå¿ŮçőĂå■ŢãĂĆåęĆæđIJä¡ăæIJL'äÿĂäÿłäÿŃéİćè

```
#!/usr/bin/env python3
import fileinput

with fileinput.input() as f_input:
    for line in f_input:
        print(line, end='')
```

éĆčäźĹä¡ăåřśèČ¡äžěåL'■éİćæŔŘåĹřçŽĎæL'ĂæIJL'æŰźåijŔæİěäÿžæ■d'èĎŽæIJňæŔŘä¿Żè¿ŞåĚěãĂĆåĄ
`filein.py` åźűåřĘåĚűåŔŸäÿžåŔŕæL'ğèąŇæŰĞäžűïijŇ éĆčäźĹä¡ăåŔŕäžěåČŔäÿŃéİćè£ŹæăůèřČçŤĺåőČïijŇ

```
$ ls | ./filein.py          # Prints a directory listing to stdout.
$ ./filein.py /etc/passwd   # Reads /etc/passwd to stdout.
$ ./filein.py < /etc/passwd # Reads /etc/passwd to stdout.
```

èőÍèőž

`fileinput.input()` åĹŻåžžåźűè£ŤåŻđäÿĂäÿł `FileInput` çśžçŽĎåőđä¿ŃãĂĆ
èŕěåőđä¿ŃéŹd'äžĘæŃěæIJL'äÿĂäžŻæIJL'çŤĺçŽĎåÿőåŁl'æŰźæşŢåd'ŰïijŇåőČè£ŸåŔŕèćńå¡ŞåĄŽäÿĂäÿłäÿŁ
åŻăæ■d'ïijŇæŢt'åŘĹèţůæİěïijŇåęĆæđIJæĹŚäžňèęĄåĘŹäÿĂäÿłæL'Şå■řåd'Žäÿłæ ŰĞäžűè¿ŞåĞžçŽĎèĎŽæIJň

```
>>> import fileinput
>>> with fileinput.input('/etc/passwd') as f:
>>>     for line in f:
...         print(f.filename(), f.lineno(), line, end='')
...
/etc/passwd 1 ##
/etc/passwd 2 # User Database
/etc/passwd 3 #

<other output omitted>
```

éĂŽè£ĞåřĘåőČä¡IJäÿžäÿĂäÿłäÿŁäÿŃæŰĞçőąçŘĘåŹĺä¡£çŤĺïijŇåŔŕäžěçąőä£ĺåőČäÿ■åĘ■ä¡£çŤĺæŮűæÚ
èĂŇäÿŤæĹŚäžňåIJĺäźŃåŘŐè£ŸæijŤçd'žäžĘ `FileInput` çŽĎäÿĂäžŻæIJL'çŤĺçŽĎåÿőåŁl'æŰźæşŢæİěèŐů

15.2 13.2 çžĹæ■ćçÍŃåžŔåźűçżŹåĞžéŤŹèŕŕä£ąæĄŕ

éŮőécŸ

ä¡ăæČşåŘŚæăĞåĞĘéŤŹèŕŕæĽŞå■řäÿĂæİąæűĹæĄŕåźűè£ŤåŻđæ§Řäÿłéİđé Žűç ŁűæĂĄçăĄæİěçżĹæ■ćçÍ

èğčåĘşæŰźæąĹ

ä¡ăæIJĽäÿĂäÿłçÍŃåžŔåČŔäÿŃéİćè£ŹæăůçżĹæ■ćïijŇæŁŻåĞžäÿĂäÿł `SystemExit` åijĆåÿÿïijŇä¡£çŤÍéŤŹèŕŕæűĹæĄŕä¡IJäÿžåŔĆæŢřãĂĆä¿ŃåęĆïijŽ

```
raise SystemExit('It failed!')
```

åőČäijŽářĘæűĹæĄŕåIJÍ `sys.stderr` äÿ■æĽŞå■řïijŇçĎůåŘŐçÍŃåžŔäžěçŁűæĂĄçăĄ1éĂĂåĞžãĂĆ

èőÍèőž

æIJňèŁĆèŹ¡çĎůå¿Łç§■ářŔïijŇä¡ĘæŸŕåőČèČ¡èğčåĘşåIJÍåĘŹèĎŽæIJňæŮűçŽĎäÿĂäÿłåÿÿèğĄéŮőécŸã äźş§ářśæŸŕèŕťïijŇå¡Şä¡ăæČşèęĄçżĹæ■ćæ§Řäÿłçí ŃåžŔæŮűïijŇä¡ăåŔŕèČ¡äijŽåČŔäÿŃéİćè£ŹæăůåĘŹïijŽ

```
import sys
sys.stderr.write('It failed!\n')
raise SystemExit(1)
```

åęĆædIJä¡ăçŻť'æŐěářĘæűĹæĄŕä¡IJäÿžåŔĆæŢřäijăçżŹ `SystemExit()` ïijŇéĆčäźĹä¡ăåŔŕäžěçIJĄçŢěåĚűäžŰæ■ěélď'ïijŇ æŕŤåęĆimportèŕ■åŘěæĹŰářĘéŤŹèŕŕæűĹæĄŕåĘŹåĚě `sys.stderr`

15.3 13.3 èğčædŘåŚ¡äžď'èąŇéĂĽéąź

éŮőécŸ

ä¡ăçŽĎçÍŃåžŔåęĆä¡ŢèČ¡åď§èğčædŘåŚ¡äžď'èąŇéĂĽéąźïijĹä¡■äžŐsys.argväÿ■ïijĽ

èğčåĘşæŰźæąĹ

`argparse` æĺąåİŮåŘŕèćńçŤĺæİèèğčædŘåŚ¡äžď'èąŇéĂĽéąźãĂĆäÿŃéİćäÿĂäÿłçőĂå■Ţä¿Ńå■ŘæijŢçď'ž

```
# search.py
'''
Hypothetical command-line tool for searching a collection of
files for one or more text patterns.
'''
import argparse
parser = argparse.ArgumentParser(description='Search some files')
```

```
parser.add_argument(dest='filenames',metavar='filename', nargs='*')

parser.add_argument('-p', '--pat',metavar='pattern', required=True,
                    dest='patterns', action='append',
                    help='text pattern to search for')

parser.add_argument('-v', dest='verbose', action='store_true',
                    help='verbose mode')

parser.add_argument('-o', dest='outfile', action='store',
                    help='output file')

parser.add_argument('--speed', dest='speed', action='store',
                    choices={'slow','fast'}, default='slow',
                    help='search speed')

args = parser.parse_args()

# Output the collected arguments
print(args.filenames)
print(args.patterns)
print(args.verbose)
print(args.outfile)
print(args.speed)
```

èŕěçÍŃåžŔåőŽäźL’äžĘäÿĂäÿłåęĆäÿŃä¡£çŤÍçŽĎåŚ¡äžd’èąŇèğčæđŘåŹÍïijŽ

```
bash % python3 search.py -h
usage: search.py [-h] [-p pattern] [-v] [-o OUTFILE] [--speed {slow,
 ↪fast}]
                 [filename [filename ...]]

Search some files

positional arguments:
  filename

optional arguments:
  -h, --help            show this help message and exit
  -p pattern, --pat pattern
                        text pattern to search for
  -v                    verbose mode
  -o OUTFILE            output file
  --speed {slow,fast}   search speed
```

äÿŃéIćçŽĎéČĺåĹĘæijŤçd’žäžĘçÍŃåžŔäÿ■çŽĎæŢřæ■őéČĺåĹĘãĂĆäżŤçżĘèğĆår§print()èí■åŘěçŽĎæL’Ş

```
bash % python3 search.py foo.txt bar.txt
usage: search.py [-h] -p pattern [-v] [-o OUTFILE] [--speed {fast,
 ↪slow}]
```

```
                [filename [filename ...]]
search.py: error: the following arguments are required: -p/--pat

bash % python3 search.py -v -p spam --pat=eggs foo.txt bar.txt
filenames = ['foo.txt', 'bar.txt']
patterns  = ['spam', 'eggs']
verbose   = True
outfile   = None
speed     = slow

bash % python3 search.py -v -p spam --pat=eggs foo.txt bar.txt -o␣
↪results
filenames = ['foo.txt', 'bar.txt']
patterns  = ['spam', 'eggs']
verbose   = True
outfile   = results
speed     = slow

bash % python3 search.py -v -p spam --pat=eggs foo.txt bar.txt -o␣
↪results \
            --speed=fast
filenames = ['foo.txt', 'bar.txt']
patterns  = ['spam', 'eggs']
verbose   = True
outfile   = results
speed     = fast
```

åŕźäžŐéĂL’éąźåĂijçŽĎè£ŻäÿĂæ■ěåď’ĎçŘĘçŤśçÍŃåžŔæÌěåĘşåőŽïijŇçŤÍä¡äèĞłåůśçŽĎéĂżè¿ŚæÌěæŻ£ `print()` åĞ¡æŢřãĂĆ

èőÍèőž

`argparse` æÍąåİŮæŸŕæăĞåĞĘåžŞäÿ■æIJĂåď’ğçŽĎæÍąåİŮäźŃäÿĂïijŇæŃěæIJL’åď’ğéĞŔçŽĎéĚ■ç¡ő éæIJňèŁĆåŘłæŸŕæijŤçď’žäžĘåĚűäÿ■æIJĂå§žçąĂçŽĎäÿĂäžŻçL’źæĂğïijŇåÿőåŁl’ä¡ääĚěéŮÍãĂĆ

äÿžäžĘèğčædŘåŚ¡äžď’èąŇéĂL’éąźïijŇä¡äéęŰåĚÍèęĄåĹŻåžžäÿĂäÿł `ArgumentParser` åőđä¿ŃïijŇ åźűä¡£çŤÍ `add_argument()` æŰźæşŢåčřæŸŐä¡äæČşèęĄæŤŕæŇĄçŽĎéĂL’éąźãĂĆ åIJÍæŕŔäÿł `add_argument()` èřČçŤÍäÿ■ïijŇ`dest` åŔĆæŢřæŇĞåőŽèğčædŘçżŞædIJèćńæŇĞæť¿çżŹåśđæĂğçŽĎåŘ■å■ŮãĂĆ `metavar` åŔĆæŢřèćńçŤÍæİěçŤ§æĹŘåÿőåŁl’ä£ąæĄŕãĂĆ`action` åŔĆæŢřæŇĞåőŽèů§åśđæĂğåŕźåžŤçŽĎåď’ĎçŘĘéĂżè¿Śïij Ň éĂŽåÿÿçŽĎåĂijäÿž `store` ,èćńçŤÍæİěå■ŸåĆÍæ§ŘäÿłåĂijæĹŮèőšåď’ŽäÿłåŔĆæŢřåĂijæŤűéŽĘåĹřäÿĂäÿłåĹŮèąÍäÿ■ãĂĆ äÿŃéİćçŽĎåŔĆæŢřæŤűéŽĘæL’ĂæIJL’åL’l’ä¡ŹçŽĎåŚ¡äžď’èąŇåŔĆæŢřåĹřäÿĂäÿłåĹŮèąÍäÿ■ãĂĆåIJÍæIJňä¿Ň

```
parser.add_argument(dest='filenames',metavar='filename', nargs='*')
```

äÿŃéİćçŽĎåŔĆæŢřæăźæ■őåŔĆæŢřæŸŕåŘęå■ŸåIJÍæİèèő¿ç¡őäÿĂäÿł `Boolean` æăĞå£ŮïijŽ

```
parser.add_argument('-v', dest='verbose', action='store_true',
                    help='verbose mode')
```

äÿŃéÍćçŽĎåŔĆæŢřæŐěåŔŮäÿĂäÿłå■ŢçŃňåĂijåźűåřĘåĚűå■ŸåĆÍäÿžäÿĂäÿłå■Ůçňęäÿšïijž

```
parser.add_argument('-o', dest='outfile', action='store',
                    help='output file')
```

äÿŃéÍćçŽĎåŔĆæŢřèŕť æŸŐåĚĄèőÿæ§ŘäÿłåŔĆæŢřéĞ■åď■åĞžçŐřåď Žæňąïij Ňåźűåř Ęåő Čäżňè£¡åŁäåÍ
`required` æäĞå£ŮèąÍçď žèŕěåŔĆæŢřèĞşåřŚèęĄæIJL'äÿĂäÿłãĂĆ`-p` åŠŇ `--pat`
èąÍçď žäÿď äÿłåŔĆæŢřåŘ■å¡ćåijŔéČ¡åŔŕä¡£çŤÍãĂĆ

```
parser.add_argument('-p', '--pat',metavar='pattern', required=True,
                    dest='patterns', action='append',
                    help='text pattern to search for')
```

æIJĂåŘŐïijŇäÿŃéÍćçŽĎåŔĆæŢřèŕť æŸŐæŐěåŔŮäÿĂäÿłåĂijïijŇä¡ĘæŸŕäijŽåřĘåĚűåŠŇåŔŕèČ¡çŽĎéĂ

```
parser.add_argument('--speed', dest='speed', action='store',
                    choices={'slow','fast'}, default='slow',
                    help='search speed')
```

äÿĂæŮęåŔĆæŢřéĂL'éąźèćńæŇĞåőŽïijŇä¡ăářšåŔŕäžěæL'ğèąŇ
`parser.parse()` æŰźæşŢäžĘãĂĆ åőČäijŽåď ĎçŘĘ `sys.argv`
çŽĎåĂijåźűè£ŤåŻđäÿĂäÿłçżŞædIJåőđä¿ŃãĂĆ æŕŔäÿłåŔĆæŢřåĂijäijŽèćńèő¿ç¡őæĹŘèŕěåőđä¿Ńäÿ■
`add_argument()` æŰźæşŢçŽĎ `dest` åŔĆæŢřæŇĞåőŽçŽĎåśđæĂğåĂijãĂĆ

è£Ÿå¿Ĺåď Žçğ■åĚűäžŰæŰźæşŢèğčæđŘåŚ¡äžď èąŇéĂL'éąźãĂĆ
ä¿ŃåęĆïijŇä¡ăåŔŕèČ¡äijŽæL'ŃåŁÍçŽĎåď ĎçŘĘ `sys.argv` æĹŰèĂĚä¡£çŤÍ `getopt`
æÍąåİŮãĂĆ ä¡ĘæŸŕïijŇåęĆæđIJä¡äéĞĞçŤÍæIJňèŁĆçŽĎæŰźåijŔïijŇårĘäijŽåĞŔårŚå¿Ĺåď ŽåĘŮä¡Źäžčçă Ąï
`argparse` æÍąåİŮåůšçżŔåÿőä¡ăåď ĎçŘĘäžĘãĂĆ ä¡ăåŔŕèČ¡è£ŸäijŽçćřåĹřä¡£çŤÍ
`optparse` åžŞèğčæđŘéĂL'éąźçŽĎäžčçăĄãĂĆ år¡çőą `optparse` åŠŇ `argparse`
å¿ĹåČŔïijŇä¡ĘæŸŕåŐŐèĂĚæŻť åĚÍè£ŻïijŇåŻäæ■d'åIJÍæŰřçŽĎçÍŃåžŔäÿ■ä¡ăåžŤèŕěä¡£çŤÍåőČãĂĆ

15.4 13.4 è£ŘèąŇæŮűåijźåĞžåŕĘçăĄè¿ŞåĚěæŔŘçď ž

éŮőécŸ

ä¡ăåĘŹäžĘäÿłèĎŽæIJňïijŇè£ŘèąŇæŮűéIJĂèęĄäÿĂäÿłårĘçăĄãĂĆæ■d'èĎŽæIJňæŸŕäžď äžŠåijŔçŽĎïij
èĂŇæŸŕéIJĂèęĄåijźåĞžäÿĂäÿłårĘçăĄè¿ŞåĚěæŔŘçď žïijŇèőľçŤÍæĹůèĞłåůśè¿ŞåĚěãĂĆ

èğčåĘşæŰźæąĹ

è£ŹæŮűåĂŹPythonçŽĎ `getpass` æÍąåİŮæ■čæŸŕä¡ăæĽĂéIJĂèęĄçŽĎãĂĆä¡ăåŔŕäžěèőľä¡ăå¿Ĺè¡żæİ¿
åźűäÿŤäÿ■äijŽåIJÍçŤÍæĹůçżĹçńŕåŽđæŸ¿årĘçăĄãĂĆäÿŃéÍćæŸŕåĚůä¡Şäžčçă Ąïijž

```
import getpass

user = getpass.getuser()
passwd = getpass.getpass()

if svc_login(user, passwd):     # You must write svc_login()
   print('Yay!')
else:
   print('Boo!')
```

åIJÍæ■d'äžčçăĄäÿ■ïijŇsvc_login() æŸŕä¡ăèęĄåőđçŐřçŽĎåd'ĎçŘĘářEçăĄçŽĎåĞ¡æŢřïijŇåĚůä¡Şç

èőÍèőž

æşÍæĎŔåIJÍåL'■éİćäžčçăĄäÿ■ getpass.getuser() äÿ■äijŽåijźåĞžçŤÍæĹůåŘ■çŽĎè¿ŞåĚěæŔŘçd'žãĂĆ åőČäijŽæăźæ■őèŕěçŤÍæĹůçŽĎshellçŐŕåćČæĹŰèĂĚäijŽä¿Íæ■őæIJňåIJřçşżçż§çŽĎårEçăĄåžŞïijĹæŤŕæŇĄ *pwd* æÍąåİŮçŽĎåźşåŔřïijL'æİěä¡£çŤÍå¡ŞåL'■çŤÍæĹůçŽĎçŹżå¡ŢåŘ■ïijŇ

åęĆæđIJä¡ăæČşæŸ¿çd'žçŽĎåijźåĞžçŤÍæĹůåŘ■è¿ŞåĚěæŔŘçd'žïijŇä¡£çŤÍåĘĚç¡őçŽĎ input åĞ¡æŢřïijŽ

```
user = input('Enter your username: ')
```

è£ŸæIJL'äÿĂçĆźå¿ĹéĞ■èęĄïijŇæIJL'äžŻçşżçż§åŔŕèČ¡äÿ■æŤŕæŇĄ getpass() æŰźæşŢéŽŘèŮŔè¿ŞåĚěåŕEçăĄąãĂĆ è£Źçğ■æČĚåĘţäÿŃïijŇPythonäijŽæŔŘåL'■è■ęåŚĹä¡ăè£ŹäžŻéŮőécŸïi

15.5 13.5 èŐůåŔŰçżĹçńŕçŽĎåd'ğářŔ

éŮőécŸ

ä¡ăéIJĂèęĄç§ěéĄŞå¡ŞåL'■çżĹçńŕçŽĎåd'ğářŔäžěä¿£æ■čçąőçŽĎæäijåijŔåŇŰè¿ŞåĞžãĂĆ

èğčåĘşæŰźæąĹ

ä¡£çŤÍ os.get_terminal_size() åĞ¡æŢřæİěåĄŽåĹřè£ŹäÿĂçĆźãĂĆ

äžčçăĄçd'žä¿ŃïijŽ

```
>>> import os
>>> sz = os.get_terminal_size()
>>> sz
os.terminal_size(columns=80, lines=24)
>>> sz.columns
80
>>> sz.lines
```

```
24
>>>
```

èőÍèőž

æIJL'åď'łåď'ŽæŰźåijŔæİěå¿Ůç§ěçżĹçńŕåď'ğářŔäžĘïijŇäžŐèřžåŔŰçŐŕåćČåŔŸéĞŔåĹřæL'ğèąŇåžŢåšĆç
`ioctl()` åĞ¡æŢřç■L'ç■L'ãĂĆ äÿ■è£ĞïijŇäÿžäżĂäźĹèęĄåŐżçăŤçl'űè£ŹäžŻåď'■æİĆçŽĎåŁđæşŢèĂŇäÿ■æ

15.6 13.6 æL'ğèąŇåď'ŰéČĺåŚ¡äžď'åźűäžèŐůåŔŰåőČçŽĎè¿ŞåĞž

éŮőécŸ

ä¡ăæČşæL'ğèąŇäÿĂäÿłåď'ŰéČĺåŚ¡äžď'åźűäžěPythonå■ŮçňęäÿšçŽĎå¡ćåijŔèŐůåŔŰæL'ğèąŇçżŞæđIJãĂ

èğčåĘşæŰźæąĹ

ä¡£çŤÍ `subprocess.check_output()` åĞ¡æŢřãĂĆä¿ŃåęĆïijŽ

```
import subprocess
out_bytes = subprocess.check_output(['netstat','-a'])
```

è£ŹæőţäžčçăĄæL'ğèąŇäÿĂäÿłæŇĞåőŽçŽĎåŚ¡äžď'åźűåřĘæL'ğèąŇçżŞæđIJäžěäÿĂäÿłå■ŮèŁĆå■Ůçňęäÿ
åęĆæđIJä¡ăéIJĂèęĄæŰĞæIJňå¡ćåijŔè£ŤåŻđïijŇåŁääÿĂäÿłèğčçăĄæ■ěéłď'å■şåŔřãĂĆä¿ŃåęĆïijŽ

```
out_text = out_bytes.decode('utf-8')
```

åęĆæđIJèćńæL'ğèąŇçŽĎåŚ¡äžď'äžěéIđéŻűçăĄè£ŤåŻđïijŇåřśäijŽæŁŻåĞžåijĆåÿÿãĂĆ
äÿŃéIćçŽĎä¿Ńå■Řæ■ŢèŐůåĹřéŤŹèŕŕåźűèŐůåŔŰè£ŤåŻđçăĄïijŽ

```
try:
    out_bytes = subprocess.check_output(['cmd','arg1','arg2'])
except subprocess.CalledProcessError as e:
    out_bytes = e.output       # Output generated before error
    code      = e.returncode   # Return code
```

éžŸèőď'æČĚåĘţäÿŃïijŇcheck_output() äžĚäžĚè£ŤåŻđè¿ŞåĚěåĹřæăĞåĞĘè¿ŞåĞžçŽĎåĂijãĂĆ
åęĆæđIJä¡ăéIJĂèęĄåŘŇæŮűæŤűéŻĘæăĞåĞĘè¿ŞåĞžåŠŇéŤŹèŕŕè¿ŞåĞžïijŇä¡£çŤÍ `stderr`
åŔĆæŢřïijŽ

```
out_bytes = subprocess.check_output(['cmd','arg1','arg2'],
                                    stderr=subprocess.STDOUT)
```

åęĆæđIJä¡ăéIJĂèęĄçŤĺäÿĂäÿłèűĚæŮűæIJžåĹűæIěæL'ğèąŇåŚ¡äžď'ïijŇä¡£çŤÍ `timeout`
åŔĆæŢřïijŽ

```
try:
    out_bytes = subprocess.check_output(['cmd','arg1','arg2'],␣
↪timeout=5)
except subprocess.TimeoutExpired as e:
    ...
```

éĂŽåÿÿæÌèèőšïijŇåŚ¡äžd'çŽĎæĽğèąŇäÿ■éIJĂèęĄä¡£çŤĺåĹřåžŢåśĆshellçŐřåćČïijĹæŕŤåęĆshãĂĄbash äÿĂäÿłå■Ůçňęäÿšå ĹŮèąĺäijŽèćńäijåéĂŠçżŹäÿĂäÿłä¡Őçžğçşżçż§åŚ¡äžd'ïijŇæŕŤåęĆ os. execve() ãĂĆ åęĆæđIJä¡ăæČşèől'åŚ¡äžd'èćńäÿĂäÿłshellæĽğèąŇïijŇäijåéĂŠäÿĂäÿłå■Ůçňęäÿšå ŔĆæŢřïij shell=True. æIJL'æŮűåĂŹä¡ăæČşèęĄPythonåŐżæĽğèąŇäÿĂäÿłåd'■æÍĆçŽĎshellåŚ¡äžd'çŽĎæŮűåĂŹè

```
out_bytes = subprocess.check_output('grep python | wc > out',␣
↪shell=True)
```

éIJĂèęĄæşĺæĎŔçŽĎæŸŕåIJĺshelläÿ■æĽğèąŇåŚ¡äžd'äijŽå■ŸåIJĺäÿĂåőŽçŽĎåőL'åĚĺéčŐéŹl'ïijŇçL'źåĹ è£ŹæŮűåĂŹåŔŕäžěä¡£çŤĺ shlex.quote() åĞ¡æŢřæÌèèőšåŔĆæŢřæ■čçąőçŽĎçŤĺåŔŇåijŢçŤĺåijŢètůæÌěã

èőĺèőž

ä¡£çŤĺ check_output() åĞ¡æŢřæŸŕæĽğèąŇåd'ŰéČĺåŚ¡äžd'åźűèŐůåŔŰåĚűè£ŤåŻđåĂijçŽĎæIJĂçĉ ä¡ĘæŸŕïijŇåęĆæđIJä¡ăéIJĂèęĄåŕźå■Řè£ŻçĺŇåĄŽæŻt'åd'■æÍĆçŽĎäžd'äžŠïijŇæŕŤåęĆçżŹåőČåŔŠéĂĄè¿Şå è£ŹæŮűåĂŹåŔŕçŻt'æŐěä¡£çŤĺ subprocess.Popen çśżãĂĆä¿ŇåęĆïijŽ

```
import subprocess

# Some text to send
text = b'''
hello world
this is a test
goodbye
'''

# Launch a command with pipes
p = subprocess.Popen(['wc'],
          stdout = subprocess.PIPE,
          stdin = subprocess.PIPE)

# Send the data and get the output
stdout, stderr = p.communicate(text)

# To interpret as text, decode
out = stdout.decode('utf-8')
err = stderr.decode('utf-8')
```

subprocess æĺąåİŮåŕźäžŐä¿İètŰTTYçŽĎåd'ŰéČĺåŚ¡äžd'äÿ■åŘĹéĂĆçŤĺãĂĆ ä¿ŇåęĆïijŇä¡ăäÿ■èČ¡ä¡£çŤĺåőČæÌèèĞłåŁĺåŇŰäÿĂäÿłçŤĺæĹůè¿ŞåĚèåŕĘçăĄçŽĎäżżåŁąïijĹæŕŤåęĆäÿĂäÿłss è£ŹæŮűåĂŹïijŇä¡ăéIJĂèęĄä¡£çŤĺåĹřçňňäÿL'æŰźæĺąåİŮäžĘïijŇæŕŤåęĆå§žäžŐèŚŮåŘ■çŽĎ expect åőűæŮŘçŽĎåůěåĚůïijĹpexpectæĹŰçśżäijijçŽĎïijL'

15.7 13.7 åď■åĹűæĹŰèĂĚçğżåŁĺæŰĞäžűåŠŇçŻőå¡Ţ

éŮőécŸ

ä¡ăæČşèęĄåď■åĹűæĹŰçğżåŁĺæŰĞäžűåŠŇçŻőå¡ŢïijŇä¡ĘæŸŕåŔĹäÿ■æČşèřČçŤĺshellåŚ¡äžď˜ãĂĆ

èğčåĘşæŰźæąĹ

shutil æĺąåİŮæIJL'å¿Ĺåď'Žä¿£æ■ůçŽĎåĞ¡æŢřåŔŕäžěåď■åĹűæŰĞäžűåŠŇçŻőå¡ŢãĂĆä¡£çŤĺèţůæİěé

```
import shutil

# Copy src to dst. (cp src dst)
shutil.copy(src, dst)

# Copy files, but preserve metadata (cp -p src dst)
shutil.copy2(src, dst)

# Copy directory tree (cp -R src dst)
shutil.copytree(src, dst)

# Move src to dst (mv src dst)
shutil.move(src, dst)
```

è£ŹäžŻåĞ¡æŢřçŽĎåŔĆæŢřéČ¡æŸŕå■Ůçňęäÿšå¡ćåijŔçŽĎæŰĞäžűæĹŰçŻőå¡ŢåŘ■ãĂĆ
åžŢåśĆèŕ■äźĽ'æĺąæŃ§äžĘçśżäijijçŽĎUnixåŚ¡äžď˜ïijŇåęĆäÿŁéİćçŽĎæşĺéĞŁéČĺåĹĘãĂĆ

éżŸèŏď'æČĚåĘţäÿŃïijŇåŕźäžŐçňęåŘůéŞ¿æŐëèĂŇåůšè£ŹäžŻåŚ¡äžď'åď'ĎçŘĘçŽĎæŸŕåőČæŇĞåŘŚçŽ
ä¿ŃåęĆïijŇåęĆæđIJæžŘæŰĞäžűæŸŕäÿĂäÿłçňęåŘůéŞ¿æŐëïijŇéĆčäźĹçŻőæăĞæŰĞäžűåřĘäijŽæŸŕçňęåŘůé
åęĆæđIJä¡ååŔłæČşåď'■åĹűçňęåŘůéŞ¿æŐëæIJňèžńïijŇéĆčäźĹéIJĂèęĄæŇĞåőŽåĚşéŤőå■ŮåŔĆæŢř
follow_symlinks ,åęĆäÿŃïijŽ

åęĆæđIJä¡ăæČşä£ĺçŢŹèćńåď'■åĹűçŻőå¡Ţäÿ■çŽĎçňęåŘůéŞ¿æŐëïijŇåČŔè£ŹæăůåĄŽïijŽ

```
shutil.copytree(src, dst, symlinks=True)
```

copytree() åŔŕäžěèőľ'ä¡ăåIJĺåď'■åĹűè£ĞçĺŃäÿ■éĂĽ'æŃľ'æĂğçŽĎå£¡çŢěæ§ŘäžŻæŰĞäžűæĹŰçŻőå
ä¡ăåŔŕäžěæŔŘä¿ŻäÿĂäÿłå£¡çŢěåĞ¡æŢřijŇæŐěåŘŮäÿĂäÿłçŻőå¡ŢåŘ■åŠŇæŰĞäžűåŘ■åĹŮèąĺä¡IJäÿžè¿ŞåŘ

```
def ignore_pyc_files(dirname, filenames):
    return [name in filenames if name.endswith('.pyc')]

shutil.copytree(src, dst, ignore=ignore_pyc_files)
```

çŤśäžŐå£¡çŢěæ§Řçğ■æĺąåijŔçŽĎæŰĞäžűåŘ■æŸŕå¿Ĺåÿÿè ĞąçŽĎïijŇåŻăæ■đ'äÿĂäÿłä¿£æ■ůçŽĎåĞ¡æ
ignore_patterns() åůšçżŘåŇĚåŘńåIJĺéĞŇéİćäžĘãĂĆä¿ŃåęĆïijŽ

```
shutil.copytree(src, dst, ignore=shutil.ignore_patterns('*~', '*.pyc
↪'))
```

èőÍèőž

ä¡£çŤÍ `shutil` åď■åĹűæŰĞäžűåŠŇçŻőå¡Ţäź§å£ŠçőĂå■ŢäžEçĆźåŘğãĂĆ
äÿ■è£ĞïijŇåŕźäžŐæŰĞäžűåĚČæŢřæ■őä£qæĄŕïijŇ`copy2()` è£ŹæăůçŽĎåĞ¡æŢřåŘłèČ¡ař¡èĞłåůśæIJĂåď ğè
èő£éŰőæŮűéŮťãĂĄåĹŻåžžæŮűéŮťåŠŇæİČéŹŘè£ŹäžŻå§žæIJňä£qæĄŕäijŽèćńä£İçŢŹïijŇ
ä¡ĘæŸŕåŕźäžŐæĽĂæIJL'èĂĚãĂĄACLsãĂĄètĎæžŘforkåŠŇåĚűäžŰæŻť'æůśåśĆæňąçŽĎæŰĞäžűåĚČä£qæA
è£Źäÿłè£Ÿå¿Ůä¿ÌètŰäžŐåžŢåśĆæŞ■ä¡IJçşżçż§çśžåđŃåŠŇçŤÍæĹůæĽĂæŃěæIJL'çŽĎèő£éŰőæİČéŹŘãĂĆ
ä¡ăéĂŽåÿÿäÿ■äijŽåŐżä¡£çŤÍ `shutil.copytree()` åĞ¡æŢřæİěæĽ'ğèąŇçşżçż§åď'Ğäż¡ãĂĆ
å¡Şåď'ĎçŘĘæŰĞäžűåŘ■çŽĎæŮűåĂŹïijŇæIJĂåě¡ä¡£çŤÍ `os.path`
äÿ■çŽĎåĞ¡æŢřæİěçąőä£İæIJĂåď ğçŽĎåŔŕçğżæď■æĂğïijĹçL'źåĹńæŸŕåŘŇæŮűèęĄéĂĆçŤÍäžŐUnixåŠŇWi
ä¿ŃåęĆïijŽ

```
>>> filename = '/Users/guido/programs/spam.py'
>>> import os.path
>>> os.path.basename(filename)
'spam.py'
>>> os.path.dirname(filename)
'/Users/guido/programs'
>>> os.path.split(filename)
('/Users/guido/programs', 'spam.py')
>>> os.path.join('/new/dir', os.path.basename(filename))
'/new/dir/spam.py'
>>> os.path.expanduser('~/guido/programs/spam.py')
'/Users/guido/programs/spam.py'
>>>
```

ä¡£çŤÍ `copytree()` åď'■åĹűæŰĞäžűåď'źçŽĎäÿĂäÿłæčŸæĽŃçŽĎéŮőécŸæŸŕåŕźäžŐéŤŹèŕŕçŽĎåď'Ď
ä¿ŃåęĆïijŇåIJĺåď'■åĹűè£ĞçĺŃäÿ■ïijŇåĞ¡æŢřåŘŕèČ¡äijŽçćřåĹřæ■§åİŔçŽĎçňęåŘůéŞ¿æŐěïijŇåŽääÿžæİČéŹ
äÿžäžĘèğčåĘşè£ŹäÿłéŮőécŸïijŇæĽĂæIJL'çćřåĹřçŽĎéŮőécŸäijŽèćńæŤűéŻĘåĹřäÿĂäÿłåĹŮèąĺäÿ■åźűæĽŞ
äÿŃéİćæŸŕäÿĂäÿłä¿Ńå■ŘïijŽ

```
try:
    shutil.copytree(src, dst)
except shutil.Error as e:
    for src, dst, msg in e.args[0]:
         # src is source name
         # dst is destination name
         # msg is error message from exception
         print(dst, src, msg)
```

åęĆædIJä¡ăæŔŘä¿ŻåĚşéŤőå■ŮåŔĆæŢř `ignore_dangling_symlinks=True` ïijŇ
è£ŹæŮűåĂŹ `copytree()` äijŽå£¡çŢěæŐĽæŮăæŢĹçňęåŘůéŞ¿æŐěãĂĆ

æIJňèŁĆæijŤçď'žçŽĎè£ŹäžŻåĞ¡æŢřéČ¡æŸŕæIJĂåÿÿèğĄçŽĎãĂĆäÿ■è£ĞïijŇ`shutil`
è£ŸæIJĽæŻť'åď'ŽçŽĎåŠŇåď'■åĹűæŢřæ■őçŻÿåĚşçŽĎæŞ■ä¡IJãĂĆ
åőĈçŽĎæŰĞæąčå¿ĹåĂijå¿ŮäÿĂçIJŃïijŇåŔĆèĂČ Python documentation

15.8 13.8 åĹŻåžžåŠŇèğčåŐŃå¡Šæąčæ ŰĞäžű

éŮőécŸ

ä¡ăéIJĂèęĄåĹŻåžžæĹŰèğčåŐŃåÿÿèğĄæăijåijŔçŽĎå¡Šæąčæ ŰĞäžűïijĹæŕŤåęĆ.tar, .tgzæĹŰ.zipïijL'

èğčåĘşæŰźæąĹ

shutil æĺąåİŮæŃěæIJL'äÿd'äÿłåĞ¡æŢřâĂŤâĂŤ make_archive() åŠŇ unpack_archive() åŔŕæt'¿äÿŁçŤĺåIJžãĂĆ ä¿ŃåęĆïijŽ

```
>>> import shutil
>>> shutil.unpack_archive('Python-3.3.0.tgz')

>>> shutil.make_archive('py33','zip','Python-3.3.0')
'/Users/beazley/Downloads/py33.zip'
>>>
```

make_archive() çŽĎçňňäžŇäÿłåŔĆæŢřæŸŕæIJ§æIJŻçŽĎè¿ŞåĞžæăijåijŔãĂĆ åŔŕäžěä¡£çŤĺ get_archive_formats() èŐůåŔŰæL'ĂæIJL'æŤŕæŇAçŽĎå¡ŠæąčæăijåijŔåĹŰèąĺãĂĆä¿Ň

```
>>> shutil.get_archive_formats()
[('bztar', "bzip2'ed tar-file"), ('gztar', "gzip'ed tar-file"),
 ('tar', 'uncompressed tar file'), ('zip', 'ZIP file')]
>>>
```

èőĺèőž

Pythonè£ŸæIJL'åĚűäžŰçŽĎæĺąåİŮåŔŕçŤĺæİěåď'ĎçŘĘåď'Žçğ■å¡ŠæąčæăijåijŔïijĹæŕŤåęĆtarfile, zipfile, gzip, bz2ïijL'çŽĎåžŢåśĆçżĘèŁĆãĂĆ äÿ■è£ĞïijŇåęĆædIJä¡ääžĔäžĔåŔłæŸŕèęĄåĹŻåžžæĹŰæŔŘåŔŰ åŔŕäžěçŻť'æŐěä¡£çŤĺ shutil äÿ■çŽĎè£ŹäžŻéńŸåśĆåĞ¡æŢřãĂĆ

è£ŹäžŻåĞ¡æŢřè£ŸæIJL'å¿Ĺåď'ŽåĚűäžŰéĂL'éąźïijŇçŤĺäžŐæŮěå£ŮæL'Şå■řãĂĄécĎæčĂãĂĄæŰĞäžűa åŔĆèĂČ shutilæŰĞæąč

15.9 13.9 éĂŽè£ĞæŰĞäžűåŘ■æ§ěæL'¿æŰĞäžű

éŮőécŸ

ä¡ăéIJĂèęĄåĘŹäÿĂäÿłæűL'åŔŁåĹřæŰĞäžűæ§ěæL'¿æŞ■ä¡IJçŽĎèĎŽæIJñïijŇæŕŤåęĆåŕźæŮěå£Ůå¡Šæą ä¡ăäÿ■æČşåIJĺPythonèĎŽæIJñäÿ■èřĆçŤĺshellïijŇæĹŰèĂĚä¡ăèęĄåőđçŐřäÿĂäžŻshelläÿ■èČ¡åĄŽçŽĎåŁ§èČ

èğčåĘşæŰźæąĹ

æ§ěæL'¿æŰĞäžűïijŇåŕŕä¡£çŤĺ `os.walk()` åĞ¡æŢřïijŇäijääÿĂäÿłéąűçžğçŻőå¡ŢåŘ■çżŹåőČãĂĆ
äÿŇéĺćæŸŕäÿĂäÿłä¿Ńå■ŘïijŇæ§ěæL'¿çL'źåőŽçŽĎæŰĞäžűåŘ■åźűç■ŤåžŤæL'ĂæIJL'çňęåŘĹæĺąäžűçŽĎæŰ

```
#!/usr/bin/env python3.3
import os

def findfile(start, name):
    for relpath, dirs, files in os.walk(start):
        if name in files:
            full_path = os.path.join(start, relpath, name)
            print(os.path.normpath(os.path.abspath(full_path)))

if __name__ == '__main__':
    findfile(sys.argv[1], sys.argv[2])
```

ä£Ĺå■ŸèĎŽæIJňäÿžæŰĞäžűfindfile.pyïijŇçĎűåŘŐåIJĺåŚ¡äžd'èąŇäÿ■æL'ğèąŇåőČãĂĆ
æŇĞåőŽåĹĺåğŃæ§ěæL'¿çŻőå¡ŢäžěåŔŁåŘ■å■Ůä¡IJäÿžä¡■ç¡őåŔĆæŢřïijŇåęĆäÿŃïijŽ

èőĺèőž

`os.walk()` æŰźæşŢäÿžæĹŚäžňéĄ■åŐĘçŻőå¡ŢæăŚïijŇ
æŕŔæňąè£ŻåĚěäÿĂäÿłçŻőå¡ŢïijŇåőČäijŽè£ŤåŻđäÿĂäÿłäÿL'åĚČçżĎïijŇåŇĚåŘńçŻÿåŕźäžŐæ§ěæL'¿çŻőå¡Ţ
äžěåŔŁéĆčäÿłçŻőå¡ŢäÿŇéĺćçŽĎæŰĞäžűåŘ■åĹŮèąĺãĂĆ

åŕźäžŐæŕŔäÿłåĚČçżĎïijŇåŔłéIJĂæčĂæţŃäÿĂäÿŃçŻőæăĞæŰĞäžűåŘ■æŸŕåŘęåIJĺæŰĞäžűåĹŮèąĺäÿ■
`os.path.join()` åŘĹåźűèůŕå¿ĎãĂĆ äÿžäžĘéĄ£åĚ■åěĞæĂłçŽĎèůŕå¿ĎåŘ■æŕŤåęĆ `./`
`./foo//bar` ïijŇä¡£çŤĺäžĘåŔęåď'Űäÿď'äÿłåĞ¡æŢřæĺëä£őæ■čçżŞædIJãĂĆ çňňäÿĂäÿłæŸŕ
`os.path.abspath()` ,åőČæŐěåŔŮäÿĂäÿłèůŕå¿ĎïijŇåŔŕèČ¡æŸŕçŽÿåŕźèůŕå¿ĎïijŇæIJĂåŘŐè£ŤåŻđçżĺå
çňňäžŇäÿłæŸŕ `os.path.normpath()` ïijŇçŤĺæĺěè£ŤåŻđæ■čåÿÿèůŕå¿ĎïijŇåŔŕäžěèğčåĘşåŔŇæŰIJæĺĘã

år¡çőąè£ŹäÿłèĎŽæIJňçŻÿåŕźäžŐUNIXåźşåŘřäÿŁéĺćçŽĎå¿Ĺåď'Žæ§ěæL'¿æĺěèőšèęĄçőĂå■Ţå¿Ĺåď'ŽïijŃ
åźűäÿŤïijŇè£ŸèČ¡å¿Ĺè¡żæĺ¿çŽĎåŁăåĚěåĚűäžŰçŽĎåŁ§èČ¡ãĂĆ
æĹŚäžňåĘ■æijŤçď'žäÿĂäÿłä¿Ńå■ŘïijŇäÿŃéĺćçŽĎåĞ¡æŢřæL'Şå■řæL'ĂæIJL'æIJĂè£Śèćńä£őæŤźè£ĞçŽĎæŰ

```
#!/usr/bin/env python3.3

import os
import time

def modified_within(top, seconds):
    now = time.time()
    for path, dirs, files in os.walk(top):
        for name in files:
            fullpath = os.path.join(path, name)
            if os.path.exists(fullpath):
                mtime = os.path.getmtime(fullpath)
                if mtime > (now - seconds):
                    print(fullpath)
```

```
if __name__ == '__main__':
    import sys
    if len(sys.argv) != 3:
        print('Usage: {} dir seconds'.format(sys.argv[0]))
        raise SystemExit(1)

    modified_within(sys.argv[1], float(sys.argv[2]))
```

åIJÍæ■d'åĞ¡æŢřçŽĎå§žçąĂäźŃäÿŁïijŇä¡£çŤÍos,os.path,globç■L'çśżäijijæÍąåİŮïijŇä¡ääřśèČ¡åőđçŐřæŻt
åŔřåŔĆèĂČ5.11åřŔèŁĆåŠŇ5.13åřŔèŁĆç■L'çŻÿåĚşçńäèŁĆãĂĆ

15.10 13.10 èŕżåŔŰéĚ■ç¡őæŰĞäżű

éŮőécŸ

æĂŐæăůèŕżåŔŰæŹőéĂŽ.iniæäijåijŔçŽĎéĚ■ç¡őæŰĞäžűïij§

èğčåĘşæŰźæąĹ

configparser æÍąåİŮèČ¡èćńçŤÍæİěèŕżåŔŰéĚ■ç¡őæŰĞäżűãĂĆä¿ŇåęĆïijŇåĄĞèő¿ä¡ăæIJL'åęĆäÿŃç

```
; config.ini
; Sample configuration file

[installation]
library=%(prefix)s/lib
include=%(prefix)s/include
bin=%(prefix)s/bin
prefix=/usr/local

# Setting related to debug configuration
[debug]
log_errors=true
show_warnings=False

[server]
port: 8080
nworkers: 32
pid-file=/tmp/spam.pid
root=/www/root
signature:
    =================================
    Brought to you by the Python Cookbook
    =================================
```

äÿŃéİćæŸŕäÿĂäÿłèŕżåŔŰåŠŇæŔŘåŔŰåĚűäÿ■åĂijçŽĎä¿Ňå■ŘïijŽ

```
>>> from configparser import ConfigParser
>>> cfg = ConfigParser()
>>> cfg.read('config.ini')
['config.ini']
>>> cfg.sections()
['installation', 'debug', 'server']
>>> cfg.get('installation','library')
'/usr/local/lib'
>>> cfg.getboolean('debug','log_errors')

True
>>> cfg.getint('server','port')
8080
>>> cfg.getint('server','nworkers')
32
>>> print(cfg.get('server','signature'))

\==================================
Brought to you by the Python Cookbook
\==================================
>>>
```

åęĆædIJæIJL'éIJĂèęĄïijŇä¡ăè£ŸèČ¡ä£őæŤźéĚ■ç¡ő åźűä¡£çŤÍ `cfg.write()` æŰźæşŢåřĘåĚűåĘŹåŻđåĹřæŰĞäżűäÿ■ãĂĆä¿ŃåęĆïijŽ

```
>>> cfg.set('server','port','9000')
>>> cfg.set('debug','log_errors','False')
>>> import sys
>>> cfg.write(sys.stdout)
```

```
[installation]
library = %(prefix)s/lib
include = %(prefix)s/include
bin = %(prefix)s/bin
prefix = /usr/local

[debug]
log_errors = False
show_warnings = False

[server]
port = 9000
nworkers = 32
pid-file = /tmp/spam.pid
root = /www/root
signature =
          ==================================
          Brought to you by the Python Cookbook
          ==================================
>>>
```

èőÍèőž

éĚ■ç¡őæŰĞäžűä¡IJäÿžäÿĂçğ■åŔŕèŕżæĂğå¿Ĺåě¡çŽĎæäijåijŔïijŇéİđåÿÿéĂĆçŤĺäžŐå■ŸåĆĺçĺŇåžŔäÿ■çŽ
åIJĺæŕŔäÿłéĚ■ç¡őæŰĞäžűäÿ■ïijŇéĚ■ç¡őæŢřæ■őäijŽèćńåĹĘçżĎïijĹæŕŤåęĆä¿Ňå■Řäÿ■çŽĎâĂIJinstallationâ
âĂIJdebugâĂİ åŠŇ âĂIJserverâĂİïijL'ãĂĆ æŕŔäÿłåĹĘçżĎåIJĺåĚűäÿ■æŇĞåőŽåŕźåžŢçŽĎåŘĎäÿłåŔŸéĞŔåĂ

åŕźäžŐåŔŕåőđçŐřåŘŇæăůåŁ§èČ¡çŽĎéĚ■ç¡őæŰĞäžűåŠŇPythonæžŘæŰĞäžűæŸŕæIJL'å¿Ĺåď'ğçŽĎäÿ■
éęŰåĚĹïijŇéĚ■ç¡őæŰĞäžűçŽĎèŕ■æşŢèęĄæŻť'èĞłçŤśäžŻïijŇäÿŇéİćçŽĎèţŇåĂijèŕ■åŘěæŸŕç■L'æŢĹçŽĎïij

```
prefix=/usr/local
prefix: /usr/local
```

éĚ■ç¡őæŰĞäžűäÿ■çŽĎåŘ■å■ŮæŸŕäÿ■åŇžåĹĘåď'ğářŔåĘŹçŽĎãĂĆä¿ŇåęĆïijŽ

```
>>> cfg.get('installation','PREFIX')
'/usr/local'
>>> cfg.get('installation','prefix')
'/usr/local'
>>>
```

åIJĺèğčæđŘåĂijçŽĎæŮűåĂŹïijŇgetboolean() æŰźæşŢæ§ěæL'¿äžżä¡ŢåŔŕèąŇçŽĎåĂijãĂĆä¿ŇåęĆ

```
log_errors = true
log_errors = TRUE
log_errors = Yes
log_errors = 1
```

æĹŰèőÿéĚ■ç¡őæŰĞäžűåŠŇPythonäžčçăĄæIJĂåď'ğçŽĎäÿ■åŘŇåIJĺäžŐïijŇåőČåźűäÿ■æŸŕäžŐäÿŁèĂŇ
æŰĞäžűæŸŕåőL'èčĚäÿĂäÿłæŢť'ä¡ŞèćńèŕżåŔŰçŽĎãĂĆåęĆæđIJçćřåĹřäžĘåŔŸéĞŔæŻ£æ■ćïijŇåőČåőđéŹĚä
ä¿ŇåęĆïijŇåIJĺäÿŇéİćè£ŹäÿłéĚ■ç¡őäÿ■ïijŇprefix åŔŸéĞŔåIJĺä¡£çŤĺåőČçŽĎåŔŸéĞŔäźŇåL'■æĹŰäźŇåŘ

```
[installation]
library=%(prefix)s/lib
include=%(prefix)s/include
bin=%(prefix)s/bin
prefix=/usr/local
```

ConfigParser æIJL'äÿłåőźæŸŞèćńå£¡èğĘçŽĎçL'źæĂğæŸŕåőČèČ¡äÿĂæňąèŕżåŔŰåď'ŽäÿłéĚ■ç¡őæŰ
ä¿ŇåęĆïijŇåĄĞèő¿äÿĂäÿłçŤĺæĹůåČŔäÿŇéİćè£ŹæåüædĎéĂääžĘäżŰäžňçŽĎéĚ■ç¡őæŰĞäžűïijŽ

```
; ~/.config.ini
[installation]
prefix=/Users/beazley/test

[debug]
log_errors=False
```

èŕżåŔŰè£ŹäÿłæŰĞäžűïijŇåőČåřśèČ¡èů§äźŇåL'■çŽĎéĚ■ç¡őåŘĹåźűèţůæİěãĂĆåęĆïijŽ

```
>>> # Previously read configuration
>>> cfg.get('installation', 'prefix')
```

```
'/usr/local'

>>> # Merge in user-specific configuration
>>> import os
>>> cfg.read(os.path.expanduser('~/.config.ini'))
['/Users/beazley/.config.ini']

>>> cfg.get('installation', 'prefix')
'/Users/beazley/test'
>>> cfg.get('installation', 'library')
'/Users/beazley/test/lib'
>>> cfg.getboolean('debug', 'log_errors')
False
>>>
```

äżŤçżĘèğĆår§äÿŃ `prefix` åŔŸéĞŔæŸŕæĂŐæăůèęĘçŻŰåĚűäżŰçŻÿåĚşåŔŸéĞŔçŽĎïijŇæŕŤåęĆ `library` çŽĎèő¿åőŽåĂijãĂĆ äžğçŤ§è£Źçğ■çżŞæđIJçŽĎåŐ§åŻăæŸŕåŔŸéĞŔçŽĎæŤźåĘźéĞĞåŔŰçŽĎæ ä¡ăåŔŕäžěåČŔäÿŃéİćè£ŹæăůåĄŽèŕŢéłŇïijŽ

```
>>> cfg.get('installation','library')
'/Users/beazley/test/lib'
>>> cfg.set('installation','prefix','/tmp/dir')
>>> cfg.get('installation','library')
'/tmp/dir/lib'
>>>
```

æIJĂåŘŐè£ŸæIJL'å¿ĹéĞ■èęĄäÿĂçĆźèęĄæşÍæĎŔçŽĎæŸŕPythonåźűäÿ■èČ¡æŤŕæŇĄ.iniæŰĞäżűåIJÍål çąőä£Ìä¡ăåůšçżŔåŔĆéŸĚäžĘconfigparseræŰĞæąčäÿ■çŽĎèŕ■æşŢèŕęæČĚäžěåŘŁæŤŕæŇĄçL'źæĂğãĂĆ

15.11 13.11 çżŹçőĂå■ŢèĎŽælJňáćđåŁäæŮěå£ŮåŁ§èČ¡

éŮőécŸ

ä¡ăåÿŇæIJŻåIJÍèĎŽæIJňåŠŇçÍŃåžŔäÿ■årĘèŕŁæŰ■ä£ąæĄŕåĘŹåĚěæŮěå£ŮæŰĞäżűãĂĆ

èğčåĘşæŰźæąĹ

æL'Şå■řæŮěå£ŮæIJĂçőĂå■ŢæŰźåijŔæŸŕä¡£çŤÍ `logging` æÍąåİŮãĂĆä¿ŃåęĆïijŽ

```
import logging

def main():
    # Configure the logging system
    logging.basicConfig(
        filename='app.log',
        level=logging.ERROR
    )
```

```
    # Variables (to make the calls that follow work)
    hostname = 'www.python.org'
    item = 'spam'
    filename = 'data.csv'
    mode = 'r'

    # Example logging calls (insert into your program)
    logging.critical('Host %s unknown', hostname)
    logging.error("Couldn't find %r", item)
    logging.warning('Feature is deprecated')
    logging.info('Opening file %r, mode=%r', filename, mode)
    logging.debug('Got here')

if __name__ == '__main__':
    main()
```

äÿŁéÍćäžŤäÿłæŮěå£ŮèřČçŤĺïijĹcritical(), error(), warning(), info(), debug()ïijĽäžéÉ■åžŔæŰźåijŔèąĺçď žäÿ■åŘŇçŽĎäÿěéĞ■çžğåĹńãĂĆ basicConfig() çŽĎ level åŔĆæŢřæŸŕäÿĂäÿłè£Ğæżď åŹĺãĂĆ æĽĂæIJĽçžğåĹńä¡ŐäžŐæ■ď çžğåĹńçŽĎæŮěå£ŮæűĹæĄŕéČ¡äijŽèćńå£¡çŢěæŐĽãĂĆ æŕŔäÿłloggingæŞ■ä¡IJçŽĎåŔĆæŢřæŸŕäÿĂäÿłæűĹæĄŕå■ŮçňęäÿšïijŇåŘŐéÍćåĘ■èů§äÿĂäÿłæĹŰåď ŽäÿłåŔĆ æđĎéĂăæIJĂçžĹçŽĎæŮěå£ŮæűĹæĄŕçŽĎæŮűåĂŹæĹŚäžňä¡£çŤĺäžĘ%æŞ■ä¡IJçňęæÍěæăijåijŔåŇŰæűĹæĄ

è£ŘèąŇè£ŹäÿłçÍŃåžŔåŘŐïijŇåIJĺæŰĞäžű app.log äÿ■çŽĎåĘĚåőźåžŤèřěæŸŕäÿŃéÍćè£ŹæăůïijŽ

```
CRITICAL:root:Host www.python.org unknown
ERROR:root:Could not find 'spam'
```

åęĆædIJä¡ăæČşæŤźåŔŸè¿ŞåĞžç■ĽçžğïijŇä¡ăåŔŕäžëä£őæŤź basicConfig() èřČçŤĺäÿ■çŽĎåŔĆæŢřãĂĆä¿ŃåęĆïijŽ

```
logging.basicConfig(
     filename='app.log',
     level=logging.WARNING,
     format='%(levelname)s:%(asctime)s:%(message)s')
```

æIJĂåŘŐè¿ŞåĞžåŔŸæĹŘåęĆäÿŃïijŽ

```
CRITICAL:2012-11-20 12:27:13,595:Host www.python.org unknown
ERROR:2012-11-20 12:27:13,595:Could not find 'spam'
WARNING:2012-11-20 12:27:13,595:Feature is deprecated
```

äÿŁéÍćçŽĎæŮěå£ŮéĚ■ç¡őéČ¡æŸŕçąńçijŰçăĄåĹřçÍŃåžŔäÿ■çŽĎãĂĆåęĆædIJä¡ăæČşä¡£çŤĺéĚ■ç¡őæŰČ åŔŕäžëåČŔäÿŃéÍćè£ŹæăůäŁőæŤź basicConfig() èřČçŤĺïijŽ

```
import logging
import logging.config

def main():
    # Configure the logging system
```

```
    logging.config.fileConfig('logconfig.ini')
    ...
```

åĹŻåžžäÿĂäÿłäÿŃéÍćè£ŹæăůçŽĎæŰĞäžűïijŇåŘ■å■ŮåŔń logconfig.ini ïijŽ

```
[loggers]
keys=root

[handlers]
keys=defaultHandler

[formatters]
keys=defaultFormatter

[logger_root]
level=INFO
handlers=defaultHandler
qualname=root

[handler_defaultHandler]
class=FileHandler
formatter=defaultFormatter
args=('app.log', 'a')

[formatter_defaultFormatter]
format=%(levelname)s:%(name)s:%(message)s
```

åęĆæđIJä¡ăæČşä£őæŤźéĚ■ç¡őïijŇåŘŕäžěçŻť'æŐěçijŰè¿ŚæŰĞäžűlogconfig.iniå■şåŔŕãĂĆ

èőÍèőž

åř¡çőąåŕźäžŐ logging æĺąåİŮèĂŇåůšæIJL'å¿Ĺåđ'ŽæŻť'éńŸçžğçŽĎéĚ■ç¡őéĂL'éąźïijŇäÿ■è£Ğè£ŹéĞŇçŽĎæŰźæąĹåŕźäžŐçőĂå■ŢçŽĎçÍŃåžŔåŠŇèĎŽæIJňåůšçżŔèűşåđ'§äžĘãĂĆåŘłæČşåIJÍěřČçŤÍæŮěå£ŮæŞ■ä¡IJåL'■åĚĹæL'ğèąŇäÿŃbasicConfig()åĞ¡æŢřæŰźæşŢïijŇä¡ăçŽĎçÍŃåžŔåřśè

åęĆæđIJä¡ăæČşèęĄä¡ăçŽĎæŮěå£ŮæűĹæĄŕåĘŹåĹřæăĞåĞĘéŤŹèŕŕäÿ■ïijŇèĂŇäÿ■æŸŕæŮěå£ŮæŰĞäž basicConfig() æŮűäÿ■äijăæŰĞäžűåŘ■åŔĆæŢřå■şåŔŕãĂĆä¿ŃåęĆïijŽ

```
logging.basicConfig(level=logging.INFO)
```

basicConfig() åIJÍçÍŃåžŔäÿ■åŘłèČ¡èćńæL'ğèąŇäÿĂæňąãĂĆåęĆæđIJä¡ăçÍ■åŘŐæČşæŤźåŔŸæŮěå åřśéIJĂèęĄåĚĹèŐůåŔŰ root logger ïijŇçĎűåŘŐçŻť'æŐëä£őæŤźåőČãĂĆä¿ŃåęĆïijŽ

```
logging.getLogger().level = logging.DEBUG
```

éIJĂèęĄåijžèřČçŽĎæŸŕæIJňèŁĆåŔłæŸŕæijŤçđ'žäžĘ logging æĺąåİŮçŽĎäÿĂäžŽå§žæIJňçŤÍæşŢãĂĆ åőČåŔŕäžěåĄŽæŻť'åđ'ŽæŻť'éńŸçžğçŽĎåőŽåĹűãĂĆ åĚşäžŐæŮěå£ŮåőŽåĹűåŇŰäÿĂäÿłå¿Ĺåě¡çŽĎèţĎæžŘæŸŕ Logging Cookbook

15.12 13.12 çžŹåĞ¡æŢřåžŞåćđåŁăæŮěå£ŮåŁ§èČ¡

éŮőécŸ

ä¡ăæČşçżŹæ§ŘäÿłåĞ¡æŢřåžŞåćđåŁăæŮěå£ŮåŁ§èČ¡ïijŇä¡ĘæŸŕåŔĹäÿ■èČ¡å¡śåŞ■åĹřéĆčäžŻäÿ■ä¡£çŤĺ

èğčåĘşæŰźæąĹ

åŕźäžŐæČşèęĄæĽğèąŇæŮěå£ŮæŞ■ä¡IJçŽĎåĞ¡æŢřåžŞèĂŇåůšïijŇä¡ăåžŤèŕěåĹŻåžžäÿĂäÿłäÿŞåśđçŽĎ `logger` åŕźèśąïijŇåźűäÿŤåČŔäÿŃéİćè£ŹæăůåĹİåğŃåŇŰéĚ■ç¡őïijŽ

```
# somelib.py

import logging
log = logging.getLogger(__name__)
log.addHandler(logging.NullHandler())

# Example function (for testing)
def func():
    log.critical('A Critical Error!')
    log.debug('A debug message')
```

ä¡£çŤĺè£ŹäÿłéĚ■ç¡őïijŃézŸèőd'æČĚåĘţäÿŃäÿ■äijŽæĽŞå■řæŮěå£ŮãĂĆä¿ŃåęĆïijŽ

```
>>> import somelib
>>> somelib.func()
>>>
```

äÿ■è£ĞïijŇåęĆæđIJéĚ■ç¡őè£ĞæŮěå£Ůçşżçż§ïijŇéĆčäźĹæŮěå£ŮæűĹæĄŕæĽŞå■řářšåijĂåğŃçŤ§æŢĹï

```
>>> import logging
>>> logging.basicConfig()
>>> somelib.func()
CRITICAL:somelib:A Critical Error!
>>>
```

èőĺèőž

éĂŽåÿÿæİěèőšïijŇä¡ääÿ■åžŤèŕěåIJĺåĞ¡æŢřåžŞäžčçăĄäÿ■èĞłåůśéĚ■ç¡őæŮěå£Ůçşżçż§ïijŇæĹŰèĂĚæŸ

èřČçŤĺ `getLogger(__name__)` åĹŻåžžäÿĂäÿłåŠŃèřČçŤĺæĺąåİŮåŘŇåŘ■çŽDlog-geræĺąåİŮãĂĆ çŤśäžŐæĺąåİŮéČ¡æŸŕåŤŕäÿĂçŽĎïijŇåŽäæ■d'åĹŻåžžçŽĎloggeräźş§ářĘæŸŕåŤŕäÿĂçŽĎãĂĆ

`log.addHandler(logging.NullHandler())` æŞ■ä¡IJåřĘäÿĂäÿłçľžåd'ĎçŘĘåŹĺçżŚåőŽåĹřåĹ äÿĂäÿłçľžåd'ĎçŘĘåŹĺéżŸèőd'äijŽå£¡çŢěřČçŤĺæĽ'ĂæIJL'çŽĎæŮěå£ŮæűĹæĄŕãĂĆ åŽăæ■d'ïijŇåęĆæđIJä¡£çŤĺèŕěåĞ¡æŢřåžŞçŽĎæŮűåĂŹè£ŸæšąæIJL'éĚ■ç¡őæŮěå£ŮïijŇéĆčäźĹářĘäÿ■äijŽæ

è£ŸæIJL'äÿĂçĆźåřśæŸŕåŕźäžŐåŘĎäÿłåĞ¡æŢřåžŞçŽĎæŮěå£ŮéĚ■ç¡őåŘŕäžěæŸŕçŽÿäžŠçŃňçńŃçŽĎïij ä¿ŃåęĆïijŇåŕźäžŐåęĆäÿŃçŽĎäžčçăĄijŽ

```
>>> import logging
>>> logging.basicConfig(level=logging.ERROR)

>>> import somelib
>>> somelib.func()
CRITICAL:somelib:A Critical Error!

>>> # Change the logging level for 'somelib' only
>>> logging.getLogger('somelib').level=logging.DEBUG
>>> somelib.func()
CRITICAL:somelib:A Critical Error!
DEBUG:somelib:A debug message
>>>
```

åIJÍè£ŹéĞŇïijŇæăźæŮěå£Ůèćńéĕ■ç¡őæĹŘäżĔäżĔè¿ŞåĞžERRORæĹŰæŻťéńŸçžğåĹńçŽĎæűĹæĄŕãĂ
äÿ■è£Ğ ïijŇsomelib çŽĎæŮěå£ŮçžğåĹńèćńå■ŢçŃňéĕ■ç¡őæĹŘåŔŕäżěè¿ŞåĞždebugçžğåĹńçŽĎæűĹæĄŕïi
åČŔè£ŹæăůæŻťæŤźå■ŢçŃňæĺąåİŮçŽĎæŮěå£Ůéĕ■ç¡őåŕźäžŐèřČèŕŢæİěèőšæŸŕå¿ĹæŰźä¿£çŽĎïijŇ
åŻääÿžä¡ăæŮăéIJĂåŐżæŻťæŤźäżżä¡ŢçŽĎåĔĺåśĂæŮěå£Ůéĕ■ç¡őâĂŤâĂŤåŔłéIJĂèęĄä£őæŤźä¡ăæČşèęĄæŻ

Logging HOWTO èŕęçżĘäżŃçż■äžĘåęĆä¡Ţéĕ■ç¡őæŮěå£ŮæĺąåİŮåŠŇåĔűäżŰæIJL'çŤĺæŁĂåůğïijŇåŔŕä

15.13 13.13 åőđçŐřäÿĂäÿłèőąæŮűåŹĺ

éŮőécŸ

ä¡ăæČşèőřå¡ŢçĺŃåžŔæL'ğèąŇåd'Žäÿłäżżå£ąæL'ĂèŁśèť źçŽĎæŮűéŮť

èğčåĘşæŰźæąĹ

time æĺąåİŮåŇĔåŘńå¿Ĺåd'ŽåĞ¡æŢřæİěæL'ğèąŇèů§æŮűéŮť'æIJL'åĔşçŽĎåĞ¡æŢřãĂĆ
år¡çőąåęĆæ■d'ïijŇéĂŽåÿÿæĹŚäżňäijŽåIJĺæ■d'å§žçąĂäźŇäÿŁædĎéĂääÿĂäÿłæŻť'éńŸçžğçŽĎæŐěåŔčæİěæ

```
import time

class Timer:
    def __init__(self, func=time.perf_counter):
        self.elapsed = 0.0
        self._func = func
        self._start = None

    def start(self):
        if self._start is not None:
            raise RuntimeError('Already started')
        self._start = self._func()

    def stop(self):
        if self._start is None:
            raise RuntimeError('Not started')
```

```
        end = self._func()
        self.elapsed += end - self._start
        self._start = None

    def reset(self):
        self.elapsed = 0.0

    @property
    def running(self):
        return self._start is not None

    def __enter__(self):
        self.start()
        return self

    def __exit__(self, *args):
        self.stop()
```

è£Źäÿłçśżåő Žäź L’äž Ęäÿ Ăäÿłå Ŕŕäżěèćńç ŤĺæĹůæăźæ■őéIJĂèęĄåŘŕåŁĺãĂĄåĄIJæ■ćåŠŇéĞ■ç¡őçŽĎèőąą åőČäijŽåIJÍ elapsed åśđæĂğäÿ■èőřå¡ŢæŢt’äÿłæűĹèĂŮæŮűéŮt’ãĂĆ äÿŃéÍćæŸŕäÿĂäÿłä¿Ńå■ŘæÍěæijŤçd’žæĂŐæăůä¡£çŤĺåőČïijŽ

```
def countdown(n):
    while n > 0:
        n -= 1

# Use 1: Explicit start/stop
t = Timer()
t.start()
countdown(1000000)
t.stop()
print(t.elapsed)

# Use 2: As a context manager
with t:
    countdown(1000000)

print(t.elapsed)

with Timer() as t2:
    countdown(1000000)
print(t2.elapsed)
```

èőÍèőž

æIJňèŁĆæŔŘä¿ŻäžĘäÿĂäÿłçőĂå■ŢèĂŇåőđçŤĺçŽĎçśżæÍěåőđçŐřæŮűéŮt’èőřå¡Ţäżěå ŔŁèĂŮæŮűèőąçé åŘŇæŮűäź§æŸŕåŕźä¡£çŤĺwithèŕ■åŔëäżěåŔŁäÿŁäÿŃæŰĞçőąçŘĘåŹĺå■Ŕèőőç ŽĎäÿĂäÿłå¿Ĺåě¡çŽĎæijŤçd’ž

åIJÍèőąæŮűäÿ■èęĄèĂČèŹŚäÿĂäÿłážŢåśĆçŽĎæŮűéŮt’åĞ¡æŢřéŮőécŸãĂĆäÿĂèĹňæÍěèŕt’ïijŇ

ä¡£çŤÍ `time.time()` æĹŰ `time.clock()` èőąçőŮçŽĎæŮűéŮť'çš¿åžęåŻăæŞ■ä¡IJçşżçż§çŽĎäÿ■åŘŇäijŹ
èĂŇä¡£çŤÍ `time.perf_counter()` åĞ¡æŢřåŔŕäžěçąőä£Ïä¡£çŤÍçşżçż§äÿŁéİćæIJĂçš¿çąőçŽĎèőąæŮűåŹ

äÿŁè£řäžčçăĄäÿ■çŤś `Timer` çśżèőřå¡ŢçŽĎæŮűéŮť'æŸŕéŠ§èąĺæŮűéŮť'ïijŇåźűåŇĚåŘńäžĘæĽ'ĂæIJĽäåęĆæđIJä¡ăåŔłæČşèőąçőŮèŕěè£ŻçÍŃæĽ'ĂèŁśèť'źçŽĎCPUæŮűéŮť'ïijŇåžŤèŕěä¡£çŤÍ `time.process_time()` æİěäžčæŻ£ïijŽ

```
t = Timer(time.process_time)
with t:
    countdown(1000000)
print(t.elapsed)
```

`time.perf_counter()` åŠŇ `time.process_time()` éČ¡äijŽè£ŤåŽđářŔæŢřå¡ćåijŔçŽĎçğŠæŢřæŮűéŮť'ãĂĆ åőđéŹĚçŽĎæŮűéŮť'åĂijæšąæIJĽäżżä¡ŢæĎŔäźĽ'ïijŁ

æŻť'åď'ŽåĚşäžŐèőąæŮűåŠŇæĂğèČ¡åĹĘæđŘçŽĎä¿Ńå■Řèŕůå ŔĆèĂČ14.13åŕŔèŁĆãĂĆ

15.14 13.14 éŹŘåĹűåĘĚå■ŸåŠŇCPUçŽĎä¡£çŤÍéĞŔ

éŮőécŸ

ä¡ăæČşåŕźåIJÍUnixçşżçż§äÿŁéİćè£ŘèąŇçŽĎçÍŃåžŔèő¿ç¡őåĘĚå■ŸæĹŰCPUçŽĎä¡£çŤÍéŹŘåĹűãĂĆ

èğčåĘşæŰźæąĹ

`resource` æÍąåİŮèČ¡åŘŇæŮűæĽ'ğèąŇè£ŹäÿđäÿłäżżåŁąãĂĆä¿ŃåęĆïijŇèęĄéŹŘåĹűCPUæŮűéŮť'ïijŁ

```
import signal
import resource
import os

def time_exceeded(signo, frame):
    print("Time's up!")
    raise SystemExit(1)

def set_max_runtime(seconds):
    # Install the signal handler and set a resource limit
    soft, hard = resource.getrlimit(resource.RLIMIT_CPU)
    resource.setrlimit(resource.RLIMIT_CPU, (seconds, hard))
    signal.signal(signal.SIGXCPU, time_exceeded)

if __name__ == '__main__':
    set_max_runtime(15)
    while True:
        pass
```

çÍŃåžŔè£ŘèąŇæŮűïijŇ`SIGXCPU` ä£ąåŔůåIJÍæŮűéŮť'è£ĞæIJ§æŮűèćńçŤ§æĹŘïijŇçĎűåŘŐæĽ'ğèąŇæÿ

èęĄéŹŘåĹűåĘĚå■Ÿä¡£çŤÍïijŇèő¿ç¡őåŔŕä¡£çŤÍçŽĎæĂżåĘĚå■ŸåĂijå■şåŔŕïijŇåęĆäÿŃïijŽ

```
import resource

def limit_memory(maxsize):
    soft, hard = resource.getrlimit(resource.RLIMIT_AS)
    resource.setrlimit(resource.RLIMIT_AS, (maxsize, hard))
```

åČŔè£Źæăůèő¿ç¡őäžĘåĘĚå■ŸéŹŘåĹűåŘŐïijŇçÍŃåžŔè£ŘèąŇåĹřæšąæIJL'åd'Žä¡ŹåĘĚå■ŸæŮűäijŽæŁŹ
`MemoryError` åijĆåÿÿãĂĆ

èőÍèőž

åIJÍæIJňèŁĆä¿Ńå■Řäÿ■ïijŇ`setrlimit()` åĞ¡æŢřèćńçŤÍæİěèő¿ç¡őçL'źåőŽètĎæžŘäÿŁéİćçŽĎè¡réŹŘ
è¡réŹŘåĹűæŸŕäÿĂäÿłåĂijïijŇå¡Şèűĕè£Ğè£ŹäÿłåĂijçŽĎæŮűåĂŹæŞ■ä¡IJçşżçż§éĂŽåÿÿäijŽåŔŚéĂĄäÿĂäÿł
çąňéŹŘåĹűæŸŕçŤÍæİěæŇĞåőŽè¡réŹŘåĹűèČ¡èő¿åőŽçŽĎæIJĂåd'ğåĂijãĂĆéĂŽåÿÿæİèèőšïijŇè£ŹäÿłçŤśçşż
år¡çőąçąňéŹŘåĹűåŔŕäžěæŤźåřŘäÿĂçĆźïijŇä¡ĘæŸŕæIJĂåě¡äÿ■èęĄä¡£çŤÍçŤÍæĹůè£ŽçÍŃåÓżä£őæŤźãĂĆ

`setrlimit()` åĞ¡æŢřè£ŸèČ¡èćńçŤÍæİěèő¿ç¡őå■Řè£ŽçÍŃæŢřéĞŔãĂĄæL'ŞåijĂæŰĞäžűæŢřäžěåŘŁç
æŻť'åd'Žèŕęæ ČĚèŕůåŘĆèĂČ `resource` æÍąåİŮçŽĎæŰĞæąčãĂĆ

éIJĂèęĄæşÍæĎŔçŽĎæŸŕæIJňèŁĆåĘĚåőźåŘŁèČ¡éĂĆçŤÍäžŐUnixçşżçż§ïijŇåźűäÿŤäÿ■ä£İèŕĄæL'ĂæIJL
æŕŤåęĆæĹŚäžňåIJÍæţŃèŕŢçŽĎæŮűåĂŹïijŇåőĆèČ¡åIJÍLinuxäÿŁéİćæ■čåÿÿè£ŘèąŇïijŇä¡ĘæŸŕåIJÍOS
XäÿŁå■t'äÿ■èČ¡ãĂĆ

15.15 13.15 åŘŕåŁÍäÿĂäÿłWEBæţŔèğĹåŹÍ

éŮőécŸ

ä¡ăæČşéĂŽè£ĞèĎŽæIJňåŘŕåŁÍæţŔèğĹåŹÍåźűæL'ŞåijĂæŇĞåőŽçŽĎURLç¡Śéąţ

èğčåĘşæŰźæąĹ

`webbrowser` æÍąåİŮèČ¡èćńçŤÍæİěåŘŕåŁÍäÿĂäÿłæţŔèğĹåŹÍïijŇåźűäÿŤäÿŐåźşåŘřæŮăåĚşãĂĆä¿ŃåęĆ

```
>>> import webbrowser
>>> webbrowser.open('http://www.python.org')
True
>>>
```

åőČäijŽä¡£çŤÍéżŸèőd'æţŔèğĹåŹÍæL'ŞåijĂæŇĞåőŽç¡ŚéąţãĂĆåęĆæđIJä¡ăè£ŸæČşåŕźç¡ŚéąţæL'ŞåijĂæŰ

```
>>> # Open the page in a new browser window
>>> webbrowser.open_new('http://www.python.org')
True
>>>

>>> # Open the page in a new browser tab
>>> webbrowser.open_new_tab('http://www.python.org')
```

```
True
>>>
```

è£ŹæăůåřśåŔŕäžěæL'ŞåijĂäÿĂäÿłæŰřçŽĎæţŔèğĹåŹÍçłŮåŔčæĹŰèĂĚæăĞç■¿ïijŇåŔłèęĄæţŔèğĹåŹÍæŤ

åęĆæđIJä¡ăæČşæŇĞåőŽæţŔèğĹåŹÍçśžåđŃïijŇåŔŕäžěä¡£çŤÍ `webbrowser.get()` åĞ¡æŢřæİěæŇĞåőŽæ§Řäÿłçl'źåőŽæţŔèğĹåŹÍãĂĆä¿ŃåęĆïijŽ

```
>>> c = webbrowser.get('firefox')
>>> c.open('http://www.python.org')
True
>>> c.open_new_tab('http://docs.python.org')
True
>>>
```

åŕźäžŐæŤŕæŇĄçŽĎæţŔèğĹåŹÍåŘ■çğřåĹŮèąĺåŔŕæ§ěéŸĚ'PythonæŰĞæąč <http://docs.python.org/3/library/webbrowser.html>'_

èőÍèőž

åIJÍèĎŽæIJñäÿ■æL'ŞåijĂæţŔèğĹåŹÍæIJL'æŮűåĂŹäijŽå¿ĹæIJL'çŤÍãĂĆä¿ŃåęĆïijŇæ§Řäÿłè ĎŽæIJñæL' ä¡ăæČşå£ńéĂ§æL'ŞåijĂäÿĂäÿłæţŔèğĹåŹÍæİěçąőä£İåőČåůšçżŔæ■čåÿÿè£ŘèąŇäžĘãĂĆ æĹŰèĂĚæŸŕæ§Řäÿłçĺ ŇåžŔäžěHTMLç¡Śéąţæăijåijŕè¿ŞåĞžæŢřæ■őïijŇä¡ăæČşæL'ŞåijĂæţŔèğĹåŹÍæ§ěçIJŇ äÿ■çőąæŸŕäÿŁéİćåŞłçğ■æČĚåĘţïijŇä¡£çŤÍ `webbrowser` æĺąåİŮéČ¡æŸŕäÿĂäÿłçőĂå■Ţåőđç ŤÍçŽĎèğčåĘşa

16 çňňå■ĄåŻŻçńäïijŽæţŃèŕŢãĂĄèřČèŕŢåŠŇåijĆåÿÿ

èŕŢéłŇè£ŸæŸŕå¿ĹæčŠçŽĎïijŇä¡ĘæŸŕèřČèŕŢïij§åřśæšąéĆčäźĹæIJL'èűčäžĘãĂĆäžŃåőđæŸŕïijŇåIJÍPytl

Contents:

16.1 14.1 æţŃèŕŢstdoutè¿ŞåĞž

éŮőécŸ

ä¡ăçŽĎçÍŃåžŔäÿ■æIJL'äÿłæŰźæşŢäijŽè¿ŞåĞžåĹřæăĞåĞĘè¿ŞåĞžäÿ■ïijĹsys.stdoutïijL'ãĂĆäź§åřśæŸŕè ä¡ăæČşåĘŹäÿłæţŃèŕŢæİèèŕĄæŸŐåőČïijŇçżŹåőŽäÿĂäÿłè¿ŞåĚëïijŇçŻÿåžŢçŽĎè¿ŞåĞžèČ¡æ■čåÿÿæŸ¿çď'žå

èğčåĘşæŰźæąĹ

ä¡£çŤÍ `unittest.mock` æĺąåİŮäÿ■çŽĎ `patch()` åĞ¡æŢřïijŇ ä¡£çŤÍèţůæİèéİđåÿÿçőĂå■ŢïijŇåŔŕäžěäÿžå■Ţäÿłæţ́NèŕŢæĺąæŃ§ `sys.stdout` çĎűåŘŐåŻđæżŽïijŇ åźűäÿŤäÿ■äžğçŢ§åď'ğéĞŔçŽĎäÿt'æŮűåŘŸéĞŔæĹŰåIJÍæţ́NèŕŢçŤÍä¿ŃçŻt'æŐěæŽt'éIJ

ä¡IJäÿžäÿĂäÿłä¿Ńå■ŘïijŇæĹŚäžňåIJÍ `mymodule` æĺąåİŮäÿ■åőŽäźL'åęĆäÿŃäÿĂäÿłåĞ¡æŢřïijŽ

```
# mymodule.py

def urlprint(protocol, host, domain):
    url = '{}://{}.{}'.format(protocol, host, domain)
    print(url)
```

éżŸèőď'æČĚåĘţäÿŃåĘĚç¡őçŽĎ print åĞ¡æŢřäijŽářĘè¿ŞåĞžåŔŠéĂĄåĹř sys.stdout ãĂĆ äÿžäžĘæţŃèŕŢè¿ŞåĞžçIJ§çŽĎåIJÍéĆčéĞŇïijŇä¡ăåŔŕäžëä¡£çŤÍäÿĂäÿłæŻ£èžńářźèśąæİěæÍąæŇ ä¡£çŤÍ unittest.mock æÍąåİŮçŽĎ patch() æŰźæşŢåŔŕäžëå¿ĹæŰźä¿£çŽĎåIJÍæţŃèŕŢè£ŘèąŇçŽĎäÿŁ åźűäÿŤå¡ŞæţŃèŕŢåőŇæĹŘæŮűåĂŹèĞłåŁÍè£ŤåŻđåőČäžňçŽĎåŐ§æIJL'çŁűæĂĄãĂĆäÿŃéÍćæŸŕåŕź mymodule æÍąåİŮçŽĎæţŃèŕŢäžčçăĄïijŽ

```
from io import StringIO
from unittest import TestCase
from unittest.mock import patch
import mymodule

class TestURLPrint(TestCase):
    def test_url_gets_to_stdout(self):
        protocol = 'http'
        host = 'www'
        domain = 'example.com'
        expected_url = '{}://{}.{}\n'.format(protocol, host, domain)

        with patch('sys.stdout', new=StringIO()) as fake_out:
            mymodule.urlprint(protocol, host, domain)
            self.assertEqual(fake_out.getvalue(), expected_url)
```

èőÍèőž

urlprint() åĞ¡æŢřæŐěåŔŮäÿL'äÿłåŔĆæŢřïijŇæţŃèŕŢæŰźæşŢåijĂåğŃäijŽåĚÍèő¿ç¡őærŕŔäÿĂäÿłåł expected_url åŔŸéĞŔèćńèő¿ç¡őæĹŘåŇĚåŘńæIJ§æIJŻçŽĎè¿ŞåĞžçŽĎå■Ůçňęäÿšã ĂĆ

unittest.mock.patch() åĞ¡æŢřèćńçŤÍä¡IJäÿĂäÿłäÿŁäÿŃæŰĞçőąçŘĘåŹĺïijŇä¡£çŤÍ StringIO årźèśąæİěäžčæŻ£ sys.stdout . fake_out åŔŸéĞŔæŸŕåIJÍèŕěè£ŻçÍŃäÿ■èćńåĹŻåžžçŽĎæĺąæŃ§årźèśąã ĂĆ åIJÍwith-èŕ■åŘěäÿ■ä¡£çŤÍåőČåŕŕäžëæL'ğèąŇåŘĎçğ■æčÄæ§ěã ĂĆå¡Şwithèŕ■åŘężŞæİ§æŮűïijŇpatch äijŽářĘæL'ĂæIJL'äÿIJèě£æĄćåd'■åĹřæţŃèŕŢåijĂåğŃåL'■çŽĎçŁűæĂĄã ĂĆ æIJL'äÿĂçĆźéIJĂèęĄæşĺæĎŘçŽĎæŸŕæ§ŘäžŻårźPythonçŽĎCæL'l'åśŢåŔŕèČ¡äijŽå£¡çŢěæŐL' sys.stdout çŽĎéĚ■ç¡őäžŇçŻt'æŐěåĘŹåĚěåĹřæäĞåĞĘè¿ŞåĞžäÿ■ã ĂĆ éŹŘäžŐçŕĞåźĚïijŇæIJňèŁĆäÿ■äijŽæűL'åŘŁåĹřè£ŹæŰźéĺćçŽĎèőšèğčïijŇåőČéĂĆçŤÍäžŐçžŕPythonäžčçăĄă åęĆæđIJä¡ăçIJ§çŽĎéIJĂèęĄåIJÍCæL'l'åśŢäÿ■æ■ŢèŐůI/OïijŇä¡ăåŔŕäžëåĚĹæL'ŞåijĂäÿĂäÿłäÿt'æŮűæŰĞäžű æŻt'åd'ŽåĚşäžŐæ■ŢèŐůäžëå■Ůçňęäÿšå¡ćåijŔæ■ŢèŐůI/OåŠŇ StringIO årźèśąèŕůåŔĆéŸĚ5.6åŕŔèŁĆãĂĆ

16.2 14.2 åIJĺå■ŢåĚČæţŃèŕŢäÿ■çżŹåŕźèśąæĽŞèąĕäÿĄ

éŮőécŸ

ä¡ăåĘŹçŽĎå■ŢåĚČæţŃèŕŢäÿ■éIJĂèęĄçżŹæŇĞåőŽçŽĎåŕźèśąæĽŞèąĕäÿĄïijŇ çŤĺæİěæŰ■èĺĂåőČäžňåIJĺæţŃèŕŢäÿ■çŽĎæIJ§æIJŻèąŇäÿžïijĹæŕŤåęĆïijŇæŰ■èĺĂèćńèřČçŤĺæŮűçŽĎåŔĆæŢ

èğčåĘşæŰźæąĹ

unittest.mock.patch() åĞ¡æŢřåŔŕèćńçŤĺæİěèğčåĘşè£ŹäÿłéŮőécŸãĂĆ patch() è£ŸåŔŕèćńçŤĺä¡IJäÿĂäÿłèčĚéěřåŹĺãĂĄäÿŁäÿŃæŰĞçőąçŘĘåŹĺæĹŰå■ŢçŃňä¡£çŤĺïijŇåř¡çőąåźűä ä¿ŃåęĆïijŇäÿŃéİćæŸŕäÿĂäÿłářĘåőČå¡ŞåĄŽèčĚéěřåŹĺä¡£çŤĺçŽĎä¿Ńå■ŘïijŽ

```
from unittest.mock import patch
import example

@patch('example.func')
def test1(x, mock_func):
    example.func(x)       # Uses patched example.func
    mock_func.assert_called_with(x)
```

åőČè£ŸåŔŕäžěèćńå¡ŞåĄŽäÿĂäÿłäÿŁäÿŃæŰĞçőąçŘĘåŹĺïijŽ

```
with patch('example.func') as mock_func:
    example.func(x)      # Uses patched example.func
    mock_func.assert_called_with(x)
```

æIJĂåŘŐïijŇä¡ăè£ŸåŔŕäžěæĽŃåŁĺçŽĎä¡£çŤĺåőČæĽŞèąĕäÿĄïijŽ

```
p = patch('example.func')
mock_func = p.start()
example.func(x)
mock_func.assert_called_with(x)
p.stop()
```

åęĆæđIJåŔŕèČ¡çŽĎèŕİïijŇä¡ăèČ¡åď§åŔăåŁăèčĚéěřåŹĺåŠŇäÿŁäÿŃæŰĞçőąçŘĘåŹĺæİěçžŹåďŽäÿłářźèś

```
@patch('example.func1')
@patch('example.func2')
@patch('example.func3')
def test1(mock1, mock2, mock3):
    ...

def test2():
    with patch('example.patch1') as mock1, \
         patch('example.patch2') as mock2, \
         patch('example.patch3') as mock3:
    ...
```

èőÍèőž

patch() æŐëåŔŮäÿĂäÿłåůšå■ŸåIJÍåŕźèśąçŽĎåĚÍèůŕå¿ĎåŘ■ïijŇåřĘåĚűæŻ£æ■ćäÿžäÿĂäÿłæŰřçŽĎåŽåŐ§æİěçŽĎåĂijäijŽåIJÍèčĚéěřåŹÍåĞ¡æŢřæĹŰäÿŁäÿŃæŰĞçőąçŘĘåŹÍåőŇæĹŘåŘŐèĞłåŁÍæĄćåď■åŻđæİěãéżŸèőď'æČĚåĘţäÿŃïijŇæĽĂæIJL'åĂijäijŽèćń MagicMock åőđä¿ŃæŻ£äžčãĂĆä¿ŃåęĆïijŽ

```
>>> x = 42
>>> with patch('__main__.x'):
...     print(x)
...
<MagicMock name='x' id='4314230032'>
>>> x
42
>>>
```

äÿ■è£ĞïijŇä¡ăåŔŕäžěéĂŽè£ĞçżŹ patch() æŔŘä¿Żçńňäž̃ŇäÿłåŔĆæŢřæİěářĘåĂijæŻ£æ■ćæĹŘäżżä¡Ţ

```
>>> x
42
>>> with patch('__main__.x', 'patched_value'):
...     print(x)
...
patched_value
>>> x
42
>>>
```

èćńçŤÍæİěä¡IJäÿžæŻ£æ■ćåĂijçŽĎ MagicMock åőđä¿ŃèČ¡åď'§æĺąæŃ§åŔŕèřČçŤÍåŕźèśąåŠŇåőđä¿ŃãĂäżŰäžňèőřå¡Ţåŕźèśą̧ŽĎä¡£çŤÍä£ąæĄŕåźűåĚĄèőÿä¡ăæĽ'ğèąŇæŰ■èÍĂæčĂæ§ěïijŇä¿ŃåęĆïijŽ

```
>>> from unittest.mock import MagicMock
>>> m = MagicMock(return_value = 10)
>>> m(1, 2, debug=True)
10
>>> m.assert_called_with(1, 2, debug=True)
>>> m.assert_called_with(1, 2)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  File ".../unittest/mock.py", line 726, in assert_called_with
    raise AssertionError(msg)
AssertionError: Expected call: mock(1, 2)
Actual call: mock(1, 2, debug=True)
>>>

>>> m.upper.return_value = 'HELLO'
>>> m.upper('hello')
'HELLO'
>>> assert m.upper.called

>>> m.split.return_value = ['hello', 'world']
>>> m.split('hello world')
```

```
['hello', 'world']
>>> m.split.assert_called_with('hello world')
>>>

>>> m['blah']
<MagicMock name='mock.__getitem__()' id='4314412048'>
>>> m.__getitem__.called
True
>>> m.__getitem__.assert_called_with('blah')
>>>
```

äÿĂèĹñæÌěèőšïijŇè£ŹäžŻæŞ■ä¡IJäijŽåIJĺäÿĂäÿłå■ŢåĚČæţŃèŕŢäÿ■åőŇæĹŘãĂĆä¿ŃåęĆïijŇåĄĞèő¿ä¡ä

```
# example.py
from urllib.request import urlopen
import csv

def dowprices():
    u = urlopen('http://finance.yahoo.com/d/quotes.csv?s=@^DJI&f=sl1
↪')
    lines = (line.decode('utf-8') for line in u)
    rows = (row for row in csv.reader(lines) if len(row) == 2)
    prices = { name:float(price) for name, price in rows }
    return prices
```

æ■čåÿÿæÌěèőšïijŇè£ŹäÿłåĞ¡æŢřäijŽä¡£çŤÍ urlopen() äžŐWe-
bäÿŁéÍćèŐůåŔŰæŢřæ■őåźűèğčædŘåőČãĂĆ åIJĺå■ŢåĚČæţŃèŕŢäÿ■ïijŇä¡ääŔŕäžěçżŹåőČäÿĂäÿłécĎåĚĹåőŽ

```
import unittest
from unittest.mock import patch
import io
import example

sample_data = io.BytesIO(b'''\
"IBM",91.1\r
"AA",13.25\r
"MSFT",27.72\r
\r
''')

class Tests(unittest.TestCase):
    @patch('example.urlopen', return_value=sample_data)
    def test_dowprices(self, mock_urlopen):
        p = example.dowprices()
        self.assertTrue(mock_urlopen.called)
        self.assertEqual(p,
                         {'IBM': 91.1,
                          'AA': 13.25,
                          'MSFT' : 27.72})

if __name__ == '__main__':
```

```
    unittest.main()
```

æIJñä¿Ńäÿ■ïijŇä¡■äžŐ example æĺąåİŮäÿ■çŽĎ urlopen() åĞ¡æŢřèćńäÿĂäÿłæĺąæŃ§åŕźèśąæŻ£äžčïijŇ èŕěåŕźèśąäijŽè£ŤåŻđäÿĂäÿłåŇĚåŘńæţŃèŕŢæŢřæ■őçŽĎ ByteIO().

è£ŸæIJL'äÿĂçĆźïijŇåIJĺæL'Şèąěäÿ ĄæŮűæĹŚäžňä¡£çŤĺäžĘ example.urlopen æİěäžčæŻ£ urllib.request.urlopen ãĂĆ å¡Şä¡ääĹŻåžžèąěäÿĄçŽĎæŮűåĂŹïijŇä¡ää£ĚéążäĄ£çŤĺåőČäžňåIJĺæţŃèŕŢäžčçăĄäÿ■çŽĎåŘ■çğřãĂĆ çŤśäžŐæţŃèŕŢäžčçăĄä¡£çŤĺäžĘ from urllib.request import urlopen ,éĆčäźĹ dowprices() åĞ¡æŢř äÿ■ä¡£çŤĺçŽĎ urlopen() åĞ¡æŢřåőđéŹĚäÿŁářśä¡■äžŐ example æĺąåİŮäžĘãĂĆ

æIJňèŁĆåőđéŹĚäÿŁåŘłæŸřåŕź unittest.mock æĺąåİŮçŽĎäÿĂæňąæţĚářİè¿Ðæ■ćãĂĆ æŻťåď'ŽæŻťéńŸçžğçŽĎçL'źæĂğïijŇèŕůåŘĆèĂČ åőŸæŰźæŰĞæąč

16.3 14.3 åIJĺå■ŢåĚČæţŃèŕŢäÿ■æţŃèŕŢåijĆåÿÿæČĚåĘţ

éŮőécŸ

ä¡ăæČşåĘŹäÿłæţŃèŕŢçŤĺä¿ŃæİěåĞĘçąőçŽĎåĹd'æŰ■æ§ŘäÿłåijĆåÿÿæŸřåŘęècńæŁŻåĞžãĂĆ

èğčåĘşæŰźæąĹ

åŕźäžŐåijĆåÿÿçŽĎæţŃèŕŢåŘŕä¡£çŤĺ assertRaises() æŰźæşŢãĂĆ ä¿ŃåęĆïijŇåęĆæđIJä¡ăæČşæţŃèŕŢæ§ŘäÿłåĞ¡æŢřæŁŻåĞžäžĘ ValueError åijĆåÿÿïijŇåČŘäÿŃéİćè£ŹæăůåĘŹïijŽ

```
import unittest

# A simple function to illustrate
def parse_int(s):
    return int(s)

class TestConversion(unittest.TestCase):
    def test_bad_int(self):
        self.assertRaises(ValueError, parse_int, 'N/A')
```

åęĆæđIJä¡ăæČşæţŃèŕŢåijĆåÿÿçŽĎåĚůä¡ŞåĂijïijŇéIJĂèęĄçŤĺåĹřåŘęåď'ŰäÿĂçğ■æŰźæşŢïijŽ

```
import errno

class TestIO(unittest.TestCase):
    def test_file_not_found(self):
        try:
            f = open('/file/not/found')
        except IOError as e:
            self.assertEqual(e.errno, errno.ENOENT)
```

```
        else:
            self.fail('IOError not raised')
```

èőÍèőž

assertRaises() æŰźæşŢäÿžæţŃèŕŢåijĆåÿÿå■ŸåIJÍæĂğæŔŘä¿ŻäžĘäÿĂäÿłçőĂä¿£æŰźæşŢãĂĆ äÿĂäÿłåÿÿèğĄçŽĎéŹůéŸśæŸŕæL'ŃåŁĺåŐżè£ŻèąŇåijĆåÿÿæčĂæţÑãĂĆæŕŤåęĆïijŽ

```
class TestConversion(unittest.TestCase):
    def test_bad_int(self):
        try:
            r = parse_int('N/A')
        except ValueError as e:
            self.assertEqual(type(e), ValueError)
```

è£Źçğ■æŰźæşŢçŽĎéŮőécŸåIJĺäžŐåőČå¿ĹåőźæŸ$éĄŮæijŔåĚűäżŰæČĚåĘţïijÑæŕŤåęĆæšąæIJL'äżżä¡T éĆčäźĹä¡ăè£Ÿå¿ŮéIJĂèęĄåćđåŁăåŔęåd'ŰçŽĎæčĂæţŃè£ĞçÍÑïijÑåęĆäÿÑéÍćè£ŻæăůïijŽ

```
class TestConversion(unittest.TestCase):
    def test_bad_int(self):
        try:
            r = parse_int('N/A')
        except ValueError as e:
            self.assertEqual(type(e), ValueError)
        else:
            self.fail('ValueError not raised')
```

assertRaises() æŰźæşŢäijŽåd'ĎçŘĘæL'ĂæIJL'çżĘèŁĆïijŇåŻăæ■d'ä¡ăåžŤèŕëä¡£çŤĺåőČăĂĆ

assertRaises() çŽĎäÿĂäÿłçijžçĆźæŸŕåőČæţÑäÿ■äžĘåijĆåÿÿåĚůä¡ŞçŽĎåĂijæŸŕåd'ŽåŕŠãĂĆ äÿžäžĘæţÑèŕŢåijĆåÿÿåĂijïijÑåŔŕäżëä¡£çŤÍ assertRaisesRegex() æŰźæşŢïijÑ åőČåŔŕåŘÑæŮűæţÑèŕŢåijĆåÿÿçŽĎå■ŸåIJÍäžëåŔŁéĂŽè£Ğæ■čåĹŹåijŔåŇźéĚ■åijĆåÿÿçŽĎå■Ůçňęäÿšèąĺçd

```
class TestConversion(unittest.TestCase):
    def test_bad_int(self):
        self.assertRaisesRegex(ValueError, 'invalid literal .*',
                               parse_int, 'N/A')
```

assertRaises() åŠŇ assertRaisesRegex() è£ŸæIJL'äÿĂäÿłåőźæŸŞå£¡çŢęçŽĎåIJřæŰźářśæŸŕåőČäžňè£ŸèČ¡èćńå¡ŞåĄŽäÿŁäÿŃæŰĞçőąçŘĘåŹĺä¡£çŤĺ

```
class TestConversion(unittest.TestCase):
    def test_bad_int(self):
        with self.assertRaisesRegex(ValueError, 'invalid literal .*
↪'):
            r = parse_int('N/A')
```

ä¡Eä¡äçŽĎæţÑèŕŢæűL'åŔŁåĹřåd'Žäÿłæl'ğèąŇæ■ěéłd'çŽĎæŮűåĂŹè£Źçğ■æŰźæşŢářšå¿ĹæIJL'çŤĺäžĘ

16.4 14.4 ářĘæţŃèŕŢè¿ŞåĞžçŤĺæŮěå£Ůèőřå¡ŢåĹřæŰĞäžűäÿ■

éŮőécŸ

ä¡ăåÿŇæIJŻåřĘå■ŢåĚČæţŃèŕŢçŽĎè¿ŞåĞžåĘŹåĹřåĹřæ§ŘäÿłæŰĞäžűäÿ■åŐżïijŇèĂŇäÿ■æŸŕæL'Şå■řå

èğčåĘşæŰźæąĹ

è£ŘèąŇå■ŢåĚČæţŃèŕŢäÿĂäÿłåÿÿèğĄæŁĂæIJŕářśæŸŕåIJĺæţŃèŕŢæŰĞäžűåžŢéČĺåŁăåĚěäÿŃéİćè£Źæő

```
import unittest

class MyTest(unittest.TestCase):
    pass

if __name__ == '__main__':
    unittest.main()
```

è£Źæăůç ŽĎèŕÍæţŃèŕŢæŰĞäžűåřśæŸŕåŘŕæL'ğèąŇçŽĎïijŇåźűäÿŤäijŽåřĘè£ŘèąŇætŃèŕŢçŽĎçżŞædIJæ
åęĆædIJä¡ăæČşéĞ■åőŽåŘŚè¿ŞåĞžïijŇåřśéIJĂèęĄåČŘäÿŃéİćè£Źæăůä£őæŤź `main()`
åĞ¡æŢřïijŽ

```
import sys

def main(out=sys.stderr, verbosity=2):
    loader = unittest.TestLoader()
    suite = loader.loadTestsFromModule(sys.modules[__name__])
    unittest.TextTestRunner(out,verbosity=verbosity).run(suite)

if __name__ == '__main__':
    with open('testing.out', 'w') as f:
        main(f)
```

èőÍèőž

æIJňèŁĆæĎ§åĚt'èűčçŽĎéČĺåĹĘåźűäÿ■æŸŕåřĘæţŃèŕŢçżŞædIJéĞ■åőŽåŘŚåĹřäÿĂäÿłæŰĞäžűäÿ■ïijŇ
èĂŇæŸŕéĂŽè£ĞèŁŹæăůåĄŽåŘŚä¡ăåśŢçd'žäžĘ `unittest`
æÍąåİŮäÿ■äÿĂäžŻåĂijå¿ŮåĚşæşÍçŽĎåĘĚéČĺåůěä¡IJåŐ§çŘĘãĂĆ

`unittest` æÍąåİŮéęŰåĚĹäijŽçżĎèčĔäÿĂäÿłæţŃèŕŢåěŮäžűãĂĆ
è£ŹäÿłæţŃèŕŢåěŮäžűåŇĚåŘńäžĘä¡ăåőŽäźL'çŽĎåŘĎçğ■æŰźæşŢãĂĆäÿĂæŮęåěŮäžűçżĎèčĔåőŇæĹŘïijŇå

è£Źäÿd'æ■ěæŸŕåĹĘåijĂçŽĎïijŇ`unittest.TestLoader`
åődä¿ŃèćńçŤĺæİěçżĎèčĔæţŃèŕŢåěŮäžűãĂĆ `loadTestsFromModule()`
æŸŕåőČåőŽäźL'çŽĎæŰźæşŢäźŃäÿĂïijŇçŤĺæİěæŤűéŻĘæţŃèŕŢçŤĺä¿ŃãĂĆ åőČäijŽäÿž
`TestCase` çśżæL'ńæŘŘæ§ŘäÿłæĹąåİŮåźűåřĘåĚűäÿ■çŽĎæţŃèŕŢæŰźæşŢæŘŘåŘŰåĞžæİěãĂĆ
åęĆædIJä¡ăæČşè£ŻèąŇçżĘçšŠåžęçŽĎæŐğåĹűïijŇ åŘŕäžěä¡£çŤĺ
`loadTestsFromTestCase()` æŰźæşŢæİěäžŐæ§ŘäÿłçżğæL'£TestCaseçŽĎçśżäÿ■æŘŘåŘŰæţŃèŕŢæŰź

TextTestRunner çśżæŸŕäÿĂäÿłæţŃèŕŢè£ŘèąŇçśżçŽĎä¿Ńå■ŘïijŇ
è£ŹäÿłçśżçŽĎäÿżèęĄçŢĺéĂŤæŸŕæL'ğèąŇæ§ŘäÿłæţŃèŕŢåěŮäżűäÿ■åŇĚåŘńçŽĎæţŃèŕŢæŰźæşŢãĂĆ
è£Źäÿłçśżèů§æL'ğèąŇ unittest.main() åĞ¡æŢřæL'Ăä¡£çŢĺçŽĎæţŃèŕŢè£ŘèąŇåŹĺæŸŕäÿĂæăůçŽĎãĂ
äÿ■è£ĞïijŇæĹŚäżňåIJĺè£ŹéĞŇåŕźåőČè£ŻèąŇäžĘäÿĂäžŻåĹŮåžŢåśĆéĚ■ç¡őïijŇåŇĚæŃňè¿ŞåĞžæŰĞäżűåŠ
ař¡çőąæIJňèŁĆä¿Ńå■Řäžčçă Ąå¿ĹařŚïijŇä¡ĘæŸŕèČ¡æŇĞåŕijä¡ăåęĆä¡Ţåŕź
unittest æąĘæđűè£ŻèąŇæŻť'è£ŻäÿĂæ■ěçŽĎèĞłåőŽäźL'ãĂĆ
èęĄæČşèĞłåőŽäźL'æţŃèŕŢåěŮäżűçŽĎèčĚéĚ■æŰźåijŔïijŇä¡ăåŔŕäžěåŕź TestLoader
çśżæL'ğèąŇæŻť'åď'ŽçŽĎæŞ■ä¡IJãĂĆ äÿžäžĘèĞłåőŽäźL'æţŃèŕŢè£ŘèąŇïijŇä¡ăåŔŕäžěæđĎéĂăäÿĂäÿłèĞłåů
TextTestRunner çŽĎåŁ§èČ¡ãĂĆ èĂŇè£ŹäžŻåůšçżŔèűĚåĞžäžĘæIJňèŁĆçŽĎèŇĆåŻť'ãĂĆunittest
æĺąåİŮçŽĎæŰĞæąčåŕźåžŢåśĆåőđçŐŕåŐ§çŘĘæIJL'æŻť'æůśåĚěçŽĎèőšèğčïijŇåŔŕäžěåŐžçIJŃçIJŃãĂĆ

16.5 14.5 å£¡çŢěæĹŰæIJ§æIJŻæţŃèŕŢåď'śèť'ě

éŮőécŸ

ä¡ăæČşåIJĺå■ŢåĚČæţŃèŕŢäÿ■å£¡çŢěæĹŰæăĞèőŕæ§ŘäžŻæţŃèŕŢäijŽæŇL'çĚğécĎæIJ§è£ŘèąŇåď'śèť'ěã

èğčåĘşæŰźæąĹ

unittest æĺąåİŮæIJL'èčĚéěřåŹĺåŔŕçŤĺæİěæŐğåĹűåŕźæŇĞåőŽæţŃèŕŢæŰźæşŢçŽĎåď'ĎçŘĘïijŇä¿Ń

```
import unittest
import os
import platform

class Tests(unittest.TestCase):
    def test_0(self):
        self.assertTrue(True)

    @unittest.skip('skipped test')
    def test_1(self):
        self.fail('should have failed!')

    @unittest.skipIf(os.name=='posix', 'Not supported on Unix')
    def test_2(self):
        import winreg

    @unittest.skipUnless(platform.system() == 'Darwin', 'Mac␣
↪specific test')
    def test_3(self):
        self.assertTrue(True)

    @unittest.expectedFailure
    def test_4(self):
        self.assertEqual(2+2, 5)

if __name__ == '__main__':
    unittest.main()
```

åęĆæđIJä¡ăåIJÍMacäÿŁè£ŘèąŇè£Źæőţäžčçă Ąïij Ňä¡ăäijŽå¿ŮåĹřåęĆäÿŃè¿ŞåĞžïijŽ

```
bash % python3 testsample.py -v
test_0 (__main__.Tests) ... ok
test_1 (__main__.Tests) ... skipped 'skipped test'
test_2 (__main__.Tests) ... skipped 'Not supported on Unix'
test_3 (__main__.Tests) ... ok
test_4 (__main__.Tests) ... expected failure

----------------------------------------------------------------------
 ↪--
Ran 5 tests in 0.002s

OK (skipped=2, expected failures=1)
```

èőÍèőž

`skip()` èčĚéěřåŹÍèČ¡èćńçŤÍæİěå£¡çŢěæ§Řäÿłä¡ăäÿ■æČşè£ŘèąŇçŽĎæţŃèŕŢãĂĆ `skipIf()` åŠŇ `skipUnless()` åŕźäžŐä¡ăåŘłæČşåIJÍæ§Řäÿłç L'źåőŽåźşåŘřæĹŰPythonçL'ĹæIJňæĹŰåĚű ä¡£çŤÍ `@expected` çŽĎåď śèť ěèčĚéěřåŹÍæİěæăĞèőřéĆčäžŻçąőåőŽäijŽåď śèť ěçŽĎæţŃèŕŢïijŇåźűäÿŤåŕźè£

å£¡çŢěæŰźæşŢçŽĎèčĚéěřåŹÍè£ŸåŘŕäžěèćńçŤÍæİěčĚéěřæŢť äÿłæţŃèŕŢçśžïijŇæŕŤåęĆïijŽ

```
@unittest.skipUnless(platform.system() == 'Darwin', 'Mac specific␣
 ↪tests')
class DarwinTests(unittest.TestCase):
    pass
```

16.6 14.6 åď ĎçŘĘåď ŽäÿłåijĆåÿÿ

éŮőécŸ

ä¡ăæIJL'äÿĂäÿłäžčçăĄçL'Ğæőţå ŔŕèČ¡äijŽæŁŻåĞžåď Žäÿłäÿ■åŘŇçŽĎåijĆåÿÿïijŇæĂŐæăůæL'■èČ¡äÿ■

èğčåĘşæŰźæąĹ

åęĆæđIJä¡ăåŔŕäžěçŤĺå■Ţäÿłäžčçă ĄåİŮåď ĎçŘĘäÿ■åŘŇçŽĎåijĆåÿÿïijŇåŔŕäžěårĘåőČäžňæŤ¿åĚěäÿĂä

```
try:
    client_obj.get_url(url)
except (URLError, ValueError, SocketTimeout):
    client_obj.remove_url(url)
```

åIJÍè£Źäÿłä¿Ńå■Řäÿ■ïijŇåĚČçěŰäÿ■äżżä¡ŢäÿĂäÿłåijĆåÿÿåŔŞçŤ§æŮűéČ¡äijŽæĽğèąŇ `remove_url()` æŰźæşŢãĂĆ åęĆæđIJä¡ăæČşåŕźåĚűäÿ■æ§Řäÿłåij Ćåÿÿè£ŻèąŇäÿ■åŘŇçŽĎåď ĎçŘĘïijŇåF `except` èŕ■åŔěäÿ■ïijŽ

```
try:
    client_obj.get_url(url)
except (URLError, ValueError):
    client_obj.remove_url(url)
except SocketTimeout:
    client_obj.handle_url_timeout(url)
```

å¿Ĺåď ŽçŽĎåijĆåÿÿäijŽæIJĽåśĆçžğåĚşçşżïijŇåŕźäžŐè£Źçğ■æČĚåĘţïijŇä¡ăåŔŕèČ¡ä¡£çŤĺåőČäżňçŽĎäÿ

```
try:
    f = open(filename)
except (FileNotFoundError, PermissionError):
    pass
```

åŔŕäżěèćńéĞ■åĘŹäÿžïijŽ

```
try:
    f = open(filename)
except OSError:
    pass
```

`OSError` æŸŕ `FileNotFoundError` åŠŇ `PermissionError` åijĆåÿÿçŽĎå§žçśżãĂĆ

èőĺèőž

åř¡çőąåď ĎçŘĘåď Žäÿłåij Ćåÿÿæ IJňèžńåźűæšąäżĂäźĹçĽźæőŁçŽĎïijŇäÿ■è£Ğä¡ăåŔŕäżěä¡£çŤĺ `as` åĚşéŤőå■ŮæİěèŐůå¿Ůèćńæ ŁŻåĞžåijĆåÿÿçŽĎåijŢçŤĺïijŽ

```
try:
    f = open(filename)
except OSError as e:
    if e.errno == errno.ENOENT:
        logger.error('File not found')
    elif e.errno == errno.EACCES:
        logger.error('Permission denied')
    else:
        logger.error('Unexpected error: %d', e.errno)
```

è£Źäÿłä¿Ńå■Řäÿ■ïijŇ `e` åŔŸéĞŔæŇĞåŘŚäÿĂäÿłèćńæŁŻåĞžçŽĎ `OSError` åijĆåÿÿåőđä¿ŃãĂĆ è£Źäÿłå IJĺä¡ăæČşæŻť è£ŻäÿĂæ■ěåĹĘæđŘè£Źäÿłåij Ćåÿÿç ŽĎæŮűåĂŹäijŽå¿ĹæIJĽçŤĺï

åŘŇæŮűè£ŸèęĄæşĺæĎŔçŽĎæŮűåĂŹ `except` èŕ■åŔěæŸŕéąžåžŔæčĂæ§ěçŽĎïijŇçńňäÿĂäÿłåŇźéĚ■ç ä¡ăåŔŕäżěå¿Ĺåőźæ ŸŞçŽĎæđĎéĂăåď Žäÿł `except` åŘŇæŮűåŇźéĚ■çŽĎæČĚå¡ćïijŇæŕŤåęĆïijŽ

```
>>> f = open('missing')
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
FileNotFoundError: [Errno 2] No such file or directory: 'missing'
>>> try:
...     f = open('missing')
... except OSError:
...     print('It failed')
... except FileNotFoundError:
...     print('File not found')
...
It failed
>>>
```

è£ŹéĞŇçŽĎ `FileNotFoundError` èŕ■åŔěåźűæšąæIJL'æL'ğèąŇçŽĎåŐ§åŻăæŸŕ `OSError` æŻť'äÿĂèĹňïijŇåőČåŔŕåŇźéĚ■ `FileNotFoundError` åijĆåÿÿïijŇäžŐæŸŕåřśæŸŕçňňäÿĂäÿłåŇźéĚ■çŽĎãĂĆ åIJĺèřČèŕŢçŽĎæŮűåĂŹïijŇåęĆæđIJä¡ăåŕźæ§Řäÿłç L'źåőŽåijĆåÿÿä¡ăåŔŕäžěéĂŽè£Ğæ§ěçIJŃèŕěåijĆåÿÿçŽĎ `__mro__` åśđæĂğæİěå£ńéĂ§æţŔèğĹãĂĆæŕŤåęĆïijŽ

```
>>> FileNotFoundError.__mro__
(<class 'FileNotFoundError'>, <class 'OSError'>, <class 'Exception'>
 ↪,
 <class 'BaseException'>, <class 'object'>)
>>>
```

äÿŁéİćåĹŮèąĺäÿ■äżżä¡ŢäÿĂäÿłçŻť'åĹř `BaseException` çŽĎçśžéČ¡èČ¡èćńçŤĺäžŐ `except` èŕ■åŔěãĂĆ

16.7 14.7 æ■ŢèŐůæL'ĂæIJL'åijĆåÿÿ

éŮőécŸ

æĂŐæăůæ■ŢèŐůäžčçăĄäÿ■çŽĎæL'ĂæIJL'åijĆåÿÿïij§

èğčåĘşæŰźæąĹ

æČşèęĄæ■ŢèŐůæL'ĂæIJL'çŽĎåijĆåÿÿïijŇåŔŕäžěçŻť'æŐěæ■ŢèŐů `Exception` å■şåŔŕïijŽ

```
try:
    ...
except Exception as e:
    ...
    log('Reason:', e)       # Important!
```

è£ŹäÿłåřĘäijŽæ■ŢèŐůéŹď'äžĘ `SystemExit` ãĂĄ `KeyboardInterrupt` åŠŇ `GeneratorExit` äźŇåď'ŰçŽĎæL'ĂæIJL'åijĆåÿÿãĂĆ

åęĆæđIJä¡ăè£ŸæČşæ■ŢèŐůè£ŹäÿĽäÿłåijĆåÿÿïijŇářĘ `Exception` æŤźæĹŘ `BaseException` å■şåŔŕãĂĆ

èőÍèőž

æ■ŢèŐůæĽĂæIJL’åijĆåÿÿéĂŽåÿÿæŸŕçŤśäžŐçÍŇåžŔåŚŸåIJÍæ§ŘäžŻåď■æİĆæŞ■ä¡IJäÿ■åźűäÿ■èČ¡èőř
åęĆæđIJä¡ääÿ■æŸŕå¿ĹçżĘå£ČçŽĎäžžïijŇè£Źäź§æŸŕçijŰåĘŹäÿ■æŸŞèřČèŕŢäžčçăĄçŽĎäÿĂäÿłçőĂå■ŢæŰź

æ■čåŻăåęĆæ■ď’ïijŇåęĆæđIJä¡ăéĂĽ’æŃľ’æ■ŢèŐůæĽ’ĂæIJL’åijĆåÿÿïijŇéĆčäźĹåIJÍæ§ŘäÿłåIJřæŰźïijĹæ
åęĆæđIJä¡ăæšąæIJL’è£ŹæăůåĄŽïijŇæIJL’æŮűåĂŹä¡ăçIJŃåĹřåijĆåÿÿæĽŞå■řæŮűåŔŕèČ¡æŚÿäÿ■çİĂåď’èĎ

```
def parse_int(s):
    try:
        n = int(v)
    except Exception:
        print("Couldn't parse")
```

èŕŢçİĂè£ŘèąŇè£ŹäÿłåĞ¡æŢřïijŇçżŞæđIJåęĆäÿŃïijŽ

```
>>> parse_int('n/a')
Couldn't parse
>>> parse_int('42')
Couldn't parse
>>>
```

è£ŹæŮűåĂŹä¡ăåřśäijŽæŇăåď’æČşïijŽâĂIJè£ŹåŠŃåŻđäžŃåŢŁïij§âĂİ
åĄĞåęĆä¡ăåČŔäÿŃéİćè£ŹæăůéĞ■åĘŹè£ŹäÿłåĞ¡æŢřïijŽ

```
def parse_int(s):
    try:
        n = int(v)
    except Exception as e:
        print("Couldn't parse")
        print('Reason:', e)
```

è£ŹæŮűåĂŹä¡ăèČ¡èŐůåŔŰåęĆäÿŃè¿ŞåĞžïijŇæŇĞæŸŐäžĘæIJL’äÿłçijŰçÍŃéŤŹèŕřïijŽ

```
>>> parse_int('42')
Couldn't parse
Reason: global name 'v' is not defined
>>>
```

å¿ĹæŸŐæŸ¿ïijŇä¡ăåžŤèŕěår¡åŔŕèČ¡årĘåijĆåÿÿåď’ĎçŘĘåŹĺåőŽäźL’çŽĎçš¿åĞĘäÿĂäžŻãĂĆ
äÿ■è£ĞïijŇèęĄæŸŕä¡ăå£Ěéążæ■ŢèŐůæĽ’ĂæIJL’åijĆåÿÿïijŇçąőä£ÍæL’Şå■řæ■čçąőçŽĎèŕŁæŰ■ä£ąæĄŕæĹŰå

16.8 14.8 åĹŻåžžèĞłåőŽäźĽåijĆåÿÿ

éŮőécŸ

åIJĺä¡ăæđĎåžžçŽĎåžŤçŤĺçĺŃåžŔäÿ■ïijŇä¡ăæČşářĘåžŢåśĆåijĆåÿÿåŇĚèčĚæĹŘèĞłåőŽäźĽçŽĎåijĆåÿÿ

èğčåĘşæŰźæąĹ

åĹŻåžžæŰřçŽĎåijĆåÿÿå¿ĹçőĂå■ŢâĂŤâĂŤåőŽäźĽæŰřçŽĎçśżïijŇèőľåőČçżğæL'£èĞł
`Exception` ïijĹæĹŰèĂĚæŸŕäżżä¡ŢäÿĂäÿłåůšå■ŸåIJĺçŽĎåijĆåÿÿçśżåđŃïijL'ãĂĆ
ä¿ŃåęĆïijŇåęĆæđIJä¡ăçijŰåĘŹç¡ŚçżIJçŻÿåĚşçŽĎçĺŃåžŔïijŇä¡ăåŔŕèČ¡äijŽåőŽäźĽäÿĂäžŻçśżäijijåęĆäÿŃçŽ

```
class NetworkError(Exception):
    pass

class HostnameError(NetworkError):
    pass

class TimeoutError(NetworkError):
    pass

class ProtocolError(NetworkError):
    pass
```

çĎűåŘŐçŤĺæĹůářśåŔŕäżěåČŔéĂŽåÿÿéĆčæăůä¡£çŤĺè£ŹäžŻåijĆåÿÿäžĘïijŇä¿ŃåęĆïijŽ

```
try:
    msg = s.recv()
except TimeoutError as e:
    ...
except ProtocolError as e:
    ...
```

èŐĺèőž

èĞłåőŽäźĽåijĆåÿÿçśżåžŤèŕěæĂżæŸŕçżğæL'£èĞłåĘĚç¡őçŽĎ `Exception`
çśżïijŇ æĹŰèĂĚæŸŕçżğæL'£èĞłéĆčäžŻæIJňèžńářśæŸŕäżŐ `Exception`
çżğæL'£èĂŇæİěçŽĎçśżãĂĆ ář¡çőąæL'ĂæIJL'çśżåŘŇæŮűäź§çżğæL'£èĞł `BaseException`
ïijŇä¡Ęä¡ääÿ■åžŤèŕěä¡£çŤĺè£Źäÿłå§žçśżæİěåőŽäźĽæŰřçŽĎåijĆåÿÿãĂĆ `BaseException`
æŸŕäÿžçşżçż§éĂĂåĞžåijĆåÿÿèĂŇä£ĺçŢŹçżĎïijŇæŕŤåęĆ `KeyboardInterrupt` æĹŰ
`SystemExit` äžěåŘŁåĚűäžŰéĆčäžŻäijŽçżŹåžŤçŤĺåŔŚéĂĄä£ąåŘůèĂŇéĂĂåĞžçŽĎåijĆåÿÿãĂĆ
åŽăæ■d'ïijŇæ■ŢèŐůè£ŹäźŻåijĆåÿÿæIJňèžńæšąäžĂäźĹæĎŘäźĽ'ãĂĆ
è£ŹæăůçŽĎèŕİïijŇåĄĞąęĆä¡ăçżğæL'£`BaseException`åŕŕèČ¡äijŽåŕijèĞťä¡ăçŽĎèĞłåőŽäźĽåijĆåÿÿäÿ■ä

åIJĺçĺŃåžŔäÿ■åijŢåĚěèĞłåőŽäźĽåijĆåÿÿåŘŕäżěä¡£å¿Ůä¡ăçŽĎäžčçăĄæŻť'åĚůåŘŕèŕźæĂğïijŇèČ¡æÿĚæ
è£ŸæIJL'äÿĂçğ■èő¿èőąæŸŕåřĘèĞłåőŽäźĽåijĆåÿÿéĂŽè£ĞçżğæL'£çżĎåŘĹèţůæİěãĂĆåIJĺåď■æİĆåžŢçŤĺçĺŃ
ä¡£çŤĺå§žçśżæİěåĹĘçżĎåŘĎçğ■åijĆåÿÿçśżäź§æŸŕå¿ĹæIJL'çŤĺçŽĎãĂĆåőČåŕŕäżěèőľçŤĺæĹůæ■ŢèŐůäÿĂä

```
try:
    s.send(msg)
except ProtocolError:
    ...
```

ä¡äè£ŸèČ¡æ■ŢèŐůæŻť'åď'ğèŇČåŻť'çŽĎåijĆåÿÿïijŇåřśåČŕäÿŃéİćè£Źæăůïijž

```
try:
    s.send(msg)
except NetworkError:
    ...
```

åęĆæđIJä¡ăæČşåőŽäźL'çŽĎæŰřåijĆåÿÿéĞ■åĘŹäžĘ `__init__()` æŰźæşŢïijŇçąőä£İä¡ăä¡£çŤĺæL'ĂæIJL'åŔĆæŢřèřČçŤĺ `Exception.__init__()` ïijŇä¿ŃåęĆïijž

```
class CustomError(Exception):
    def __init__(self, message, status):
        super().__init__(message, status)
        self.message = message
        self.status = status
```

çIJŃäÿŁåŐżæIJL'çĆźåěĞæĂłïijŇäÿ■è£ĞExceptionçŽĎéżŸèőď'èąŇäÿžæŸŕæŐěåŔŮæL'ĂæIJL'äijăéĂŠç `.args` åśđæĂğäÿ■. å¿Ĺåď'ŽåĚűäžŰåĞ¡æŢřåžŞåŠŇéČĺåĹĘPythonåžŞéżŸèőď'æL'ĂæIJL'åijĆåÿÿéČ¡å£Ěéąża `.args` åśđæĂğïijŇ åŻăæ■ď'åęĆæđIJä¡ăå£¡çŢěäžĘè£ŹäÿĂæ■ěïijŇä¡ääijŽåŔŠçŐřæIJL'äžŻæŮűåĂŹä¡ååőŽäź äÿžäžĘæijŤçď'ž `.args` çŽĎä¡£çŤĺïijŇèĂČèŹŠäÿŃäÿŃéİćè£Źäÿłä¡£çŤĺåĘĚç¡őçŽĎ *RuntimeError*' åijĆåÿÿçŽĎäžď'äžŠäijŽèŕĺïijŇ æşĺæĎŔçIJŃraiseèŕ■åŔëäÿ■ä¡£çŤĺçŽĎåŔĆæŢřäÿłæŢřæŸŕæĂŐæă

```
>>> try:
...     raise RuntimeError('It failed')
... except RuntimeError as e:
...     print(e.args)
...
('It failed',)
>>> try:
...     raise RuntimeError('It failed', 42, 'spam')
... except RuntimeError as e:

...     print(e.args)
...
('It failed', 42, 'spam')
>>>
```

åĚşäžŐåĹŻåżžèĞłåőŽäźL'åijĆåÿÿçŽĎæŻť'åď'Žä£qæĄřïijŇèřůåŔĆèĂČ'PythonåőŸæŰźæŰĞæąč <https://docs.python.org/3/tutorial/errors.html>'_

16.9 14.9 æ■ŢèŐůåijĆåÿÿåŘŐæŁŻåĞžåŔęåď'ŰçŽĎåijĆåÿÿ

éŮőécŸ

ä¡ăæČşæ■ŢèŐůäÿĂäÿłåijĆåÿÿåŘŐæŁŻåĞžåŔęåď'ŰäÿĂäÿłäÿ■åŘŇçŽĎåijĆåÿÿïijŇåŘŇæŮűè£Ÿå¿ŮåIJ

èğčåĘşæŰźæąĹ

äÿžäžĘéŞ¿æŐěåijĆåÿÿïijŇä¡£çŤÍ `raise from` èŕ■åŔěæİěäżčæŻ£çőĂå■ŢçŽĎ `raise` èŕ■åŔěãĂĆ åőČäijŽèőľä¡ăåŘŇæŮűä£İçŢŹäÿď'äÿłåijĆåÿÿçŽĎä£ąæĄŕãĂĆä¿ŃåęĆïijŽ

```
>>> def example():
...     try:
...             int('N/A')
...     except ValueError as e:
...             raise RuntimeError('A parsing error occurred') from␣
 ↪e
...
>>> example()
Traceback (most recent call last):
  File "<stdin>", line 3, in example
ValueError: invalid literal for int() with base 10: 'N/A'
```

äÿŁéİćçŽĎåijĆåÿÿæŸŕäÿŃéİćçŽĎåijĆåÿÿäžğçŤ§çŽĎçŻť'æŐěåŐ§åŻăïijŽ

```
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  File "<stdin>", line 5, in example
RuntimeError: A parsing error occurred
>>>
```

åIJÍåŻđæžŕäÿ■åŔŕäżěçIJŃåĹřïijŇäÿď'äÿłåijĆåÿÿéČ¡èćńæ■ŢèŐůãĂĆ èęĄæČşæ■ŢèŐůè£ŹæăůçŽĎåijĆåÿÿïijŇä¡ăåŔŕäżěä¡£çŤÍäÿĂäÿłçőĂå■ŢçŽĎ `except` èŕ■åŔěãĂĆ äÿ■è£ĞïijŇä¡ăè£ŸåŔŕäżěéĂŽè£Ğæ§ěçIJŃåijĆåÿÿårźèśąçŽĎ `__cause__` åśđæĂğæİěèů§èÿłåijĆåÿÿéŞ¿ãĂĆä¿ŃåęĆïijŽ

```
try:
    example()
except RuntimeError as e:
    print("It didn't work:", e)

    if e.__cause__:
        print('Cause:', e.__cause__)
```

å¡ŞåIJÍ `except` åİŮäÿ■åŔĹæIJL'åŘęåď'ŰçŽĎåijĆåÿÿèćńæŁŻåĞžæŮűäijŽårijèĞť'äÿĂäÿłéŽŘèŮŘçŽĎå

```
>>> def example2():
...     try:
...             int('N/A')
```

```
...     except ValueError as e:
...             print("Couldn't parse:", err)
...
>>>
>>> example2()
Traceback (most recent call last):
  File "<stdin>", line 3, in example2
ValueError: invalid literal for int() with base 10: 'N/A'
```

åIJÍåď ĎçŘĘäýŁè£řåijĆåÿÿçŽĎæŮűåĂŹïijŇåŔęåď ŰäýĂäýłåijĆåÿÿåŔŠçŤ§äžĘïijŽ

```
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  File "<stdin>", line 5, in example2
NameError: global name 'err' is not defined
>>>
```

è£ŹäýłäżŃå■Řäÿ■ïijŇä¡ääŘŇæŮűèŐůå¿ŮäžĘäÿď äÿłåijĆåÿÿçŽĎä£ąæĄřïijŇä¡ĘæŸŕåŕźåijĆåÿÿçŽĎèğč è£ŹæŮűåĂŹïijŇNameError åijĆåÿÿèćńä¡IJäÿžçÍŇåžŔæIJĂçżĹåijĆåÿÿèćńæŁŻåĞžïijŇèĂŇäÿ■æŸŕä¡■äžŐ

åęĆæđIJïijŇä¡ăæČşå£¡çŢěæŐĽåijĆåÿÿéŞ¿ïijŇåŔŕä¡£çŤÍ raise from None:

```
>>> def example3():
...     try:
...             int('N/A')
...     except ValueError:
...             raise RuntimeError('A parsing error occurred') from␣
 ↪None
...
>>>
example3()
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  File "<stdin>", line 5, in example3
RuntimeError: A parsing error occurred
>>>
```

èőÍèőž

åIJÍèő¿èőąäžčçăĄæŮűïijŇåIJÍåŔęåď ŰäýĂäýł except äžčçăĄåİŮäÿ■ä¡£çŤÍ raise èŕ■åŘěçŽĎæŮűåĂŹä¡ăèęĄçĽźåĹńářŔå£ČäžĘãĂĆ åď ğåď ŽæŢřæČĚåĘţäýŃïijŇè£Źçğ■ raise èŕ■åŘěéČ¡åžŤèŕěèćńæŤźæĹŘ raise from èŕ■åŘěãĂĆäź§åřśæŸŕèŕťä¡ăåžŤèŕěä¡£çŤÍäýŃéİćè£Źçğ

```
try:
   ...
except SomeException as e:
   raise DifferentException() from e
```

è£Źæăůå ĄŽçŽĎåŐ§åŽăæŸŕä¡ăåžŤèŕěæŸ¿çď žçŽĎářĘåŐ§åŽăéŞ¿æŐěţůæİěãĂĆ

äź§åřśæŸŕèŕťʼïijŇDifferentException æŸŕçŻťʼæŐëäžŐ SomeException èąŗçŤ§èĂŇæİěãĂĆ è£Źçğ■åĚşçşžåŔŕäžěäžŐåŻđæžŕçżŞæđIJäÿ■çIJŃåĞžæİěãĂĆ

åęĆæđIJä¡ăåČŔäÿŃéİćè£ŹæăůåĘŹäżčçăĄïijŇä¡ăäż■çĎűäijŽå¿ŮåĹřäÿĂäÿłéŞ¿æŐěåijĆåÿÿïijŇ äÿ■è£Ğè£ŹäÿłåźűæšąæIJL'å¿ĹæÿĚæŹřçŽĎèŕťæŸŐè£ŹäÿłåijĆåÿÿéŞ¿åĹřåžŢæŸŕåĘĚéČĺåijĆåÿÿè£ŸæŸŕæ§

```
try:
   ...
except SomeException:
   raise DifferentException()
```

å¡Şä¡ää¡£çŤĺ raise from èŕ■åŔěçŽĎèŕİïijŇåřśå¿ĹæÿĚæěŽçŽĎèąĺæŸŐæŁŻåĞžçŽĎæŸŕçňňäžŇäÿłå

æIJĂåŘŐäÿĂäÿłä¿Ńå■Řäÿ■éŽŘèŮŔåijĆåÿÿéŞ¿ä£ąæĄŕãĂĆ åř¡çőąéŽŘèŮŔåijĆåÿÿéŞ¿ä£ąæĄŕäÿ■åĹľäžŐåŻđæžŕïijŇåŘŇæŮűåőČäź§äÿćåď śäžĘå¿Ĺåď ŽæIJL'çŤĺçŽĎèřČ äÿ■è£ĞäÿĞäžŇçŽĘåźşç■L'ïijŇæIJL'æŮűåĂŹåŔłä£İçŢŹéĂĆå¡ŞçŽĎä£ąæĄŕäź§æŸŕå¿ĹæIJL'çŤĺçŽĎãĂĆ

16.10 14.10 éĞ■æŰřæŁŻåĞžèćńæ■ŢèŐůçŽĎåijĆåÿÿ

éŮőécŸ

ä¡ăåIJĺäÿĂäÿł except åİŮäÿ■æ■ŢèŐůäžĘäÿĂäÿłåijĆåÿÿïijŇçŐřåIJĺæČşéĞ■æŰřæŁŻåĞžåőČãĂĆ

èğčåĘşæŰźæąĹ

çőĂå■ŢçŽĎä¡£çŤĺäÿĂäÿłå■ŢçŃňçŽĎ rasie èŕ■åŔěå■şåŔŕïijŇä¿ŃåęĆïijŽ

```
>>> def example():
...     try:
...             int('N/A')
...     except ValueError:
...             print("Didn't work")
...             raise
...

>>> example()
Didn't work
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  File "<stdin>", line 3, in example
ValueError: invalid literal for int() with base 10: 'N/A'
>>>
```

èőĺèőž

è£ŹäÿłéŭőécŸéĂŽåÿÿæŸŕå¡Şä¡ăéIJĂèęĄåIJĺæ■ŢèŐůåijĆåÿÿåŘŐæĽğèąŇæ§Řäÿłæŝ■ä¡IJïijĹæŕŤåęĆèč äÿĂäÿłå¿Ĺåÿÿèğ ĄçŽĎçŤĺæşŢæŸŕåIJĺæ■ŢèŐůæĽĂæIJL'åijĆåÿÿçŽĎåď ĎçŘĘåŹĺäÿ■ïijŽ

```
try:
   ...
except Exception as e:
   # Process exception information in some way
   ...

   # Propagate the exception
   raise
```

16.11 14.11 è¿ŞåĞžè■ęåŚLä£ąæĄŕ

éŮőécŸ

ä¡ăåÿŇæIJŻèĞłåůśçŽĎçÍŃåžŔèČ¡çŤ§æĹŘè■ęåŚLä£ąæĄŕïijĹærŤåęĆåž§åijČçL'źæĂğæĹŰä¡£çŤĺéŮőéć

èğčåĘşæŰźæąĹ

èęĄè¿ŞåĞžäÿĂäÿłè■ęåŚLæűĹæĄŕïijŇåŔŕä¡£çŤĺ warning.warn() åĞ¡æŢřãĂĆä¿ŃåęĆïijŽ

```
import warnings

def func(x, y, logfile=None, debug=False):
    if logfile is not None:
         warnings.warn('logfile argument deprecated',␣
↪DeprecationWarning)
    ...
```

warn() çŽĎåŔĆæŢřæŸŕäÿĂäÿłè■ęåŚLæűĹæĄŕåŠŇäÿĂäÿłè■ęåŚLçśżïijŇè■ęåŚLçśżæIJL'åęĆäÿŃåĞă DeprecationWarning, SyntaxWarning, RuntimeWarning, ResourceWarning, æĹŰ FutureWarning.

åŕźè■ęåŚLçŽĎåd'ĎçŘEåŔŰåEşäžŐä¡ăåęĆä¡Ţè£ŘèąŇèğčéĞŁåŹĺäżěåŔŁäÿĂäžŽåĚűäżŰéĚ■ç¡õãĂĆ ä¿ŃåęĆïijŇåęĆæđIJä¡ää¡£çŤĺ -W all éĂL'éąźåŐżè£ŘèąŇPythonïijŇä¡ääijŽå¿ŮåĹřåęĆäÿŃçŽĎè¿ŞåĞžïijŽ

```
bash % python3 -W all example.py
example.py:5: DeprecationWarning: logfile argument is deprecated
  warnings.warn('logfile argument is deprecated',␣
↪DeprecationWarning)
```

éĂŽåÿÿæİèèőšïijŇè■ęåŚLäijŽè¿ŞåĞžåĹřæăĞåĞEéŤŹèŕŕäÿŁãĂĆåęĆæđIJä¡ăæČşèőšè■ęåŚLè¡ñæ■ćäÿžå -W error éĂL'éąźïijŽ

```
bash % python3 -W error example.py
Traceback (most recent call last):
  File "example.py", line 10, in <module>
    func(2, 3, logfile='log.txt')
```

```
  File "example.py", line 5, in func
    warnings.warn('logfile argument is deprecated',␣
↪DeprecationWarning)
DeprecationWarning: logfile argument is deprecated
bash %
```

èőÍèőž

åIJÍä¡ăçžťæŁď'è¡ŕäżűĭijŇæŔŘçď'žçŤÍæÍŮæ§ŘäžŻä£ąæĄŕĭijŇä¡ĘæŸŕåŔÍäÿ■éIJĂèęĄåřĘåĚűäÿŁå■ĞäÿÍ
ä¿ŇåęĆĭijŇåĄĞèő¿ä¡ăåĞĘåď'Ğä£őæŤźæ§ŘäÿłåĞ¡æŢřåžŞæÍŰæąĘæđűçŽĎåŁ§èČ¡ĭijŇä¡ăåŔŕäżěåĚÍäÿžä¡ăè
ä¡ăè£ŸåŔŕäżěè■ęåŚŁçŤÍæÍŮäÿĂäžŻåŕźäżčçăĄæIJL'éŮőécŸçŽĎä¡£çŤÍæŰźåijŔãĂĆ

ä¡IJäÿžåŔęåď'ŰäÿĂäÿłåĘĚç¡őåĞ¡æŢřåžŞçŽĎè■ęåŚŁä¡£çŤÍä¿Ńå■ŘĭijŇäÿŃéÍćæijŤçď'žäžĘäÿĂäÿłæšąæ

```
>>> import warnings
>>> warnings.simplefilter('always')
>>> f = open('/etc/passwd')
>>> del f
__main__:1: ResourceWarning: unclosed file <_io.TextIOWrapper name=
↪'/etc/passwd'
 mode='r' encoding='UTF-8'>
>>>
```

éżŸèőď'æČĚåĘţäÿŃĭijŇåźűäÿ■æŸŕæL'ĂæIJL'è■ęåŚŁæűĹæĄŕéČ¡äijŽåĞžçŐřãĂĆ`-W` éĂL'éąźèČ¡æŐğåĹűè■ęåŚŁæűĹæĄŕçŽĎè¿ŞåĞžãĂĆ `-W all` äijŽè¿ŞåĞžæL'ĂæIJL'è■ęåŚŁæűĹæĄŕĭijŇ`-W ignore` å£¡çŢěæŐL'æL'ĂæIJL'è■ęåŚŁĭijŇ`-W error` åřĘè■ęåŚŁè¡ňæ■ćæĹŘåijĆåÿÿãĂĆ åŔęåď'ŰäÿĂçğ■éĂL'æŃl'ïijŇä¡ăè£ŸåŔŕäżěä¡£çŤÍ `warnings.simplefilter()` åĞ¡æŢřæŐğåĹűè¿ŞåĞžãĂĆ `always` åŔĆæŢřäijŽèől'æL'ĂæIJL'è■ęåŚŁæűĹæĄŕåĞžçŐřĭijŇ`` `ignore`` å£¡çŢěèřČæL'ĂæIJL'çŽĎè■ęåŚŁĭijŇ`error` åřĘè■ęåŚŁè¡ňæ■ćæĹŘåijĆåÿÿãĂĆ

åŕźäžŐçőĂå■ŢçŽĎçŤ§æĹŘè■ęåŚŁæűĹæĄŕçŽĎæČĚåĘţè£ŹäžŻåůšçżŔèűşåď'§äžĘãĂĆ `warnings` æĺąåİŮåŕźè£Ğæżď'åŠŇè■ęåŚŁæűĹæĄŕåď'ĎçŘĘæŔŘä¿ŻäžĘåď'ğéĞŔçŽĎæŻť'énŸçžğçŽĎéĚ■ç¡æŻť'åď'Žä£ąæĄŕèřůåŔĆèĂČ PythonæŰĞæąč

16.12 14.12 èřČèŕŢå§žælJňçŽĎçÍŃåžŔåť'l'æžČéŤŹèŕŕ

éŮőécŸ

ä¡ăçŽĎçÍŃåžŔåť'l'æžČåŘŐèřěæĂŐæăůåŐżèřČèŕŢåőČïij§

èğčåĘşæŰźæąĹ

åęĆædIJä¡ăçŽĎçÍŃåžŔåŻääÿžæ§ŘäÿłåijĆåÿÿèĂŇåť'l'æžČïijŇè£ŘèąŇ `python3 -i someprogram.py` åŔŕæL'ğèąŇçőĂå■ŢçŽĎèřČèŕŢãĂĆ

-i éĂL'éąźåŘŕèőľçÍŃåžŘçżŞæİ§åŘŐæL'Şåij Ăäÿ Ăäÿłäžď'äžŠåijŔshellãĂĆçĎűåŘŐä¡ăářśèČ¡æ§ěçIJŃçŐŕáćČïijŇä¿ŃåęĆïijŇåĄĝèő¿ä¡ăæIJL'äÿŃéİćçŽĎäžčçăĄïijŽ

```
# sample.py

def func(n):
    return n + 10

func('Hello')
```

è£ŘèąŇ `python3 -i sample.py` äijŽæIJL'çśżäijijåęĆäÿŃçŽĎè¿ŞåĞžïijŽ

```
bash % python3 -i sample.py
Traceback (most recent call last):
  File "sample.py", line 6, in <module>
    func('Hello')
  File "sample.py", line 4, in func
    return n + 10
TypeError: Can't convert 'int' object to str implicitly
>>> func(10)
20
>>>
```

åęĆædIJä¡ăçIJŃäÿ■åĹřäÿŁéİćè£ŹæăůçŽĎïijŇåŔŕäžěåIJÍçÍŃåžŔåť'l'æžČåŘŐæL'ŞåijĂPythonçŽĎèřČèŕĘ

```
>>> import pdb
>>> pdb.pm()
> sample.py(4)func()
-> return n + 10
(Pdb) w
  sample.py(6)<module>()
-> func('Hello')
> sample.py(4)func()
-> return n + 10
(Pdb) print n
'Hello'
(Pdb) q
>>>
```

åęĆædIJä¡ăçŽĎäžčçăĄæL'ĂåIJÍçŽĎçŐŕåćČå¿ĹéŽ¿èŐůåŘŰäžď'äžŠshellïijĹæŕŤåęĆåIJÍæ§Řäÿłæ IJ■åŁą éĂŽåÿÿåŔŕäžěæ■ŢèŐůåijĆåÿÿåŘŐèĞłåůśæL'Şå■řèů§èÿłä£ąæĄŕãĂĆä¿ŃåęĆïijŽ

```
import traceback
import sys

try:
    func(arg)
except:
    print('**** AN ERROR OCCURRED ****')
    traceback.print_exc(file=sys.stderr)
```

èęĄæŸŕä¡ăçŽĎçÍŃåžŔæšąæIJL'åť'l'æžČïijŇèĂŇåŔłæŸŕäžğçŢ§äžĘäÿĂäžŻä¡ăçIJŃäÿ■æĞĆçŽĎçżŞædI

ä¡ååIJÍæĎ§åĚť'èűčçŽĎåIJřæŰźæŔŠåĚěäÿĂäÿŃ `print()` èí■åŘěäź§æŸŕäÿłäÿ■éŤŹçŽĎéĂL'æŃl'ãĂĆ
äÿ■è£ĞïijŇèęĄæŸŕä¡ăæL'ŞçőŮè£ŹæăůåĄŽïijŇæIJL'äÿĂäžŽářŔæŁĂåůğåŘŕäžěåÿőåŁl'ä¡ăãĂĆ
éęŰåĚĹïijŇ`traceback.print_stack()` åĞ¡æŢřäijŽä¡ăçÍŃåžŔè£ŘèąŇåĽřéĆčäÿłçĆźçŽĎæŮűåĂŹåĹŻ

```
>>> def sample(n):
...     if n > 0:
...             sample(n-1)
...     else:
...             traceback.print_stack(file=sys.stderr)
...
>>> sample(5)
  File "<stdin>", line 1, in <module>
  File "<stdin>", line 3, in sample
  File "<stdin>", line 3, in sample
  File "<stdin>", line 3, in sample
  File "<stdin>", line 3, in sample
  File "<stdin>", line 3, in sample
  File "<stdin>", line 5, in sample
>>>
```

åŘęåď'ŰïijŇä¡ăè£ŸåŘŕäžěåČŘäÿŃéÍćè£ŹæăůäĄ£çŤÍ `pdb.set_trace()` åIJÍäżżä¡ŢåIJřæŰźæL'ŃåŁÍçŽĎåŘŕåŁÍèřČèŕŢåŹÍïijŽ

```
import pdb

def func(arg):
    ...
    pdb.set_trace()
    ...
```

å¡ŞçÍŃåžŘæŕŤè¿Čåď'ğèĂŇä¡ăæČşèřČèŕŢæŐğåĹűæţĄçÍŃäżěåŘŁåĞ¡æŢřåŔĆæŢřçŽĎæŮűåĂŹè£Źäÿłåìä¿ŃåęĆïijŇäÿĂæŮęèřČèŕŢåŹÍåijĂåğŃè£ŘèąŇïijŇä¡ăářśèČ¡åď'§ä¡£çŤÍ `print` æÍèèğĆæţŃåŘŸéĞŘåĂijæĹŰæŢšåĞżæ§Řäÿłåŝ¡äžď'æŕŤåęĆ w æÍèèŐůåŘŰè£¡èÿłä£ąæĄŕãĂĆ

èőÍèőž

äÿ■èęĄåřĘèřČèŕŢåijĎçŽĎè£ĞäžŐåď'■æÍĆåŇŰãĂĆäÿĂäžŽçőÅå■ŢçŽĎéŤŹèŕŕåŘłéIJÅèęĄèğĆåŕ§çÍŃåžåődéŹĚçŽĎéŤŹèŕŕäÿĂèĹňæŸŕåăĘæăĹçŽĎæIJÅåŘŐäÿĂèąŇãĂĆ
ä¡ååIJÍåijĂåŘŚçŽĎæŮűåĂŹïijŇäźŞåŘŕäžěåIJÍä¡ăéIJÅèęĄèřČèŕŢçŽĎåIJřæŰźæŘŠåĚěäÿĂäÿŃ `print()` åĞ¡æŢræÍèèŕŁæŰ■ä£ąæĄŕïijĹåŘłéIJÅèęĄæIJÅåŘŐåŘŚåÿČçŽĎæŮűåĂŹåĹăéŹď'è£ŹäžŻæL'Şå■ř

èřČèŕŢåŹÍçŽĎäÿĂäÿłåÿÿèğĄçŤÍæşŢæŸŕèğĆæţŃæ§Řäÿłåůšçżŕåť'l'æžČçŽĎåĞ¡æŢřäÿ■çŽĎåŘŸéĞŘãĂçş¢éĄŞæĂŐæăůåIJÍåĞ¡æŢřåť'l'æžČåŘŐè£ŻåĚèèřČèŕŢåŹÍæŸŕäÿĂäÿłå¿ĹæIJL'çŤÍçŽĎæŁĂèČ¡ãĂĆ

å¡Şä¡ăæČşèğčåL'ŰäÿĂäÿłéIđåÿÿåď'■æÍĆçŽĎçÍŃåžŔïijŇåžŢåśĆçŽĎæŐğåĹűéĂżè¿Śä¡ääÿ■æŸŕå¿ĹæÿĚæŘŠåĚě `pdb.set_trace()` è£ŹæăůçŽĎèŕ■åŘěářšå¿ĹæIJL'çŤÍäžĘãĂĆ

åőđéŹĚäÿŁïijŇçÍŃåžŔäijŽäÿĂçŻť'è£ŘèąŇåĹřçćřåĹř `set_trace()` èŕ■åŘěä¡■ç¡őïijŇçĎűåŘŐçńŃél'ňè£ŻåĚèèřČèŕŢåŹÍãĂĆ çĎűåŘŐä¡ăářśåŘŕäžěåĄŽæŻť'åď'ŽçŽĎäžŃäžĘãĂĆ

åęĆædIJä¡ăä¡£çŤÍIDEæİěåĄŽPythonåijĂåŔŠïijŇéĂŽåÿÿIDEéČ¡äijŽæŔŘä¿ŻèĞłåůśçŽĎèřČèřŢåŹÍæİěæŻťåď Žè£ŹæŰźéİćçŽĎä£ąæĄŕåŔŕäžěåŔĆèĂČä¡ăä¡£çŤÍçŽĎIDEæĽŃåĘÑãĂĆ

16.13 14.13 çżŹä¡äçŽĎçÍŃåžŔåĄŽæĂğèČ¡æţŃèŕŢ

éŮőécŸ

ä¡ăæČşæţŃèŕŢä¡ăçŽĎçÍŃåžŔè£ŘèąÑæĽĂèŁśèť źçŽĎæŮűéŮť åźűåĄŽæĂğèČ¡æţŃèŕŢãĂĆ

èğčåĘşæŰźæąĹ

åęĆædIJä¡ääŔłæŸŕçőĂå■ŢçŽĎæČşæţŃèŕŢäÿŃä¡äçŽĎçÍŃåžŔæŢť ä¡ŞèŁśèť źçŽĎæŮűéŮť ïijÑéĂŽåÿÿä¡£çŤÍUnixæŮűéŮť åĞ¡æŢřářšèąÑäžĘïijÑærŤåęĆïijŽ

```
bash % time python3 someprogram.py
real 0m13.937s
user 0m12.162s
sys  0m0.098s
bash %
```

åęĆædIJä¡äè£ŸéIJĂèęĄäÿĂäÿłçÍŃåžŔåŘĎäÿłçżĘèŁĆçŽĎèŕęçżĘæŁěåŚŁïijŇåŔŕäžěä¡£çŤÍ `cProfile` æÍąåİŮïijŽ

```
bash % python3 -m cProfile someprogram.py
         859647 function calls in 16.016 CPU seconds

   Ordered by: standard name

   ncalls  tottime  percall  cumtime  percall␣
↪filename:lineno(function)
   263169    0.080    0.000    0.080    0.000 someprogram.
↪py:16(frange)
      513    0.001    0.000    0.002    0.000 someprogram.
↪py:30(generate_mandel)
   262656    0.194    0.000   15.295    0.000 someprogram.py:32(
↪<genexpr>)
        1    0.036    0.036   16.077   16.077 someprogram.py:4(
↪<module>)
   262144   15.021    0.000   15.021    0.000 someprogram.py:4(in_
↪mandelbrot)
        1    0.000    0.000    0.000    0.000 os.py:746(urandom)
        1    0.000    0.000    0.000    0.000 png.py:1056(_readable)
        1    0.000    0.000    0.000    0.000 png.py:1073(Reader)
        1    0.227    0.227    0.438    0.438 png.py:163(<module>)
      512    0.010    0.000    0.010    0.000 png.py:200(group)
    ...
bash %
```

äÿ■è£ĞéĂŽåÿÿæČĚåĘţæŸŕäżŃäžŐè£ŹäÿďäÿłæđĄçńŕäźŃéŮťãĂĆæŕŤåęĆä¡ääůšçżŔç§ěéĄŞäžčçăĄè£Ł
åŕźäžŐè£ŹäžŻåĞ¡æŢřçŽĎæĂğèČ¡æţŃèŕŢïijŇåŔŕäżěä¡£çŤĺäÿĂäÿłçőĂå■ŢçŽĎèčĚéěřåŹĺïijŽ

```
# timethis.py

import time
from functools import wraps

def timethis(func):
    @wraps(func)
    def wrapper(*args, **kwargs):
        start = time.perf_counter()
        r = func(*args, **kwargs)
        end = time.perf_counter()
        print('{}.{} : {}'.format(func.__module__, func.__name__,␣
↪end - start))
        return r
    return wrapper
```

èęĄä¡£çŤĺè£ŹäÿłèčĚéěřåŹĺïijŇåŔłéIJĂèęĄåřĘåĚűæŤ¿ç¡őåIJĺä¡ăèęĄè£ŻèąŇæĂğèČ¡æţŃèŕŢçŽĎåĞ¡æŢ

```
>>> @timethis
... def countdown(n):
...     while n > 0:
...             n -= 1
...
>>> countdown(10000000)
__main__.countdown : 0.803001880645752
>>>
```

èęĄæţŃèŕŢæ§Řäÿłäžčçă ĄåİŮè£ŘèąŇæŮűéŮťïijŇä¡ääŔŕäżěåőŽäźĽäÿĂäÿłäÿŁäÿŃæŰĞçőąçŘĘåŹĺïijŇ

```
from contextlib import contextmanager

@contextmanager
def timeblock(label):
    start = time.perf_counter()
    try:
        yield
    finally:
        end = time.perf_counter()
        print('{} : {}'.format(label, end - start))
```

äÿŃéİćæŸŕä¡£çŤĺè£ŹäÿłäÿŁäÿŃæŰĞçőąçŘĘåŹĺçŽĎä¿Ńå■ŘïijŽ

```
>>> with timeblock('counting'):
...     n = 10000000
...     while n > 0:
...             n -= 1
...
counting : 1.5551159381866455
```

```
>>>
```

åŕźäžŐæţŃèŕŢå¿ĹåřŔçŽĎäżčçăĄçL’Ğæőţè£ŘèąŇæĂğèČ¡ïijŇä¡£çŤÍ timeit æĺąåİŮäijŽå¿ĹæŰźä¿£ïijŇä¿ŃåęĆïijŽ

```
>>> from timeit import timeit
>>> timeit('math.sqrt(2)', 'import math')
0.1432319980012835
>>> timeit('sqrt(2)', 'from math import sqrt')
0.10836604500218527
>>>
```

timeit äijŽæL’ğèąŇçňňäÿĂäÿłåŔĆæŢřäÿ■èŕ■åŔě100äÿĞæňąåźűèőąçőŮè£ŘèąŇæŮűéŮt’ãĂĆ çňňäžŇäÿłåŔĆæŢřæŸŕè£ŘèąŇæţŃèŕŢäźŃåL’■éĚ■ç¡őçŐŕåćČãĂĆåęĆæđIJä¡äæČşæŤźåŔŸå¿łçŐŕæL’ğèąŇæň åŔŕäžěåČŔäÿŃéİćè£Źæăůèő¿ç¡ő number åŔĆæŢřçŽĎåĂijïijŽ

```
>>> timeit('math.sqrt(2)', 'import math', number=10000000)
1.434852126003534
>>> timeit('sqrt(2)', 'from math import sqrt', number=10000000)
1.0270336690009572
>>>
```

èőÍèőž

å¡ŞæL’ğèąŇæĂğèČ¡æţŃèŕŢçŽĎæŮűåĂŹïijŇéIJĂèęĄæşÍæĎŔçŽĎæŸŕä¡äèŐůåŔŰçŽĎçžŞæđIJéČ¡æŸŕè time.perf_counter() åĞ¡æŢřäijŽåIJÍçżŹåőŽåźşåŔŕäÿŁèŐůåŔŰæIJĂéńŸçš¿åžęçŽĎèőąæŮűåĂijãĂĆ äÿ■è£ĞïijŇåőČäż■çĎűè£ŸæŸŕå§žäžŐæŮűéŠ§æŮűéŮt’ïijŇå¿Ĺåd’ŽåŻäçt’ăäijŽå¡śåŞ■åĹřåőČçŽĎçš¿çąőåžęï åęĆæđIJä¡ăåŕźäžŐæL’ğèąŇæŮűéŮt’æŻt’æĎ§åĚt’èűčïijŇä¡£çŤÍ time.process_time() æİěäžčæŻ£åőČãĂĆä¿ŃåęĆïijŽ

```
from functools import wraps
def timethis(func):
    @wraps(func)
    def wrapper(*args, **kwargs):
        start = time.process_time()
        r = func(*args, **kwargs)
        end = time.process_time()
        print('{}.{} : {}'.format(func.__module__, func.__name__,␣
↪end - start))
        return r
    return wrapper
```

æIJĂåŘŐïijŇåęĆæđIJä¡äæČşè£ŻèąŇæŻt’æůšåĚěçŽĎæĂğèČ¡åĹĘæđŘïijŇéĆčäźĹä¡äéIJĂèęĄèŕęçżĘéŸİ time ãĂĄtimeit åŠŇåĚűäžŰçŻÿåĚşæĺąåİŮçŽĎæŰĞæąčãĂĆ è£Źæăůä¡ăåŔŕäžěçŘĘèğčåŠŇåźşåŔŕçŻÿåĚşçŽĎåůőåijĆäžěåŔŁäÿĂäžŻåĚűäžŰéŹůéŸśãĂĆ è£ŸåŔŕäžěåŔĆèĂČ13.13åřŔèŁĆäÿ■çŻÿåĚşçŽĎäÿĂäÿłåĹŻåżžèőąæŮűåŹĺçśżçŽĎä¿Ńå■ŘãĂĆ

16.14 14.14 åŁăéĂ§çÍŃåžŔè£ŘèąŇ

éŮőécŸ

ä¡ăçŽĎçÍŃåžŔè£ŘèąŇåď łæĚćïijŇä¡ăæČşåIJÍäÿ■ä¡£çŤÍåď■æİĆæŁĂæIJŕæŕŤåęĆCæĽľ åśŢæĹŰJITçijŰ

èğčåĘşæŰźæąĹ

åĚşäžŐçÍŃåžŔäijŸåŇŰçŽĎçňňäÿĂäÿłåĞĘåĹŹæŸŕâĂIJäÿ■èęĄäijŸåŇŰâĂİïijŇçňňäžŇäÿłåĞĘåĹŹæŸŕ
åęĆæđIJä¡ăçŽĎçÍŃåžŔè£ŘèąŇçijŞæĚćïijŇéęŰåĚĹä¡ăå¿Ůä¡£çŤÍ14.13åřŔèŁĆçŽĎæŁĂæIJŕåĚĹåŕźåőČè£Żèă

éĂŽåÿÿæİěèőšä¡ăäijŽåŔŚçŐřä¡ăå¿ŮçÍŃåžŔåIJÍåřŚæŢřåĞääÿłçČ■çĆźåIJřæŰźèŁśèť źäžĘåď ğéĞŔæŮűé
ærŤåęĆåĘĚå■ŸçŽĎæŢřæ■őåď ĎçŘĘå¿łçŐŕãĂĆäÿĂæŮęä¡ăåőŽä¡■åĹrè£ŹäžŻçĆźïijŇä¡ăåřśåŔŕäžěä¡£çŤÍäÿN

ä¡£çŤÍåĞ¡æŢř

å¿Ĺåď ŽçÍŃåžŔåŚŸåĹŽåijĂåğŃäijŽä¡£çŤÍPythonèŕ■èÍĂåĘŹäÿĂäžŻçőĂå■ŢèĎŽæIJñãĂĆ
å¡ŞçijŰåĘŹèĎŽæIJňçŽĎæŮűåĂŹïijŇéĂŽåÿÿäźăæČŕäžĘåĘŹæŕńæŮăçżŞæđĎçŽĎäžčçăĄïijŇærŤåęĆïijŽ

```
# somescript.py

import sys
import csv

with open(sys.argv[1]) as f:
     for row in csv.reader(f):

          # Some kind of processing
          pass
```

å¿ĹåřŚæIJL’äžžç§ěéĄŞïijŇåČŔè£ŹæăůåőŽäźL’åIJĺåĚĺśĂèŇČåŻť çŽĎäžčçăĄè£ŘèąŇèţůæİěèęĄæŕŤåőŽ
è£Źçğ■éĂ§åžęåůőåijĆæŸŕçŤśäžŐåśĂéČĺåŔŸéĞŔåŠŇåĚĺåśĂåŔŸéĞŔçŽĎåőđçŐřæŰźåijŔïijĹä¡£çŤĺåśĂéČĺ
åŻăæ■d’ïijŇåęĆæđIJä¡ăæČşèől’çÍŃåžŔè£ŘèąŇæŻť å£ńäžŻïijŇåŔłéIJĂèęĄåřĘèĎŽæIJñèŕ■åŔěæŤ¿åĚěåĞ¡æŢ

```
# somescript.py
import sys
import csv

def main(filename):
    with open(filename) as f:
         for row in csv.reader(f):
             # Some kind of processing
             pass

main(sys.argv[1])
```

éĂ§åžęçŽĎåůőåijĆåŔŰåĘşäžŐåőđéŹĚè£ŘèąŇçŽĎçÍŃåžŔïijŇäÿ■è£Ğæăźæ■őçżŔéłŇïijŇä¡£çŤĺåĞ¡æŢï
30%çŽĎæĂğèČ¡æŔŘå■ĞæŸŕå¿Ĺåÿÿèğ Ąç ŽĎãĂĆ

ař¡åŔŕèČ¡åŐżæŐL’åśđæĂğèó£éŰő

æfŔäÿĂæňąä¡£çŤÍçĆź(.)æŞ■ä¡IJçňęæÌěëő£éŮőåśđæĂğçŽĎæŮűåĂŹäijŽåÿęæÌěéćÌåď¯ŰçŽĎåijĂéŤĂãĂ
åőČäijŽèğęåŔŚçĽźåőŽçŽĎæŰźæşŢïijŇærŤåęĆ `__getattribute__()` åŠŇ `__getattr__()` ïijŇè£ŹäžŽæŰźæşŢäijŽè£ŻèąŇå■ŮåĚÿæŞ■ä¡IJæŞ■ä¡IJãĂĆ

éĂŽåÿÿä¡ääŔŕäžěä¡£çŤÍ `from module import name` è£ŹæăůçŽĎåŕijåĚěå¡ćåijŔïijŇäžěåŔŁä¡£çŤÍçżŚåőŽçŽĎæŰźæşŢãĂĆ åĄĞèő¿ä¡ăæIJL’åęĆäÿŃçŽĎäžčçăĄçL’Ğæőţ̈ijŽ

```
import math

def compute_roots(nums):
    result = []
    for n in nums:
        result.append(math.sqrt(n))
    return result

# Test
nums = range(1000000)
for n in range(100):
    r = compute_roots(nums)
```

åIJÍæĹŚäžňæIJžåŹÍäÿŁéİćæţŃèŕŢçŽĎæŮűåĂŹïijŇè£ŹäÿłçÍŃåžŔèŁśèť źäžĘåď¯ğæęĆ40çğŠãĂĆçŐřåIJÍa `compute_roots()` åĞ¡æŢřåęĆäÿŃïijŽ

```
from math import sqrt

def compute_roots(nums):

    result = []
    result_append = result.append
    for n in nums:
        result_append(sqrt(n))
    return result
```

ä£őæŤźåŘŐçŽĎçL’ĹæIJňè£ŘèąŇæŮűéŮť åď¯ğæęĆæŸŕ29çğŠãĂĆåŤŕäÿĂäÿ■åŘŇäźŃåď¯ĎåřśæŸŕæűĹéź çŤÍ `sqrt()` äžčæŻ£äžĘ `math.sqrt()` ãĂĆ `The result.append()` æŰźæşŢèćńètŃçżŹäÿĂäÿłåśĂéČĺåŔŸéĞŔ `result_append` ïijŇçĎűåŘŐåIJÍåĘĚéČĺå¿łçŐŕäÿ■ä¡£çŤÍåőČãĂĆ

äÿ■è£ĞïijŇè£ŹäžŻæŤźåŔŸåŔłæIJL’åIJÍåď¯ğéĞŔéĞ■åď¯■äžčçăĄäÿ■æL’■æIJL’æĎŔäźL’ïijŇærŤåęĆå¿łçĆ åŻăæ■ď¯ïijŇè£ŹäžŻäijŸåŇŰäź§åŔłæŸŕåIJÍæ§ŘäžŽçL’źåőŽåIJřæŰźæL’■åžŢèŕěèćńä¡£çŤÍãĂĆ

çŘĘèğčåśĂéČĺåŔŸéĞŔ

äźŃåL’■æŔŘè£ĞïijŇåśĂéČĺåŔŸéĞŔäijŽærŤåĚĺåśĂåŔŸéĞŔè£ŘèąŇéĂ§åžęå£ńãĂĆ åŕźäžŐéćŚçźĄèő£éŮőçŽĎåŘ■çğřïijŇéĂŽè£ĞåřĘè£ŹäžŻåŘ■çğřåŔŸæĹŘåśĂéČĺåŔŸéĞŔåŕźäžěåŁäéĂ§çÍŃä ä¿ŃåęĆïijŇçIJŃäÿŃäźŃåL’■åŕźäžŐ `compute_roots()` åĞ¡æŢřè£ŻèąŇä£őæŤźåŘŐçŽĎçL’ĹæIJňïijŽ

```
import math

def compute_roots(nums):
    sqrt = math.sqrt
```

```
    result = []
    result_append = result.append
    for n in nums:
        result_append(sqrt(n))
    return result
```

åIJÍè£Źäÿłç L'ÍæIJñäÿ■ïijÑsqrt äżŐ match æÍąåİÙèćńæŃ£åĞžåźűæŤ¿åĚëäžĘäÿĂäÿłåśĂéČÍåŔŸéĞŔ åęĆæđIJä¡ãè£ŘèąÑè£ŹäÿłäżčçăĄïijÑåď ğæęĆèŁśèť ź25çğŠïijÍåŕźäžŐäźŃåL'■29çğŠåŔÍæŸŕäÿĂäÿłæŤźè£Żè£Źäÿłécİåď ŰçŽĎåŁäéĂ§åŐ§åŻãæŸŕåŻãäÿžåŕźäžŐåśĂéČÍåŔŸéĞŔ sqrt çŽĎæ§ěæL'¿èęĄå£ńäžŐåĚÍåśĂåŔŸéĞŔ sqrt

åŕźäžŐçśżäÿ■çŽĎåśđæĂğèő£éŮőäź§åŘÑæăůéĂĆçŤÍäžŐè£ŹäÿłåŐ§çŘĘãĂĆ éĂŽåÿÿæİěèőšïijÑæ§ěæL'¿æ§Räÿłå Äijæŕ Ťåę Ć self.name äijŽæŕŤèő£éŮőäÿĂäÿłåśĂéČÍåŔŸéĞŔèęĄæĚćäÿĂäžŻãĂĆ åIJÍåĘĚéČÍå¿łçŐŕäÿ■ïijÑåŔŕäžěårĘæ§Räÿłé IJÄè

```
# Slower
class SomeClass:
    ...
    def method(self):
         for x in s:
             op(self.value)

# Faster
class SomeClass:

    ...
    def method(self):
         value = self.value
         for x in s:
             op(value)
```

éĄ£åĚ■äÿ■å£ĚèęĄçŽĎæŁ¡èśą

äżżä¡ŢæŮűåĂŹå¡Şä¡ää¡£çŤÍécİåď ŰçŽĎåď ĎçŘĘåśĆïijÍæŕŤåęĆèčĚéěřåŹÍãĂĄåśđæĂğèő£éŮőãĂĄæŔ æŕŤåęĆçIJŃäÿŃåęĆäÿŃçŽĎè£ŹäÿłçśżïijŽ

```
class A:
    def __init__(self, x, y):
        self.x = x
        self.y = y
    @property
    def y(self):
        return self._y
    @y.setter
    def y(self, value):
        self._y = value
```

çŐřåIJÍè£ŻèąÑäÿĂäÿłçőÅå■ŢæţŃèŕŢïijŽ

```
>>> from timeit import timeit
>>> a = A(1,2)
```

```
>>> timeit('a.x', 'from __main__ import a')
0.07817923510447145
>>> timeit('a.y', 'from __main__ import a')
0.35766440676525235
>>>
```

åŔŕäžěçIJŃåĹřïijŇèő£éŮőåśđæĂğyçŻÿæŕŤåśđæĂğxèĂŇèĺĂæĚćçŽĎäÿ■æ■ćäÿĂçĆźçĆźïijŇåď˙ğæęĆæł
åęĆæđIJä¡ăåIJĺæĎŔæĂğèČ¡çŽĎèŕİïijŇéĆčäźĹåřśéIJĂèęĄéĞ■æŰřåőąèğĘäÿŃářźäžŐyçŽĎåśđæĂğèő£éŮőåŽ
åęĆæđIJæšąæIJL’å£ĚèęĄïijŇåřśä¡£çŤĺçőĂå■ŢåśđæĂğåŘğãĂĆ
åęĆæđIJäżĚäżĚæŸŕåŻääÿžåĚűäžŰçijŰçĺŃèŕ■èĺĂéIJĂèęĄä¡£çŤĺgetter/setteråĞ¡æŢřåřśåŐżä£őæŤźäžčçăĄéč

ä¡£çŤĺåĘĚç¡őçŽĎåőźåŹÍ

åĘĚç¡őçŽĎæŢřæ■őçśżåđŃærŤåęĆå■Ůçňęäÿšã ĂĄåĚČçżĎãĂĄåĹŮèąĺãĂĄéŻĘåŘĹåŠŇå■ŮåĚÿéČ¡æŸŕ
åęĆæđIJä¡ăæČşèĞłåůśåőđçŐřæŰřçŽĎæŢřæ■őçżŞæđĎïijĹærŤåęĆéŞ¿æŐěåĹŮèąĺãĂĄåźşèąąæăŞç■L’ïijL’ïijŇ
éĆčäźĹèęĄæČşåIJĺæĂğèČ¡äÿŁè¿¿åĹřåĘĚç¡őçŽĎéĂ§åžęåĞääźŐäÿ■åŔŕèČ¡ïijŇåŻăæ■d’ïijŇè£ŸæŸŕäźŰäźŰ

éĄ£åĚ■åĹŻåžžäÿ■å£ĚèęĄçŽĎæŢřæ■őçżŞæđĎæĹŰåd’■åĹű

æIJL’æŮűåĂŹçĺŃåžŔåŚŸæČşæŸ¿æŚĘäÿŃïijŇæđĎéĂääÿĂäžŻåźűæšąæIJL’å£ĚèęĄçŽĎæŢřæ■őçżŞæđ

```
values = [x for x in sequence]
squares = [x*x for x in values]
```

äź§èőÿè£ŹéĞŇçŽĎæČşæşŢæŸŕéęŰåĚĹåřĘäÿĂäžŻåĂijæŤűéŻĘåĹřäÿĂäÿłåĹŮèąĺäÿ■ïijŇçĎűåŘŐä¡£çŤ
äÿ■è£ĞïijŇçňňäÿĂäÿłåĹŮèąĺåőŇåĚĺæšąæIJL’å£ĚèęĄïijŇåŔŕäžěçőĂå■ŢçŽĎåČŔäÿŃéİćè£ŹæăůåĘŹïijŽ

```
squares = [x*x for x in sequence]
```

äÿŐæ■d’çŻÿåĚşïijŇè£ŸèęĄæşĺæĎŔäÿŃéĆčäźŻåŕźPythonçŽĎåĚśäžńæŢřæ■őæIJžåĹűè£ĞäźŐåĄŔæL’ğ
æIJL’äźŻäžžåźűæšąæIJL’å¿Ĺåě¡çŽĎçŘĘèğčæĹŰä£ąäżżPythonçŽĎåĘĚå■ŸæĺąåđŃïijŇæžěçŤĺ
`copy.deepcopy()` äźŃçśżçŽĎåĞ¡æŢřãĂĆ éĂŽåÿÿåIJĺè£ŹäźŻäžčçăĄäÿ■æŸŕåŔŕäžěåŐżæŐL’åd’■åĹűæŞ

èőĺèőž

åIJĺäijŸåŇŰäźŃåL’■ïijŇæIJL’å£ĚèęĄåĚĹçăŤçl’űäÿŃä¡£çŤĺçŽĎçőŮæşŢãĂĆ
éĂL’æŃl’äÿĂäÿłåd’■æİĆåžęäÿž O(n log n) çŽĎçőŮæşŢèęĄæŕŤä¡ăåŐżèŕČæŢt’äÿĂäÿłåd’■æİĆåžęäÿž
O(n**2) çŽĎçőŮæşŢæL’ĂåÿęæİěçŽĎæĂğèČ¡æŔŘå■ĞèęĄåd’ğå¿Ůåd’ŽãĂĆ

åęĆæđIJä¡ăèğL’å¿Ůä¡ăè£ŸæŸŕå¿Ůè£ŻèąŇäijŸåŇŰïijŇéĆčäźĹèŕůäžŐæŢt’ä¡ŞèĂČèŹŠãĂĆ
ä¡IJäÿžäÿĂèĹňåĞĘåĹŹïijŇäÿ■èęĄåŕźçĺŃåžŔçŽĎæŕŔäÿĂäÿłéČĺåĹĘéČ¡åŐżäijŸåŇŰ,åŻăäÿžè£ŹäžŻä£őæŤź
ä¡ăåžŤèŕěäÿŞæşĺäžŐäijŸåŇŰäžğçŤ§æĂğèČ¡çŞűécĹçŽĎåIJŕæŰźïijŇæŕŤåęĆåĘĚéČĺå¿łçŐŕãĂĆ

ä¡ăè£ŸèęĄæşĺæĎŔå¿őåŕŔäijŸåŇŰçŽĎçżŞæđIJãĂĆä¿ŃåęĆèĂČèŹŠäÿŃéİćåĹŻåžžäÿĂäÿłå■ŮåĚÿçŽĎă

```
a = {
    'name' : 'AAPL',
    'shares' : 100,
    'price' : 534.22
}
```

```
b = dict(name='AAPL', shares=100, price=534.22)
```

åŘŐéÍćäÿĂçğ■åĘŹæşŢæŻťçőĂæťĄäÿĂäžŻïijĹä¡ăäÿ■éIJĂèęĄåIJĺåĚşéŤőå■ŮäÿŁè¿ŞåĚěåijŢåŔůïijL'ãĂ
äÿ■è£ĞïijŇåęĆæđIJä¡ăářĘè£Źäÿd'äÿłäžčçăĄçL'Ğæőţè£ŻèąŇæĂğèČ¡æţŃèŕŢářźæŕŤæŮűïijŇäijŽåŔŚçŐřä¡£ç
dict() çŽĎæŰźåijŔäijŽæĚćäžĘ3åĂ■ãĂĆ çIJŃåĹřè£ŹäÿłïijŇä¡ăæŸŕäÿ■æŸŕæIJL'åĘšåŁĺæŁŁæL'ĂæIJL'ä¡£
dict() çŽĎäžčçăĄéČ¡æŻ£æ■ćæĹŘçňňäÿĂçğ■ãĂĆ äÿ■åd'§ïijŇèĄłæŸŐçŽĎçĺŃåžŔåŚŸåŔłäijŽåĘşæşĺäžŰ

åęĆæđIJä¡ăçŽĎäijŸåŇŰèęĄæśĆæŕŤè¿ČéńŸïijŇæIJňèŁĆçŽĎè£ŹäžŻçőĂå■ŢæŁĂæIJŕæżąèűşäÿ■äžĘïij
ä¿ŃåęĆïijŇPyPyåůěçĺŃæŸŕPythonèğčéĞŁåŹĺçŽĎåŔęåd'ŰäÿĂçğ■åőđçŐřïijŇåőČäijŽåĹĘæđŘä¡ăçŽĎçĺŃåžĺ
åőČæIJL'æŮűåĂŹèČ¡æđĄåd'ğçŽĎæŔŘå■ĞæĂğèČ¡ïijŇéĂŽåÿÿåŔŕäžěæŐěè£ŚCäžčçăĄçŽĎéĂ§åžęãĂĆ
äÿ■è£ĞåŔŕæČIJçŽĎæŸŕïijŇåĹřåĘŹè£ŹæIJňäźęä¡■ç¡őïijŇPyPyè£Ÿäÿ■èČ¡åőŇåĚĺæŤŕæŇĄPython3.
åŽăæ■d'ïijŇè£ŹäÿłæŸŕä¡ăářĘæÌěéIJĂèęĄåŐżçăŤçl'űçŽĎãĂĆä¡ăè£ŸåŔŕäžěèĂČèŹŚäÿŃNumbaåůěçĺŃïijŇ
NumbaæŸŕäÿĂäÿłåIJĺä¡ăä¡£çŤĺèčĚéěřåŹĺæÌěéĂL'æŃl'PythonåĞ¡æŢřè£ŻèąŇäijŸåŇŰæŮűçŽĎåŁĺæĂĄçijŰ
è£ŹäžŽåĞ¡æŢřäijŽä¡£çŤĺLLVMèćńçijŰèŕŚæĹŘæIJňåIJřæIJžåŹĺçăĄãĆĂőČåŘŇæăůåŔŕäžěæđĄåd'ğçŽĎæŔ
ä¡ĘæŸŕïijŇèů§PyPyäÿĂæăůïijŇåőČåŕźäžŐPython 3çŽĎæŤŕæŇĄçŐřåIJĺè£ŸåĄIJçŢŹåIJĺåőđéłŇéŸűæőţãĂĆ

æIJĂåŘŐæĹŚåijŢçŤĺJohn Ousterhoutèŕť'è£ĞçŽĎèŕÍä¡IJäÿžçżŞår¿ïijŽâĂIJæIJĂåě¡çŽĎæĂğèČ¡äijŸåŇŰ
çŻťåĹřä¡ăçIJ§çŽĎéIJĂèęĄäijŸåŇŰçŽĎæŮűåĂŹåĘ■åŐżèĂČèŹŚäőČãĂĆçąőä£Ía¡ăçĺŃåžŔæ■čçąőçŽĎè£Řè

17 çňňå■ĄäžŤçńäïijŽCèŕ■èÍĂæĽľåśŢ

æIJňçńăçİĂçIJijäžŐäžŐPythonèő£éŮőCäžčçăĄçŽĎéŮőécŸãĂĆèőÿåď'ŽPythonåĘĚç¡őåžŞæŸŕçŤĺCåĘŹ
èő£éŮőCæŸŕèőľPythonçŽĎåŕźçŐřæIJL'åžŞè£ŻèąŇäžd'äžŠäÿĂäÿłéĞ■èęĄçŽĎçżĎæĹŘéČĺåĹĘãĂĆ
è£Źäź§æŸŕäÿĂäÿłå¡Şä¡ăéÍćäÿťäžŐPython 2 åĹř Python 3æL'l'åśŢäžčçăĄçŽĎéŮőécŸãĂĆ
èŹ¡çĎűPythonæŘŘä¿ŻäžĘäÿĂäÿłåź£æşŽçŽĎçijŰçĺŃAPIïijŇåőđéŹĚäÿŁæIJL'å¿Ĺåd'ŽæŰźæşŢæÌěåd'ĎçŘĘ
çŻÿæŕŤèŕŢåŽ¿çżŹåĞžåŕźäžŐæŕŘäÿĂäÿłåŘŕèČ¡çŽĎåůěåĚůæĹŰæŁĂæIJŕçŽĎèŕęçżĘåŔĆèĂČïijŇ
æĹŚäźĹéĞĞçŤĺçŽĎæŸŕæŸŕéŽĘäÿ■åIJĺäÿĂäÿłåřŘçL'Ğæőţç ŽĎC++äžčçăĄijŇäžěåŘŁäÿĂäžŻæIJL'äžčèąĺæ
è£ŹäÿłçŵőæăĞæŸŕæŘŘä¿ŻäÿĂçşžåĹŰçŽĎçijŰçĺŃæĺąæÌ£ïijŇæIJL'çżŔéłŇçŽĎçĺŃåžŔåŚŸåŔŕäžěæL'l'åśŢè

è£ŹéĞŇæŸŕæĹŚäžňåřĘåIJĺåd'ğéČĺåĹĘçğŸçś■äÿ■åůëä¡IJçŽĎäžčçăĄijŽ

```
/* sample.c */_method
#include <math.h>

/* Compute the greatest common divisor */
int gcd(int x, int y) {
    int g = y;
    while (x > 0) {
        g = x;
        x = y % x;
        y = g;
    }
    return g;
}

/* Test if (x0,y0) is in the Mandelbrot set or not */
int in_mandel(double x0, double y0, int n) {
```

```
    double x=0,y=0,xtemp;
    while (n > 0) {
        xtemp = x*x - y*y + x0;
        y = 2*x*y + y0;
        x = xtemp;
        n -= 1;
        if (x*x + y*y > 4) return 0;
    }
    return 1;
}

/* Divide two numbers */
int divide(int a, int b, int *remainder) {
    int quot = a / b;
    *remainder = a % b;
    return quot;
}

/* Average values in an array */
double avg(double *a, int n) {
    int i;
    double total = 0.0;
    for (i = 0; i < n; i++) {
        total += a[i];
    }
    return total / n;
}

/* A C data structure */
typedef struct Point {
    double x,y;
} Point;

/* Function involving a C data structure */
double distance(Point *p1, Point *p2) {
    return hypot(p1->x - p2->x, p1->y - p2->y);
}
```

è£Źæőţäžčçă Ąå ŇĚåŘńäžĘåď Žçğ■äÿ■åŘŇçŽĎCèŕ■èÍĂçijŰçÍŃçĽźæĂğãĂĆ éęŰåĚĹïijŇè£ŹéĞŇæIJĽå¿Ĺåď ŽåĞ¡æŢřæŕŤåęĆ `gcd()` åŠŇ `is_mandel()` ãĂĆ `divide()` åĞ¡æŢřæŸŕäÿĂäÿłè£ŤåŻđåď ŽäÿłåĂijçŽĎCåĞ¡æŢřä¿Ńå■ŘïijŇåĚűäÿ■æIJĽäÿĂäÿłæŸŕéĂŽè£Č `avg()` åĞ¡æŢřéĂŽè£ĞäÿĂäÿłCæŢřçżĎæĽğèąŇæŢřæ■őèĄŽéŻĘæŞ■ä¡IJãĂĆ`Point` åŠŇ `distance()` åĞ¡æŢřæűĽåŔŁåĹřäžĘCçżŞæđĎä¡ŞãĂĆ

åŕźäžŐæŐěäÿŃæİěçŽĎæĽĂæIJĽåřŔèŁĆïijŇåĚĹåĄĞåőŽäÿŁéİćçŽĎäžčçăĄåůšçżŔèćńåĘŹåĚěäžĘąäÿĂ çĎűåŘŐåőČäžńçŽĎåőŽäźĽèćńåĘŹåĚěäÿĂäÿłåŘ■åŔńâĂIJsample.hâĂİçŽĎåď ť æŰĞäżűäÿ■ïijŇ åźűäÿŤèćńçijŰèŕŚäÿžäÿĂäÿłåžŞåŔńâĂIJlibsampleâĂİïijŇèČ¡èćńéŞ¿æŐěåĹřåĚűäžŰCèŕ■èÍĂäžčçăĄäÿ■ãĂĆ çijŰèŕŚåŠŇéŞ¿æŐěçŽĎçżĘèŁĆä¿Ía■őçşżçż§çŽĎäÿ■åŘŇèĂŇäÿ■åŘŇïijŇä¡ĘæŸŕè£ŹäÿłäÿæŸŕæĹŚäžňåĚ åęĆæđIJä¡äèęĄåď ĎçŘĘCäžčçăĄïijŇæĹŚäžňåĄĞåőŽè£ŹäžŽå§žçąĂçŽĎäÿIJèě£ä¡äéČ¡æŐŇæŔąäžĘãĂĆ

Contents:

17.1 15.1 ä¡£çŤÍctypesèő£éŮőCäžčçăĄ

éŮőécŸ

ä¡ăæIJL'äÿĂäžŻCåĞ¡æŢřåůšçżŔèćńçijŰèŕŠåĹřåĚśäžńåžŞæĹŰDLLäÿ■ãĂCä¡ääÿŇæIJŻåŔŕäžěä¡£çŤÍçžńèĂŇäÿ■çŤÍçijŰåĘŹéćÍåď'ŰçŽĎCäžčçăĄæĹŰä¡£çŤÍçňňäÿL'æŰźæL'ľåśŢåůěåĚůãĂĆ

èğčåĘşæŰźæąĹ

åŕźäžŐéIJĂèęĄèřČçŤÍCäžčçăĄçŽĎäÿĂäžŻåřŔçŽĎéŮőécŸïijŇéĂŽåÿÿä¡£çŤÍPythonæăĞåĞĘåžŞäÿ■çŽctypes æÍąåİŮåřśèűşåď'§äžĘãĂĆ èęĄä¡£çŤÍ ctypes ïijŇä¡ăéęŰåĚĹèęĄçąőä£İä¡ăèęĄèő£éŮőçŽĎCäžčçăĄïijĹåŘŇæăůçŽĎæđűædĐãĂĄå■Ůåď'ğåřŔãĂĄçijŰèŕŠåŹÍç■L'ïijL'çŽĎæ§ŘäÿłåĕśäžńåžŞäÿ■äžĘãĂĆäÿžäžĘè£ŻèąŇæIJňèŁĆçŽĎæijŢçď'žïijŇåĄĞèő¿ä¡ăæIJL'äÿĂäÿłåĕśäžńåžŞåŘ■å■ŮåŔńlibsample.so ïijŇéĞŇéİćçŽĎåĘĕåőźåřśæŸŕ15çńääżŇçż■éČĺåĹĘéĆčæăůãĂĆåŔęåď'Úè£ŸåĄĞèő¿è£Źäÿł libsample.so æŰĞäžűèćnæŢ¿ç¡őåĹřä¡■äžŐ sample.py æŰĞäžűçŻÿåŘŇçŽĎçŻőå¡Ţäÿ■äžĘãĂĆ

èęĄèő£éŮőè£ŹäÿłåĞ¡æŢřåžŞïijŇä¡ăèęĄåĚĹæđĎåžžäÿĂäÿłåŇĚèčĚåőČçŽĎPythonæÍąåİŮïijŇåęĆäÿŇè

```
# sample.py
import ctypes
import os

# Try to locate the .so file in the same directory as this file
_file = 'libsample.so'
_path = os.path.join(*(os.path.split(__file__)[:-1] + (_file,)))
_mod = ctypes.cdll.LoadLibrary(_path)

# int gcd(int, int)
gcd = _mod.gcd
gcd.argtypes = (ctypes.c_int, ctypes.c_int)
gcd.restype = ctypes.c_int

# int in_mandel(double, double, int)
in_mandel = _mod.in_mandel
in_mandel.argtypes = (ctypes.c_double, ctypes.c_double, ctypes.c_
↪int)
in_mandel.restype = ctypes.c_int

# int divide(int, int, int *)
_divide = _mod.divide
_divide.argtypes = (ctypes.c_int, ctypes.c_int, ctypes.
↪POINTER(ctypes.c_int))
_divide.restype = ctypes.c_int

def divide(x, y):
```

```
    rem = ctypes.c_int()
    quot = _divide(x, y, rem)

    return quot,rem.value

# void avg(double *, int n)
# Define a special type for the 'double *' argument
class DoubleArrayType:
    def from_param(self, param):
        typename = type(param).__name__
        if hasattr(self, 'from_' + typename):
            return getattr(self, 'from_' + typename)(param)
        elif isinstance(param, ctypes.Array):
            return param
        else:
            raise TypeError("Can't convert %s" % typename)

    # Cast from array.array objects
    def from_array(self, param):
        if param.typecode != 'd':
            raise TypeError('must be an array of doubles')
        ptr, _ = param.buffer_info()
        return ctypes.cast(ptr, ctypes.POINTER(ctypes.c_double))

    # Cast from lists/tuples
    def from_list(self, param):
        val = ((ctypes.c_double)*len(param))(*param)
        return val

    from_tuple = from_list

    # Cast from a numpy array
    def from_ndarray(self, param):
        return param.ctypes.data_as(ctypes.POINTER(ctypes.c_double))

DoubleArray = DoubleArrayType()
_avg = _mod.avg
_avg.argtypes = (DoubleArray, ctypes.c_int)
_avg.restype = ctypes.c_double

def avg(values):
    return _avg(values, len(values))

# struct Point { }
class Point(ctypes.Structure):
    _fields_ = [('x', ctypes.c_double),
                ('y', ctypes.c_double)]

# double distance(Point *, Point *)
distance = _mod.distance
```

```
distance.argtypes = (ctypes.POINTER(Point), ctypes.POINTER(Point))
distance.restype = ctypes.c_double
```

åęĆæđIJäÿĂåĹĞæ■čåÿÿïijŇä¡ääřśåŘŕäžěåŁäè¡¡åźűä¡£çŤĺéĞŇéİcåőŽäźL’çŽĎCåĞ¡æŢřäžĘãĂĆä¿ŃåęĆï

```
>>> import sample
>>> sample.gcd(35,42)
7
>>> sample.in_mandel(0,0,500)
1
>>> sample.in_mandel(2.0,1.0,500)
0
>>> sample.divide(42,8)
(5, 2)
>>> sample.avg([1,2,3])
2.0
>>> p1 = sample.Point(1,2)
>>> p2 = sample.Point(4,5)
>>> sample.distance(p1,p2)
4.242640687119285
>>>
```

èőÍèőž

æIJňářŔèŁĆæIJL’å¿Ĺåď’ŽåĂijå¿ŮæĹŚäžňèŕęçżĘèőÍèőžçŽĎåIJřæŰźãĂĆ éęŰåĚĹæŸŕářźäžŐCåŠŇPythonäžčçăĄäÿĂètůæL’ŞåŇĚçŽĎéŮőécŸïijŇåęĆæđIJä¡ääIJÍä¡£çŤÍ `ctypes` æİèèő£éŮőçijŰèŕŚåŘŐçŽĎCäžčçăĄïijŇ éĆčäźĹéIJĂèęĄçąőä£Ìè£ŹäÿłåĚśäžńåžŞæŤ¿åIJÍ `sample.py` æÍąåİŮåŘŇäÿĂäÿłåIJřæŰźãĂĆ äÿĂçğ■åŔŕèČ¡æŸŕářĘçŤ$æĹŘçŽĎ . `so` æŰĞäżűæŤ¿ç¡őåIJÍèęĄä¡£çŤĺåőČçŽĎPythonäžčçăĄåŘŇäÿĂäÿłçŻőå¡ŢäÿŇãĂĆ æĹŚäžňåIJÍ `recipeâĂŤsample.py` äÿ■ä¡£çŤÍ `__file__` åŔŸéĞŔæİèæ§ěçIJŃåőČècńåőL’ečĚçŽĎä¡■ç¡őïijŇ çĎűåŘŐæđĎéĂääÿĂäÿłæŇĞåŘŚåŘŇäÿĂäÿłçŻőå¡Ţäÿ■ç `libsample.so` æŰĞäżűçŽĎèůŕå¿ĎãĂĆ

åęĆæđIJCåĞ¡æŢřåžŞècńåőL’èčĚåĹřåĚűäžŰåIJřæŰźïijŇéĆčäźĹä¡ääřśèęĄä£őæŤźçŻÿåžŤçŽĎèůŕå¿ĎãĂ åęĆæđIJCåĞ¡æŢřåžŞåIJÍä¡ăæIJžåŹÍäÿŁècńåőL’èčĚäÿžäÿĂäÿłæăĞåĞĘåžŞäžĘïijŇ éĆčäźĹåŔŕäžěä¡£çŤÍ `ctypes.util.find_library()` åĞ¡æŢřæİěæ§ěæL’¿ïijŽ

```
>>> from ctypes.util import find_library
>>> find_library('m')
'/usr/lib/libm.dylib'
>>> find_library('pthread')
'/usr/lib/libpthread.dylib'
>>> find_library('sample')
'/usr/local/lib/libsample.so'
>>>
```

äÿĂæŮęä¡ăç§ěéĄŞäžĘCåĞ¡æŢřåžŞçŽĎä¡■ç¡őïijŇéĆčäźĹářśåŘŕäžěåČŔäÿŇéİcè£Źæăůä¡£çŤÍ `ctypes.cdll.LoadLibrary()` æİěåŁäè¡¡åőČïijŇ åĚűäÿ■ `_path` æŸŕæăĞåĞĘåžŞçŽĎåĚÍèůŕå¿ĎïijŽ

```
_mod = ctypes.cdll.LoadLibrary(_path)
```

åĞ¡æŢřåžŞèćńåŁäè¡¡åŘŐïijÑä¡ăéIJĂèęĄçijŰåĘŹåĞääÿłèŕ■åŔěæİěæŔŘåŔŰçL'źåőŽçŽĎçňęåŔůåźűæŇĞ
åřśåČŔäÿŃéİćè£Źäÿłäžčçă Ąç L'Ğæőţäÿ Ăæăůïijž

```
# int in_mandel(double, double, int)
in_mandel = _mod.in_mandel
in_mandel.argtypes = (ctypes.c_double, ctypes.c_double, ctypes.c_
↪int)
in_mandel.restype = ctypes.c_int
```

åIJÍè£Źæőţäžčçă Ąäÿ■ïijÑ .argtypes åśđæĂğæŸŕäÿĂäÿłåĚČçžĎïijÑåŇĚåŘńäžĘæ§ŘäÿłåĞ¡æŢřçŽĎè
èĂŇ .restype åřśæŸŕçŽÿåžŤçŽĎè£ŤåŽđçśžåđŃãĂĆ ctypes
åőŽäźL'äžĘåď ğéĞŔçŽĎçśžåđŃåŕźèśąïijĹærŤåęĆc_double, c_int, c_short, c_floatç■L'ïijL'ïijÑ
äžčèąĺäžĘåŕźåžŤçŽĎCæŢřæ■őçśžåđŃãĂĆåęĆæđIJä¡ăæČşèől' PythonèČ¡åď §äijăéĂŠæ■čçąőçŽĎåŔĆæŢřçśžå
éĆčäźĹè£ŹäžŽçśžåđŃç■¿åŘ■çŽĎçżŠåőŽæŸŕå¿ĹéĞ■èęĄçŽĎäÿĂæ■ěãĂĆåęĆæđIJä¡ăæšąæIJL'è£ŹäźĹåĄŽïi
è£ŸåŔŕèČ¡äijŽåŕijèĞt' æŢt' äÿłèğčéĞŁåŹĺè£ŽçĺŃæŇĆæŐL'ãĂĆ
ä¡£çŤĺctypesæIJL'äÿĂäÿłéžžçČęçĆźçŽĎåIJřæŰźæŸŕåŐ§çŤ§çŽĎCäžčçăĄä¡£çŤĺçŽĎæIJŕèŕ■åŔŕèČ¡èů§Pytho
divide() åĞ¡æŢřæŸŕäÿĂäÿłå¿Ĺåě¡çŽĎä¿Ńå■ŘïijÑåőĆéĂŽè£ĞäÿĂäÿłåŔĆæŢřéŹd' äžěåŔęäÿĂäÿłåŔĆæŢ
ař¡çőąè£ŹæŸŕäÿĂäÿłå¿Ĺåÿÿèğ ĄçŽĎCæŁĂæIJŕïijÑä¡ĘæŸŕåIJĺPythonäÿ■å■t' äÿ■ç§ěéĄŞæĂŐæăůæÿĚæŹřçŽ
ä¿ŃåęĆïijÑä¡ääÿ■èČ¡åČŔäÿŃéİćè£ŹæăůçőĂå■ŢçŽĎåĄŽïijž

```
>>> divide = _mod.divide
>>> divide.argtypes = (ctypes.c_int, ctypes.c_int, ctypes.
↪POINTER(ctypes.c_int))
>>> x = 0
>>> divide(10, 3, x)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ctypes.ArgumentError: argument 3: <class 'TypeError'>: expected LP_
↪c_int
instance instead of int
>>>
```

åřśçőŮè£ŹäÿłèČ¡æ■čçąőçŽĎåůëä¡IJïijÑåőČäijŽè£ĺåŔ■PythonåŕźäžŐæŢt' æŢřçŽĎäÿ■åŘŕæŻt' æŤźåŐ§å
åŕźäžŐæűL'åŘŁåĹřæŇĞéŠĹçŽĎåŔĆæŢřïijÑä¡ăéĂŽåÿÿéIJĂèęĄåĚĹædĎåžžäÿĂäÿłçŻÿåžŤçŽĎctypesåŕźèśą

```
>>> x = ctypes.c_int()
>>> divide(10, 3, x)
3
>>> x.value
1
>>>
```

åIJÍè£ŹéĞŇïijÑäÿĂäÿł ctypes.c_int åőđä¿ŃèćńåĹŻåžžåźűä¡IJäÿžäÿĂäÿłæŇĞéŠĹèćńäijăè£ŽåŐžã
èů§æŹőéĂŽPythonæŢt' å¡ćäÿ■åŘŇçŽĎæŸŕïijÑäÿĂäÿł c_int
åŕźèśąæŸŕåŔŕäžěèćńä£őæŤźçŽĎãĂĆ .value åśđæĂğåŔŕèćńçŤĺæİěèŐůåŘŰæĹŰæŻt' æŤźè£ŹäÿłåĂijãĂĆ

åŕźäžŐéĆčäžŽäÿ■åČŔPythonçŽĎCèřČçŤĺïijÑéĂŽåÿÿåŔŕäžěåĘŹäÿĂäÿłåřŘçŽĎåŇĚèčĚåĞ¡æŢřãĂĆ
è£ŹéĞŇïijÑæĹŚäžňèől' divide() åĞ¡æŢréĂŽè£ĞåĚČçżĎæİěè£ŤåŽđäÿd' äÿłçżŞæđIJïijž

```
# int divide(int, int, int *)
_divide = _mod.divide
_divide.argtypes = (ctypes.c_int, ctypes.c_int, ctypes.
↪POINTER(ctypes.c_int))
_divide.restype = ctypes.c_int

def divide(x, y):
    rem = ctypes.c_int()
    quot = _divide(x,y,rem)
    return quot, rem.value
```

avg() åĞ¡æŢřåŔĹæŸŕäÿĂäÿłæŰřçŽĎæŇŚæĹŸãĂĆCäžčçăĄæIJ§æIJŻæŐěåŔŮåĹřäÿĂäÿłæŇĞéŠĹåŠ
ä¡ĘæŸŕïijŇåIJĺPythonäÿ■ïijŇæĹŚäžňå£Ěéążè ĂČèŹŚè£ŹäÿłéŮőécŸïijŽæŢřçžĎæŸŕåŢěïij§åőČæŸŕäÿĂäÿłåĹ
è£ŸæŸŕ array æĺąåĺŮäÿ■çŽĎäÿĂäÿłæŢřçžĎïij§è£ŸæŸŕäÿĂäÿł numpy
æŢřçžĎïij§è£ŸæŸŕèŕťæĽĂæIJL'éČ¡æŸŕïij§ åőđéŹĚäÿŁïijŇäÿĂäÿłPythonâĂIJæŢřçžĎâĂİæIJL'åđ'Žçğ■å¡ćå

DoubleArrayType æijŤçđ'žäžĘæĂŐæăůåđ'ĎçŘĘè£Źçğ■æČĚåĘţãĂĆ
åIJĺè£Źäÿłçśžäÿ■åőŽäźL'äžĘäÿĂäÿłå■ŢäÿłæŰźæşŢ from_param() ãĂĆ
è£ŹäÿłæŰźæşŢçŽĎèğŠèL'šæŸŕæŐěåŔŮäÿĂäÿłå■ŢäÿłåŔĆæŢřçĎůåŘŐářĘåĚűåŘŚäÿŃè¡ňæ■ćäÿžäÿĂäÿłåŘĺ
ïijĹæIJňä¿Ńäÿ■æŸŕäÿĂäÿł ctypes.c_double çŽĎæŇĞéŠĹïijL'ãĂĆ
åIJĺ from_param() äÿ■ïijŇä¡ăåŔŕäžěåĄŽäżżä¡Ţä¡ăæČşåĄŽçŽĎäžŃãĂĆ
åŔĆæŢřçŽĎçśžåđŃåŘ■èćńæŔŘåŔŮåĞžæİěåźűèćńçŤĺäžŐåĹĘåŘŚåĹřäÿĂäÿłæŻť'åĚůä¡ŞçŽĎæŰźæşŢäÿ■åŐ
ä¿ŃåęĆïijŇåęĆæđIJäÿĂäÿłåĹŮèąĺèćńäijăéĂŠè£ĞæİěïijŇéĆčäźĹ typename åřśæŸŕ list
ïijŇ çĎűåŘŐ from_list æŰźæşŢèćńèřČçŤĺãĂĆ

åŕźäžŐåĹŮèąĺåŠŇåĚČçżĎïijŇfrom_list æŰźæşŢåřĘåĚűè¡ňæ■ćäÿžäÿĂäÿł ctypes
çŽĎæŢřçžĎåŕźèśąãĂĆ è£ŹäÿłçIJŃäÿŁåŐżæIJL'çĆźåěĞæĂłïijŇäÿŃéİćæĹŚäžňä¡£çŤĺäÿĂäÿłäžď'äžŠåijŔä¿Ń
ctypes æŢřçžĎïijŽ

```
>>> nums = [1, 2, 3]
>>> a = (ctypes.c_double * len(nums))(*nums)
>>> a
<__main__.c_double_Array_3 object at 0x10069cd40>
>>> a[0]
1.0
>>> a[1]
2.0
>>> a[2]
3.0
>>>
```

åŕźäžŐæŢřçžĎåŕźèśąïijŇfrom_array() æŔŘåŔŮåžŢåśĆçŽĎåĘĚå■ŸæŇĞéŠĹåźűåřĘåĚűè¡ňæ■ćäÿž
ctypes æŇĞéŠĹåŕźèśąãĂĆä¿ŃåęĆïijŽ

```
>>> import array
>>> a = array.array('d',[1,2,3])
>>> a
array('d', [1.0, 2.0, 3.0])
>>> ptr_ = a.buffer_info()
>>> ptr
4298687200
```

```
>>> ctypes.cast(ptr, ctypes.POINTER(ctypes.c_double))
<__main__.LP_c_double object at 0x10069cd40>
>>>
```

from_ndarray() æijŤçd'žäžĘåŕźäžŐ numpy æŢřçżĎçŽĎè¡ňæ■ćæŞ■ä¡IJãĂĆ éĂŽè£ĞåőŽäźL' DoubleArrayType çśžåźűåIJÍ avg() çśžåđŃç■¿åŘ■äÿ■ä¡£çŤÍåőČïijŇ éĆčäźĹè£ŹäÿłåĞ¡æŢřåřśèČ¡æŐěåŔŮåd'Žäÿłäÿ■åŘŇçŽĎçśżæŢřçżĎè¿ŞåĚěäžĘïijŽ

```
>>> import sample
>>> sample.avg([1,2,3])
2.0
>>> sample.avg((1,2,3))
2.0
>>> import array
>>> sample.avg(array.array('d',[1,2,3]))
2.0
>>> import numpy
>>> sample.avg(numpy.array([1.0,2.0,3.0]))
2.0
>>>
```

æIJňèŁĆæIJĂåŘŐäÿĂéČÍåĹĘåŘŚä¡ăæijŤçd'žäžĘæĂŐæăůåd'ĎçŘĘäÿĂäÿłçőĂå■ŢçŽĎCçżŞæđĎãĂĆ åŕźäžŐçżŞæđĎä¡ŞïijŇä¡ääŔłéIJĂèęĄåČŔäÿŃéÍćè£ŹæăůçőĂå■ŢçŽĎåőŽäźL'äÿĂäÿłçśžïijŇåŇĚåŘńçŻÿåžŤç

```
class Point(ctypes.Structure):
    _fields_ = [('x', ctypes.c_double),
                ('y', ctypes.c_double)]
```

äÿĂæŮęçśżèćńåőŽäźL'åŘŐïijŇä¡ääŕśåŔŕäžěåIJÍçśżåđŃç■¿åŘ■äÿ■æĹŰèĂĚæŸŕéIJĂèęĄåőđä¿ŃåŇŰçżŞ

```
>>> p1 = sample.Point(1,2)
>>> p2 = sample.Point(4,5)
>>> p1.x
1.0
>>> p1.y
2.0
>>> sample.distance(p1,p2)
4.242640687119285
>>>
```

æIJĂåŘŐäÿĂäžŽåŕŔçŽĎæŔŘçd'žïijŽåęĆæđIJä¡ăæČşåIJÍPythonäÿ■èő£éŮőäÿĂäžŽåŕŔçŽĎCåĞ¡æŢřïijŇ ctypes æŸŕäÿĂäÿłå¿ĹæIJL'çŤÍçŽĎåĞ¡æŢřåžŞãĂĆ år¡çőąåęĆæ■d'ïijŇåęĆæđIJä¡ăæČşèęĄåŐżèő£éŮőäÿĂä Swig (15.9èŁĆäijŽèőšåĹř) æĹŰ CythonïijĹ15.10èŁĆïijL'ãĂĆ

åŕźäžŐåd'ğåđŃåžŞçŽĎèő£éŮőæIJL'äÿłäÿżèęĄéŮőécŸïijŇçŤšäžŐctypesåźűäÿ■æŸŕåőŇåĚÍèĞłåŁÍåŇŰï éĆčäźĹä¡ääŕšå£ĚéążèŁśèt'źåd'ğéĞŔæŮűéŮt'æÍěçijŰåĘŹæL'ĂæIJL'çŽĎçśżåđŃç¿åŘ■ïijŇåŕšåČŔä¿Ńå■Řäÿ åęĆæđIJåĞ¡æŢřåžŞåd'§åd'■æÍĆïijŇä¡ăè£Ÿå¿ŮåŐżçijŰåĘŹå¿Ĺåd'ŽåŕŔçŽĎåŇĚèčĚåĞ¡æŢřåŠŇæŤŕæŇĄçśż åŔęåd'ŰïijŇéŹd'éÍđä¡ääůšçżŔåőŇåĚÍçš¿éĂŽäžĘæL'ĂæIJL'åžŢåśĆçŽĎCæŐěåŔčçżĘèŁĆïijŇåŇĚæŃňåĘĚå éĂŽåÿÿäÿĂäÿłå¿ĹåŕŔçŽĎäžčçăĄçijžéŹůãĂĄèő£éŮőèűŁçŢŇæĹŰåĚűäžŰçśżäijijéŤŹèŕŕåŕśèČ¡èől'PythonçÍŇ

ä¡IJäÿž ctypes çŽĎäÿĂäÿłæŻ£äżčïijŇä¡ăè£ŸåŔŕäžěèĂČèŹŚäÿŃCFFIãĂĆCFFIæŔŘä¿ŻäžĘå¿Ĺåd'Žç

ä¡ĘæŸŕä¡£çŤÍCèŕ■æşŢåźűæŤŕæŇĄæŻtˇådˇŽéńŸçžğçŽĎCäžčçăĄçśżåđŃãĂĆ
åĹřåĘŹè£ŹæIJñäźęäÿžæ■ćïijŇCFFIè£ŸæŸŕäÿĂäÿłçŽÿåŕźè¿ČæŰřçŽĎåůěçÍŃïijŇ
ä¡ĘæŸŕåőČçŽĎæţĄèąŇåžęæ■čåIJĺå£néĂ§äÿŁå■ĞãĂĆ çŤŽèĞşè£ŸæIJL’åIJÍèőÍèőžåIJÍPythonářĘæİěçŽĎçL’Í

17.2 15.2 çőĂå■ŢçŽĎCæĽľåśŢæÍąåİŮ

éŮőécŸ

ä¡ăæČşäÿ■ä¿İéİăåĚűäžŰåůěåĚůïijŇçŻtˇæŐěä¡£çŤÍPythonçŽĎæĽľåśŢAPIæİěçijŰåĘŹäÿĂäžŽçőĂå■ŢçZ

èğčåĘşæŰźæąĹ

åŕźäžŐçőĂå■ŢçŽĎCäžčçăĄïijŇæđĎåżžäÿĂäÿłèĞłåőŽäźĽæĽľåśŢæÍąåİŮæŸŕå¿ĹåőźæŸ§çŽĎãĂĆ
ä¡IJäÿžçňňäÿĂæ■ěïijŇä¡ăéIJĂèęĄçąőä£İä¡ăçŽĎCäžčçăĄæIJL’äÿĂäÿłæ■čçąőçŽĎåď’æŰĞäžűãĂĆä¿ŃåęĆïij

```
/* sample.h */

#include <math.h>

extern int gcd(int, int);
extern int in_mandel(double x0, double y0, int n);
extern int divide(int a, int b, int *remainder);
extern double avg(double *a, int n);

typedef struct Point {
    double x,y;
} Point;

extern double distance(Point *p1, Point *p2);
```

éĂŽåÿÿæİěèőšïijŇè£ŹäÿłåďˇæŰĞäžűèęĄåŕźåžŤäÿĂäÿłåůšçżŔèćńå■ŢçŃňçijŰèŕŚè£ĞçŽĎåžŞãĂĆ
æIJL’äžĘè£ŹäžŻïijŇäÿŃéİćæĹŚäžňæijŤçďžäÿŃçijŰåĘŹæĽľåśŢåĞ¡æŢřçŽĎäÿĂäÿłçőĂå■Ţä¿Ńå■ŘïijŽ

```
#include "Python.h"
#include "sample.h"

/* int gcd(int, int) */
static PyObject *py_gcd(PyObject *self, PyObject *args) {
  int x, y, result;

  if (!PyArg_ParseTuple(args,"ii", &x, &y)) {
    return NULL;
  }
  result = gcd(x,y);
  return Py_BuildValue("i", result);
}

/* int in_mandel(double, double, int) */
```

```
static PyObject *py_in_mandel(PyObject *self, PyObject *args) {
  double x0, y0;
  int n;
  int result;

  if (!PyArg_ParseTuple(args, "ddi", &x0, &y0, &n)) {
    return NULL;
  }
  result = in_mandel(x0,y0,n);
  return Py_BuildValue("i", result);
}

/* int divide(int, int, int *) */
static PyObject *py_divide(PyObject *self, PyObject *args) {
  int a, b, quotient, remainder;
  if (!PyArg_ParseTuple(args, "ii", &a, &b)) {
    return NULL;
  }
  quotient = divide(a,b, &remainder);
  return Py_BuildValue("(ii)", quotient, remainder);
}

/* Module method table */
static PyMethodDef SampleMethods[] = {
  {"gcd",  py_gcd, METH_VARARGS, "Greatest common divisor"},
  {"in_mandel", py_in_mandel, METH_VARARGS, "Mandelbrot test"},
  {"divide", py_divide, METH_VARARGS, "Integer division"},
  { NULL, NULL, 0, NULL}
};

/* Module structure */
static struct PyModuleDef samplemodule = {
  PyModuleDef_HEAD_INIT,

  "sample",           /* name of module */
  "A sample module",  /* Doc string (may be NULL) */
  -1,                 /* Size of per-interpreter state or -1 */
  SampleMethods       /* Method table */
};

/* Module initialization function */
PyMODINIT_FUNC
PyInit_sample(void) {
  return PyModule_Create(&samplemodule);
}
```

èęĄçżŚåőŽè£ŹäÿłæĽľåśŢæĺąåİŮïijŇåČŔäÿŃéİćè£ŹæăůåĹŻåżžäÿĂäÿł `setup.py` æŰĞäżűïijŽ

```
# setup.py
from distutils.core import setup, Extension

setup(name='sample',
      ext_modules=[
        Extension('sample',
                  ['pysample.c'],
                  include_dirs = ['/some/dir'],
                  define_macros = [('FOO','1')],
                  undef_macros = ['BAR'],
                  library_dirs = ['/usr/local/lib'],
                  libraries = ['sample']
                  )
        ]
)
```

äÿžäžĘæđĎåžžæIJĂçżĹçŽĎåĞ¡æŢřåžŞïijŇåŔłéIJĂçőĂå■ŢçŽĎä¡£çŤÍ `python3 buildlib.py build_ext --inplace` åŚ¡äžď'å■şåŔřïijŽ

```
bash % python3 setup.py build_ext --inplace
running build_ext
building 'sample' extension
gcc -fno-strict-aliasing -DNDEBUG -g -fwrapv -O3 -Wall -Wstrict-
 ↪prototypes
 -I/usr/local/include/python3.3m -c pysample.c
 -o build/temp.macosx-10.6-x86_64-3.3/pysample.o
gcc -bundle -undefined dynamic_lookup
build/temp.macosx-10.6-x86_64-3.3/pysample.o \
 -L/usr/local/lib -lsample -o sample.so
bash %
```

åęĆäÿŁæL'Ăçđ'žïijŇåőČäijŽåĹŻåžžäÿĂäÿłåŘ■å■ŮåŔń `sample.so` çŽĎåĚśäžńåžŞãĂĆå¡Şèćńçij Űèŕ ŚåŘŐïijŇä¡ăářśèČ¡ářĘåőČä¡IJäÿžäÿĂäÿłæĺąåİŮåŕijåĚěè£ŻæİěäžĘïijŽ

```
>>> import sample
>>> sample.gcd(35, 42)
7
>>> sample.in_mandel(0, 0, 500)
1
>>> sample.in_mandel(2.0, 1.0, 500)

0
>>> sample.divide(42, 8)
(5, 2)
>>>
```

åęĆæđIJä¡ăæŸŕåIJĺWindowsæIJžåŹĺäÿŁéĺćåřİèŕŢè£ŹäžŻæ■ěéłď'ïijŇåŔŕèČ¡äijŽéĄĞåĹřåŘĎçğ■çŐŕåćČ PythonçŽĎäžŇè£ŻåĹűåĹĘåŔŚéĂŽåÿÿä¡£çŤĺäžĘMicrosoft Visual StudioæİěæđĎåžžãĂĆ äÿžäžĘèől'è£ŹäžŻæL'l'åśŢèČ¡æ■čåÿÿåůěä¡IJïijŇä¡ăéIJĂèęĄä¡£çŤĺåŘŇæăůæĹŰåĚijåőźçŽĎåůěåĚůæİěçijŰè åŔĆèĂČçŻÿäžŤçŽĎ PythonæŰĞæąč

èőÍèőž

åIJÍåřÌèŕŢäžžä¡ŢæĽŃåĘŹæĽ'ľåśŢäźŃåĽ■ïijŇæIJĂåě¡èČ¡åĚĹåŔĆèĂČäÿŃPythonæŰĞæąčäÿ■çŽĎ
æĽ'ľåśŢåŠŇåţŇåĚěPythonèğčéĞŁåŹÍ . PythonçŽĎCæĽ'ľåśŢAPIå¿Ĺåď'ğïijŇåIJÍè£ŹéĞŇæŢť'äÿłåŐżèőšè£řå
äÿ■è£Ğåŕźäž0æIJĂæäÿå£ČçŽĎéČĺåĹĘè£ŸæŸŕåŔŕäžěèőÍèőžäÿŃçŽĎãĂĆ

éęŰåĚĹïijŇåIJÍæĽ'ľåśŢæĺąåİŮäÿ■ïijŇä¡ăåĘŹçŽĎåĞ¡æŢřéČ¡æŸŕåČŔäÿŃéİćè£ŹæăůçŽĎäÿĂäÿłæŹőéĂ

```
static PyObject *py_func(PyObject *self, PyObject *args) {
  ...
}
```

`PyObject` æŸŕäÿĂäÿłèČ¡èąĺçď'žäžžä¡ŢPythonåŕźèśąçŽĎCæŢřæ■őçśžåđŃãĂĆ
åIJÍäÿĂäÿłéńŸçžğåśĆéİćïijŇäÿĂäÿłæĽ'ľåśŢåĞ¡æŢřåřśæŸŕäÿĂäÿłæŐěåŔŮäÿĂäÿłPythonåŕźèśą
ïijĹåIJÍ PyObject *argsäÿ■ïijĽåĚČçžĎåźűè£ŤåŽđäÿĂäÿłæŰřPythonåŕźèśąçŽĎCåĞ¡æŢřãĂĆ
åĞ¡æŢřçŽĎ `self` åŔĆæŢřåŕźäžŐçőĂå■ŢçŽĎæĽ'ľåśŢåĞ¡æŢræšąæIJL'èćńä¡£çŤĺåĹřïijŇ
äÿ■è£ĞåęĆæđIJä¡ăæČşåőŽäźĽæŰřçŽĎçśžæĹŰèĂĚæŸŕĆäÿ■çŽĎåŕźèśąçśžåđŃçŽĎèŕĺåřśèČ¡æť¿äÿŁçŤĺåIJž
éĆčäźĹ `self` åřśèČ¡åijŢçŤĺéĆčäÿłåőđä¿ŃäžĘãĂĆ

`PyArg_ParseTuple()` åĞ¡æŢřèćńçŤĺæİěåřĘPythonäÿ■çŽĎåĂijè¡ñæ■ćæĹŘCäÿ■åŕźåžŤèąĺçď'žãĂĆ
åőČæŐěåŔŮäÿĂäÿłæŇĞåőŽè¿ŞåĚěæăijåijŔçŽĎæăijåijŔåŇŰå■Ůçňęäÿšä¡IJäÿžè¿ŞåĚěïijŇæŕŤåęĆâĂIJiâĂİ
åŘŇæăůè£ŸæIJL'å■ŸæŤ¿è¡ñæ■ćåŘŐçżŞæđIJçŽĎCåŔŸéĞŔçŽĎåIJřåİĂãĂĆ
åęĆæđIJè¿ŞåĚěçŽĎåĂijäÿ■åŇźéĚ■è£ŹäÿłæăijåijŔåŇŰå■ŮçňęäÿšïijŇåřśäijŽæŁŻåĞžäÿĂäÿłåijĆåÿÿåźűè£Ťá
éĂŽè£ĞæčĂæ§ěåźűè£ŤåŽđNULLïijŇäÿĂäÿłåŘĹéĂĆçŽĎåijĆåÿÿäijŽåIJÍèŕĈçŤĺäžčçăĄäÿ■èćńæŁŻåĞžãĂĆ

`Py_BuildValue()` åĞ¡æŢřèćńçŤĺæİěæăźæ■őCæŢřæ■őçśžåđŃåĹŻåžžPythonåŕźèśąãĂĆ
åőČåŘŇæăůæŐěåŔŮäÿĂäÿłæăijåijŔåŇŰå■ŮçňęäÿšæİěæŇĞåőŽæIJ§æIJŻçśžåđŃãĂĆ
åIJÍæĽ'ľåśŢåĞ¡æŢřäÿ■ïijŃåőČèćńçŤĺæİěè£ŤåŽđçżŞæđIJçżŹPythonãĂĆ
`Py_BuildValue()` çŽĎäÿĂäÿłçĽźæĂğæŸŕåőČèČ¡æđĎåžžæŻť'åŁăåď'■æİĆçŽĎåŕźèśąçśžåđŃïijŇæŕŤåęĆ
åIJÍ `py_divide()` äžčçăĄäÿ■ïijŇäÿĂäÿłä¿Ńå■ŘæijŤçď'žäžĘæĂŐæăůè£ŤåŽđäÿĂäÿłåĚČçżĎãĂĆäÿ■è£Ğï

```
return Py_BuildValue("i", 34);       // Return an integer
return Py_BuildValue("d", 3.4);      // Return a double
return Py_BuildValue("s", "Hello"); // Null-terminated UTF-8 string
return Py_BuildValue("(ii)", 3, 4); // Tuple (3, 4)
```

åIJÍæĽ'ľåśŢæĺąåİŮåžŢéČĺïijŇä¡ăäijŽåŔŚçŐřäÿĂäÿłåĞ¡æŢřèąĺïijŇæŕŤåęĆæIJňèŁĆäÿ■çŽĎ
`SampleMethods` èąĺãĂĆ è£ŹäÿłèąĺåŔŕäžěåĹŮåĞžCåĞ¡æŢřãĂĄPythonäÿ■ä¡£çŤĺçŽĎåŘ■å■ŮãĂĄæŰĞæa
æĽĂæIJL'æĺąåİŮéČ¡éIJĂèęĄæŇĞåőŽè£ŹäÿłèąĺïijŇåŽăäÿžåőČåIJÍæĺąåİŮåĹİåğŇåŇŰæŮűèęĄèćńä¡£çŤĺåĹř

æIJĂåŘŐçŽĎåĞ¡æŢř `PyInit_sample()` æŸŕæĺąåİŮåĹİåğŇåŇŰåĞ¡æŢřïijŇä¡ĘèŕěæĺąåİŮçňňäÿĂæì
è£ŹäÿłåĞ¡æŢřçŽĎäÿžèęĄåůěä¡IJæŸŕåIJÍèğčéĞŁåŹĺäÿ■æşĺåĘŇæĺąåİŮåŕźèśąãĂĆ

æIJĂåŘŐäÿĂäÿłèęĄçĆźéIJĂèęĄæŔŘåĞžæİěïijŇä¡£çŤĺCåĞ¡æŢřæİěæĽ'ľåśŢPythonèęĄèĂČèŹŚçŽĎäžl
ïijĹåőđéŹĚäÿŁïijŃC APIåŇĚåŘńäžĘèűĚè£Ğ500äÿłåĞ¡æŢřïijĽãĂĆä¡ăåžŤèŕěårĘæIJňèŁĆå¡ŞåĄŽæŸŕäÿĂäÿ
æŻť'åď'ŽéńŸçžğåĘĚåőźïijŇåŔŕäžěçIJŃçIJŃ `PyArg_ParseTuple()` åŠŇ
`Py_BuildValue()` åĞ¡æŢřçŽĎæŰĞæąčïijŃ çĎűåŘŐè£ŻäÿĂæ■ěæĽ'ľåśŢåijĂãĂĆ

17.3 15.3 çijŰåĘŹæĽľåśŢåĞ¡æŢřæŞ■ä¡IJæŢřçżĎ

éŮőécŸ

ä¡ăæČşçijŰåĘŹäÿĂäÿłCæĽ'ľåśŢåĞ¡æŢřæİěæŞ■ä¡IJæŢřçżĎïijŇåŔřèČ¡æŸřèćńarrayæĺąåİŮæĹŰçśžäijijN
äÿ■è£ĞïijŇä¡ăæČşèőľä¡ăçŽĎåĞ¡æŢřæŻť'åŁăéĂŽçŤĺïijŇèĂŇäÿ■æŸřéŠĹåŕźæ§Řäÿłç L'źåőŽçŽĎåžŞæĽĂçŤ

èğčåĘşæŰźæąĹ

äÿžäžĘèČ¡èőľæŐěåŔŮåŠŇåď'ĎçŘĘæŢřçżĎåĚůæIJL'åŔřçğżæď'■æĂğïijŇä¡ăéIJĂèęĄä¡£çŤĺåĹř
Buffer Protocol . äÿŃéİćæŸřäÿĂäÿłæĽ'ŃåĘŹçŽĎCæĽ'ľåśŢåĞ¡æŢřä¿Ńå■ŘïijŇ
çŤĺæİěæŐěåŔŮæŢřçżĎæŢřæ■őåźűèřČçŤĺæIJňçńăåijĂçŕĞéČĺåĹĘçŽĎ `avg(double *buf, int len)` åĞ¡æŢřïijŽ

```
/* Call double avg(double *, int) */
static PyObject *py_avg(PyObject *self, PyObject *args) {
  PyObject *bufobj;
  Py_buffer view;
  double result;
  /* Get the passed Python object */
  if (!PyArg_ParseTuple(args, "O", &bufobj)) {
    return NULL;
  }

  /* Attempt to extract buffer information from it */

  if (PyObject_GetBuffer(bufobj, &view,
      PyBUF_ANY_CONTIGUOUS | PyBUF_FORMAT) == -1) {
    return NULL;
  }

  if (view.ndim != 1) {
    PyErr_SetString(PyExc_TypeError, "Expected a 1-dimensional array
↪");
    PyBuffer_Release(&view);
    return NULL;
  }

  /* Check the type of items in the array */
  if (strcmp(view.format,"d") != 0) {
    PyErr_SetString(PyExc_TypeError, "Expected an array of doubles
↪");
    PyBuffer_Release(&view);
    return NULL;
  }

  /* Pass the raw buffer and size to the C function */
  result = avg(view.buf, view.shape[0]);
```

```
  /* Indicate we're done working with the buffer */
  PyBuffer_Release(&view);
  return Py_BuildValue("d", result);
}
```

äÿŃéÌćæĹŚäžňæijŤçď'žäÿŃè£ŹäÿłæL'ľåśŢåĞ¡æŢřæŸŕåęĆä¡Ţåůěä¡IJçŽĎïijŽ

```
>>> import array
>>> avg(array.array('d',[1,2,3]))
2.0
>>> import numpy
>>> avg(numpy.array([1.0,2.0,3.0]))
2.0
>>> avg([1,2,3])
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: 'list' does not support the buffer interface
>>> avg(b'Hello')
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: Expected an array of doubles
>>> a = numpy.array([[1.,2.,3.],[4.,5.,6.]])
>>> avg(a[:,2])
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: ndarray is not contiguous
>>> sample.avg(a)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: Expected a 1-dimensional array
>>> sample.avg(a[0])

2.0
>>>
```

èőÍèőž

åřĘäÿĂäÿłæŢřçżĎåŕźèśąäijąçżŹCåĞ¡æŢřåŔŕèČ¡æŸŕäÿĂäÿłæL'ľåśŢåĞ¡æŢřåĄŽçŽĎæIJÅåÿÿèğĄçŽĎäž
å¿Ĺåď'ŽPythonåžŤçŤĺçĺŃåžŔïijŃäżŐåŻ¿åČŔåď'ĎçŘĘåĹřçğŚå■ęèőąçőŮïijŃéČ¡æŸŕå§žäžŐéńŸæĂğèČ¡çŽĎ
éĂŽè£ĞçijŰåĘŹèČ¡æŐěåŔŮåźűæŞ■ä¡IJæŢřçżĎçŽĎäžčçăĄïijŃä¡ăåŘŕäžěçijŰåĘŹå¿Ĺåě¡çŽĎåĚijåőźè£ŹäžŽ
èĂŃäÿ■æŸŕåŔłèČ¡åĚijåőźä¡äèĞłåůśçŽĎäžčçăĄąăĂĆ

äžčçăĄçŽĎåĚşéŤőçĆźåIJĺäžŐ `PyBuffer_GetBuffer()` åĞ¡æŢřãĂĆ
çżŹåőŽäÿĂäÿłäżżæĎŔçŽĎPythonåŕźèśąïijŃåőČäijŽèŕŢçİĂåŐżèŐůåŔŮåžŢåśĆåĘĚå■Ÿä£ąæĄŕïijŃåőČçőĂå
1. äijăçżŹ `PyBuffer_GetBuffer()` çŽĎçL'źæőŁæăĞå£ŮçżŹåĞžäžĘæL'ĂéIJĂçŽĎåĘĚå■ŸçijŞåĘšçśžåď
ä¿ŃåęĆïijŃ`PyBUF_ANY_CONTIGUOUS` èąĺçď'žæŸŕäÿĂäÿłè£đçż■çŽĎåĘĚå■ŸåŇžå§§ãĂĆ

åŕźäžŐæŢřçżĎãĂĄå■ŮèŁĆå■Ůçňęäÿšå§ŇåĚűäžŰçśżäijijåŕźèśąèĂŇèĺĂïijŃäÿĂäÿł
`Py_buffer` çżŞædĎä¡ŞåŇĚåŘńäžĘæL'ĂæIJL'åžŢåśĆåĘĚå■ŸçŽĎä£ąæĄŕãĂĆ

åőČåŇĚåŘńäÿĂäÿłæŇĞåŘŚåĘĚå■ŸåIJřåİĂãĂĄåď ğářŔãĂĄåĚČçť ăåď ğářŔãĂĄæăijåijŔåŠŇåĚűäžŰçżĘèŁ

```
typedef struct bufferinfo {
    void *buf;              /* Pointer to buffer memory */
    PyObject *obj;          /* Python object that is the owner */
    Py_ssize_t len;         /* Total size in bytes */
    Py_ssize_t itemsize;    /* Size in bytes of a single item */
    int readonly;           /* Read-only access flag */
    int ndim;               /* Number of dimensions */
    char *format;           /* struct code of a single item */
    Py_ssize_t *shape;      /* Array containing dimensions */
    Py_ssize_t *strides;    /* Array containing strides */
    Py_ssize_t *suboffsets; /* Array containing suboffsets */
} Py_buffer;
```

æIJňèŁĆäÿ■ïijŇæĹŚäžňåŔłåĚşæşĺæŐĕåŔŮäÿĂäÿłåŔŇçš¿åžęæţőçĆźæŢřæŢřçżĎä¡IJäÿžåŔĆæŢřãĂĆ
èęĄæčĂæ§ĕåĚČçť ăæŸŕåŘęæŸŕäÿĂäÿłåŔŇçš¿åžęæţőçĆźæŢřïijŇåŔłéIJĂéłŇèŕĄ
`format` åšđæĂğæŸŕäÿ■æŸŕå■ŮçňęäÿšâİdâĂİ. è£Źäÿłäź§æŸŕ `struct` æĺąåİŮçŤĺæİěçijŰçăĄäžŇè£ŻåĹűæŢřæ■őçŽĎãĂĆ éĂŽåÿÿæİěèőšïijŇ`format` åŘŕäžěæŸŕäżä¡ŢåĚijåőź `struct` æĺąåİŮçŽĎæăijåijŔåŇŰå■ŮçňęäÿšïijŇ
åźűäÿŤåęĆæđIJæŢřçżĎåŇĚåŘńäžĘĆçżŞæđĎçŽĎèŕİåőĆåŔŕäžěåŇĚåŘńåď ŽäÿłåĂijãĂĆ
äÿĂæŮęæĹŚäžňåůšçżŔçąőåőŽäžĘåžŢåśĆçŽĎçijŞå■ŸåŇžä£ąæĄŕïijŇéĆčåŔłéIJĂèęĄçőĂå■ŢçŽĎårĘåőČäij
åőđéŹĚäÿŁïijŇæĹŚäžňäÿ■å£ĔæŃĚå£ĈæŸŕæĂŐæăůçŽĎæŢřçżĎçśżåđŃæĹŰèĂĚåőČæŸŕèćńäžĂäźĹåžŞåĹŽ
è£Źäź§æŸŕäÿžäžĂäźĹè£Źäÿłåĝ¡æŢřèČ¡åĚijåőź `array` æĺąåİŮäź§èČ¡åĚijåőź `numpy` æĺąåİŮäÿ■çŽĎæŢřçżĎäžĘãĂĆ

åIJĺè£ŤåŻđæIJĂçżĹçżŞæđIJäźŃåL’■ïijŇåžŢåśĆçŽĎçijŞåĘšåŇžèğĘåŻ¿å£Ěéążä¡£çŤĺ
`PyBuffer_Release()` éĞŁæŤ¿æŐL’ãĂĆ äźŃæL’ĂäžěèęĄè£ŹäÿĂæ■ěæŸŕäÿžäžĘèČ¡æ■ĉçąőçŽĎçőąçŘĚ

åŘŇæăůïijŇæIJňèŁĆäź§äžĔäžĔåŔłæŸŕæijŤçď žäžĘąæŐěåŔŮæŢřçżĎçŽĎäÿĂäÿłåřĹçŽĎäžĉçăĄçL’Ğæő
åęĆæđIJä¡ăçIJ§çŽĎèęĄåď ĎçŘĘæŢřçżĎïijŇä¡ăåŔŕèČ¡äijŽçćřåĹřåď Žçżť æŢřæ■őãĂĄåď ğæŢřæ■őãĂĄäÿ■å
éĆĉäźĹåřšå¿ŮåŐżå■ęæŽť énŸçžğçŽĎäÿIJèè£äžĘãĂĆä¡äéIJĂèęĄåŔĆèĂČåőŸæŰźæŰĞæąćæİěèŐůåŔŰæŽť

åęĆæđIJä¡ăéIJĂèęĄçijŰåĘŹæűL’åŔŁåĹřæŢřçżĎåď ĎçŘĘçŽĎåď ŽäÿłæL’ľåśŢïijŇéĆčäźĹéĂŽè£ĞCytho

17.4 15.4 åIJĺCæL’ľåśŢæĺąåİŮäÿ■æŞ■ä¡IJéŽŘå¡ćæŇĞéŠĹ

éŮőécŸ

ä¡ăæIJL’äÿĂäÿłæL’ľåśŢæĺąåİŮéIJĂèęĄåď ĎçŘĘCçżŞæđĎä¡Şäÿ■çŽĎæŇĞéŠĹïijŇ
ä¡ĘæŸŕä¡ăåŔĹäÿ■æČşæŽť éIJšçżŞæđĎä¡Şäÿ■äžžä¡ŢåĘĚéČĺçżĘèŁĆçżŹPythonãĂĆ

èğčåĘşæŰźæąĹ

éŽŘå¡ćçżŞæđĎä¡ŞåŔŕäžěå¿ĹåőźæŸ§çŽĎéĂŽè£ĞårĘåőČäžňåŇĚècĚåIJĺèČűåŻŁårźèśąäÿ■æİěåď ĎçŘĘ
èĂČèŹŚæĹŚäžňä¿Ńå■ŘäžčçăĄäÿ■çŽĎäÿŇåĹŮCäžčçăĄçL’Ğæőţïijž

```
typedef struct Point {
    double x,y;
```

```
} Point;

extern double distance(Point *p1, Point *p2);
```

äÿŃéİćæŸŕäÿĂäÿłä¡£çŤĺèČűåŻŁåŃĚèčĚPointçżŞæđĎä¡ŞåŠŃ distance() åĞ¡æŢřçŽĎæĽľåśŢäżčçăĄåőđä¿ŃïijŽ

```
/* Destructor function for points */
static void del_Point(PyObject *obj) {
  free(PyCapsule_GetPointer(obj,"Point"));
}

/* Utility functions */
static Point *PyPoint_AsPoint(PyObject *obj) {
  return (Point *) PyCapsule_GetPointer(obj, "Point");
}

static PyObject *PyPoint_FromPoint(Point *p, int must_free) {
  return PyCapsule_New(p, "Point", must_free ? del_Point : NULL);
}

/* Create a new Point object */
static PyObject *py_Point(PyObject *self, PyObject *args) {

  Point *p;
  double x,y;
  if (!PyArg_ParseTuple(args,"dd",&x,&y)) {
    return NULL;
  }
  p = (Point *) malloc(sizeof(Point));
  p->x = x;
  p->y = y;
  return PyPoint_FromPoint(p, 1);
}

static PyObject *py_distance(PyObject *self, PyObject *args) {
  Point *p1, *p2;
  PyObject *py_p1, *py_p2;
  double result;

  if (!PyArg_ParseTuple(args,"OO",&py_p1, &py_p2)) {
    return NULL;
  }
  if (!(p1 = PyPoint_AsPoint(py_p1))) {
    return NULL;
  }
  if (!(p2 = PyPoint_AsPoint(py_p2))) {
    return NULL;
  }
  result = distance(p1,p2);
```

```
  return Py_BuildValue("d", result);
}
```

åIJÍPythonäÿ■åŔŕäžěåČŔäÿŃéÍćè£ŹæăůæÌěä¡£çŤÍè£ŹäžŻåĞ¡æŢřïijŽ

```
>>> import sample
>>> p1 = sample.Point(2,3)
>>> p2 = sample.Point(4,5)
>>> p1
<capsule object "Point" at 0x1004ea330>
>>> p2
<capsule object "Point" at 0x1005d1db0>
>>> sample.distance(p1,p2)
2.8284271247461903
>>>
```

èőÍèőž

èČűåŻŁåŠŇCæŇĞéŠĹçśżäijijãĂĆåIJÍåĘĚéČĺïijŇåőČäžňèŐůåŔŰäÿĂäÿłéĂŽçŤÍæŇĞéŠĹåŠŇäÿĂäÿłåŔ
`PyCapsule_New()` åĞ¡æŢřå¿Ĺåőźæ ŸŞçŽĎèćńåĹŻåżžãĂĆ
åŔęåd'ŰïijŇäÿĂäÿłåŔŕéĂĽ'çŽĎædŘædĎåĞ¡æŢřèČ¡èćńçżŚåőŽåĹřèČűåŻŁäÿŁïijŇçŤÍæÌěåIJÍèČűåŻŁåŕźèśąè

èęĄæŔŘåŔŰèČűåŻŁäÿ■çŽĎæŇĞéŠĹïijŇåŔŕä¡£çŤÍ `PyCapsule_GetPointer()`
åĞ¡æŢřåźűæŇĞåőŽåŘ■çğřãĂĆ åęĆædIJæŔŘä¿ŻçŽĎåŘ■çğřåŠŇèČűåŻŁäÿ■åŃźéĚ■æĹŰåĚűäżŰéŤŹèŕŕåĞž

æIJňèŁĆäÿ■ïijŇäÿĂåŕźåůěåĚůåĞ¡æŢřâĂŤâĂŤ `PyPoint_FromPoint()`
åŠŇ `PyPoint_AsPoint()` èćńçŤÍæÌěåĹŻåżžåŠŇäżÕèČűåŻŁåŕźèśąäÿ■æŔŘåŔŰ-
Pointåőđä¿ŃãĂĆ åIJÍäżžä¡ŢæĽ'ľåśŢåĞ¡æŢřäÿ■ïijŇæĹŚäžňäijŽä¡£çŤÍè£ŹäžŻåĞ¡æŢřèĂŇäÿ■æŸŕçŻt'æŐěä¡
è£Źçğ■èő¿èőąä¡£å¿ŮæĹŚäžňåŔŕäžěå¿Ĺåőźæ ŸŞçŽĎåžŤåŕźářĘæÌěåŕźPointåžŢäÿŃçŽĎåŇĚèčĚçŽĎæŻt'æŤź
ä¿ŃåęĆïijŇåęĆædIJä¡ääĘşåőŽä¡£çŤÍåŘęåd'ŰäÿĂäÿłèČűåŻŁäžĘïijŇéĆčäźĹåŘłéIJĂèęĄæŻt'æŤźè£Źäÿd'äÿłă

åŕźäžŐèČűåŻŁåŕźèśąäÿĂäÿłéŽ¿çĆźåIJÍäžŐåđČåIJ¿åŻđæŤűåŠŇåĘĚå■ŸçőąçŘĘãĂĆ
`PyPoint_FromPoint()` åĞ¡æŢřæŐěåŔŮäÿĂäÿł `must_free`
åŔĆæŢřïijŇ çŤÍæÌěæŇĞåőŽå¡ŞèČűåŻŁèćńéŤĂæŕĄæŮűåžŢåśĆPoint *
çżŞædĎä¡ŞæŸŕåŘęåžŤèŕěèćńåŻđæŤűãĂĆ åIJÍæ§ŘäžŻCäžčçăĄäÿ■ïijŇå¡ŠåśđéŭőécŸéĂŽåÿÿå¿ĹéŽ¿èćńåd'Ì
çÍŃåžŘåŚŸåŕźäžěä¡£çŤÍ `extra` åŔĆæŢřæÌěæŐğåĹűïijŇèĂŇäÿ■æŸŕå■ŢæŰźéÍćçŽĎåĘşåőŽåđČåIJ¿åŻđæŤ
èęĄæşÍæĎŔçŽĎæŸŕåŠŇçŐřæIJL'èČűåŻŁæIJL'åĚşçŽĎædŘædĎåŹÍèČ¡ä¡£çŤÍ
`PyCapsule_SetDestructor()` åĞ¡æŢřæÌěæŻt'æŤźãĂĆ

åŕźäžŐæűL'åŘŁåĹřçżŞædĎä¡ŞçŽĎCäžčçăĄèĂŇèÍĂïijŇä¡£çŤÍèČűåŻŁæŸŕäÿĂäÿłæŕŤè¿ČåŘĹçŘĘçŽĎè
ä¿ŃåęĆïijŇæIJL'æŮűåĂŹä¡ååźűäÿ■åĚşå£ČæŽt'éIJšçżŞædĎä¡ŞçŽĎåĘĚéČÍïå£ąæĄŕæĹŰèĂĚårĘåĚűè¡ñæ■ćæ
éĂŽè£Ğä¡£çŤÍèČűåŻŁïijŇä¡ääŔŕäžěåIJÍåőČäÿŁéÍćæŤ¿äÿĂäÿłè¡žéĞŔçžğçŽĎåŇĚèčĚåŹÍïijŇçĎűåŘŐårĘåőČ

17.5 15.5 äžŐæĽľåśŢæÍąåİŮäÿ■åőŽäźĽåŠŇåŕijåĞžCçŽĎAPI

éŮőécŸ

ä¡ăæIJL'äÿĂäÿłCæL'ľåśŢæÍąåİŮïijŇåIJÍåĘĚéČÍåőŽäźL'äžĘå¿Ĺåď'ŽæIJL'çŤÍçŽĎåĞ¡æŢřïijŇä¡ăæČşåřĘå APIä¿ŻåĚűäžŰåIJřæŰźä¡£çŤÍãĂĆ ä¡ăæČşåIJÍåĚűäžŰæL'ľåśŢæÍąåİŮäÿ■ä¡£çŤÍè£ŹäžŻåĞ¡æŢřïijŇä¡ĘæŸŕäÿ åźűäÿŤéĂŽè£ĞCçijŰèŕŚåŹÍ/éŞ¿æŐěåŹÍæİěåĄŽçIJŃäÿŁåŐżçL'źåĹńåď'■æİĆïijĹæĹŰèĂĚäÿ■åŔŕèČ¡åĄŽåĹř

èğčåĘşæŰźæąĹ

æIJňèŁĆäÿżèęĄéŮőécŸæŸŕåęĆä¡Ţåď'ĎçŘĘ15.4åřŔèŁĆäÿ■æŔŘåĹřçŽĎPointåŕźèśąãĂĆäżŤçżĘåŻđäÿ

```
/* Destructor function for points */
static void del_Point(PyObject *obj) {

  free(PyCapsule_GetPointer(obj,"Point"));
}

/* Utility functions */
static Point *PyPoint_AsPoint(PyObject *obj) {
  return (Point *) PyCapsule_GetPointer(obj, "Point");
}

static PyObject *PyPoint_FromPoint(Point *p, int must_free) {
  return PyCapsule_New(p, "Point", must_free ? del_Point : NULL);
}
```

çŐřåIJÍçŽĎéŮőécŸæŸŕæĂŐæăůåřĘ `PyPoint_AsPoint()` åŠŇ `Point_FromPoint()` åĞ¡æŢřä¡IJäÿžAPIåŕijåĞžïijŇ è£ŹæăůåĚűäžŰæL'ľåśŢæÍąåİŮèČ¡ä¡£çŤÍåźűéŞ¿æŐěåőČäżñïijŇærŤåęĆåęĆædIJä¡ăæIJL'åĚűäžŰæL'ľåśŢäź§

èęĄèğčåĘşè£ŹäÿłéŮőécŸïijŇéęŰåĚÍèęĄäÿž `sample` æL'ľåśŢåĘŹäÿłæŰřçŽĎåď't'æŰĞäžűåŘ■åŔń `pysample.h` ïijŇåęĆäÿŃïijŽ

```
/* pysample.h */
#include "Python.h"
#include "sample.h"
#ifdef __cplusplus
extern "C" {
#endif

/* Public API Table */
typedef struct {
  Point *(*aspoint)(PyObject *);
  PyObject *(*frompoint)(Point *, int);
} _PointAPIMethods;

#ifndef PYSAMPLE_MODULE
/* Method table in external module */
```

```
static _PointAPIMethods *_point_api = 0;

/* Import the API table from sample */
static int import_sample(void) {
  _point_api = (_PointAPIMethods *) PyCapsule_Import("sample._point_
↪api",0);
  return (_point_api != NULL) ? 1 : 0;
}

/* Macros to implement the programming interface */
#define PyPoint_AsPoint(obj) (_point_api->aspoint)(obj)
#define PyPoint_FromPoint(obj) (_point_api->frompoint)(obj)
#endif

#ifdef __cplusplus
}
#endif
```

è£ŹéĞŇæIJĂéĞ■èęĄçŽĎéČĺåĹĘæŸŕåĞ¡æŢřæŇĞéŠĹèąĺ _PointAPIMethods . åőČäijŽåIJĺåŕijåĞžæĺąåİŮæŮűèćńåĹĺåğŃåŇŰïijŇçĎűåŘŐåŕijåĚěæĺąåİŮæŮűèćńæ§ěæL'¿åĹřãĂĆä£őæŤźåŐ§ågŃçŽĎæL'ľåśŢæĺąåİŮæİěåąńåĚĚèąĺæäijåźűåřĘåőČåČŔäÿŃéİćè£ŹæăůåŕijåĞžïijŽ

```
/* pysample.c */

#include "Python.h"
#define PYSAMPLE_MODULE
#include "pysample.h"

...
/* Destructor function for points */
static void del_Point(PyObject *obj) {
  printf("Deleting point\n");
  free(PyCapsule_GetPointer(obj,"Point"));
}

/* Utility functions */
static Point *PyPoint_AsPoint(PyObject *obj) {
  return (Point *) PyCapsule_GetPointer(obj, "Point");
}

static PyObject *PyPoint_FromPoint(Point *p, int free) {
  return PyCapsule_New(p, "Point", free ? del_Point : NULL);
}

static _PointAPIMethods _point_api = {
  PyPoint_AsPoint,
  PyPoint_FromPoint
};
...
```

```
/* Module initialization function */
PyMODINIT_FUNC
PyInit_sample(void) {
  PyObject *m;
  PyObject *py_point_api;

  m = PyModule_Create(&samplemodule);
  if (m == NULL)
    return NULL;

  /* Add the Point C API functions */
  py_point_api = PyCapsule_New((void *) &_point_api, "sample._point_
↪api", NULL);
  if (py_point_api) {
    PyModule_AddObject(m, "_point_api", py_point_api);
  }
  return m;
}
```

æIJĂåŘŐïijŇäÿŃéİćæŸŕäÿĂäÿłæŰřçŽĎæĽľ'åśŢæĺąåİŮä¿Ńå■ŘïijŇçŤĺæİěåŁăè¡¡åźűä¡£çŤĺè£ŹäžŻAPIå

```
/* ptexample.c */

/* Include the header associated with the other module */
#include "pysample.h"

/* An extension function that uses the exported API */
static PyObject *print_point(PyObject *self, PyObject *args) {
  PyObject *obj;
  Point *p;
  if (!PyArg_ParseTuple(args,"O", &obj)) {
    return NULL;
  }

  /* Note: This is defined in a different module */
  p = PyPoint_AsPoint(obj);
  if (!p) {
    return NULL;
  }
  printf("%f %f\n", p->x, p->y);
  return Py_BuildValue("");
}

static PyMethodDef PtExampleMethods[] = {
  {"print_point", print_point, METH_VARARGS, "output a point"},
  { NULL, NULL, 0, NULL}
};

static struct PyModuleDef ptexamplemodule = {
  PyModuleDef_HEAD_INIT,
```

```
  "ptexample",           /* name of module */
  "A module that imports an API",  /* Doc string (may be NULL) */
  -1,                 /* Size of per-interpreter state or -1 */
  PtExampleMethods       /* Method table */
};

/* Module initialization function */
PyMODINIT_FUNC
PyInit_ptexample(void) {
  PyObject *m;

  m = PyModule_Create(&ptexamplemodule);
  if (m == NULL)
    return NULL;

  /* Import sample, loading its API functions */
  if (!import_sample()) {
    return NULL;
  }

  return m;
}
```

çijŰèŕŚè£ŹäýłæŰřæÍąåİŮæŮűïijŇä¡ăçŤŽèĞşäý■éIJÄèęĄåŐżèĂČèŹŚæĂŐæăůåřĘåĞ¡æŢřåžŞæĹŰäżčçà
ä¿ŇåęĆïijŇä¡ăåŔŕäżěåČŔäýŇéÍćè£ŹæăůåĹŻåžžäýĂäýłçőĂå■ŢçŽĎ `setup.py` æŰĞäżűïijŽ

```
# setup.py
from distutils.core import setup, Extension

setup(name='ptexample',
      ext_modules=[
        Extension('ptexample',
                  ['ptexample.c'],
                  include_dirs = [],   # May need pysample.h␣
 ↪directory
                  )
        ]
)
```

åęĆæđIJäýĂåĹĞæ■čåýÿïijŇä¡ääijŽåŔŚçŐřä¡ăçŽĎæŰřæL'l'åśŢåĞ¡æŢřèČ¡åŠŇåőŽäźL'åIJÍåĚűäżŰæÍąåİ
APIåĞ¡æŢřäýĂèţůè£ŘèąŇçŽĎå¿Ĺåě¡ãĂĆ

```
>>> import sample
>>> p1 = sample.Point(2,3)
>>> p1
<capsule object "Point *" at 0x1004ea330>
>>> import ptexample
>>> ptexample.print_point(p1)
2.000000 3.000000
>>>
```

èőÍèőž

æIJňèŁĆå§žäžŐäÿĂäÿłåL’■æŔŘåřśæŸŕĭijŇèČűåŻŁåŕźèśąèČ¡èŐůåŔŰäżżä¡Ţä¡ăæČşèęĄçŽĎåŕźèśąçŽĎ
è£Źæăůç ŽĎèŕĬĭijŇåőŽäźĽæÍąåİŮäijŽåąńåĚĚäÿĂäÿłåĞ¡æŢřæŇĞéŠĹçŽĎçżŞæđĎä¡ŞĭijŇåĹŽåżžäÿĂäÿłæŇČ
ä¿ŃåęĆ `sample._point_api`.

åĚűäžŰæÍąåİŮèČ¡åď§åIJÍåŕijåĚěæŮűèŐůåŔŰåĹřè£ŹäÿłåśđæĂğåźűæŔŘåŔŰåžŢåśĆçŽĎæŇĞéŠĹãĂĆ
äžŃåőđäÿŁĭijŇPythonæŔŘä¿ŻäžĘ `PyCapsule_Import()`
åůěåĚůåĞ¡æŢřĭijŇäÿžäžĘåőŇæĹŘæĽĂæIJĽçŽĎæ■ěéłď ãĂĆ
ä¡ääŔłéIJĂæŔŘä¿Żåśđæ ĂğçŽĎåŘ■å■Ůå■şåŔŕĭijĹærŤåęĆsample._point_apiĭijĽĭijŇçĎűåŘŐäžŰåŕśäijŽäÿĂ

åIJÍåřĘèćńåŕijåĞžåĞ¡æŢřåŔŸäÿžåĚűäžŰæÍąåİŮäÿ■æŹőéĂŽåĞ¡æŢřæŮűĭijŇæIJL’äÿĂäžŻCçijŰçÍŃéŹů
åIJÍ `pysample.h` æŰĞäżűäÿ■ĭijŇäÿĂäÿł `_point_api`
æŇĞéŠĹèćńçŤÍæİěæŇĞåŘŚåIJÍåŕijåĞžæÍąåİŮäÿ■èćńåĹİåğŃåŇŰçŽĎæŰźæşŢèąÍãĂĆ
äÿĂäÿłçŻÿåĚşçŽĎåĞ¡æŢř `import_sample()` èćńçŤÍæİěæŇĞåŘŚèČűåŽĹåŕijåĚěźűåĹİåğŃåŇŰè£Źäÿłæ
è£ŹäÿłåĞ¡æŢřå£Ěéążå IJÍäżżä¡ŢåĞ¡æŢřèćńä¡£çŤÍäźŃåĽ■èćńèŕČçŤÍãĂĆéĂŽåÿÿæİèèőšĭijŇåőČäijŽåIJÍæÍąåİ
æIJĂåŘŐĭijŇCçŽĎéćĎåď ĎçŘĘåőŔèćńåőŽäźĽĭijŇèćńçŤÍæİěéĂŽè£ĞæŰźæşŢèąÍåŐżåĹĘåŔŚè£ŹäžŻAPIåĞ
çŤÍæĹůåŘłéIJĂèęĄä¡£çŤÍè£ŹäžŻåŐ§ågŃåĞ¡æŢřåŘ■çğřå■şåŔŕĭijŇäÿ■éIJĂèęĄéĂŽè£ĞåőŔåŐżäžĘèğčåĚűä

æIJĂåŘŐĭijŇè£ŸæIJL’äÿĂäÿłéĞ■èęĄçŽĎåŐ§åŻăèőľä¡ăåŐżä¡£çŤÍè£ŹäÿłæŁĂæIJŕæİěéŞ¿æŐěæÍąåİŮâ
åęĆæđIJä¡ăäÿ■æČşä¡£çŤÍæIJňæIJžçŽĎæŁĂæIJŕĭijŇéĆčä¡åářšå£Ěéążä¡£çŤÍåĚśäžńåžŞçŽĎéńŸçžğçL’źæĂğå
ä¿ŃåęĆĭijŇářĘäÿĂäÿłæŹőéĂŽçŽĎAPIåĞ¡æŢřæŤ¿åĚěäÿĂäÿłåĚśäžńåžŞåźűçąőä£ÍæL’ĂæIJL’æL’l’åśŢæÍąåİŮ
è£ŹçğæŰźæşŢçąőåőđåŘŕèąŇĭijŇä¡ĘæŸŕåőČçŽÿářźçźĄçŘŘĭijŇçL’źåĹńæŸŕåIJÍåď ğåđŃçşžçž§äÿ■ãĂĆ
æIJňèŁĆæijŤçď žäžĘåęĆä¡ŢéĂŽè£ĞPythonçŽĎæŹőéĂŽåŕijåĚěæIJžåĹűåŠŇäžĚäžĚåĞääÿłèČűåŽŁèřČçŤÍæ
åŕźäžŐæÍąåİŮçŽĎçijŰèŕŚĭijŇä¡ăåŘłéIJĂèęĄåőŽäźĽåď ťæŰĞäźűĭijŇèĂŇäÿ■éIJĂèęĄèĂČèŹŚåĞ¡æŢřåžŞçŽ

æŽťåď ŽåĚşäžŐåĹl’çŤÍC APIæİěædĎéĂăæL’l’åśŢæÍąåİŮçŽĎä£qæĄŕåŘŕäžěåŘĆèĂČ
PythonçŽĎæŰĞæąč

17.6 15.6 äżŐCèŕ■èÍĂäÿ■èřČçŤÍPythonäžčçăĄ

éŮőécŸ

ä¡ăæČşåIJÍCäÿ■åőL’åĚÍçŽĎæL’ğèąŇæ§ŘäÿłPythonèřČçŤÍåźűè£ŤåŽđçżŞæđIJçżŹCãĂĆ
ä¿ŃåęĆĭijŇä¡ăæČşåIJÍCèŕ■èÍĂäÿ■ä¡£çŤÍæ§ŘäÿłPythonåĞ¡æŢřä¡IJäÿžäÿĂäÿłåŽđèřČãĂĆ

èğčåĘşæŰźæąĹ

åIJÍCèŕ■èÍĂäÿ■èřČçŤÍPythonéİđåÿÿçőÅå■ŢĭijŇäÿ■è£Ğèő¿èőąåĹřäÿĂäžŽåřŔçł■éŮÍãĂĆ
äÿŃéİćçŽĎCäžčçăĄåŚŁèŕL’ä¡ăæĂŐæăůåőL’åĚÍçŽĎèřČçŤÍĭijŽ

```
#include <Python.h>

/* Execute func(x,y) in the Python interpreter.  The
   arguments and return result of the function must
   be Python floats */

double call_func(PyObject *func, double x, double y) {
```

```
  PyObject *args;
  PyObject *kwargs;
  PyObject *result = 0;
  double retval;

  /* Make sure we own the GIL */
  PyGILState_STATE state = PyGILState_Ensure();

  /* Verify that func is a proper callable */
  if (!PyCallable_Check(func)) {
    fprintf(stderr,"call_func: expected a callable\n");
    goto fail;
  }
  /* Build arguments */
  args = Py_BuildValue("(dd)", x, y);
  kwargs = NULL;

  /* Call the function */
  result = PyObject_Call(func, args, kwargs);
  Py_DECREF(args);
  Py_XDECREF(kwargs);

  /* Check for Python exceptions (if any) */
  if (PyErr_Occurred()) {
    PyErr_Print();
    goto fail;
  }

  /* Verify the result is a float object */
  if (!PyFloat_Check(result)) {
    fprintf(stderr,"call_func: callable didn't return a float\n");
    goto fail;
  }

  /* Create the return value */
  retval = PyFloat_AsDouble(result);
  Py_DECREF(result);

  /* Restore previous GIL state and return */
  PyGILState_Release(state);
  return retval;

fail:
  Py_XDECREF(result);
  PyGILState_Release(state);
  abort();   // Change to something more appropriate
}
```

èęĄä¡£çŤĺè£ŹäÿłåĞ¡æŢřïijŇä¡ăéIJĂèęĄèŐůåŔŰäijăéĂŠè£ĞæİěçŽĎæ§Řäÿłåůšå■ŸåIJÍPythonèřČçŤĺçŽ
æIJL’å¿Ĺåď’Žçğ■æŰźæşŢåŔŕäżěèől’ä¡ăè£ŹæăůåĄŽïijŇ æŕŤåęĆåřĘäÿĂäÿłåŔŕèřČçŤĺåŕźèśąäijăçżŹäÿĂäÿłæĽ

äÿŃéÍćæŸŕäÿĂäÿłçŏĂå■Ţä¿Ńå■ŘçŤÍæÌěæŐľéěŕäžŐäÿĂäÿłåţŇåĚěçŽĎPythonèğčéĞŁåŹÍäÿ■èřČçŤÍäÿ

```
#include <Python.h>

/* Definition of call_func() same as above */
...

/* Load a symbol from a module */
PyObject *import_name(const char *modname, const char *symbol) {
  PyObject *u_name, *module;
  u_name = PyUnicode_FromString(modname);
  module = PyImport_Import(u_name);
  Py_DECREF(u_name);
  return PyObject_GetAttrString(module, symbol);
}

/* Simple embedding example */
int main() {
  PyObject *pow_func;
  double x;

  Py_Initialize();
  /* Get a reference to the math.pow function */
  pow_func = import_name("math","pow");

  /* Call it using our call_func() code */
  for (x = 0.0; x < 10.0; x += 0.1) {
    printf("%0.2f %0.2f\n", x, call_func(pow_func,x,2.0));
  }
  /* Done */
  Py_DECREF(pow_func);
  Py_Finalize();
  return 0;
}
```

èęĄæđĎåżžä¿Ńå■ŘäżčçăĄïijŇä¡ăéIJĂèęĄçijŰèŕŚCåźűåřĘåőČéŞ¿æŐěåĹřPythonèğčéĞŁåŹÍãĂĆ
äÿŃéÍćçŽĎMakefileåŔŕäžěæŢŹä¡ăæĂŐæăůåĄŽïijĹäÿ■è£ĞåIJÍä¡ăæIJžåŹÍäÿŁéÍćéIJĂèęĄäÿĂäžŽéĚ■ç¡őïijĽ

```
all::
        cc -g embed.c -I/usr/local/include/python3.3m \
          -L/usr/local/lib/python3.3/config-3.3m -lpython3.3m
```

çijŰèŕŚåźűè£ŘèąŇäijŽäžğçŤ§çśżäijijäÿŃéÍćçŽĎè¿ŞåĞžïijŽ

```
0.00 0.00
0.10 0.01
0.20 0.04
0.30 0.09
0.40 0.16
...
```

äÿŃéÌćæŸŕäÿĂäÿłçÍ■å¿ő䟄åŘŇçŽĎä¿Ńå■ŘïijŇåśŢçď žäžĘäÿĂäÿłæĽľ åśŢåĞ¡æŢřïijŇ åőČæŐěåŘŮäÿĂäÿłåŔŕèřČçŤĺåŕźèśąåŠŇåĚűäžŰåŔĆæŢřïijŇåźűářĘåőČäžňäijäéĂŠçżŹ `call_func()` æÌěåĄŽæţŃèŕŢïijŽ

```
/* Extension function for testing the C-Python callback */
PyObject *py_call_func(PyObject *self, PyObject *args) {
  PyObject *func;

  double x, y, result;
  if (!PyArg_ParseTuple(args,"Odd", &func,&x,&y)) {
    return NULL;
  }
  result = call_func(func, x, y);
  return Py_BuildValue("d", result);
}
```

ä¡£çŤĺè£ŹäÿłæĽľ åśŢåĞ¡æŢřïijŇä¡ăèęĄåČŔäÿŃéÌćè£ŹæăůæţŃèŕŢåőČïijŽ

```
>>> import sample
>>> def add(x,y):
...     return x+y
...
>>> sample.call_func(add,3,4)
7.0
>>>
```

èőÍèőž

åęĆæđIJä¡ăåIJÍCèŕ■èÍĂäÿ■èřČçŤĺPythonïijŇèęĄèőŕä¡ŔæIJĂéĞ■èęĄçŽĎæŸŕCèŕ■èÍĂäijŽæŸŕäÿżä¡ŞãĂ äźş§åřśæŸŕèŕťˇïijŇCèŕ■èÍĂèť §èť čæđĎéĂăåŔĆæŢřãĂĄèřČçŤĺPythonåĞ¡æŢřãĂĄæčĂæ§ěäijĆåÿÿãĂĄæčĂæ

ä¡IJäÿžçňňäÿĂæ■ěïijŇä¡ăå£ĚéążåĚĹæIJL’äÿĂäÿłèąÍçď žä¡ăåřĘèęĄèřČçŤĺçŽĎPythonåŔŕèřČçŤĺåŕźèśąãĂ è£ŹåŔŕäżěæŸŕäÿĂäÿłåĞ¡æŢřãĂĄçśžãĂĄæŰźæşŢãĂĄåĘĚç¡őæŰźæşŢæĹŰåĚűäžŰäżżæĎŔåőđçŐřäžĘ `__call__()` æŞ■ä¡IJçŽĎäÿIJèě£ãĂĆ äÿžäžĘçąőä£ÍæŸŕåŔŕèřČçŤĺçŽĎïijŇåŔŕäżěåČŔäÿŃéÌćçŽĎäžčçăĄè `PyCallable_Check()` åĄŽæčĂæ§ěïijŽ

```
double call_func(PyObject *func, double x, double y) {
  ...
  /* Verify that func is a proper callable */
  if (!PyCallable_Check(func)) {
    fprintf(stderr,"call_func: expected a callable\n");
    goto fail;
  }
  ...
```

åIJÍCäžčçăĄéĞŇåď ĎçŘĘéŤŹèŕŕä¡ăéIJĂèęĄæăijåď ŰçŽĎåřŔå£ČãĂĆäÿĂèĹňæÌěèőšïijŇä¡ăäÿ■èČ¡äžĚä éŤŹèŕŕåžŤèŕěä¡£çŤĺCäžčçăĄæŰźåijŔæÌěèćńåď ĎçŘĘãĂĆåIJÍè£ŹéĞŇïijŇæĹŚäžňæL’ŞçőŮåřĘåŕźéŤŹèŕŕçŽĎ `abort()` çŽĎéŤŹèŕŕåď ĎçŘĘåŹĺãĂĆ åőČäijŽçżŞæÌ§æŐL’æŢť äÿłçÍŇåžŘïijŇåIJÍçIJ§åőđçŐŕáćČäÿŃéÌćä¡ăă ä¡ăèęĄèőŕä¡ŔçŽĎæŸŕåIJÍè£ŹéĞŇCæŸŕäÿżèğŠïijŇåŽăæ■ď åźűæšąæIJL’èů§æŁŻåĞžåijĆåÿÿçŻÿåŕźåžŤçŽĎæ éŤŹèŕŕåď ĎçŘĘæŸŕä¡ăåIJÍçijŰçÍŇæŮűå£ĚéążèęĄèĂČèŹŠçŽĎäžŇæČĚãĂĆ

èřČçŤÍäÿĂäÿłåĞ¡æŢřçŻÿåŕźæİěèőšå¿ĹçőĂå■ŢâĂŤâĂŤåŔŧéIJĂèęĄä¡£çŤÍ
PyObject_Call() ïijŇ äijääÿĂäÿłåŔŕèřČçŤÍåŕźèśąçżŹåőČãĂĄäÿĂäÿłåŔĆæŢřåĚČçżĎåŠŇäÿĂäÿłåŔŕéĂ
èęĄæđĎåżžåŔĆæŢřåĚČçżĎæĹŰå■ŮåĚÿïijŇä¡ååŔŕäžěä¡£çŤÍ Py_BuildValue()
,åęĆäÿŇïijŽ

```
double call_func(PyObject *func, double x, double y) {
  PyObject *args;
  PyObject *kwargs;

  ...
  /* Build arguments */
  args = Py_BuildValue("(dd)", x, y);
  kwargs = NULL;

  /* Call the function */
  result = PyObject_Call(func, args, kwargs);
  Py_DECREF(args);
  Py_XDECREF(kwargs);
  ...
```

åęĆædIJæšąæIJL'åĚşéŤőå■ŮåŔĆæŢřïijŇä¡ääŔŕäžěäijäéĂŠNULLãĂĆå¡Şä¡ăèęĄèřČçŤÍåĞ¡æŢřæŮűïijŇ
éIJĂèęĄçąőä£İä¡£çŤÍäžĘ Py_DECREF() æĹŰèĂĚ Py_XDECREF() æÿĚçŘĘåŔĆæŢřãĂĆ
çňňäžŇäÿłåĞ¡æŢřçŻÿåŕźåőL'åĚÍçĆźïijŇåŻääÿžåőČåĚĄèőÿäijäéĂŠNULLæŇĞéŠĹïijÍçŻť'æŐěå£¡çŢěåőČïijÍ
è£Źäź§æŸŕäÿžäżĂäźĹæĹŚäżňä¡£çŤÍåőČæİěæÿĚçŘĘåŔŕéĂL'çŽĎåĚşéŤőå■ŮåŔĆæŢřãĂĆ

èřČçŤÍäÿĞPythonåĞ¡æŢřäźŃåŘŐïijŇä¡ää£Ěéążæč Ăæ§ěæŸŕåŘęæIJL'åijĆåÿÿåŔŚçŤ§ãĂĆ
PyErr_Occurred() åĞ¡æŢřåŔŕèćńçŤÍæİěåĄŽè£ŹäżűäžŇãĂĆ
åŕźåŕźäžŐåijĆåÿÿçŽĎåď'ĎçŘĘåŕśæIJL'çĆźžżçČęäžĘïijŇçŤśäžŐæŸŕçŤÍCèŕ■èÍÅåĘŹçŽĎïijŇä¡ăæšąæIJL'åČ
åŻăæ■ď'ïijŇä¡ää£ĚéążèęĄèő¿ç¡őäÿĂäÿłåijĆåÿÿçŁűæĂĄçĂąïijŇæL'Şå■řåijĆåÿÿä£ąæĄŕæĹŰåĚűäżŰçŻÿåžŤ
åIJÍè£ŹéĞŇïijŇæĹŚäżňéĂL'æŃľäžĘçőĂå■ŢçŽĎ abort()
æİěåď'ĎçŘĘãĂĆåŘęåď'ŰïijŇäijăçż§CçÍŇåžŘåŚŸåŕŕèČ¡äijŽçŻť'æŐěěľ'çÍŇåžŘåěŤæžČãĂĆ

```
...
/* Check for Python exceptions (if any) */
if (PyErr_Occurred()) {
  PyErr_Print();
  goto fail;
}
...
fail:
  PyGILState_Release(state);
  abort();
```

äżŐèřČçŤÍPythonåĞ¡æŢřçŽĎè£ŤåŻđåĂijäÿ■æŔŘåŔŰä£ąæĄŕéĂŽåÿÿèęĄè£ŻèąŇçśżåđŃæčĂæ§ěåŠŇæ
èęĄè£ŹæăůåĄŽçŽĎèŕİïijŇä¡ää£Ěéążä¡£çŤÍPythonåŕźèśąåśĆäÿ■çŽĎåĞ¡æŢřãĂĆ
åIJÍè£ŹéĞŇæĹŚäżňä¡£çŤÍäžĘ PyFloat_Check() åŠŇ PyFloat_AsDouble()
æİěæčĂæ§ěåŠŇæŘŘåŔŰPythonæţőçĆźæŢřãĂĆ

æIJĂåŘŐäÿĂäÿłéŮőécŸæŸŕåŕźäžŐPythonåĚĺåśĂéŤĄçŽĎçőąçŘĘãĂĆ
åIJÍCèŕ■èÍÅäÿ■ëő£éŮőPythonçŽĎæŮűåĂŹïijŇä¡äéIJĂèęĄçąőä£İĠILèćńæ■čçąőçŽĎèŐůåŔŰåŠŇéĞŁæŤ¿äž
äÿ■çĎűçŽĎèŕİïijŇåŘŕèČ¡äijŽåŕijèĞť'èğčéĞŁåŹÍè£ŤåŻđéŤŹèŕŕæŢřæ■őæĹŰèĂĚçŻť'æŐěåěŤæžČãĂĆ

èřČçŤÍ PyGILState_Ensure() åŠŇ PyGILState_Release() åŔŕäžěçąőä£ÍäÿĂåĹĞéČ¡èČ¡æ■čåÿÿãĂĆ

```
double call_func(PyObject *func, double x, double y) {
  ...
  double retval;

  /* Make sure we own the GIL */
  PyGILState_STATE state = PyGILState_Ensure();
  ...
  /* Code that uses Python C API functions */
  ...
  /* Restore previous GIL state and return */
  PyGILState_Release(state);
  return retval;

fail:
  PyGILState_Release(state);
  abort();
}
```

äÿĂæŮęè£ŤåŻđïijŇPyGILState_Ensure() åŔŕäžěçąőä£ÍèřČçŤÍçž£çÍŃçŃňå■ăPythonèğčéĞŁåŹÍãA
åřśçőŮCäżčçăAè£ŘèąŇäžŐåŔęåd'ŰäÿĂäÿłèğčéĞŁåŹÍäÿ■ç§ěéĄŞçŽĎçž£çÍŃäź§æšąäžŃãĂĆ
è£ŹæŮűåĂŹïijŇCäżčçăAąåŔŕäžěèĞłçŤśçŽĎä¡£çŤÍäżżä¡ŢåőČæČşèęĄçŽĎPython C-API
åĞ¡æŢřãĂĆ èřČçŤÍæĹŘåŁ§åŘŐïijŇPyGILState_Release()èćńçŤÍæÍěèőšèğčéĞŁåŹÍæĄćåd'■åĹřåŐ§ågŃçŁűa

èęĄæşÍæĎŔçŽĎæŸŕæŕŔäÿĂäÿł PyGILState_Ensure()
èřČçŤÍå£ĚéążèůçÍĂäÿĂäÿłåŇźéĚ■çŽĎ PyGILState_Release()
èřČçŤÍâĂŤâĂŤå■şä¿£æIJL'éŤŹèŕŕåŔŚçŤ§ãĂĆ åIJÍè£ŹéĞŇïijŇæĹŚäżňä¡£çŤÍäÿĂäÿł goto
èŕ■åŘěçIJŃäÿŁåŐżæŸŕäÿłåŘŕæĂŢçŽĎèő¿èőąïijŇ ä¡ĘæŸŕåőđéŹĚäÿŁæĹŚäżňä¡£çŤÍåőČæÍèèőšæŐğåĹűæÍČè
åIJÍ fail: æăĞç■¿åŘŐéÍćçŽĎäżčçăĄåŠŇPythonçŽĎ fianl:
åİŮçŽĎçŤÍéĂŤæŸŕäÿĂæăůçŽĎãĂĆ

åęĆæđIJä¡ăä¡£çŤÍæL'ĂæIJL'è£ŹäžŻçžęåőŽæÍěçijŰåĘŹCäżčçăĄïijŇåŇĚæŃňåŕźGILçŽĎçőąçŘĘãĂĄåij
ä¡ăäijŽåŔŚçŐŕäžŐCèŕ■èÍĂäÿ■èřČçŤÍPythonèğčéĞŁåŹÍæŸŕåŔŕéÍăçŽĎâĂŤâĂŤåŕšçőŮåĘ■åd'■æÍĆçŽĎçÍŃåž

17.7 15.7 äżŐCæL'ľåśŢäÿ■éĞŁæŤ¿åĚÍåśĂéŤĄ

éŮőécŸ

ä¡ăæČşèől'CæL'l'åśŢäżčçăĄåŠŇPythonèğčéĞŁåŹÍäÿ■çŽĎåĚűäżŰè£ŻçÍŃäÿĂèţůæ■čçąőçŽĎæL'ğèąŇïij
éĆčäźĹä¡ăåřśéIJĂèęĄåŐżéĞŁæŤ¿åźűéĞ■æŰřèŐůåŘŮåĚÍåśĂèğčéĞŁåŹÍéŤĄïijĹGILïijL'ãĂĆ

èğčåĘşæŰźæąĹ

åIJÍCæL'l'åśŢäżčçăĄäÿ■ïijŇGILåŔŕäžěéĂŽè£ĞåIJÍäżčçăĄäÿ■æŔŠåĚěäÿŃéÍćè£ŹæăůçŽĎåőŔæÍěéĞŁæ

```
#include "Python.h"
...

PyObject *pyfunc(PyObject *self, PyObject *args) {
   ...
   Py_BEGIN_ALLOW_THREADS
   // Threaded C code.  Must not use Python API functions
   ...
   Py_END_ALLOW_THREADS
   ...
   return result;
}
```

èőÍèőž

åŘłæIJL'å¡Şä¡ăçąőä£İæšąæIJL'Python C APIåĞ¡æŢřåIJÍCäÿ■æL'ğèąŇçŽĎæŮűåĂŹä¡ăæL'■èČ¡åőL'åĚÍçŽ
GILéIJĂèęĄèćńéĞŁæŤ¿çŽĎåÿÿèğĄçŽĎåIJžæŹŕæŸŕåIJÍèőąçőŮåŕĘéŻĘåđŇäžčçăĄäÿ■éIJĂèęĄåIJÍCæŢřçżĎ
æĹŰèĂĚæŸŕèęĄæL'ğèąŇéŸżåąđçŽĎI/OæŞ■ä¡IJæŮűïijĹæŕŤåęĆåIJÍäÿĂäÿłæŰĞäžűæŘŔè£řçňęäÿŁèŕżåŘŰa

å¡ŞGILèćńéĞŁæŤ¿åŘŐïijŇåĚűäžŰPythonçž£çÍŃæL'■èćńåĚĄèőÿåIJÍèğčéĞŁåŹÍäÿ■æL'ğèąŇãĂĆ
`Py_END_ALLOW_THREADS` åőŔäijŽéŸżåąđæL'ğèąŇçŻť'åĹřèřČçŤÍçž£çÍŃéĞ■æŰřèŐůåŘŰäžĘGILãĂĆ

17.8 15.8 CåŠŇPythonäÿ■çŽĎçž£çÍŃæůúçŤÍ

éŮőécŸ

ä¡ăæIJL'äÿĂäÿłçÍŃåžŔéIJĂèęĄæůůåŘĹä¡£çŤÍCãĂĄPythonåŠŇçž£çÍŃïijŇ
æIJL'äžŻçž£çÍŃæŸŕåIJÍCäÿ■åĹŻåżžçŽĎïijŇèűĚåĞžäžĘPythonèğčéĞŁåŹÍçŽĎæŐğåĹűèŇČåŻť'ãĂĆ
åźűäÿŤäÿĂäžŻçž£çÍŃè£Ÿä¡£çŤÍäžĘPython C APIäÿ■çŽĎåĞ¡æŢřãĂĆ

èğčåĘşæŰźæąĹ

åęĆædIJä¡ăæČşåřĘCãĂĄPythonåŠŇçž£çÍŃæůůåŘĹåIJÍäÿĂèţůïijŇä¡ăéIJĂèęĄçąőä£İæ■čçąőçŽĎåĹİåğŇ
èęĄæČşè£ŹæăůåĄŽïijŇåŘŕäžěåřĘäÿŃåĹŮäžčçăĄæŤ¿åĹřä¡ăçŽĎCäžčçăĄäÿ■åźűçąőä£İåőČåIJÍäżżä¡Ţçž£çÍŃ

```
#include <Python.h>
  ...
  if (!PyEval_ThreadsInitialized()) {
    PyEval_InitThreads();
  }
  ...
```

åŕźäžŐäżżä¡ŢèřČçŤÍPythonåŕźèśąæĹŰPython C APIçŽĎCäžčçăĄïijŇçąőä£İä¡ăéęŰåĚĹåůšçżŔæ■čçąőåI
è£ŹåŘŕäžěçŤÍ `PyGILState_Ensure()` åŠŇ `PyGILState_Release()`
æİěåĄŽåĹřïijŇåęĆäÿŃæL'Ăçď'žïijŽ

```
...
/* Make sure we own the GIL */
PyGILState_STATE state = PyGILState_Ensure();

/* Use functions in the interpreter */
...
/* Restore previous GIL state and return */
PyGILState_Release(state);
...
```

æfŔæňąèřČçŤÍ `PyGILState_Ensure()` éČ¡èęAçŻÿåžŤçŽĎèřČçŤÍ `PyGILState_Release()`.

èőÍèőž

åIJÍæűL'åŘŁåĹřCåŠŇPythonçŽĎéńŸçžğçÍŃåžŔäÿ■ïijŇå¿Ĺåď'ŽäžŃæČĚäÿĂèţůåĄŽæŸŕå¿Ĺåÿÿè ğĄçŽĎ åŘŕèČ¡æŸŕåŕźCãĂĄPythonãĂĄCçž£çÍŃãĂĄPythonçž£çÍŃçŽĎæůůåŘĹä¡£çŤÍãĂĆ åŘłèęAä¡ăçąőä£Ìè ğčéĞŁåŹÍèćńæ■čçąőçŽĎåĹİåğŃåŇŰïijŇåźűäÿŤæűL'åŘŁåĹřè ğčéĞŁåŹÍçŽĎCäžčçăĄæL'ğ

èęĄæşÍæĎŘçŽĎæŸŕèřČçŤÍ `PyGILState_Ensure()` åźűäÿ■äijŽçńŇåĹżæŁćå■ăæĹŰäÿ■æŰ■èğčéĞŁåŹÍãĂĆ åęĆæđIJæIJL'åĚűäžŰäžčçăĄæ■čåIJÍæL'ğèąŇïijŇè£Ź åIJÍåĘĚéČĺïijŇèğčéĞŁåŹÍäijŽæL'ğèąŇåŚÍæIJ§æĂğçŽĎçž£çÍŃåĹĞæ■ćïijŇåŻăæ■ď'åęĆæđIJåĚűäžŰçž£çÍŃå èřČçŤÍèĂĚæIJĂçżĹè£ŸæŸŕåŘŕäžčè£ŘèąŇçŽĎïijĹår¡çőąåŘŕèČ¡èęĄåĚĹç■L'äÿĂäijŽïijL'ãĂĆ

17.9 15.9 çŤÍWSIGåŇĚèčĚCäžčçăĄ

éŮőécŸ

ä¡ăæČşèől'ä¡ăåĘŹçŽĎCäžčçăĄä¡IJäÿžäÿĂäÿłCæL'l'åśŢæÍąåİŮæİčèő£éŮőïijŇæČşéĂŽè£Ğä¡£çŤÍ SwigåŇĚèčĚçŤ§æĹŘåŹÍ æİčåőŇæĹŘãĂĆ

èğčåĘşæŰźæąĹ

SwigéĂŽè£Ğèğčæđ ŘCåď'ťæŰĞäžűåźűèĞłåŁÍåĹŻåžžæL'l'åśŢäžčçăĄæİčæŞ■ä¡IJãĂĆ èęĄä¡£çŤÍåőČïijŇä¡ăåĚĹèęĄæIJL'äÿĂäÿłCåď'ťæŰĞäžűãĂĆä¿ŃåęĆïijŇæĹŚäžňçď'žä¿ŃçŽĎåď'ťæŰĞäžűåę

```
/* sample.h */

#include <math.h>
extern int gcd(int, int);
extern int in_mandel(double x0, double y0, int n);
extern int divide(int a, int b, int *remainder);
extern double avg(double *a, int n);

typedef struct Point {
    double x,y;
```

```
} Point;

extern double distance(Point *p1, Point *p2);
```

äÿĂæŮęä¡ăæIJL'äžĘè£Źäÿłåđ't'æŰĞäžűïijŇäÿŃäÿĂæ■ěåřśæŸŕçijŰåĘŹäÿĂäÿłSwigâĂİæŐěåŔčâĂİæŰ
æŇL'çĚğçžęåőŽïijŇè£ŹäžŻæŰĞäžűäżěâĂİ.iâĂİåŘŐçijĂåźűäÿŤçśżäijijäÿŃéİćè£Źæăůïij Ž

```
// sample.i - Swig interface
%module sample
%{
#include "sample.h"
%}

/* Customizations */
%extend Point {
    /* Constructor for Point objects */
    Point(double x, double y) {
        Point *p = (Point *) malloc(sizeof(Point));
        p->x = x;
        p->y = y;
        return p;
   };
};

/* Map int *remainder as an output argument */
%include typemaps.i
%apply int *OUTPUT { int * remainder };

/* Map the argument pattern (double *a, int n) to arrays */
%typemap(in) (double *a, int n)(Py_buffer view) {
  view.obj = NULL;
  if (PyObject_GetBuffer($input, &view, PyBUF_ANY_CONTIGUOUS |␣
↪PyBUF_FORMAT) == -1) {
    SWIG_fail;
  }
  if (strcmp(view.format,"d") != 0) {
    PyErr_SetString(PyExc_TypeError, "Expected an array of doubles
↪");
    SWIG_fail;
  }
  $1 = (double *) view.buf;
  $2 = view.len / sizeof(double);
}

%typemap(freearg) (double *a, int n) {
  if (view$argnum.obj) {
    PyBuffer_Release(&view$argnum);
  }
}
```

```
/* C declarations to be included in the extension module */

extern int gcd(int, int);
extern int in_mandel(double x0, double y0, int n);
extern int divide(int a, int b, int *remainder);
extern double avg(double *a, int n);

typedef struct Point {
    double x,y;
} Point;

extern double distance(Point *p1, Point *p2);
```

äÿĂæŮęä¡ăåĘŹåě¡äžĘæŐěåŘčæŰĞäżűïijÑářśåŘŕäžěåIJÍåŚ¡äžd'èąŇåůěåĚůäÿ■èřČçŤÍSwigäžĘïijŽ

```
bash % swig -python -py3 sample.i
bash %
```

swigçŽĎè¿ŞåĞžářśæŸŕäÿd'äÿłæŰĞäżűïijÑsample_wrap.cåŠŇsample.pyãĂĆ åŘŐéÍćçŽĎæŰĞäżűåřśæŸŕçŤÍæĹůéIJĂèęĄåŕijåĚěçŽĎãĂĆ èĂŇsample_wrap.cæŰĞäżűæŸŕéIJĂèęĄęćńçijŰèŕŚåĽřåŘ■åŔń _sample çŽĎæŤŕæŇĄæÍąåİŮçŽĎCäžčçăĄãĂĆ è£ŹäÿłåŕäžěéĂŽè£ĞèůŞæŹőéĂŽæĽľåśŢæÍąåİŮäÿĂæăůçŽĎæŁĂæ ä¿ŇåęĆïijÑä¡ăåĹŻåžžäžĘäÿĂäÿłåęĆäÿŇæĽĂçd'žçŽĎ `setup.py` æŰĞäżűïijŽ

```
# setup.py
from distutils.core import setup, Extension

setup(name='sample',
      py_modules=['sample.py'],
      ext_modules=[
        Extension('_sample',
                  ['sample_wrap.c'],
                  include_dirs = [],
                  define_macros = [],

                  undef_macros = [],
                  library_dirs = [],
                  libraries = ['sample']
                  )
        ]
)
```

èęĄçijŰèŕŚåŠŇæţŃèŕŢïijŇåIJÍsetup.pyäÿŁæĽğèąŇpython3ïijÑåęĆäÿŃïijŽ

```
bash % python3 setup.py build_ext --inplace
running build_ext
building '_sample' extension
gcc -fno-strict-aliasing -DNDEBUG -g -fwrapv -O3 -Wall -Wstrict-
 ↪prototypes
-I/usr/local/include/python3.3m -c sample_wrap.c
```

```
 -o build/temp.macosx-10.6-x86_64-3.3/sample_wrap.o
sample_wrap.c: In function âĂŸSWIG_InitializeModuleâĂŹ:
sample_wrap.c:3589: warning: statement with no effect
gcc -bundle -undefined dynamic_lookup build/temp.macosx-10.6-x86_64-
 ↪3.3/sample.o
 build/temp.macosx-10.6-x86_64-3.3/sample_wrap.o -o _sample.so -
 ↪lsample
bash %
```

åęĆædIJäÿĂåĹĞæ■čåÿÿçŽĎèŕİïijŇä¡ăäijŽåŔŞçŐřä¡ăåřšåŔŕäžěå¿ĹæŰźä¿£çŽĎä¡£çŤĺçŢ§æĹŘçŽĎCæĽ

```
>>> import sample
>>> sample.gcd(42,8)
2
>>> sample.divide(42,8)
[5, 2]
>>> p1 = sample.Point(2,3)
>>> p2 = sample.Point(4,5)
>>> sample.distance(p1,p2)
2.8284271247461903
>>> p1.x
2.0
>>> p1.y
3.0
>>> import array
>>> a = array.array('d',[1,2,3])
>>> sample.avg(a)
2.0
>>>
```

èőĺèőž

SwigæŸŕPythonåŐĘåŔšäÿ■æđĎåžžæĽľåśŢæĺąåİŮçŽĎæIJĂåŔďèĂĄçŽĎåůěåĚůäźŃäÿĂãĂĆ SwigèČ¡èĞłåŁĺåŇŰå¿Ĺåď˙ŽåŇĚèčĚçŤ§æĹŘåŹĺçŽĎåď˙ĎçŘĘãĂĆ

æĽĂæIJL˝SwigæŐěåŔčéČ¡äžěçśżäijijäÿŃéİćè£Źæăůç˙ŽĎäÿžåijĂåď˙ťïijŽ

```
%module sample
%{
#include "sample.h"
%}
```

è£ŹäÿłäżĚäżĚåŔłæŸŕåčřæŸŐäžĘæĽľåśŢæĺąåİŮçŽĎåŘ■çğřåźűæŇĞåőŽäžĘCåď˙ťæŰĞäżűïijŇ äÿžäžĘèČ¡èőľçijŰèŕŚéĂŽè£ĞĺĚéążèęĄåŇĚåŘńè£ŹäžŽåď˙ťæŰĞäżűïijĹä¡■äžŐ %{ åŠŇ %} çŽĎäžčçĂïijL˝ïijŇ åřĘåőČäžňäźŃéŮť˙åď˙■åĹűçšŸèť˙ťåĹřè¿ŞåĞžäżčçĂąäÿ■ïijŇè£Źäź§æŸŕä¡äèęĄæŢ¿ç¡őæ

SwigæŐěåŔčçŽĎåžŢäÿŃéČĺåĹĘæŸŕäÿĂäÿłCåčřæŸŐåĹŮèąĺïijŇä¡äéIJĂèęĄåIJÍæĽľåśŢäÿ■åŇĚåŘńåő è£ŹéĂŽåÿÿäżŐåď˙ťæŰĞäżűäÿ■èćńåď˙■åĹűãĂĆåIJÍæĹŚäžňçŽĎä¿Ńå■Řäÿ■ïijŇæĹŚäžňäžĚäżĚåČŔäÿŃéİćè£

```
%module sample
%{
#include "sample.h"
%}
...
extern int gcd(int, int);
extern int in_mandel(double x0, double y0, int n);
extern int divide(int a, int b, int *remainder);
extern double avg(double *a, int n);

typedef struct Point {
    double x,y;
} Point;

extern double distance(Point *p1, Point *p2);
```

æIJL'äÿĂçĆźéIJĂèęĄåijžèřČçŽĎæŸŕè£ŹäžŽåčřæŸŐäijŽåŚŁèŕL'Swigä¡ăæČşèęĄåIJÍPythonæÍąåİŮäÿ■å
éĂŽåÿÿä¡ăéIJĂèęĄçijÚè¿Śè£ŹäÿłåčřæŸŐåĹŮèąĺæĹŰçŻÿåžŤçŽĎä£őæŤźäÿŃåőČãĂĆ
ä¿ŃåęĆïijŇåęĆæđIJä¡ääÿ■æČşæ§ŘäžŽåčřæŸŐèćńåŇĚåŘńè£ŻæİěïijŇä¡ăèęĄårĘåőČäżŐåčřæŸŐåĹŮèąĺäÿ■

ä¡£çŤÍSwigæIJĂåď■æİĆçŽĎåIJřæŰźæŸŕåőČèČ¡çżŹCäžčçăĄæŔŘä¿Żåď ğéĞŔçŽĎèĞłåőŽäźL'æŞ■ä¡IJ
è£ŹäÿłäÿżécŸåď łåď ğïijŇè£ŹéĞŇæŮăæşŢåśŢåijĂïijŇä¡ĘæŸŕæĹŚäžňåIJÍæIJńèŁĆè£ŸåL'l'åśŢçď žäžĘäÿĂäž

çňňäÿĂäÿłèĞłåőŽäźL'æŸŕ `%extend` æŇĞäžď åĚĄèőÿæŰźæşŢèćńéŹĎåŁääĹřåůšå■ŸåIJÍçŽĎçżŞæđĎä
æĹŚä¿Ńå■Řäÿ■ïijŇè£ŹäÿłèćńçŤÍæİěæůżåŁääÿĂäÿłPointçżŞæđĎä¡ŞçŽĎæđĎéĂääŹÍæŰźæşŢãĂĆ
åőČåŘŕäžěèőľ'ä¡ääČŔäÿŃéİćè£Źæăůä¡£çŤÍè£ŹäÿłçżŞæđĎä¡Şïijž

```
>>> p1 = sample.Point(2,3)
>>>
```

åęĆæđIJçŢěè£ĞçŽĎèŕİïijŇPointåŕźèśąåřśå£ĚéążäžěæŻť'åŁääď'■æİĆçŽĎæŰźåijŔæİěèćńåĹŻåżžïijž

```
>>> # Usage if %extend Point is omitted
>>> p1 = sample.Point()
>>> p1.x = 2.0
>>> p1.y = 3
```

çňňäžŇäÿłèĞłåőŽäźL'æűL'åŔŁåĹřåŕź `typemaps.i` åžŞçŽĎåijŢåĚěåŠŇ
`%apply` æŇĞäžď'ïijŇ åőČäijŽæŇĞçď'žSwigåŔĆæŢřç■¿åŘ■ `int *remainder`
èęĄèćńå¡ŞåĄŽæŸŕè¿ŞåĞžåĂijãĂĆ è£ŹäÿłåőđéŹĚäÿŁæŸŕäÿĂäÿłæĺąåijŔåŇźéĚ■èğĎåĹŹãĂĆ
åIJÍæŐěäÿŃæİěçŽĎæL'ĂæIJL'åčřæŸŐäÿ■ïijŇäżżä¡ŢæŮűåĂŹåŘłèęĄçćřäÿŁ `int
*remainder` ïijŇäżŰåřśäijŽèćńä¡IJäÿžè¿ŞåĞžãĂĆ è£ŹäÿłèĞłåőŽäźL'æŰźæşŢåŔŕäžěèőľ'
`divide()` åĞ¡æŢřè£ŤåŽđäÿd'äÿłåĂijãĂĆ

```
>>> sample.divide(42,8)
[5, 2]
>>>
```

æIJĂåŘŐäÿĂäÿłæűL'åŔŁåĹř `%typemap` æŇĞäžď'çŽĎèĞłåőŽäźL'åŔŕèČ¡æŸŕè£ŹéĞŇåśŢçď žçŽĎæIJĂ
äÿĂäÿłtypemapåřśæŸŕäÿĂäÿłåIJÍè¿ŞåĚěäÿ■çL'źåőŽåŔĆæŢřæĺąåijŔçŽĎèğĎåĹŹãĂĆ
åIJÍæIJńèŁĆäÿ■ïijŇäÿĂäÿłtypemapèćńåőŽäźL'äÿžåŇźéĚ■åŔĆæŢřæĺąåijŔ `(double *a,`

`int n)`. åIJÍtypemapåĘĚéČÍæŸŕäÿĂäÿłCäżčçăĄçL'Ğæőţïij Ňåő ČåŚŁèŕL'SwigæĂŐæăůåřĘäÿĂäÿłPythonåŕ
æIJňèŁĆäżčçăĄä¡£çŤÍäžĘPythonçŽĎçijŞå■Ÿå■ŘèőőåőżåŇźéĚ■äżżä¡ŢçIJŃäÿŁåŐżçśżäijijåŘŇçš¿åžęæŢřçż
ïijĹæŕŤåęĆNumPyæŢřçżĎãĂĄarrayæÍąåİŮåĹŻåžžçŽĎæŢřçżĎç■L'ïijL'ïijŇæŻť'åď'ŽèŕůåŘĆèĂČ15.3åřŘèŁĆ

åIJÍtypemapäżčçăĄåĘĚéČÍïijŇ$1åŠŇ$2è£ŹæăůçŽĎåŘŸéĞŘæŻ£æ■ćäijŽèŐůåŘŰtypemapæÍąåijŘçŽĎC
ïijĹæŕŤåęĆ$1æŸăåřĎäÿž `double *a` ïijL'ãĂĆ$inputæŇĞåŘŠäÿĂäÿłä¡IJäÿžè¿ŞåĚěçŽĎ
`PyObject *` åŘĆæŢřïijŇ èĂŇ `$argnum` åřśäžčèąĺåŘĆæŢřçŽĎäÿłæŢřãĂĆ

çijŰåĘŹåŠŇçŘĘèğčtypemapsæŸŕä¡£çŤÍSwigæIJĂå§žæIJńçŽĎåL'■æŘŘãĂĆ
äÿ■äžĚæŸŕèŕť'äžčçăĄæŻť'çěđçğŸïijŇèĂŇäÿŤä¡ăéIJĂèęĄçŘĘèğčPython C
APIåŠŇSwigåŠŇåőČäžď'äžŠçŽĎæŰźåijŘãĂĆ SwigæŰĞæąčæIJL'æŻť'åď'Žè£ŹæŰźéİćçŽĎçżĘèŁĆïijŇåŘŕäz

äÿ■è£ĞïijŇåęĆæđIJä¡ăæIJL'åď'ğéĞŘçŽĎCäżčçăĄéIJĂèęĄèćńæŽť'éIJšäÿžæL'ľ'åśŢæĺąåİŮãĂĆ
SwigæŸŕäÿĂäÿłéİđåÿÿåijžåď'ğçŽĎåůěåĚůãĂĆåĚşéŤőçĆźåIJÍäžŐSwigæŸŕäÿĂäÿłåď'ĎçŘĘCåčřæŸŐçŽĎçij
éĂŽè£Ğåijžåď'ğçŽĎæĺąåijŘåŇźéĚ■åŠŇèĞłåőŽäźL'çžĎäżűïijŇåŘŕäžèèőľä¡ăæŻť'æŤźåčřæŸŐæŇĞåőŽåŠŇçş
æŻť'åď'Žä£ąæĄŕèŕůåŐżæ§ěéŸĚ Swigç¡ŚçńŹ ïijŇ è£ŸæIJL'
çL'źåőŽäžŐPythonçŽĎçŽÿåĚşæŰĞæąč

17.10 15.10 çŤÍCythonåŇĚèčĚCäżčçăĄ

éŮőécŸ

ä¡ăæČşä¡£çŤÍCythonæİěåĹŻåžžäÿĂäÿłPythonæL'ľ'åśŢæĺąåİŮïijŇçŤÍæİěåŇĚèčĚæ§Řäÿłåůšå■ŸåIJÍçŽĎ

èğčåĘşæŰźæąĹ

ä¡£çŤÍCythonæđĎåžžäÿĂäÿłæL'ľ'åśŢæĺąåİŮçIJŃäÿŁåŐżå¿ĹæL'ŃåĘŹæL'ľ'åśŢæIJL'äžŽçśżäijijïijŇ
åŽăäÿžä¡ăéIJĂèęĄåĹŻåžžå¿Ĺåď'ŽåŇĚèčĚåĞ¡æŢřãĂĆäÿ■è£ĞïijŇèů§åL'■éİćäÿ■åŘŇçŽĎæŸŕïijŇä¡ääÿ■éIJĂ

ä¡IJäÿžåĞĘåď'ĞïijŇåĄĞèő¿æIJńçńääżŃçż■éČĺåĹĘçŽĎçď'žä¿Ńäžčçă ĄåůšçżŕèćńçijŰèŕŚåĹřæ§Řäÿłåŕ
`libsample` çŽĎCåĞ¡æŢřåžŞäÿ■äžĘãĂĆ éęŰåĚĺåĹŻåžžäÿĂäÿłåŘ■åŕń `csample.pxd`
çŽĎæŰĞäżűïijŇåęĆäÿŃæL'Ăçď'žïijŽ

```
# csample.pxd
#
# Declarations of "external" C functions and structures

cdef extern from "sample.h":
    int gcd(int, int)
    bint in_mandel(double, double, int)
    int divide(int, int, int *)
    double avg(double *, int) nogil

    ctypedef struct Point:
         double x
         double y

    double distance(Point *, Point *)
```

è£Źäÿłæ ŰĞäżűåIJĺCythonäÿ■çŽĎä¡IJçŤĺåřśèů§CçŽĎåď'ť'æŰĞäżűäÿĂæăůãĂĆ åĹİåğŃåčřæŸŐ `cdef extern from "sample.h"` æŇĞåőŽäžĘæĽ'Ăå■ęçŽĎCåď'ť'æŰĞäżűãĂĆ æŐěäÿŃæİěçŽĎåčřæŸŐéČ¡æŸŕæİěèĞłäžŐéĆčäÿłåď'ť'æŰĞäżűãĂĆæŰĞäżűåŘ■æŸŕ `csample.pxd` ïijŇèĂŇäÿ■æŸŕ `sample.pxd` âĂŤâĂŤè£ŹçĆźå¿ĹéĞ■èęĄãĂĆ

äÿŃäÿĂæ■ěïijŇåĹŻåžžäÿĂäÿłåŘ■äÿž `sample.pyx` çŽĎéŮőécŸãĂĆ èŕěæŰĞäżűäijŽåőŽäźĽ'åŇĚèčĚåŹĺïijŇçŤĺæİěæąěæŐěPythonèğčéĞŁåŹĺåĹř `csample.pxd` äÿ■åčřæŸŐçŽĎCäžčçăĄãĂĆ

```
# sample.pyx

# Import the low-level C declarations
cimport csample

# Import some functionality from Python and the C stdlib
from cpython.pycapsule cimport *

from libc.stdlib cimport malloc, free

# Wrappers
def gcd(unsigned int x, unsigned int y):
    return csample.gcd(x, y)

def in_mandel(x, y, unsigned int n):
    return csample.in_mandel(x, y, n)

def divide(x, y):
    cdef int rem
    quot = csample.divide(x, y, &rem)
    return quot, rem

def avg(double[:] a):
    cdef:
        int sz
        double result

    sz = a.size
    with nogil:
        result = csample.avg(<double *> &a[0], sz)
    return result

# Destructor for cleaning up Point objects
cdef del_Point(object obj):
    pt = <csample.Point *> PyCapsule_GetPointer(obj,"Point")
    free(<void *> pt)

# Create a Point object and return as a capsule
def Point(double x,double y):
    cdef csample.Point *p
    p = <csample.Point *> malloc(sizeof(csample.Point))
    if p == NULL:
```

```
        raise MemoryError("No memory to make a Point")
    p.x = x
    p.y = y
    return PyCapsule_New(<void *>p,"Point",<PyCapsule_Destructor>
 ↪del_Point)

def distance(p1, p2):
    pt1 = <csample.Point *> PyCapsule_GetPointer(p1,"Point")
    pt2 = <csample.Point *> PyCapsule_GetPointer(p2,"Point")
    return csample.distance(pt1,pt2)
```

èŕěæŰĞäżűæŻťåď ŽçŽĎçżĘèŁĆéČĺåĹĘäijŽåIJĺèőĺèőžéČĺåĹĘèŕęçżĘåśŢåijĂãĂĆ æIJĂåŘŐïijŇäÿžäžĘæđĎåžžæĽľåśŢæĺąåİŮïijŇåČŔäÿŃéİćè£ŹæăůåĹŻåžžäÿĂäÿł `setup.py` æŰĞäżűïijŽ

```
from distutils.core import setup
from distutils.extension import Extension
from Cython.Distutils import build_ext

ext_modules = [
    Extension('sample',

              ['sample.pyx'],
              libraries=['sample'],
              library_dirs=['.'])]
setup(
  name = 'Sample extension module',
  cmdclass = {'build_ext': build_ext},
  ext_modules = ext_modules
)
```

èęĄæđĎåžžæĹŚäžňæţŃèŕŢçŽĎçŻőæăĞæĺąåİŮïijŇåČŔäÿŃéİćè£ŹæăůåĄŽïijŽ

```
bash % python3 setup.py build_ext --inplace
running build_ext
cythoning sample.pyx to sample.c
building 'sample' extension
gcc -fno-strict-aliasing -DNDEBUG -g -fwrapv -O3 -Wall -Wstrict-
 ↪prototypes
 -I/usr/local/include/python3.3m -c sample.c
 -o build/temp.macosx-10.6-x86_64-3.3/sample.o
gcc -bundle -undefined dynamic_lookup build/temp.macosx-10.6-x86_64-
 ↪3.3/sample.o
  -L. -lsample -o sample.so
bash %
```

åęĆæđIJäÿĂåĹĞéąžåĹľçŽĎèŕÎïijŇä¡ååžŤèŕěæIJĽäžĘäÿĂäÿłæĽľåśŢæĺąåİŮ `sample.so` ïijŇåŔŕåIJĺäÿŃéİćä¿Ńå■Řäÿäÿ■ä¡£çŤĺïijŽ

```
>>> import sample
>>> sample.gcd(42,10)
2
>>> sample.in_mandel(1,1,400)
False
>>> sample.in_mandel(0,0,400)
True
>>> sample.divide(42,10)
(4, 2)
>>> import array
>>> a = array.array('d',[1,2,3])
>>> sample.avg(a)
2.0
>>> p1 = sample.Point(2,3)
>>> p2 = sample.Point(4,5)
>>> p1
<capsule object "Point" at 0x1005d1e70>
>>> p2
<capsule object "Point" at 0x1005d1ea0>
>>> sample.distance(p1,p2)
2.8284271247461903
>>>
```

èőÍèőž

æIJňèŁĆåŇĚåŘńäžĘå¿Ĺåď ŽåĽ■éİćæĽ Ăèőšç ŽĎéńŸçžğçĽźæĂğïijŇåŇĚæŃňæŢřçżĎæŞ■ä¡IJãĂĄåŇĚæřŔäÿĂéČĺåĹĘéČ¡äijŽéĂŘäÿłèćńèőšè£řåĹřïijŇä¡ĘæŸřæĹŚäžňæIJĂåě¡èČ¡åď■äźăäÿĂäÿŃåĽ■éİćåĞăářŔèŁåIJĺéąűåśĆïijŇä¡£çŢÍCythonæŸřå§žäžŐCäźŃäÿŁãĂĆ.pxdæŰĞäżűäžĚäżĚåŔłåŇĚåŘńCåőŽäźĽ'ïijĹçśżäijij.hä.pyxæŰĞäżűåŇĚåŘńäžĘåőđçŐřïijĹçśżäijij.cæŰĞäżűïijĽ'ãĂĆcimport èŕ■åŘèèćńCythonçŢÍæİěåŕijåĚě.pxdæŰĞäżűäÿ■çŽĎåőŽäźĽ'ãĂĆ åőČèů§ä¡£çŢÍæŹőéĂŽçŽĎåŁăè¡¡PythonæĺąåİŮçŽĎåŕijåĚèèŕ■åŘěæŸřäÿ■åŘŇçŽĎãĂĆ

åř¡çőą.*pxd* æŰĞäżűåŇĚåŘńäžĘåőŽäźĽ'ïijŇä¡ĘåőČäżňåźűäÿ■æŸŕçŢÍæİěèĞłåŁÍåĹŻåžžæĽ'l'åśŢäžčçăĄçåŻăæ■ď'ïijŇä¡ăè£ŸæŸŕèęĄåĘŹåŇĚèčĚåĞ¡æŢřãĂĆä¿ŃåęĆïijŇåřśçőŮ csample.pxd æŰĞäżűåčřæŸŐäžĘ int gcd(int, int) åĞ¡æŢřïijŇ ä¡ääż■çĎűéIJĂèęĄåIJÍ sample.pyx äÿ■äÿžåőČåĘŹäÿĂäÿłåŇĚèčĚåĞ¡æŢřãĂĆä¿ŃåęĆïijŽ

```
cimport csample

def gcd(unsigned int x, unsigned int y):
    return csample.gcd(x,y)
```

åŕźäžŐçőĂå■ŢçŽĎåĞ¡æŢřïijŇä¡ääźűäÿ■éIJĂèęĄåŐżåĄŽåď'łåď'ŽçŽĎæŮűãĂĆ CythonäijŽçŤ§æĹŘåŇĚèčĚäżčçăĄæİěæ■čçąőçŽĎè¡ñæ■ćåŔĆæŢřåŠŇè£ŤåŻđåĂijãĂĆ çżŠåőŽåĹřåśđæĂğäÿŁçŽĎCæŢřæ■őçśżåđŃæŸŕåŘŕéĂĽ'çŽĎãĂĆäÿ■è£ĞïijŇåęĆæđIJä¡ääŇĚåŘńäžĘåőČäżňï ä¿ŃåęĆïijŇåęĆæđIJæIJĽ'äžžä¡£çŢÍèť §æŢřæİěěřČçŤÍè£ŹäÿłåĞ¡æŢřïijŇäijŽæŁŻåĞžäÿĂäÿłåijĆåÿÿïijŽ

```
>>> sample.gcd(-10,2)
Traceback (most recent call last):
```

```
  File "<stdin>", line 1, in <module>
  File "sample.pyx", line 7, in sample.gcd (sample.c:1284)
    def gcd(unsigned int x,unsigned int y):
OverflowError: can't convert negative value to unsigned int
>>>
```

åęĆædIJä¡ăæČşåŕźåŇĚèčĚåĞ¡æŢřåĄŽåŔęåď˙ŰçŽĎæčĂæ§ëïijŇåŔłéIJĂèęĄä¡£çŤĺåŔęåď˙ŰçŽĎåŇĚèčĚ

```
def gcd(unsigned int x, unsigned int y):
    if x <= 0:
        raise ValueError("x must be > 0")
    if y <= 0:
        raise ValueError("y must be > 0")
    return csample.gcd(x,y)
```

åIJÍcsample.pxdæŰĞäżűäÿ■çŽĎ‘‘in_mandel()‘‘ åčřæŸŐæIJL’äÿłå¿ĹæIJL’èűčä¡ĘæŸŕæŕŤè¿ČéŽ¿çŘĘèğ
åIJÍè£ŹäÿłæŰĞäżűäÿ■ïijŇåĞ¡æŢřèćńåčřæŸŐäÿžçĎůåŘŐäÿĂäÿłbintèĂŇäÿ■æŸŕäÿĂäÿłintãĂĆ
åőČäijŽèőľåĞ¡æŢřåĹŻåžžäÿĂäÿłæ■čçąőçŽĎBooleanåĂijèĂŇäÿ■æŸŕçőĂå■ŢçŽĎæŢt’æŢřãĂĆ
åŻăæ■d’ïijŇè£ŤåŻđåĂij0èąĺçd’žFalseèĂŇ1èąĺçd’žTrueãĂĆ

åIJÍCythonåŇĚèčĚåŹĺäÿ■ïijŇä¡ăåŔŕäżěéĂL’æŃl’åčřæŸŐCæŢřæ■őçśżåđŃïijŇäź§åŔŕäżěä¡£çŤĺæL’ĂæIJ
åŕźäžŐ `divide()` çŽĎåŇĚèčĚåŹĺåśŢçd’žäžĘè£ŹæăůäÿĂäÿłä¿Ńå■ŘïijŇåŘŇæŮűè£ŸæIJL’åęĆä¡ŢåŐżåd’Ď

```
def divide(x,y):
    cdef int rem
    quot = csample.divide(x,y,&rem)
    return quot, rem
```

åIJÍè£ŹéĞŇïijŇrem åŘŸéĞŔèćńæŸ¿çd’žçŽĎåčřæŸŐäÿžäÿĂäÿłCæŢt’ådŃåŘŸéĞŔãĂĆ
å¡ŞåőČèćńäijăåĚě `divide()` åĞ¡æŢřçŽĎæŮűåĂŹïijŇ`&rem`
åĹŻåžžäÿĂäÿłèů§CäÿĂæăůçŽĎæŇĞåŘŚåőČçŽĎæŇĞéŠĹãĂĆ `avg()`
åĞ¡æŢřçŽĎäżčçăĄæijŤçd’žäžĘCythonæŻt’énŸçžğçŽĎçL’źæĂğãĂĆ
éęŰåĚĹ `def avg(double[:] a)` åčřæŸŐäžĘ `avg()`
æŐěåŔŮäÿĂäÿłäÿĂçżt’çŽĎåŔŇçš¿åžęåĘĚå■ŸèğĘåŻ¿ãĂĆ æIJĂæČŁåěĞçŽĎéČĺåĹĘæŸŕè£ŤåŻđçŽĎçżŞæđ

```
>>> import array
>>> a = array.array('d',[1,2,3])
>>> import numpy
>>> b = numpy.array([1., 2., 3.])
>>> import sample
>>> sample.avg(a)
2.0
>>> sample.avg(b)
2.0
>>>
```

åIJÍæ■d’åŇĚèčĚåŹĺäÿ■ïijŇ`a.size0` åŠŇ `&a[0]` åĹĘåĹńåijŢçŤĺæŢřçżĎåĚČçt’ääÿłæŢřåŠŇåžŢåśĆæŇ
èŕ■æşŢ `<double *> &a[0]` æŢŹä¡ăæĂŐæăůåřĘæŇĞéŠĹè¡ňæ■ćäÿžäÿ■åŘŇçŽĎçśżåđŃãĂĆ
åL’■æŘŘæŸŕCäÿ■çŽĎ `avg()` æŐěåŔŮäÿĂäÿłæ■čçąőçśżåđŃçŽĎæŇĞéŠĹãĂĆ
åŔĆèĂČäÿŃäÿĂèŁĆåĚşäžŐCythonåĘĚå■ŸèğĘåŻ¿çŽĎæŻt’énŸçžğèőšè£řãĂĆ

éŹď˙äžĘåď˙ĎçŘĘéĂŽåÿÿçŽĎæŢřçżĎåď˙ŰïijŇavg() çŽĎè£ŹäÿłäĄ¿Ńå■Řè£ŸåśŢçď˙žäžĘåęĆä¡Ţåď˙ĎçŘ
èŕ■åŘě with nogil: åčřæŸŐäžĘäÿĂäÿłäÿ■éIJĂèęĄGILåřśèČ¡æĽ˙ğèąŇçŽĎäżčçăĄåİŮãĂĆ
åIJĺè£ŹäÿłåİŮäÿ■ïijŇäÿ■èČ¡æIJL˙äżżä¡ŢçŽĎæŹőéĂŽPythonåŕźèśąâĂŤâĂŤåŔłèČ¡ä¡£çŤĺèćńåčřæŸŐäÿž
cdef çŽĎåŕźèśąåŠŇåĞ¡æŢřãĂĆ åŘęåď˙ŰïijŇåď˙ŰéČĺåĞ¡æŢřå£Ëéążç Őřåőđç ŽĎåčřæŸŐåőČäżňèČ¡äÿ■ä¿Ièţ
åŽăæ■ď˙ïijŇåIJĺcsample.pxdæŰĞäżűäÿ■ïijŇavg() èćńåčřæŸŐäÿž double avg(double
*, int) nogil.

åŕźPointçżŞæđĎä¡ŞçŽĎåď˙ĎçŘĘæŸŕäÿĂäÿłæŇŚæĹŸãĂĆæIJňèŁĆä¡£çŤĺèČűåŻŁåŕźèśąåřĘPointåŕźèśąå
èęĄè£ŹæăůåĄŽçŽĎèŕÏïijŇåžŢåśĆCythonäžčçăĄçĺ■å¿őæIJL˙çĆźåď˙■æÍĆãĂĆ
éęŰåĚĹïijŇäÿŇéÍćçŽĎåŕijåĚěèćńçŤĺæÍěåijŢåĚěCåĞ¡æŢřåžŞåŠŇPython C
APIäÿ■åőŽäźL˙çŽĎåĞ¡æŢřïijŽ

```
from cpython.pycapsule cimport *
from libc.stdlib cimport malloc, free
```

åĞ¡æŢř del_Point() åŠŇ Point() ä¡£çŤĺè£ŹäÿłåŁ§èČ¡æÍěåĹŻåžžäÿĂäÿłèČűåŻŁåŕźèśąïijŇ
åőČäijŽåŇĚèčĚäÿĂäÿł Point * æŇĞéŠĹãĂĆcdef del_Point() åřĘ del_Point()
åčřæŸŐäÿžäÿĂäÿłåĞ¡æŢřïijŇ åŔłèČ¡éĂŽè£ĞCythonèő£éŮőïijŇèĂŇäÿ■èČ¡äżŐPythonäÿ■èő£éŮőãĂĆ
åŽăæ■ď˙ïijŇè£ŹäÿłåĞ¡æŢřåŕźåď˙ŰéČĺæŸŕäÿ■åŔŕèğĄçŽĎâĂŤâĂŤåőČèćńçŤĺæÍěå¡ŞåĄŽäÿĂäÿłåŽđèřČåĞ¡æ
åĞ¡æŢřèŘČçŤĺæŕŤåęĆ PyCapsule_New() ãĂĄPyCapsule_GetPointer()
çŻť˙æŐěæÍěèĞłPython C APIåźűäÿŤäžěåŘŇæăůçŽĎæŰźåijŔèćńä¡£çŤĺãĂĆ

distance åĞ¡æŢřäžŐ Point() åĹŽåžžçŽĎèČűåŻŁåŕźèśąäÿ■æŘŔåŘŰæŇĞéŠĹãĂĆ
è£ŹéĞŇèęĄæşĺæĎŔçŽĎæŸŕä¡ääÿ■éIJĂèęĄæŃĚå£ČåijĆåÿÿåď˙ĎçŘĘãĂĆ
åęĆæđIJäÿĂäÿłéŤŹèŕŕçŽĎåŕźèśąèćńäijäè£ŻæÍěïijŇPyCapsule_GetPointer()
äijŽæŁŽåĞžäÿĂäÿłåijĆåÿÿïijŇ ä¡ĘæŸŕCythonåůšçżŔç§ěéĄŞæĂŐäźĹæ§ěæL˙¿åĹřåőČïijŇåźűårĘåőČäžŐ
distance() äijäéĂŠåĞžåŐżãĂĆ

åď˙ĎçŘĘPointçżŞæđĎä¡ŞäÿĂäÿłçijžçĆźæŸŕåőČçŽĎåőđçŐřæŸŕäÿ■åŔŕèğĄçŽĎãĂĆ
ä¡ääÿ■èČ¡è£¢éŮőäżžä¡ŢåśđæĂğæÍěæ§ěçIJŃåőČçŽĎåĘěéČĺãĂĆ
è£ŹéĞŇæIJL˙åŘęåď˙ŰäÿĂçğ■æŰźæşŢåŐżåŇĚèčĚåőČïijŇårśæŸŕåőŽäźL˙äÿĂäÿłæL˙l˙åśŢçśżåđŃïijŇåęĆäÿŃ

```
# sample.pyx

cimport csample
from libc.stdlib cimport malloc, free
...

cdef class Point:
    cdef csample.Point *_c_point
    def __cinit__(self, double x, double y):
        self._c_point = <csample.Point *> malloc(sizeof(csample.
↪Point))
        self._c_point.x = x
        self._c_point.y = y

    def __dealloc__(self):
        free(self._c_point)

    property x:
        def __get__(self):
```

```
            return self._c_point.x
        def __set__(self, value):
            self._c_point.x = value

    property y:
        def __get__(self):
            return self._c_point.y
        def __set__(self, value):
            self._c_point.y = value

def distance(Point p1, Point p2):
    return csample.distance(p1._c_point, p2._c_point)
```

åIJÍè£ŹéĞŇïijŇcdifçśż Point åřĘPointåčřæŸŐäÿžäÿĂäÿłæĽľåśŢçśżåđŃãĂĆ çśżåśđæĂğ cdef csample.Point *_c_point åčřæŸŐäžĘäÿĂäÿłåőđä¿ŃåŔŸéĞŔïijŇ æŃěæIJĽäÿĂäÿłæŇĞåŘŠåžŢåśĆPointçżŞæđĎä¡ŞçŽĎæŇĞéŠĹãĂĆ __cinit__() åŠŇ __dealloc__() æŰźæşŢéĂŽè£Ğ malloc() åŠŇ free() åĹŻåżžåźűéŤĂæŕĄåžŢåśĆCçżŞæđĎä¡ŞãĂĆ xåŠŇyåśđæĂğçŽĎåčřæŸŐèőľä¡ãèŐůåŔŰåŠŇèő¿ç¡őåžŢåśĆçżŞæđĎä¡ŞçŽĎåśđæĂğåĂijãĂĆ distance() çŽĎåŇĚèčĚåŹÍè£ŸåŔŕäżěèćńä£őæŤźïijŇä¡£å¿ŮåőČèČ¡æŐěåŔŮ Point æĽľåśŢçśżåđŃåőđä¿Ńä¡IJäÿžåŔĆæŢřïijŇ èĂŇäijäéĂŠåžŢåśĆæŇĞéŠĹçżŹĆåĞ¡æŢřãĂĆ

åĄŽäžĘè£ŹäÿłæŤźåŔŸåŘŐïijŇä¡ääijŽåŔŞçŐřæŞ■ä¡IJPointåŕźèśąåřśæŸ¿å¿ŮæŻť åŁäèĞłçĎűäžĘïijŽ

```
>>> import sample
>>> p1 = sample.Point(2,3)
>>> p2 = sample.Point(4,5)
>>> p1
<sample.Point object at 0x100447288>
>>> p2
<sample.Point object at 0x1004472a0>
>>> p1.x
2.0
>>> p1.y
3.0
>>> sample.distance(p1,p2)
2.8284271247461903
>>>
```

æIJňèŁĆåůšçżŔæijŤçd'žäžĘå¿Ĺåd'ŽCythonçŽĎæäÿå£ČçĽźæĂğïijŇä¡ååŔŕäžěäżěæ■d'äÿžå§žåĞĘæİěæ äÿ■è£ĞïijŇä¡ăæIJĂåě¡åĚĹåŐžéŸĚèŕżäÿŃåőŸæŰźæŰĞæąćæİěäžĘèğčæŻť åd'Žä£qæĄřãĂĆ

æŐěäÿŃæİěåĞäèŁĆè£ŸäijŽçżğçż■æijŤçd'žäÿĂäžŻCythonçŽĎåĚűäžŰçĽźæĂğãĂĆ

17.11 15.11 çŤÍCythonåĘŹéńŸæĂğèČ¡çŽĎæŢřçżĎæŞ■ä¡IJ

éŮőécŸ

ä¡ăèęĄåĘŹéńŸæĂğèČ¡çŽĎæŞ■ä¡IJæİéèĞłNumPyäźŃçśżçŽĎæŢřçżĎèőąçőŮåĞ¡æŢřãĂĆ
ä¡ăåůšçżŔç§ěéĄŞäžĘCythonè£ŹæăůçŽĎåůěåĚůäijŽèőľ'åőČåŔŸå¿ŮçőĂå■ŢïijÑä¡ĘæŸŕåźűäÿ■çąőåőŽèřěæĂ

èğčåĘşæŰźæąĹ

ä¡IJäÿžäÿĂäÿłä¿Ńå■ŘïijÑäÿŃéİćçŽĎäžčçăĄæijŤçd'žäžĘäÿĂäÿłCythonåĞ¡æŢřïijÑçŤÍæİëä£őæŢt'äÿĂä

```
# sample.pyx (Cython)

cimport cython

@cython.boundscheck(False)
@cython.wraparound(False)
cpdef clip(double[:] a, double min, double max, double[:] out):
    '''
    Clip the values in a to be between min and max. Result in out
    '''
    if min > max:
        raise ValueError("min must be <= max")
    if a.shape[0] != out.shape[0]:
        raise ValueError("input and output arrays must be the same␣
↪size")
    for i in range(a.shape[0]):
        if a[i] < min:
            out[i] = min
        elif a[i] > max:
            out[i] = max
        else:
            out[i] = a[i]
```

èęĄçijŰèŕŚåŠŇædĎåžžè£ŹäÿłæL'l'åśŢïijÑä¡ăéIJĂèęĄäÿĂäÿłåČŔäÿŃéİćè£ŹæăůçŽĎ
`setup.py` æŰĞäžű ïijĹä¡£çŤÍ `python3 setup.py build_ext --inplace`
æİëædĎåžžåőČïijL'ïijŽ

```
from distutils.core import setup
from distutils.extension import Extension
from Cython.Distutils import build_ext

ext_modules = [
    Extension('sample',
              ['sample.pyx'])
]

setup(
  name = 'Sample app',
```

```
  cmdclass = {'build_ext': build_ext},
  ext_modules = ext_modules
)
```

ä¡ääijŽåŔŠçŐřçżŞæđIJåĞ¡æŢřçąőåőđåŕźæŢřçżĎè£ŻèąŇçŽĎä£őæ■čïijŇåźűäÿŤåŔŕäżěéĂĆçŤĺäžŐåď'Žç

```
>>> # array module example
>>> import sample
>>> import array
>>> a = array.array('d',[1,-3,4,7,2,0])
>>> a

array('d', [1.0, -3.0, 4.0, 7.0, 2.0, 0.0])
>>> sample.clip(a,1,4,a)
>>> a
array('d', [1.0, 1.0, 4.0, 4.0, 2.0, 1.0])

>>> # numpy example
>>> import numpy
>>> b = numpy.random.uniform(-10,10,size=1000000)
>>> b
array([-9.55546017,  7.45599334,  0.69248932, ...,  0.69583148,
       -3.86290931,  2.37266888])
>>> c = numpy.zeros_like(b)
>>> c
array([ 0.,  0.,  0., ...,  0.,  0.,  0.])
>>> sample.clip(b,-5,5,c)
>>> c
array([-5.        ,  5.        ,  0.69248932, ...,  0.69583148,
       -3.86290931,  2.37266888])
>>> min(c)
-5.0
>>> max(c)
5.0
>>>
```

ä¡ãè£ŸäijŽåŔŠçŐřè£ŘèąŇçŤ§æĹŘçżŞæđIJéİđåÿÿçŽĎå£ñãĂĆ
äÿŃéİćæĹŚäżňåřĘæIJňä¿ŃåŠŇnumpyäÿ■çŽĎåůšå■ŸåIJĺçŽĎ clip()
åĞ¡æŢřåĄŽäÿĂäÿłæĂğèČ¡åŕźærŤïijŽ

```
>>> timeit('numpy.clip(b,-5,5,c)','from __main__ import b,c,numpy',
 ↪number=1000)
8.093049556000551
>>> timeit('sample.clip(b,-5,5,c)','from __main__ import b,c,sample
 ↪',
...           number=1000)
3.760528204000366
>>>
```

æ■čåęĆä¡äçIJŃåĹřçŽĎïijŇåőČèęĄå£ńå¿Ĺåď'ŽâĂŤâĂŤè£ŹæŸŕäÿĂäÿłå¿ĹæIJL'èűčçŽĎçżŞæđIJïijŇåŻă

èőÍèőž

æIJňèŁĆåĹľçŤĺäžĘCythonçśžåđŃçŽĎåĘĚå■ŸèğĘåŻ¿ïijŇæđĄåď˘ğçŽĎçőĂåŇŰäžĘæŢřçżĎçŽĎæŞ■ä¡I
`cpdef clip()` åčřæŸŐäžĘ `clip()` åŘŇæŮűäÿžCçžğåĹńåĞ¡æŢřäžěåŔŁPythonçžğåĹńåĞ¡æŢřãĂĆ
åIJÍCythonäÿ■ïijŇè£ŹäÿłæŸŕå¿ĹéĞ■èęĄçŽĎïijŇåŻääÿžåőČèąĺçď˘žæ■ď˘åĞ¡æŢřěřČçŤĺèęĄæŕŤåĚűäżŰCytho
ïijĹæŕŤåęĆä¡ăæČşåIJĺåŔęåď˘ŰäÿĂäÿłäÿ■åŘŇçŽĎCythonåĞ¡æŢřäÿ■èřČçŤĺclip()ïijL˘ãĂĆ

çśžåđŃåŔĆæŢř `double[:] a` åŠŇ `double[:] out` åčřæŸŐè£ŹäžŻåŔĆæŢřäÿžäÿĂçżt˘çŽĎåŔŇçš¿ážęæŢřçżĎãĂĆ
ä¡IJäÿžè¿ŞåĚëïijŇåőČäžñäijŽèő£éŰőäżä¡ŢåđçŐřäžĘåĘĚå■ŸèğĘåŻ¿æŐěåŔčçŽĎæŢřçżĎåŕźèśąïijŇè£ŹäÿłŰ
3118æIJL˘èŕęçżĘåőŽäźL˘ãĂĆ åŇĚæŃňäžĘNumPyäÿ■çŽĎæŢřçżĎåŠŇåĘĚç¡őçŽĎarrayåžŞãĂĆ

å¡Şä¡ăçijŰåĘŹçŤ§æĹŘçżŞæđIJäÿžæŢřçżĎçŽĎäžčçăĄæŮűïijŇä¡ăåžŤèŕëéĄţå¿łäÿŁéİćçđ˘žä¿ŃéĆčæăůè
åőČäijŽåřĘåĹŻåżžè¿ŞåĞžæŢřçżĎçŽĎèt˘čäżçżŹèřČçŤĺèĂĚïijŇäÿ■éIJĂèęĄç§ěéĄŞä¡ăæŞ■ä¡IJçŽĎæŢřçżĎç
ïijĹåőČäżĚäźĚåĄĞëő¿æŢřçżĎåůšçżŔåĞĘåď˘Gåě¡äžĘïijŇåŘłéIJĂèęĄåĄžäÿĂäžŽåřŘçŽĎæčÄæ§ěæŕŤåęĆçą
åIJÍåČŔNumPyäźŃçśżçŽĎåžŞäÿ■ïijŇä¡£çŤÍ `numpy.zeros()` æĹŰ `numpy.zeros_like()` åĹŻåżžè¿ŞåĞžæŢřçżĎçŻÿåŕźèĂŇèÍĂæŕŤè¿Čåőźæ ŸŞãĂĆåŘęåď˘ŰïijŇèęĄåĹŻåżžæIJłåĹİ
ä¡ääŘŕäžěä¡£çŤÍ `numpy.empty()` æĹŰ `numpy.empty_like()` .
åęĆæđIJä¡ăæČşèęĘçŻŰæŢřçżĎåĘĚåőźä¡IJäÿžçżŞæđIJçŽĎèŕÍéĂL˘æŃľè£Źäÿd˘äÿłäijŽæŕŤè¿Čå£ńçĆźãĂĆ

åIJÍä¡ăçŽĎåĞ¡æŢřåőđçŐřäÿ■ïijŇä¡ääŘłéIJĂèęĄçőĂå■ŢçŽĎéĂŽè£ĞäÿŇæăĞè£ŘçőŮåŠŇæŢřçżĎæ§ěæ
CythonäijŽèt˘§èt˘čäÿžä¡ăçŤ§æĹŘéńŸæŢĹçŽĎäžčçăĄãĂĆ

`clip()` åőŽäźL˘äźŃåL˘■çŽĎäÿd˘äÿłèčĚéěřåŹĺåŕŕäžěäijŸåŇŰäÿŇæĂğèČ¡ãĂĆ
`@cython.boundscheck(False)` çIJĄåŐżäžĘæL˘ĂæIJL˘çŽĎæŢřçżĎèűŁçŢŇæčÄæ§ěijŇ
å¡Şä¡ăç§ěéĄŞäÿŇæăĞèő£éŰőäÿ■äijŽèűŁçŢŇçŽĎæŮűåĂŹåŕŕäžěä¡£çŤĺåőČãĂĆ
`@cython.wraparound(False)` æűĹéŹd˘äžĘçŻÿåŕźæŢřçżĎår¿éČĺçŽĎèt˘§æŢřäÿŇæăĞçŽĎåd˘ĎçŘĘïijĺ
åijŢåĚèè£Źäÿd˘äÿłèčĚéěřåŹĺåŕŕäžěædĄåd˘ğçŽĎæŔŘå■ĞæĂğèČ¡ïijĹæţŃèŕŢè£Źäÿłä¿Ńå■ŘçŽĎæŮűåĂŹåd˘

äżżä¡ŢæŮűåĂŹåd˘ĎçŘĘæŢřçżĎæŮűïijŇçăŤçl˘űåźűæŤźåŰĎåžŢåśĆçőŮæşŢåŘŇæăůåŔŕäžěædĄåd˘ğçŽ
ä¿ŃåęĆïijŇèĂČèŹŠåŕź `clip()` åĞ¡æŢřçŽĎåęĆäÿŃä£őæ■čïijŇä¡£çŤĺæİąäżűèąĺè¿¿åijŔïijŽ

```
@cython.boundscheck(False)
@cython.wraparound(False)
cpdef clip(double[:] a, double min, double max, double[:] out):
    if min > max:
        raise ValueError("min must be <= max")
    if a.shape[0] != out.shape[0]:
        raise ValueError("input and output arrays must be the same␣
↪size")
    for i in range(a.shape[0]):
        out[i] = (a[i] if a[i] < max else max) if a[i] > min else␣
↪min
```

åőđéŹĚæţŃèŕŢçżŞæđIJæŸŕïijŇè£ŹäÿłçL˘ĹæIJňçŽĎäžčçăĄè£ŘèąŇéĂ§åžęèęĄå£ń50%äžěäÿŁïijĹ2.44çğ
`timeit()` æţŃèŕŢçŽĎ3.76çğŠïijL˘ãĂĆ

åĹŕè£ŹéĞŇäÿžæ■ćïijŇä¡ääŔŕèČ¡æČşç§ěéĄŞè£Źçğ■äžčçăĄæĂŐäźĹèČ¡èů§æL˘ŃåĘŹCèŕ■èĺĂPKåŚćïij§
ä¿ŃåęĆïijŇä¡ääŔŕèČ¡åĘŹäžĘåęĆäÿŇçŽĎCåĞ¡æŢřåźűä¡£çŤĺåL˘■éİćåĞäèŁĆçŽĎæŁĂæIJŕæİèæL˘ŃåĘŹæL˘l˘

```
void clip(double *a, int n, double min, double max, double *out) {
  double x;
```

```
  for (; n >= 0; n--, a++, out++) {
    x = *a;

    *out = x > max ? max : (x < min ? min : x);
  }
}
```

æĹŚäžňæšąæIJL’åśŢçd’žè£ŹäÿłçŽĎæL’l’åśŢäžčçăĄïijŇä¡ĘæŸŕèŕŢélŇäźŃåŘŐïijŇæĹŚäžňåŔŚçŐřäÿĂäj
æIJĂåžŢäÿŃçŽĎäÿĂèąŇæŕŤä¡ăæČşèšąçŽĎè£ŘèąŇçŽĎå£ńå¿Ĺåd’ŽãĂĆ

ä¡ăåŔŕäžěåŕźåőđä¿Ńäžčçă Ąæđ Ďåžžåd’ŽäÿłæL’l’åśŢãĂĆ åŕźäžŐæ§ŘäžŻæŢřçżĎæŞ■ä¡IJïijŇæIJĂåě¡èęĄ
èęĄ£ŹæăůåĄŽçŽĎèŕÍïijŇéIJĂèęĄä£őæŤźäžčçăĄïijŇä¡£çŤÍ `with nogil:` èŕ■åŘěïijŽ

```
@cython.boundscheck(False)
@cython.wraparound(False)
cpdef clip(double[:] a, double min, double max, double[:] out):
    if min > max:
        raise ValueError("min must be <= max")
    if a.shape[0] != out.shape[0]:
        raise ValueError("input and output arrays must be the same␣
↪size")
    with nogil:
        for i in range(a.shape[0]):
            out[i] = (a[i] if a[i] < max else max) if a[i] > min␣
↪else min
```

åęĆæđIJä¡ăæČşåĘŹäÿĂäÿłæŞ■ä¡IJäžŇçżt’æŢřçżĎçŽĎçL’ĹæIJňïijŇäÿŃéİćæŸŕåŔŕäžěåŔĆèĂČäÿŃïijŽ

```
@cython.boundscheck(False)
@cython.wraparound(False)
cpdef clip2d(double[:,:] a, double min, double max, double[:,:]␣
↪out):
    if min > max:
        raise ValueError("min must be <= max")
    for n in range(a.ndim):
        if a.shape[n] != out.shape[n]:
            raise TypeError("a and out have different shapes")
    for i in range(a.shape[0]):
        for j in range(a.shape[1]):
            if a[i,j] < min:
                out[i,j] = min
            elif a[i,j] > max:
                out[i,j] = max
            else:
                out[i,j] = a[i,j]
```

åÿŇæIJŻèŕźèĂĚäÿ■èęĄå£ŸäžĘæIJňèŁĆæL’ĂæIJL’äžčçăĄéČ¡äÿ■äijŽçźŚåőŽåĹŕæ§ŘäÿłçL’źåőŽæŢřçżĎ
è£ŹæăůäžčçăĄåřśæŻt’æIJL’çĄţæt’żæĂğãĂĆ äÿ■è£ĞïijŇèęĄæşĺæĎŔçŽĎæŸŕåęĆæđIJåd’ĎçŘĘæŢřçżĎèęĄæ
è£ŹäžŻåĘĚåőźåůšçżŔèűĚåĞžæIJňèŁĆèŇČåŻt’ïijŇæŻt’åd’Žä£ąæĄŕèŕůåŔĆèĂČ PEP
3118 ïijŇ åŘŇæŮű CythonæŰĞæąčäÿ■åĚşäžŐâĂIJçśżåđŃåĘĚå■ŸèğĘåŻ¿âĂİ
çŕĞäź§åĂijå¿ŮäÿĂèŕźãĂĆ

17.12 15.12 åřĘåĞ¡æŢřæŇĞéŠĹè¡ňæ■ćäÿžåŔŕèřČçŤĺåŕźèśą

éŮőécŸ

ä¡ăåůšçżŔèŐůå¿ŮäžĘäÿĂäÿłèćńçijŰèŕŚåĞ¡æŢřçŽĎåĘĚå■ŸåIJřåİĂïijŇæČşåřĘåőČè¡ňæ■ćæĹŘäÿĂäÿłP
è£Źæăůç ŽĎèŕİä¡ăåřśåŔŕäžěåřĘåőČä¡IJäÿžäÿĂäÿłæL'ľåśŢåĞ¡æŢřä¡£çŤĺäžĘãĂĆ

èğčåĘşæŰźæąĹ

ctypes æĺąåİŮåŔŕèćńçŤĺæİěåĹŻåžžåŇĚèčĚäżżæĎŔåĘĚå■ŸåIJřåİĂçŽĎPythonåŔŕèřČçŤĺåŕźèśąãĂĆ
äÿŃéİćçŽĎä¿Ńå■ŘæijŤçd'žäžĘæĂŐæăůèŐůåŔŰCåĞ¡æŢřçŽĎåŐ§ågŃãĂĄåžŢåśĆåIJřåİĂïijŇäžěåŔŁąęĆä¡

```
>>> import ctypes
>>> lib = ctypes.cdll.LoadLibrary(None)
>>> # Get the address of sin() from the C math library
>>> addr = ctypes.cast(lib.sin, ctypes.c_void_p).value
>>> addr
140735505915760

>>> # Turn the address into a callable function
>>> functype = ctypes.CFUNCTYPE(ctypes.c_double, ctypes.c_double)
>>> func = functype(addr)
>>> func
<CFunctionType object at 0x1006816d0>

>>> # Call the resulting function
>>> func(2)
0.9092974268256817
>>> func(0)
0.0
>>>
```

èőÍèőž

èęĄæđĎåžžäÿĂäÿłåŔŕèřČçŤĺåŕźèśąïijŇä¡ăéęŰåĚĹéIJĂèęĄåĹŻåžžäÿĂäÿł
CFUNCTYPE åőđä¿ŃãĂĆ CFUNCTYPE() çŽĎçňňäÿĂäÿłåŔĆæŢřæŸŕè£ŤåŻđçśžåđŃãĂĆ
æŐěäÿŃæİěçŽĎåŔĆæŢřæŸŕåŔĆæŢřçśžåđŃãĂĆäÿĂæŰęä¡ăåőŽäźL'äžĘåĞ¡æŢřçśžåđŃïijŇä¡ăåřśèČ¡åřĘåőČ
çŤ§æĹŘçŽĎåŕźèśąèćńå¡ŞåĄŽæŹőéĂŽçŽĎåŔŕéĂŽè£Ğ ctypes
èő£éŮőçŽĎåĞ¡æŢřæİěä¡£çŤĺãĂĆ

æIJňèŁĆçIJŃäÿŁåŐżåŔŕèČ¡æIJL'çĆźçěđçğŸïijŇåĄŘåžŢåśĆäÿĂçĆźãĂĆ
ä¡ĘæŸŕïijŇä¡ĘæŸŕåőČèćńáź£æşŻä¡£çŤĺäžŐåŘĎçğ■énŸçžğäžčçăĄçŤ§æĹŘæŁĂæIJŕæŕŤåęĆå■şæŮűçijŰèŕŚ

ä¿ŃåęĆïijŇäÿŃéİćæŸŕäÿĂäÿłä¡£çŤĺ llvmpy æL'ľåśŢçŽĎçőÅå■Ţä¿Ńå■ŘïijŇçŤĺæİěæđĎåžžäÿĂäÿłåřI
åźűåřĘåĚűè¡ňæ■ćäÿžäÿĂäÿłPythonåŔŕèřČçŤĺåŕźèśąãĂĆ

```
>>> from llvm.core import Module, Function, Type, Builder
>>> mod = Module.new('example')
```

```
>>> f = Function.new(mod,Type.function(Type.double(), \
                     [Type.double(), Type.double()], False), 'foo')
>>> block = f.append_basic_block('entry')
>>> builder = Builder.new(block)
>>> x2 = builder.fmul(f.args[0],f.args[0])
>>> y2 = builder.fmul(f.args[1],f.args[1])
>>> r = builder.fadd(x2,y2)
>>> builder.ret(r)
<llvm.core.Instruction object at 0x10078e990>
>>> from llvm.ee import ExecutionEngine
>>> engine = ExecutionEngine.new(mod)
>>> ptr = engine.get_pointer_to_function(f)
>>> ptr
4325863440
>>> foo = ctypes.CFUNCTYPE(ctypes.c_double, ctypes.c_double, ctypes.
↪c_double)(ptr)

>>> # Call the resulting function
>>> foo(2,3)
13.0
>>> foo(4,5)
41.0
>>> foo(1,2)
5.0
>>>
```

åźűäÿ■æŸŕèŕťåIJĺè£Źäÿłåś Céİçç Łŕäž Ęäżżä¡ŢéŤŹèŕŕåřśäijŽåŕijèĞť Pythonèğčé ĞŁåŹĺæŇĆæŐL'ãĂĆ èęĄèőřå¿ŮçŽĎæŸŕä¡ăæŸŕåIJĺçŻť æŐěèů§æIJžåŹĺçžğåĹńçŽĎåĘĚå■ŸåIJřåİĂåŠŇæIJňåIJřæIJžåŹĺçăĄæĽŞä

17.13 15.13 äijäéĂŠNULLçżŞář¿çŽĎå■ŮçňęäÿšçżŹCåĞ¡æŢřážŞ

éŮőécŸ

ä¡ăèęĄåĘŹäÿĂäÿłæĽ'ĺåśŢæĺąåİŮïijŇéIJĂèęĄäijăéĂŠäÿĂäÿłNULLçżŞář¿çŽĎå■ŮçňęäÿšçżŹCåĞ¡æŢřå äÿ■è£ĞïijŇä¡ăäÿ■æŸŕå¿ĹçąőåőžæĂŐæăůä¡£çŤĺPythonçŽĎUnicodeå■Ůçňęäÿšå Őżåőđç Őřåő ČãĂĆ

èğčåĘşæŰźæąĹ

èőÿåď ŽCåĞ¡æŢřážŞåŇĚåŘńäÿĂäžŽæŞ■ä¡IJNULLçżŞář¿çŽĎå■ŮçňęäÿšïijŇèćńåčřæŸŐçśżåđŃäÿž `char *`. èĂČèŹŠåęĆäÿŃçŽĎCåĞ¡æŢřïijŇæĹŚäżňçŤĺæİěåĄŽæijŤçď žåŠŇæţŃèŕŢçŤĺçŽĎïijŽ

```
void print_chars(char *s) {
    while (*s) {
        printf("%2x ", (unsigned char) *s);

        s++;
    }
```

```
    printf("\n");
}
```

æ■ď åĞ¡æŢřäijŽæĽŞå■řèćńäijàè£ŻæİěåĽÛçňęäÿšçŽĎæŕŔäÿłå■ÛçňęçŽĎå■ĄåĚ■è£ŻåĹűèąÍçď žïijŇè£Ź

```
print_chars("Hello");    // Outputs: 48 65 6c 6c 6f
```

åŕźäžŐåIJÍPythonäÿ■èřČçŤÍè£ŹæăůçŽĎCåĞ¡æŢřïijŇä¡ăæIJL’åĞăçğ■éĂĽ’æŃľãĂĆ éęŰåĚĹïijŇä¡ăåŘŕäžěéĂŽè£ĞèřČçŤÍ PyArg_ParseTuple() åźűæŇĞåőŽâĂİyâĂIJè¡ňæ■ćçăĄæİěéŹŘåĹűåőČåŘłèČ¡æŞ■ä¡IJå■ÛèŁĆïijŇåęĆäÿŃïijŽ

```
static PyObject *py_print_chars(PyObject *self, PyObject *args) {
  char *s;

  if (!PyArg_ParseTuple(args, "y", &s)) {
    return NULL;
  }
  print_chars(s);
  Py_RETURN_NONE;
}
```

çżŞæđIJåĞ¡æŢřçŽĎä¡£çŤÍæŰźæşŢåęĆäÿŃãĂĆäžŤçżĘèğĆår§åţŇåĚěäžĘNULLå■ÛèŁĆçŽĎå■Ûçňęäÿš

```
>>> print_chars(b'Hello World')
48 65 6c 6c 6f 20 57 6f 72 6c 64
>>> print_chars(b'Hello\x00World')
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: must be bytes without null bytes, not bytes
>>> print_chars('Hello World')
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: 'str' does not support the buffer interface
>>>
```

åęĆæđIJä¡ăæČşäijåéĂŠUnicodeå■ÛçňęäÿšïijŇåIJÍ PyArg_ParseTuple() äÿ■ä¡£çŤÍâĂİsâĂIJæăijåijŔçăĄïijŇåęĆäÿŃïijŽ

```
static PyObject *py_print_chars(PyObject *self, PyObject *args) {
  char *s;

  if (!PyArg_ParseTuple(args, "s", &s)) {
    return NULL;
  }
  print_chars(s);
  Py_RETURN_NONE;
}
```

å¡Şèćńä¡£çŤÍçŽĎæŮűåĂŹïijŇåőČäijŽèĞłåŁÍářĘæĽ’ĂæIJL’å■Ûçňęäÿšè¡ňæ■ćäÿžäžěNULLçżŞář¿çŽĎU 8çijŰçăĄãĂĆä¿ŃåęĆïijŽ

```
>>> print_chars('Hello World')
48 65 6c 6c 6f 20 57 6f 72 6c 64
>>> print_chars('Spicy Jalape\u00f1o')  # Note: UTF-8 encoding
53 70 69 63 79 20 4a 61 6c 61 70 65 c3 b1 6f
>>> print_chars('Hello\x00World')
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: must be str without null characters, not str
>>> print_chars(b'Hello World')
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: must be str, not bytes
>>>
```

åęĆædIJåŻääÿžæ§ŘäžŻåŐ§åŻäïijŇä¡ăèęĄçŻťæŐěä¡£çŤÍ
PyObject * èĂŇäÿ■èČ¡ä¡£çŤÍ PyArg_ParseTuple() ïijŇ
äÿŃéÍćçŽĎä¿Ńå■ŘåŘŚä¡ååśŢçd'žäžĘæĂŐæăůäżŐå■ŮèŁĆåŠŇå■Ůçňęäÿšåŕźèśąäÿ■ačĂæ§ěåŠŇæŔŘåŔŰäÿ
char * åijŢçŤÍïijŽ

```
/* Some Python Object (obtained somehow) */
PyObject *obj;

/* Conversion from bytes */
{
   char *s;
   s = PyBytes_AsString(o);
   if (!s) {
      return NULL;    /* TypeError already raised */
   }
   print_chars(s);
}

/* Conversion to UTF-8 bytes from a string */
{
   PyObject *bytes;
   char *s;
   if (!PyUnicode_Check(obj)) {
       PyErr_SetString(PyExc_TypeError, "Expected string");
       return NULL;
   }
   bytes = PyUnicode_AsUTF8String(obj);
   s = PyBytes_AsString(bytes);
   print_chars(s);
   Py_DECREF(bytes);
}
```

åL'■éÍćäÿď'çğ■è¡ňæ■ćéČ¡åŔŕäžěçąőä£ÍæŸŕNULLçżŞář¿çŽĎæŢřæ■őïijŇ
ä¡ĘæŸŕåőČäżňåźűäÿ■ačĂæ§ěå■Ůçňęäÿšäÿ■éŮt'æŸŕåŘęåţŇåĚěäžĘNULLå■ŮèŁĆãĂĆ
åŻäæ■ď'ïijŇåęĆædIJè£ŹäÿŁå¿ĹéĞ■èęĄçŽĎèŕÍïijŇéĆčä¡äéIJĂèęĄèĞłåůśåŐżåĄŽačĂæ§ěäžĘãĂĆ

èőÍèőž

åęĆæđIJåŔŕèČ¡çŽĎèŕÍïijŇä¡ăåžŤèŕěéĄ£åĚ■åŐżåĘŹäÿĂäžŻä¿ÌèţŰäžŐNULLçżŞář¿çŽĎå■Ůçňęäÿšïij
æIJĂåě¡çżŞåŘĹä¡£çŤÍäÿĂäÿłæŇĞéŠĹåŠŇéŢ£åžęåĂijæÌěåď ĎçŘĘå■Ůçňęäÿšã
äÿ■è£ĞïijŇæIJL'æŮűåĂŹä¡ăå£ĚéążåŐżåď ĎçŘĘCèŕ■èÍĂéĄŮçŢŹäżčçăĄæŮűářśæšąå¿ŮéĂL'æŃl'äžĘãĂĆ

ář¡çőąå¿Ĺåőźæ ŸŞä¡£çŤÍïijŇä¡ĘæŸŕå¿Ĺåőźæ ŸŞå£¡ègĘçŽĎäÿĂäÿłéŮőécŸæŸŕåIJÍ
`PyArg_ParseTuple()` äÿ■ä¡£çŤÍâĂIJsâĂÌæăijåijŔåŇŰçăĄäijŽæIJL'åĘĚå■Ÿæ■§èĂŮãĂĆ
ä¡Ęä¡ăéIJĂèęĄä¡£çŤÍè£Źçğ■è¡ňæ■ćçŽĎæŮűåĂŹïijŇäÿĂäÿłUTF-
8å■ŮçňęäÿšècńåĹŽåžžåźűæřÿäźĚéŹĎåŁåâIJÍåŐ§ågŃå■ŮçňęäÿšářźèśąäÿŁéÍćãĂĆ
åęĆæđIJåŐ§ågŃå■Ůçňęäÿšå ŇĚåŘńéÍđASCIIå■Ůçňę ŽĎèŕÍïijŇářšäijŽářijèĞť'å■Ůçňęäÿšç ŽĎářžářÿáćđåĹřäÿ

```
>>> import sys
>>> s = 'Spicy Jalape\u00f1o'
>>> sys.getsizeof(s)
87
>>> print_chars(s)      # Passing string
53 70 69 63 79 20 4a 61 6c 61 70 65 c3 b1 6f
>>> sys.getsizeof(s)    # Notice increased size
103
>>>
```

åęĆæđIJä¡ăåIJÍäźŐè£ŹäÿłåĘĚå■ŸçŽĎæ■§èĂŮïijŇä¡ăæIJĂåě¡éĞ■åĘŹä¡ăçŽĎCæL'l'åśŢäžčçăĄïijŇèől'å
`PyUnicode_AsUTF8String()` åĞ¡æŢřãĂĆåęĆäÿŃïijŽ

```
static PyObject *py_print_chars(PyObject *self, PyObject *args) {
  PyObject *o, *bytes;
  char *s;

  if (!PyArg_ParseTuple(args, "U", &o)) {
    return NULL;
  }
  bytes = PyUnicode_AsUTF8String(o);
  s = PyBytes_AsString(bytes);
  print_chars(s);
  Py_DECREF(bytes);
  Py_RETURN_NONE;
}
```

éĂŽè£Ğè£ŹäÿÌä£őæŤźïijŇäÿĂäÿłUTF-8çijŰçăĄçŽĎå■Ůçňęäÿšæăźæ■őéIJĂèęĄèćńåĹŽåžžïijŇçĎűåŘĈ

```
>>> import sys
>>> s = 'Spicy Jalape\u00f1o'
>>> sys.getsizeof(s)
87
>>> print_chars(s)
53 70 69 63 79 20 4a 61 6c 61 70 65 c3 b1 6f
>>> sys.getsizeof(s)
87
>>>
```

åęĆædIJä¡ăèŕŢçİĂäijăéĂŠNULLçżŞář¿å■ŮçňęäÿšçżŹctypesåŇĚècĚè£ĞçŽĎåĞ¡æŢřïijŇ
èęĄæşÍæĎŔçŽĎæŸŕctypesåŔłèČ¡åĚĄèőÿäijăéĂŠå■ŮèŁĆïijŇåźűäÿŤåőČäÿ■äijŽæčĂæ§ěäÿ■éŮť åţŇåĚěçŽĎ

```
>>> import ctypes
>>> lib = ctypes.cdll.LoadLibrary("./libsample.so")
>>> print_chars = lib.print_chars
>>> print_chars.argtypes = (ctypes.c_char_p,)
>>> print_chars(b'Hello World')
48 65 6c 6c 6f 20 57 6f 72 6c 64
>>> print_chars(b'Hello\x00World')
48 65 6c 6c 6f
>>> print_chars('Hello World')
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ctypes.ArgumentError: argument 1: <class 'TypeError'>: wrong type
>>>
```

åęĆædIJä¡ăæČşäijăéĂŠå■ŮçňęäÿšèĂŇäÿ■æŸŕå■ŮèŁĆïijŇä¡ăéIJĂèęĄåĚĹæĽğèąŇæĽŃåŁĺçŽĎUTF-8çijŰçăĄãĂĆä¿ŃåęĆïijŽ

```
>>> print_chars('Hello World'.encode('utf-8'))
48 65 6c 6c 6f 20 57 6f 72 6c 64
>>>
```

åŕźäžŐåĚűäżŰæĽľåśŢåůěåĚůïijĹæŕŤåęĆSwigãĂĄCythonïijĽïijŇ
åIJĺä¡ää¡£çŤĺåőČäżñäijăéĂŠå■ŮçňęäÿšçżŹCäżčçăĄæŮűèęĄåĚĹåě¡åě¡å■ęäźăçŻÿåžŢçŽĎäÿIJèě£äžEãĂĆ

17.14 15.14 äijăéĂŠUnicodeå■ŮçňęäÿšçżŹCåĞ¡æŢřåžŞ

éŮőécŸ

ä¡ăèęĄåĘŹäÿĂäÿłæĽľåśŢæĹąåİŮïijŇéIJĂèęĄåřĘäÿĂäÿłPythonå■ŮçňęäÿšäijăéĂŠçżŹCçŽĎæ§ŘäÿłåžŞ

èğčåĘşæŰźæąĹ

è£ŹéĞŇæĹŚäżñéIJĂèęĄèĂČèŹŚå¿Ĺåď ŽçŽĎéŮőécŸïijŇä¡ĘæŸŕæIJĂäÿżèęĄçŽĎéŮőécŸæŸŕçŐřå■Ÿç
åŻăæ■ď ïijŇä¡ăçŽĎæŇŚæĹŸæŸŕåřĘPythonå■Ůçňęäÿšè¡ňæ■ćäÿžäÿĂäÿłèČ¡èćńCçŘĘèğčçŽĎå¡ćåijŔãĂĆ

äÿžäžĘæijŤçď žçŽĎçŻőçŽĎïijŇäÿŃéİćæIJĽäÿď äÿłCåĞ¡æŢřïijŇçŤĺæİěæŞ■ä¡IJå■ŮçňęäÿšæŢřæ■őåźűè
äÿĂäÿłä¡£çŤĺå¡ćåijŔäÿž `char *, int` å¡ćåijŔçŽĎå■ŮèŁĆïijŇ
èĂŇåŘęäÿĂäÿłä¡£çŤĺå¡ćåijŔäÿž `wchar_t *, int` çŽĎåő¡å■Ůçňęå¡ćåijŔïijŽ

```
void print_chars(char *s, int len) {
  int n = 0;

  while (n < len) {
    printf("%2x ", (unsigned char) s[n]);
    n++;
```

```
  }
  printf("\n");
}

void print_wchars(wchar_t *s, int len) {
  int n = 0;
  while (n < len) {
    printf("%x ", s[n]);
    n++;
  }
  printf("\n");
}
```

åŕźäžŐéİćåŘŠå■ÛèŁĆçŽĎåĞ¡æŢř `print_chars()` ïijŇä¡ăéIJĂèęĄåřĘPythonå■Ůçňęäÿšè¡ňæ■ćäÿžäy
8. äÿŃéİćæŸŕäÿĂäÿłè£Źæăůç ŽĎæĽ'ĺåśŢåĞ¡æŢřä¿Ńå■ŘïijŽ

```
static PyObject *py_print_chars(PyObject *self, PyObject *args) {
  char *s;
  Py_ssize_t  len;

  if (!PyArg_ParseTuple(args, "s#", &s, &len)) {
    return NULL;
  }
  print_chars(s, len);
  Py_RETURN_NONE;
}
```

åŕźäžŐéĆčäžŽéIJĂèęĄåd'ĎçŘĘæIJžåŹĺæIJňåIJř `wchar_t` çśżåđŃçŽĎåžŞåĞ¡æŢřijŇä¡ăåŔŕäżěåČŔäÿŃéİćè£ŹæăůçijŰåĘŹæĽ'ĺåśŢäžčçăĄïijŽ

```
static PyObject *py_print_wchars(PyObject *self, PyObject *args) {
  wchar_t *s;
  Py_ssize_t  len;

  if (!PyArg_ParseTuple(args, "u#", &s, &len)) {
    return NULL;
  }
  print_wchars(s,len);
  Py_RETURN_NONE;
}
```

äÿŃéİćæŸŕäÿĂäÿłäžd'äžŠäijŽèŕÍæİěæijŤçd'žè£ŹäÿłåĞ¡æŢřæŸŕåęĆä¡Ţåůëä¡IJçŽĎïijŽ

```
>>> s = 'Spicy Jalape\u00f1o'
>>> print_chars(s)
53 70 69 63 79 20 4a 61 6c 61 70 65 c3 b1 6f
>>> print_wchars(s)
53 70 69 63 79 20 4a 61 6c 61 70 65 f1 6f
>>>
```

äžŤçżĘèğĆåŕ§è£ŹäÿłéİćåŘŠå■ÛèŁĆçŽĎåĞ¡æŢř `print_chars()`

æŸŕæĂŐæăůæŐěåŔŮUTF-8çijŰçăĄæŢřæ■őçŽĎïijŇ äžěåŔŁ `print_wchars()` æŸŕæĂŐæăůæŐěåŔŮUnicodeçijŰçăĄåĂijçŽĎ

èőĺèőž

åIJĺçżğçż■æIJňèŁĆäźŃåL'■ïijŇä¡ăåžŤèŕěéęŰåĚĹå■ęäźăä¡ăèő£éŮőçŽĎCåĞ¡æŢřåžŞçŽĎçL'źå¿ĄãĂĆ åŕźäžŐå¿Ĺåď'ŽCåĞ¡æŢřåžŞïijŇéĂŽåÿÿäijăéĂŠå■ŮèŁĆèĂŇäÿ■æŸŕå■ŮçňęäÿšäijŽæŕŤè¿Čåě¡äžŻãĂĆèęĄè£

```
static PyObject *py_print_chars(PyObject *self, PyObject *args) {
  char *s;
  Py_ssize_t  len;

  /* accepts bytes, bytearray, or other byte-like object */
  if (!PyArg_ParseTuple(args, "y#", &s, &len)) {
    return NULL;
  }
  print_chars(s, len);
  Py_RETURN_NONE;
}
```

åęĆæđIJä¡ăäż■çĎűè£ŸæŸŕæČşèęĄäijăéĂŠå■ŮçňęäÿšïijŇ ä¡ăéIJĂèęĄç§ěéĄŞPython 3åŔŕä¡£çŤĺäÿĂäÿłåŘĹéĂĆçŽĎå■Ůçňęäÿšèąĺçd'žïijŇ åőČåźűäÿ■çŻť'æŐěæŸăářĎåĹřä¡£çŤĺæăĞåĞĘçśžåđŃ `char *` æĹŰ `wchar_t *` ïijĹæŻť'åď'ŽçżĘèŁĆåŔĆèĂČPEP 393ïijL'çŽĎCåĞ¡æŢřåžŞãĂĆ åŻăæ■ď'ïijŇèęĄåIJĺCäÿ■èąĺçď'žè£Źäÿłå■ŮçňęäÿšæŢřæ■őïijŇäÿĂäžŻè¡ňæ■ćè£ŸæŸŕå£Éęąžèę ĄçŽĎãĂĆ åIJĺ `PyArg_ParseTuple()` äÿ■ä¡£çŤĺâĂİs#âĂİ åŠŇâĂİu#âĂİæăijåijŔåŇŰçăĄåŔŕäžěåőL'åĚĺçŽĎæL'ğèą

äÿ■è£Ğè£Źçğ■è¡ňæ■ćæIJL'äÿłçijžçĆźåřśæŸŕåőČåŔŕèČ¡äijŽåŕijèĞť'åŐ§ăğŇå■ŮçňęäÿšåŕźèśąçŽĎåřžåŕý äÿĂæŮęè¡ňæ■ćè£ĞåŘŐïijŇäijŽæIJL'äÿĂäÿłè¡ňæ■ćæŢřæ■őçŽĎåď'■åĹűéŹĎåŁăåĹřåŐ§ăğŇå■Ůçňęäÿšåŕźèśą ä¡ăåŔŕäžěèğĆåŕ§äÿŇè£Źçğ■æŢĹæđIJïijŽ

```
>>> import sys
>>> s = 'Spicy Jalape\u00f1o'
>>> sys.getsizeof(s)
87
>>> print_chars(s)
53 70 69 63 79 20 4a 61 6c 61 70 65 c3 b1 6f
>>> sys.getsizeof(s)
103
>>> print_wchars(s)
53 70 69 63 79 20 4a 61 6c 61 70 65 f1 6f
>>> sys.getsizeof(s)
163
>>>
```

åŕźäžŐåřŠéĞŔçŽĎå■ŮçňęäÿšåŕźèśąïijŇåŔŕèČ¡æšąäżĂäźĹå¡śåŞ■ïijŇ ä¡ĘæŸŕåęĆæđIJä¡ăéIJĂèęĄåIJĺæL'l'åśŢäÿ■åď'ĎçŘĘåď'ğéĞŔçŽĎæŰĞæIJňïijŇä¡ăåŔŕèČ¡æČşéĄ£åĚ■è£ŹäÿłäÿŃéĺćæŸŕäÿĂäÿłä£őèőćçL'ĹæIJňåŔŕäžěéĄ£åĚ■è£Źçğ■åĘĚå■Ÿæ■§èĂŮïijŽ

```
static PyObject *py_print_chars(PyObject *self, PyObject *args) {
  PyObject *obj, *bytes;
  char *s;
  Py_ssize_t   len;

  if (!PyArg_ParseTuple(args, "U", &obj)) {
    return NULL;
  }
  bytes = PyUnicode_AsUTF8String(obj);
  PyBytes_AsStringAndSize(bytes, &s, &len);
  print_chars(s, len);
  Py_DECREF(bytes);
  Py_RETURN_NONE;
}
```

èĂŇåŕź wchar_t çŽĎåď ĎçŘĘæŮűæČşèęĄéĄ£åĚ■åĘĚå■Ÿæ■§èĂŮåřśæŻť åŁăéŽ¿åŁđäžĘãĂĆ
åIJĺåĘĚéČĺïijŇPythonä¡£çŤĺæIJĂéńŸæŢĹçŽĎèąĺçď žæİěå■ŸåĆĺå■Ůçňęäÿšã ĂĆ
ä¿ŃåęĆïijŇåŔłåŇĚåŘńASCIIçŽĎå■Ůçňęäÿšèćńå■ŸåĆĺäÿžå■ŮèŁĆæŢřçżĎïijŇ
èĂŇåŇĚåŘńèŇČåŻť äżŐU+0000åĹřU+FFFFçŽĎå■ŮçňęçŽĎå■Ůçňęäÿšä¡£çŤĺåŔŇå■ŮèŁĆèąĺçď žãĂĆ
çŤśäžŐåŕźäžŐæŢřæ■őçŽĎèąĺçď žå¡ćåijŔäÿ■æŸŕå■ŢäÿĂçŽĎïijŇä¡ăäÿ■èČ¡åřĘåĘĚéČĺæŢřçżĎè¡ňæ■ćäÿž
wchar_t * çĎűåŘŐæIJ§æIJŻåőČèČ¡æ■čçąőçŽĎåůěä¡IJãĂĆ ä¡ăåžŤèŕěåĹŻåżžäÿĂäÿł
wchar_t æŢřçżĎåźűåŘŚåĚűäÿ■åď ■åĹűæŰĞæIJñãĂĆ PyArg_ParseTuple()
çŽĎâĂİu#âĂİæăijåijŘçăĄåŔŕäžěåÿőåŁľä¡ăénŸæŢĹçŽĎåőŇæĹŘåőČïijĹåőČåřĘåď ■åĹűçżŞæđIJéŹĎåŁăåĹi

åęĆæđIJä¡ăæČşéĄ£åĚ■éŢ£æŮűéŮťåĘĚå■Ÿæ■§èĂŮïijŇä¡ăåŤŕäÿĂçŽĎéĂĽ'æŃľåřśæŸŕåď ■åĹűUnicoc
åřĘåőČäijăéĂŠçżŹCåĞ¡æŢřïijŇçĎűåŘŐåŻđæŤűè£ŹäÿłæŢřçżĎçŽĎåĘĚå■ŸãĂĆäÿŃéİćæŸŕäÿĂäÿłåŘŕèČ¡çŽ

```
static PyObject *py_print_wchars(PyObject *self, PyObject *args) {
  PyObject *obj;
  wchar_t *s;
  Py_ssize_t len;

  if (!PyArg_ParseTuple(args, "U", &obj)) {
    return NULL;
  }
  if ((s = PyUnicode_AsWideCharString(obj, &len)) == NULL) {
    return NULL;
  }
  print_wchars(s, len);
  PyMem_Free(s);
  Py_RETURN_NONE;
}
```

åIJÍè£ŹäÿłåőđçŐřäÿ■ïijŇPyUnicode_AsWideCharString()
åĹŻåżžäÿĂäÿłäÿťæŮűçŽĎwchar_tçijŞåĘšåźűåď ■åĹűæŢřæ■őè£ŻåŐżãĂĆ
è£Źäÿłçij ŞåĕšèćńäijăéĂŠçżŹCçĎűåŘŐèćńéĞŁæŤ¿æŐĽ'ãĂĆ ä¡ĘæŸŕæĹŚåĘŹè£ŹæIJñäźęçŽĎæŮűåĂŹïijŇè

åęĆæđIJä¡ăç§ěéĄŞCåĞ¡æŢřåžŞéIJĂèęĄçŽĎå■ŮèŁĆçijŰçăĄåźűäÿ■æŸŕUTF-8ïijŇ
ä¡ăåŔŕäžěåijžåĹűPythonä¡£çŤĺæĽ'ĺåśŢçăĄæİěæĽ'ğèąŇæ■čçąőçŽĎè¡ňæ■ćïijŇåŕśåČŔäÿŃéİćè£Źæăůïij Ž

```
static PyObject *py_print_chars(PyObject *self, PyObject *args) {
  char *s = 0;
  int   len;
  if (!PyArg_ParseTuple(args, "es#", "encoding-name", &s, &len)) {
    return NULL;
  }
  print_chars(s, len);
  PyMem_Free(s);
  Py_RETURN_NONE;
}
```

æIJĂåŘŐïijŇåęĆæđIJä¡ăæČşçŻťæŐěåďĎçŘĘUnicodeå■ŮçňęäÿšïijŇäÿŃéİćçŽĎæŸŕä¿Ńå■ŘïijŇæijŤç

```
static PyObject *py_print_wchars(PyObject *self, PyObject *args) {
  PyObject *obj;
  int n, len;
  int kind;
  void *data;

  if (!PyArg_ParseTuple(args, "U", &obj)) {
    return NULL;
  }
  if (PyUnicode_READY(obj) < 0) {
    return NULL;
  }

  len = PyUnicode_GET_LENGTH(obj);
  kind = PyUnicode_KIND(obj);
  data = PyUnicode_DATA(obj);

  for (n = 0; n < len; n++) {
    Py_UCS4 ch = PyUnicode_READ(kind, data, n);
    printf("%x ", ch);
  }
  printf("\n");
  Py_RETURN_NONE;
}
```

åIJÍè£ŹäÿłäžčçăĄäÿ■ïijŇPyUnicode_KIND() åŠŇ PyUnicode_DATA() è£ŹäÿďäÿłåőŘåŠŇUnicodeçŽĎåŕŕåŔŸåő¡åžęå■ŸåĆÍæIJL'åĚşïijŇè£ŹäÿłåIJÍPEP 393äÿ■æIJL'æŘŔè£řãĂĆ kind åŔŸéĞŔçijŰçăĄåžŢåśĆå■ŸåĆÍïijĹ8ä¡■ãĂĄ16ä¡■æĹŰ32ä¡■ïijL'äżěåŘŁæŇ åIJÍåőđéŹĚæČĚåĘţäÿ■ïijŇä¡ăåźűäÿ■éIJĂèęĄç§ěéĄŞäżżä¡Ţèů§è£ŹäžŻåĂijæIJL'åĚşçŽĎäÿIJèě£ïijŇ åŘłéIJĂèęĄåIJÍæŔŘåŔŰå■ŮçňęçŽĎæŮűåĂŹårĘåőČäžňäijăçżŹ PyUnicode_READ() åőŔãĂĆ

è£ŸæIJL'æIJĂåŘŐåĞăåŔěïijŽå¡ŞäżŐPythonäijăéĂŠUnicodeå■ŮçňęäÿšçżŹCçŽĎæŮűåĂŹïijŇä¡ăåžŤèŕě åęĆæđIJæIJL'UTF-8åŠŇåő¡å■Ůçňęäÿď'çğ■éĂL'æŃl'ïijŇèŕůéĂL'æŃl'UTF-8. åŕźUTF-8çŽĎæŤŕæŇĄæŻť'åŁăæŹőéĄ■äÿĂäžŻïijŇäź§äÿ■åőźæŸŞçŁŕéŤŹïijŇèğčéĞŁåŹĺäź§èČ¡æŤŕæŇĄçŽĎæŻť'åě æIJĂåŘŐïijŇçąőä£Ïä¡ăäžŤçżĘéŸĚèŕżäžĘ åĚşäžŐåď'ĎçŘĘUnicodeçŽĎçŻÿåĚşæŰĞæąč

17.15 15.15 Cå■Ůçňęäÿšè¡ňæ■ćäÿžPythonå■Ůçňęäÿš

éŮőécŸ

æĂŐæăůåřĘCäÿ■çŽĎå■Ůçňęäÿšè¡ňæ■ćäÿžPythonå■ŮèŁĆæĹŰäÿĂäÿłå■Ůçňęäÿšåŕźèśąïij§

èğčåĘşæŰźæąĹ

Cå■Ůçňęäÿšä¡£çŤĺäÿĂåŕź `char *` åŠŇ `int` æİěèąĺçd'žïijŇ ä¡ăéIJĂèęĄåEşåőŽå■Ůçňęäÿšå£řåžŢæŸŕçŤĺäÿĂäÿłåŐ§ågŃå■ŮèŁĆå■Ůçňęäÿšè£ŸæŸŕäÿĂäÿłUnicodeå■Ůç å■ŮèŁĆåŕźèśąåŔŕäžěåČŔäÿŃéİćè£ŹæăůäĄ£çŤĺ `Py_BuildValue()` æİěædĎåżžïijŽ

```
char *s;      /* Pointer to C string data */
int   len;    /* Length of data */

/* Make a bytes object */
PyObject *obj = Py_BuildValue("y#", s, len);
```

åęĆædIJä¡ăèęĄåĹŻåżžäÿĂäÿłUnicodeå■ŮçňęäÿšïijŇåźűäÿŤä¡ăç§ěéĄŞ `s` æŇĞåŘŚäžĘUTF-8çijŰçăĄçŽĎæŢřæ■őïijŇåŔŕäžěä¡£çŤĺäÿŃéİćçŽĎæŰźåijŔïijŽ

```
PyObject *obj = Py_BuildValue("s#", s, len);
```

åęĆædIJ `s` ä¡£çŤĺåĚűäžŰçijŰçăĄæŰźåijŔïijŇéĆčäźĹåŔŕäžěåČŔäÿŃéİćä¡£çŤĺ `PyUnicode_Decode()` æİěædĎåżžäÿĂäÿłå■ŮçňęäÿšïijŽ

```
PyObject *obj = PyUnicode_Decode(s, len, "encoding", "errors");

/* Examples /*
obj = PyUnicode_Decode(s, len, "latin-1", "strict");
obj = PyUnicode_Decode(s, len, "ascii", "ignore");
```

åęĆædIJä¡ăæĄřåě¡æIJL'äÿĂäÿłçŤĺ `wchar_t *, len` åŕźèąĺçd'žçŽĎåő¡å■ŮçňęäÿšïijŇ æIJL'åĞăçğ■éĂL'æŃl'æĂğãĂĆéęŰåĚĹä¡ăåŔŕäžěä¡£çŤĺ `Py_BuildValue()` ïijŽ

```
wchar_t *w;     /* Wide character string */
int len;        /* Length */

PyObject *obj = Py_BuildValue("u#", w, len);
```

åŔęåd'ŰïijŇä¡ăè£ŸåŔŕäžěä¡£çŤĺ `PyUnicode_FromWideChar()`:

```
PyObject *obj = PyUnicode_FromWideChar(w, len);
```

åŕźäžŐåő¡å■ŮçňęäÿšïijŇåźűæšąæIJL'åŕźå■ŮçňęæŢřæ■őè£ŻèąŇèğčædŘâĂŤâĂŤåőČèćńåĄĞåőŽæŸŕåŐ§

èőÍèőž

åřĘCäÿ■çŽĎå■Ůçňęäÿšè¡ňæ■ćäÿžPythonå■ŮçňęäÿšéĄţå¿łåŠŇI/OåŘŇæăůçŽĎåŐ§åĹŹãĂĆ äźš§åřśæŸŕèřťˇïijŇæÍèèĞłCäÿ■çŽĎæŢřæ■őå£Ěéążæăźæ■őäÿĂäžŻèğčçăĄåŹÍèćńæŸ¿åijŔçŽĎèğčçăĄäÿžäÿĂä éĂŽåÿÿçijŰçăĄæăijåijŔåŇĚæŃňASCIIãĂĄLatin-1åŠŇUTF-8. åęĆæđIJä¡ääźűäÿ■çąőåőŽçijŰçăĄæŰźåijŔæĹŰèĂĚæŢřæ■őæŸŕäžŇè£ŻåĹűçŽĎïijŇä¡ăæIJĂåě¡åřĘå■Ůçňęäÿ å¡ŞæđĎéĂăäÿĂäÿłåŕźèšąçŽĎæŮűåĂŹïijŇPythonéĂŽåÿÿäijŽåďˇ■åĹűä¡ăæŔŘä¿ŻçŽĎå■ŮçňęäÿšæŢřæ■őãĂĆ åęĆæđIJæIJLˇå£ĚèęĄçŽĎèŕÍïijŇä¡ăéIJĂèęĄåIJĺåŘŐéÍćåŐžéĞŁæŤ¿Cå■Ůçňęäÿšã ĂĆ åŘŇæŮűïijŇäÿžäžĘèőľçĺŃåžŔæŻťˇåŁăăĄěåčőïijŇä¡ăäžŤèŕěåŘŇæŮűä¡£çŤĺäÿĂäÿłæŇĞéŠĹåŠŇäÿĂäÿłåďˇğ èĂŇäÿ■æŸŕä¿ÍètŰNULLçżŞår¿æŢřæ■őæÍěåĹŻåžžå■Ůçňęäÿšã ĂĆ

17.16 15.16 äÿ■çąőåőŽçijŰçăĄæăijåijŔçŽĎCå■Ůçňęäÿš

éŮőécŸ

ä¡ăèęĄåIJĺCåŠŇPythonçŻťˇæŐěæÍěåŻđè¡ňæ■ćå■ŮçňęäÿšïijŇä¡ĘæŸŕCäÿ■çŽĎçijŰçăĄæăijåijŔåźűäÿ■çă ä¿ŇåęĆïijŇåŘŕèČ¡Cäÿ■çŽĎæŢřæ■őæIJ§æIJŻæŸŕUTF-8ïijŇä¡ĘæŸŕåźűæšąæIJLˇåijžåĹűåőCå£Ěéążæ ŸŕãĂĆ ä¡ăæČşçijŰåĘŹäžčçăĄæÍěäžěäÿĂçğ■äijŸéŻĚçŽĎæŰźåijŔåďˇĎçŘĘè£ŹäžŻäÿ■åŘĹæăijæŢřæ■őïijŇè£Źæăůå

èğčåĘşæŰźæąĹ

äÿŃéÍćæŸŕäÿĂäžŻCçŽĎæŢřæ■őåŠŇäÿĂäÿłåĞ¡æŢřæÍěæijŤçďˇžè£ŹäÿłéŮőécŸïijŽ

```
/* Some dubious string data (malformed UTF-8) */
const char *sdata = "Spicy Jalape\xc3\xb1o\xae";
int slen = 16;

/* Output character data */
void print_chars(char *s, int len) {
  int n = 0;
  while (n < len) {
    printf("%2x ", (unsigned char) s[n]);
    n++;
  }
  printf("\n");
}
```

åIJÍè£ŹäÿłäžčçăĄäÿ■ïijŇå■Ůçňęäÿš `sdata` åŇĚåŘńäžĘUTF-8åŠŇäÿ■åŘĹæăijæŢřæ■őãĂĆ äÿ■è£ĞïijŇåęĆæđIJçŤÍæĹůåIJÍCäÿ■èřĈçŤÍ `print_chars(sdata, slen)` ïijŇåőČçijžèČ¡æ■čåÿÿåůëä¡IJãĂĆ çŐřåIJĺåĄĞèő¿ä¡ăæČşåřĘ `sdata` çŽĎåĘĚåőźè¡ňæ■ćäÿžäÿĂäÿłPythonå■Ůçňęäÿšã ĂĆ è£ŻäÿĂæ■ěåĄĞèő¿ä¡ääIJĺåŘŐéÍćè£ŸæČşéĂŽè£ĞäÿĂäÿłæĽˇå śŢåřĘéĆčäÿłå■Ůçňęäÿšäijääÿł `print_chars()` åĞ¡æŢřãĂĆ äÿŃéÍćæŸŕäÿĂçğ■çŤÍæÍěä£ÍæŁdˇåŐ§ågŃæŢřæ■őçŽĎæŰźæşŢïijŇåřśçőŮå

```
/* Return the C string back to Python */
static PyObject *py_retstr(PyObject *self, PyObject *args) {
  if (!PyArg_ParseTuple(args, "")) {
```

```
    return NULL;
  }
  return PyUnicode_Decode(sdata, slen, "utf-8", "surrogateescape");
}

/* Wrapper for the print_chars() function */
static PyObject *py_print_chars(PyObject *self, PyObject *args) {
  PyObject *obj, *bytes;
  char *s = 0;
  Py_ssize_t   len;

  if (!PyArg_ParseTuple(args, "U", &obj)) {
    return NULL;
  }

  if ((bytes = PyUnicode_AsEncodedString(obj,"utf-8",
↪"surrogateescape"))
        == NULL) {
    return NULL;
  }
  PyBytes_AsStringAndSize(bytes, &s, &len);
  print_chars(s, len);
  Py_DECREF(bytes);
  Py_RETURN_NONE;
}
```

åęĆædIJä¡ăåIJÍPythonäÿ■åřÌèřŢè£ŹäžŻåĞ¡æŢřïijŇäÿŃéİćæŸŕè£ŘèąŇæŢĹædIJïijŽ

```
>>> s = retstr()
>>> s
'Spicy JalapeÃśo\udcae'
>>> print_chars(s)
53 70 69 63 79 20 4a 61 6c 61 70 65 c3 b1 6f ae
>>>
```

äžŤçżĘèğĆår§çżŞædIJä¡ăäijŽåŔŞçŐřïijŇäÿ■åŘĹæăijå■ŮçňęäÿšèćńçijŰçăĄåĹřäÿĂäÿłPythonå■Ůçňęäÿ
åźűäÿŤå¡ŞåőčèćńåžđäijäçżŹCçŽĎæŮűåĂŹïijŇèćńè¡ňæ■ćäÿžåŠŇäźŃåĽ■åŐ§ågŃCå■ŮçňęäÿšäÿĂæăůçŽĎå

èőÍèőž

æIJňèŁĆåśŢçd'žäžĘåIJÍæĽl'åśŢæÍąåİŮäÿ■åd'ĎçŘĘå■ŮçňęäÿšæŮűäijŽéĚ■åĹřçŽĎäÿĂäÿłæčŸæĽ'ŃåŔÍ
äź§åřśæŸŕèŕť'ïijŇåIJÍæĽl'åśŢäÿ■çŽĎCå■ŮçňęäÿšåŕŕèČ¡äÿ■äijŽäÿěæäijéĄţå¿łPythonæĽ'ĂæIJ§æIJŻçŽĎUn
åŻăæ■d'ïijŇå¿ĹåŔŕèČ¡äÿĂäžŽäÿ■åŘĹæäijCæŢřæ■őäijăéĂŠåĹřPythonäÿ■åŐżãĂĆ
äÿĂäÿłå¿Ĺåě¡çŽĎä¿Ńå■ŘåřśæŸŕæűĽ'åŔŁåĹřåžŢåśĆçşżçż§èřČçŤĺæŕŤåęĆæŰĞäžűåŘ■è£ŹæăůçŽĎå■Ůçňęä
ä¿ŃåęĆïijŇåęĆædIJäÿĂäÿłçşżçż§èřČçŤĺè£ŤåŻđçżŹèğčéĞŁåŹĺäÿĂäÿłæ■§åİŔçŽĎå■ŮçňęäÿšïijŇäÿ■èČ¡èćńa

äÿĂèĹňæİěèőšïijŇåŔŕäžěéĂŽè£ĞåĹűåőŽäÿĂäžŽéŤŹèŕŕç■ŰçŢěærŤåęĆäÿěæäijãĂĄå£¡çŢěãĂĄæŻ£äżč
äÿ■è£ĞïijŇè£ŹäžŽç■ŰçŢěçŽĎäÿĂäÿłçijžçĆźæŸŕåőČäžňærÿäźĚæĂğçăť'åİŔäžĘåŐ§ågŃå■ŮçňęäÿšçŽĎåĘĚ
ä¿ŃåęĆïijŇåęĆædIJä¿Ńå■Řäÿ■çŽĎäÿ■åŘĹæäijæŢřæ■őä¡£çŤĺè£ŹäžŽç■ŰçŢěäźŃäÿĂèğčçĂąïijŇä¡ăäijŽå¿Ů

```
>>> raw = b'Spicy Jalape\xc3\xb1o\xae'
>>> raw.decode('utf-8','ignore')
'Spicy JalapeÃśo'
>>> raw.decode('utf-8','replace')
'Spicy JalapeÃśo?'
>>>
```

surrogateescape éŤŹèŕŕåď'ĎçŘĘç■ŰçŢěäijŽářĘæĽ'ĂæIJĽ'äÿ■åŔŕèğčçăĄå■ŮèŁĆè¡ňåŇŰäÿžäÿĂä ä¿ŃåęĆïijŽ

```
>>> raw.decode('utf-8','surrogateescape')
'Spicy JalapeÃśo\udcae'
>>>
```

å■ŢçŃňçŽĎä¡Őä¡■äžčçŘĘå■Ůçňęæŕ'ŤåęĆ \udcae åIJÍUnicodeäÿ■æŸŕéİđæşŢçŽĎãĂĆ åŻăæ■ď'ïijŇè£ŹäÿŁå■ŮçňęäÿšářśæŸŕäÿĂäÿłéİđæşŢèąĺçď'žãĂĆ åőđéŹĚäÿŁïijŇåęĆæđIJä¡ååřĘåőČäijăäÿłäÿĂäÿłæĽ'ğèąŇè¿ŞåĞžçŽĎåĞ¡æŢřïijŇä¡ääijŽå¿ŮåĹřäÿĂäÿłéŤŹèŕŕ

```
>>> s = raw.decode('utf-8', 'surrogateescape')
>>> print(s)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
UnicodeEncodeError: 'utf-8' codec can't encode character '\udcae'
in position 14: surrogates not allowed
>>>
```

çĎűèĂŇïijŇåĚĄèőÿäžčçŘĘè¡ňæ■ćçŽĎåĚşéŤőçĆźåIJÍäžŐäžŐCäijăçżŹPythonåŔĹåŻđäijăçżŹCçŽĎäÿ■ å¡Şè£ŹäÿłåŮçňęäÿšåE■æňąä¡£çŤÍ surrogateescape çijŰçăĄæŮűïijŇäžčçŘĘå■ŮçňęäijŽè¡ňæ■ćåŻđåŐ

```
>>> s
'Spicy JalapeÃśo\udcae'
>>> s.encode('utf-8','surrogateescape')
b'Spicy Jalape\xc3\xb1o\xae'
>>>
```

ä¡IJäÿžäÿĂèĹňåĞĘåĹŹïijŇæIJĂåě¡éĄ£åĚ■äžčçŘĘçijŰçăĄâĂŤâĂŤåęĆæđIJä¡ăæ■čçąőçŽĎä¡£çŤÍäžĘçij äÿ■è£ĞïijŇæIJĽ'æŮűåĂŹçąőåőđäijŽåĞžçŐŕä¡ăåźűäÿ■èČ¡æŐğåĹűæŢŕæ■őçijŰçăĄåźűäÿŤä¡ăåŔĹäÿ■èČ¡å£¡ç éĆčäźĹåřśåŔŕäžěä¡£çŤÍæIJňèŁĆçŽĎæŁĂæIJŕäžĘãĂĆ

æIJĂåŘŐäÿĂçĆźèęĄæşÍæĎŘçŽĎæŸŕïijŇPythonäÿ■èőÿåď'ŽéİćåŘŚçşżçż§çŽĎåĞ¡æŢřïijŇçĽ'źåĹńæŸŕå éČ¡äijŽä¡£çŤÍäžčçŘĘçijŰçăĄãĂĆä¿ŃåęĆæđIJä¡ăä¡£çŤÍåČŘ os.listdir() è£ŹæăůçŽĎåĞ¡æŢřïijŇ äijååĚěäÿĂäÿłåŇĚåŘńäžĘäÿ■åŔŕèğčçăĄæŰĞäžűåŘ■çŽĎçŻőå¡ŢçŽĎèŕİïijŇåőČäijŽ åŔĆèĂČ5.15çŽĎçŻÿåĚşçńäèŁĆãĂĆ

PEP 383 äÿ■æIJĽ'æŻť'åď'ŽåĚşäžŐæIJňæIJžæŔŘåĹřçŽĎäžěåŔŁåŠŇsurrogateescapeéŤŹèŕŕåď'ĎçŘĘçŻÿåĚşçŽĎä£ąæĄŕãĂĆ

17.17 15.17 äijăéĂŠæŰĞäžůåŘ■çżŹCæĽľåśŢ

éŮőécŸ

ä¡ăéIJĂèęĄåŘŠCåžŞåĞ¡æŢřäijăéĂŠæŰĞäžůåŘ■ïijŇä¡ĘæŸŕéIJĂèęAçąőä£ÍæŰĞäžůåŘ■æăźæ■őçşżçż§a

èğčåĘşæŰźæąĹ

åĘŹäÿĂäÿłæŐěåŔŮäÿĂäÿłæŰĞäžůåŘ■äÿžåŔĆæŢřçŽĎæĽľåśŢåĞ¡æŢřïijŇåęĆäÿŃè£ŹæăůïijŽ

```
static PyObject *py_get_filename(PyObject *self, PyObject *args) {
  PyObject *bytes;
  char *filename;
  Py_ssize_t len;
  if (!PyArg_ParseTuple(args,"O&", PyUnicode_FSConverter, &bytes)) {
    return NULL;
  }
  PyBytes_AsStringAndSize(bytes, &filename, &len);
  /* Use filename */
  ...

  /* Cleanup and return */
  Py_DECREF(bytes)
  Py_RETURN_NONE;
}
```

åęĆædIJä¡ăåůšçżŔæIJL'äžĘäÿĂäÿł`PyObject *` ïijŇåÿŇæIJŻåřĘåĚűè¡ñæ■ćæĹŘäÿĂäÿłæŰĞäžůåŘ■ï

```
PyObject *obj;    /* Object with the filename */
PyObject *bytes;
char *filename;
Py_ssize_t len;

bytes = PyUnicode_EncodeFSDefault(obj);
PyBytes_AsStringAndSize(bytes, &filename, &len);
/* Use filename */
...

/* Cleanup */
Py_DECREF(bytes);

If you need to return a filename back to Python, use the following␣
↪code:

/* Turn a filename into a Python object */

char *filename;       /* Already set */
int   filename_len;   /* Already set */
```

```
PyObject *obj = PyUnicode_DecodeFSDefaultAndSize(filename, filename_
↪len);
```

èőÍèőž

äžěåŘŕçğžæď■æŰźåijŔæÍěåď ĎçŘĘæŰĞäžűåŘ■æŸŕäÿĂäÿłå¿ĹæčŸæĽŃçŽĎéŮőécŸïijŇæIJĂåŘŐäžď åęĆæđIJä¡ăåIJÍæĽľåśŢäžčçăĄäÿ■ä¡£çŤÍæIJňèŁĆçŽĎæŁĂæIJŕïijŇæŰĞäžűåŘ■çŽĎåď ĎçŘĘæŰźåijŔåŠŇåŠ åŇĚæŃňçijŰçăA/çŢŇéÍćå■ŮèŁĆïijŇåď ĎçŘĘåİŔå■Ůçňęïij Näžčç ŘĘè¡ňæ■ćåŠŇåĚűäžŮåď■æİĆæČĚåĘţãĂĆ

17.18 15.18 äijäéĂŠåůšæĽŞåijĂçŽĎæŰĞäžűçżŹCæĽľåśŢ

éŮőécŸ

ä¡ăåIJÍPythonäÿ■æIJL'äÿĂäÿłæĽŞåijĂçŽĎæŰĞäžűåŕźèśąïijŇä¡ĘæŸŕéIJĂèęĄåřĘåőČäijăçżŹèęĄä¡£çŤÍ

èğčåĘşæŰźæąĹ

èęĄåřĘäÿĂäÿłæŰĞäžűè¡ňæ■ćäÿžäÿĂäÿłæŢť'åđŃçŽĎæŰĞäžűæŔŔè£řçňęïijŇä¡£çŤÍ `PyFile_FromFd()` ïijŇåęĆäÿŃïijŽ

```
PyObject *fobj;     /* File object (already obtained somehow) */
int fd = PyObject_AsFileDescriptor(fobj);
if (fd < 0) {
   return NULL;
}
```

çżŞæđIJæŰĞäžűæŔŔè£řçňęæŸŕéĂŽè£ĞèřČçŤÍ `fobj` äÿ■çŽĎ `fileno()` æŰźæşŢèŐůå¿ŮçŽĎãĂĆ åŽăæ■ď'ïijŇäżžä¡Ţäžèè£Źçğ■æŰźåijŔæŽť'éIJšçżŹäÿĂäÿłæŔŔè£řåŹĺçŽĎåŕźèśąéČ äÿĂæŮęä¡ăæIJL'äžĘè£ŹäÿłæŔŔè£řåŹĺïijŇåőČåřśèČ¡èćńäijăéĂŠçżŹåď'Žäÿłä¡ŐçžğçŽĎåŘŕåď'ĎçŘĘæŰĞäžű

åęĆæđIJä¡ăéIJĂèęĄè¡ňæ■ćäÿĂäÿłæŢť'åđŃæŰĞäžűæŔŔè£řçňęäÿžäÿĂäÿłPythonåŕźèśąïijŇéĂĆçŤÍäÿŃé `PyFile_FromFd()`:

```
int fd;      /* Existing file descriptor (already open) */
PyObject *fobj = PyFile_FromFd(fd, "filename","r",-1,NULL,NULL,NULL,
↪1);
```

`PyFile_FromFd()` çŽĎåŔĆæŢřåŕźåžŤåĘĚç¡őçŽĎ `open()` åĞ¡æŢřãĂĆ NULL-LèąÍçď'žçijŰçăĄãĂĄéŤŹèŕŕåŠŇæ■ćèąŇåŔĆæŢřä¡£çŤÍéżŸèőď'åĂijãĂĆ

èőÍèőž

åęĆæđIJåřĘPythonäÿ■çŽĎæŰĞäžűåŕźèśąäijăçżŹCïijŇæIJL'äÿĂäžŽæşÍæĎŔäžŃéąźãĂĆ éęŰåĚĹïijŇPythonéĂŽè£Ğ `io` æÍąåİŮæL'ğèąŇèĞłåůśçŽĎI/OçijŞåĘšãĂĆ

åIJÍäijåéĂŠäżżä¡Ţçśżåđ́ÑçŽĎæŰĞäżűæŔŘè£řçňęçżŹCäźŃåĽ■ïijÑä¡ăéČ¡èęĄéęŰåĚĹåIJÍçŻÿåžŤæŰĞäżűåŕź
äÿ■çĎűçŽĎèŕİïijÑä¡ăäijŽæĽŞäźśæŰĞäżűçşżçż§äÿŁéİćçŽĎæŢřæ■őãĂĆ

åĚűæňąïijÑä¡ăéIJĂèęĄçĽźåĹńæşĺæĎŘæŰĞäżűçŽĎå¡Šåśđè ĂĚäżěåŘŁåĚşéŮ■æŰĞäżűçŽĎèĄÑèť čãĂĆ
åęĆæđIJäÿĂäÿłæŰĞäżűæŔŘè£řçňęèćńäijäçżŹCïijÑä¡ĘæŸŕåIJÍPythonäÿ■è£ŸåIJÍèćńä¡£çŤÍçİĂïijÑä¡ăéIJĂèę
çśżäijijçŽĎïijÑåęĆæđIJäÿĂäÿłæŰĞäżűæŔŘè£řçňęèćńè¡ňæ■ćäÿžäÿĂäÿłPythonæŰĞäżűåŕźèśąïijÑä¡ăéIJĂèęA
`PyFile_FromFd()` çŽĎæIJĂåŘŐäÿĂäÿłåŔĆæŢřèćńèő¿ç¡őæĹŘ1ïijÑçŤÍæİěæŇĞåĞżPythonåžŤèŕěåĚşéŮ

åęĆæđIJä¡ăéIJĂèęĄäżŐCæăĞåĞĘI/OåžŞäÿ■ä¡£çŤÍåęĆãĂĂ`fdopen()`
åĞ¡æŢřæİěåĹŻåžžäÿ■åŘÑçśżåđ́ÑçŽĎæŰĞäżűåŕźèśąæŕŤåęĆ `FILE *` åŕźèśąïijÑ
ä¡ăéIJĂèęĄçĽźåĹńåřŔå£ČäžĘãĂĆè£ŹæăůåĄŽäijŽåIJÍI/OåäĘæăĹäÿ■äžğçŤ§äÿď äÿłåőÑåĚÍäÿ■åŘÑçŽĎI/Oç
ïijĹäÿĂäÿłæŸŕæİěèĞłPythonçŽĎ `io` æĺąåİŮïijÑåŔęäÿĂäÿłæİěèĞłCçŽĎ `stdio`
ïijĽãĂĆ åČŔCäÿ■çŽĎ `fclose()` äijŽåĚşéŮ■PythonèęĄ¡£çŤÍçŽĎæŰĞäżűãĂĆ
åęĆæđIJèőľä¡ăéĂĽçŽĎèŕİïijÑä¡ăåžŤèŕěäijŽéĂĽæŃľåŐżæđĎåžžäÿĂäÿłæĽľåšŢäžčçĄąæİěåď ĎçŘĘåžŢåśĆ
èĂÑäÿ■æŸŕä¡£çŤÍæİěèĞł<stdio.h>çŽĎéńŸåśĆæŁ¡èśąåŁ§èČ¡ãĂĆ

17.19 15.19 äžŐCèŕ■èÍĂäÿ■èŕżåŘŰçśżæŰĞäżűåŕźèśą

éŮőécŸ

ä¡ăèęĄåĘŹCæĽľåšŢæİěèŕżåŘŰæİěèĞłäżżä¡ŢPythonçśżæŰĞäżűåŕźèśąäÿ■çŽĎæŢřæ■őïijĹæŕŤåęĆæŹőé

èğčåĘşæŰźæąĹ

èęĄèŕżåŘŰäÿĂäÿłçśżæŰĞäżűåŕźèśąçŽĎæŢřæ■őïijÑä¡ăéIJĂèęĄéĞ■åď■èřČçŤÍ
`read()` æŰźæşŢïijÑçĎűåŘŐæ■čçąőçŽĎèğčçăĄèŐůå¿ŮçŽĎæŢřæ■őãĂĆ

äÿŃéİćæŸŕäÿĂäÿłCæĽľåšŢåĞ¡æŢřä¿Ńå■ŘïijÑäžĚäžĚåŘłæŸŕèŕżåŘŰäÿĂäÿłçśżæŰĞäżűåŕźèśąäÿ■çŽĎ

```
#define CHUNK_SIZE 8192

/* Consume a "file-like" object and write bytes to stdout */
static PyObject *py_consume_file(PyObject *self, PyObject *args) {
  PyObject *obj;
  PyObject *read_meth;
  PyObject *result = NULL;
  PyObject *read_args;

  if (!PyArg_ParseTuple(args,"O", &obj)) {
    return NULL;
  }

  /* Get the read method of the passed object */
  if ((read_meth = PyObject_GetAttrString(obj, "read")) == NULL) {
    return NULL;
  }

  /* Build the argument list to read() */
  read_args = Py_BuildValue("(i)", CHUNK_SIZE);
```

```
  while (1) {
    PyObject *data;
    PyObject *enc_data;
    char *buf;
    Py_ssize_t len;

    /* Call read() */
    if ((data = PyObject_Call(read_meth, read_args, NULL)) == NULL)
↪{
      goto final;
    }

    /* Check for EOF */
    if (PySequence_Length(data) == 0) {
      Py_DECREF(data);
      break;
    }

    /* Encode Unicode as Bytes for C */
    if ((enc_data=PyUnicode_AsEncodedString(data,"utf-8","strict
↪"))==NULL) {
      Py_DECREF(data);
      goto final;
    }

    /* Extract underlying buffer data */
    PyBytes_AsStringAndSize(enc_data, &buf, &len);

    /* Write to stdout (replace with something more useful) */
    write(1, buf, len);

    /* Cleanup */
    Py_DECREF(enc_data);
    Py_DECREF(data);
  }
  result = Py_BuildValue("");

 final:
  /* Cleanup */
  Py_DECREF(read_meth);
  Py_DECREF(read_args);
  return result;
}
```

èęĄæţŃèŕŢè£ŹäÿłäžčçăĄïijŇåĚĹæđĎéĂăäÿĂäÿłçśżæŰĞäžűåŕźèśąæŕŤåęĆäÿĂäÿłStringIOåőđä¿ŃïijŇç

```
>>> import io
>>> f = io.StringIO('Hello\nWorld\n')
>>> import sample
>>> sample.consume_file(f)
```

```
Hello
World
>>>
```

èőÍèőž

åŠÑæŹőéĂŽçşżçż§æŰĞäżűäÿ■åŘÑçŽĎæŸŕïijÑäÿĂäÿłçśżæŰĞäżűåŕźèśąåźűäÿ■éIJĂèęĄä¡£çŤÍä¡ŐçžğåŻăæ■ď˙ïijÑä¡ăäÿ■èČ¡ä¡£çŤÍæŹőéĂŽçŽĎCåžŞåĞ¡æŢřæİèèő£éŮőåőČãĂĆä¡ăéIJĂèęĄä¡£çŤÍPythonçŽĎC APIæİěåČŔæŹőéĂŽæŰĞäżűçśżäijijçŽĎéĆčæăůæŞ■ä¡IJçśżæŰĞäżűåŕźèśąãĂ

åIJÍæĹŚäżňçŽĎèğčåEşæŰźæąĹäÿ■ïijÑread() æŰźæşŢäżŐèćńäijăéĂŠçŽĎåŕźèśąäÿ■æŔŘåŔŰåĞžæİěäÿĂäÿłåŔĆæŢřåĹŮèąÍèćńæđĎåżžçĎűåŘŐäÿ■æŰ■çŽĎèćńäijăçżŹ PyObject_Call() æİèèřČçŤÍè£ŹäÿłæŰźæşŢãĂĆ èęĄæčĂæ§ěæŰĞäżűæIJńår¿ïijĹEOFïijL’ïijÑä¡£çŤÍäžĘ PySequence_Length() æİěæ§ěçIJÑæŸŕåŘęè£ŤåŻđåŕźèśąéŢ£åžęäÿž0.

åŕźäžŐæL’ĂæIJL’çŽĎI/OæŞ■ä¡IJïijÑä¡ăéIJĂèęĄåĚşæşĺåžŢåśĆçŽĎçijŰçăĄæäijåijŔïijÑè£ŸæIJL’å■ŮèŁæIJñèŁĆæijŤçd’žäžĘåęĆä¡ŢäžěæŰĞæIJñæĺąåijŔèŕžåŔŰäÿĂäÿłæŰĞäżűåźűåřĘçżŞæđIJæŰĞæIJñèğčçăĄäÿžåęĆæđIJä¡ăæČşäžěäžÑè£ŻåĹűæĺąåijŔèŕžåŔŰæŰĞäżűïijÑåŘłéIJĂèęĄä£őæŤźäÿĂçĆźçĆźå■şåŔŕïijÑä¿ŃåęĆ

```
...
/* Call read() */
if ((data = PyObject_Call(read_meth, read_args, NULL)) == NULL) {
  goto final;
}

/* Check for EOF */
if (PySequence_Length(data) == 0) {
  Py_DECREF(data);
  break;
}
if (!PyBytes_Check(data)) {
  Py_DECREF(data);
  PyErr_SetString(PyExc_IOError, "File must be in binary mode");
  goto final;
}

/* Extract underlying buffer data */
PyBytes_AsStringAndSize(data, &buf, &len);
...
```

æIJñèŁĆæIJĂéŽ¿çŽĎåIJřæŰźåIJÍäžŐåęĆä¡Ţè£ŻèąÑæ■čçąőçŽĎåĘĚå■ŸçőąçŘĘãĂĆ å¡Şåď˙ĎçŘĘ PyObject * åŔŸéĞŔçŽĎæŮűåĂŹïijÑéIJĂèęĄæşĺæĎŔçőąçŘĘåijŢçŤÍèőąæŢřäžěåŘŁåIJÍäÿ■åŕź Py_DECREF() çŽĎèřČçŤÍåřśæŸŕæİěåĄŽè£ŹäÿłçŽĎãĂĆ

æIJñèŁĆäžčçăĄäżěäÿĂçğ■éĂŽçŤÍæŰźåijŔçijŰåĘŹïijÑåŻăæ■ď˙äžŰäź§èČ¡éĂĆçŤÍäžŐåĚűäżŰçŽĎæŰĞä¿ŃåęĆïijÑèęĄåĘŹæŢřæ■őïijÑåŘłéIJĂèęĄèŐůåŔŰçśżæŰĞäżűåŕźèśąçŽĎ write() æŰźæşŢïijÑåřĘæŢřæ■őè¡ñæ■ćäÿžåŘĹéĂĆçŽĎPythonåŕźèśą ïijĹå■ŮèŁĆæĹŰUnicodeïijL’ïijÑçĎűåŘŐèřČçŤÍèřěæŰźæşŢåřĘè¿ŞåĚěåĘŹåĚěåĹřæŰĞäżűãĂĆ

æIJĂåŘŐïijÑår¡çőąçśżæŰĞäżűåŕźèśąéĂŽåÿÿè£ŸæŔŘä¿ŻåĚűäżŰæŰźæşŢïijĹærŤåęĆreadline(),

read_info()ïijL'ïijÑ æĹŚäžňæIJĂåě¡åŔłä¡£çŤĺå§žæIJňçŽĎ `read()` åŠŇ `write()` æŰźæşŢãĂĆ åIJĺåĘŹCæL'ľåśŢçŽĎæŮűåĂŹïijŇèČ¡çőĂå■Ţåřśår¡éĞŔçőĂå■ŢãĂĆ

17.20 15.20 åďĎçŘĘCèń■èĺĂäÿ■çŽĎåŔŕè£■äžčåŕźèśą

éŮőécŸ

ä¡ăæČşåĘŹCæL'ľåśŢäžčçăĄåď'ĎçŘĘæİěèĞłäżżä¡ŢåŔŕè£■äžčåŕźèśąåęĆåĹŮèąĺãĂĄåĚČçżĎãĂĄæŰĞä

èğčåĘşæŰźæąĹ

äÿŃéİćæŸŕäÿĂäÿłCæL'ľåśŢåĞ¡æŢřä¿Ńå■ŘïijŇæijŤçď'žäžĘæĂŐæăůåď'ĎçŘĘåŔŕè£■äžčåŕźèśąäÿ■çŽĎå

```
static PyObject *py_consume_iterable(PyObject *self, PyObject␣
↪*args) {
  PyObject *obj;
  PyObject *iter;
  PyObject *item;

  if (!PyArg_ParseTuple(args, "O", &obj)) {
    return NULL;
  }
  if ((iter = PyObject_GetIter(obj)) == NULL) {
    return NULL;
  }
  while ((item = PyIter_Next(iter)) != NULL) {
    /* Use item */
    ...
    Py_DECREF(item);
  }

  Py_DECREF(iter);
  return Py_BuildValue("");
}
```

èőÍèőž

æIJňèŁĆäÿ■çŽĎäžčçăĄåŠŇPythonäÿ■åŕźåžŤäžčçăĄçśżäijijãĂĆ `PyObject_GetIter()` çŽĎèřČçŤĺåŠŇèřČçŤÍ `iter()` äÿĂæăůåŔŕèŐůå¿ŮäÿĂäÿłè£■äžčåŹĺãĂĆ `PyIter_Next()` åĞ¡æŢřèřČçŤÍ `next` æŰźæşŢè£ŤåŻđäÿŃäÿĂäÿłåĚČçť'ăæĹŰNULL(åęĆæđIJæšąæIJL'åĚČçť'ääžĘ)ãĂĆ èęĄæşÍæĎŔæ■čçąőçŽĎåĘĚå■ŸçőąçŘĘâĂŤâĂŤ `Py_DECREF()` éIJĂèęĄåŘŇæŮűåIJĺäžğçŤ§çŽĎåĚČçť'ääŠŇè£■äžčåŹĺåŕźèśąæIJňèžńäÿŁåŘŇæŮűèćńèřČçŤĺïijŇ äžěéĄ£åĚ■åĞžçŐřåĘĚå■ŸæşĎéIJšãĂĆ

17.21 15.21 èŕŁæŰ■åĹĘæőţéŤŹèŕŕ

éŮőécŸ

èğčéĞŁåŹĺåŽääÿžæ§Řäÿłå Ĺ Ęæőţé ŤŹèŕŕãĂĄæĂżçž£éŤŹèŕŕãĂĄèő£éŮőèűŁçŢŇæĹŰåĚűäžŰèĞťåŚ¡éŤ
ä¡ăæČşèŐůå¿ŮPythonåăĘæăĹä£ąæĄŕïijŇäžŐèĂŇæĽ¿åĞžåIJĺåŔŚçŤ§éŤŹèŕŕçŽĎæŮűåĂŹä¡äçŽĎçÍŃåžŔè£

èğčåĘşæŰźæąĹ

faulthandler æĺąåİŮèČ¡èćńçŤĺæİěåÿőä¡äèğčåĘşè£ŹäÿłéŮőécŸãĂĆ
åIJĺä¡äçŽĎçÍŃåžŔäÿ■åijŢåĚěäÿŃåĹŮäžčçăĄïijŽ

```
import faulthandler
faulthandler.enable()
```

åŔęåď Űè£ŸåŔŕäžěåČŔäÿŃéİćè£ŹæăůäĄ£çŤÍ -Xfaulthandler
æİěè£ŘèąŇPythonïijŽ

```
bash % python3 -Xfaulthandler program.py
```

æIJĂåŘŐïijŇä¡ääŔŕäžěèő¿ç¡ő PYTHONFAULTHANDLER çŐŕåćČåŔŸéĞŔãĂĆ åijĂåŘŕ-
faulthandleråŘŐïijŇåIJÍCæĽľåśŢäÿ■çŽĎèĞťåŚ¡éŤŹèŕŕäijŽåŕijèĞťäÿĂäÿłPythonéŤŹèŕŕääĘæăĹèćńæĽŞå■ř

```
Fatal Python error: Segmentation fault

Current thread 0x00007fff71106cc0:
  File "example.py", line 6 in foo
  File "example.py", line 10 in bar
  File "example.py", line 14 in spam
  File "example.py", line 19 in <module>
Segmentation fault
```

ař¡çőąè£Źäÿłåźűäÿ■èČ¡åŚŁèŕĽä¡ăCäžčçăĄäÿ■åŞłéĞŇåĞžéŤŹäžĘïijŇä¡ĘæŸŕèĞşařŚèČ¡åŚŁèŕĽä¡ăPyth

èőÍèőž

faulthandleräijŽåIJÍPythonäžčçăĄæĽğèąŇåĞžéŤŹçŽĎæŮűåĂŹåŘŚä¡ääśŢçd'žèů§èÿłä£ąæĄŕãĂĆ
èĞşařŚïijŇåőČäijŽåŚŁèŕĽä¡ääĞžéŤŹæŮűèćńèřČçŤÍçŽĎæIJĂéąűçžğæĽľåśŢåĞ¡æŢřæŸŕåŞłäÿłãĂĆ
åIJÍpdbåŠŇåĚűäžŰPythonèřČèŕŢåŹÍçŽĎåÿőåŁľäÿŃïijŇä¡ääřśèČ¡è£¡æăźæžŕæžŘæĽ¿åĹŕéŤŹèŕŕæĽĂåIJÍçŽĎ

faulthandleräÿ■äijŽåŚŁèŕĽä¡ääżžä¡ŢCèŕ■èÍĂäÿ■çŽĎéŤŹèŕŕä£ąæĄŕãĂĆ
åŻăæ■ď ïijŇä¡ăéIJĂèęĄä¡£çŤÍäijăçż§çŽĎCèřČèŕŢåŹÍïijŇæŕŤåęĆgdbãĂĆ
äÿ■è£ĞïijŇåIJÍfaulthandlerè£¡èÿłä£ąæĄŕåŘŕäžěèőľä¡ääŐżåĹď æŰ■äžŐåŞłéĞŇçİĂæĽŃãĂĆ
è£ŸèęĄæşÍæĎŘçŽĎæŸŕåIJÍCäÿ■æ§ŘäžŽçśžåđŃçŽĎéŤŹèŕŕåŘŕèČ¡äÿ■åď łåőźæŸŞæĄćåď ■ãĂĆ
ä¿ŃåęĆïijŇåęĆæđIJäÿĂäÿłCæĽľåśŢäÿćåijČäžĘçÍŃåžŘåăĘæăĹä£ąæĄŕïijŇåőČäijŽèőľ faulthandleräÿ■åŘŕçŤ
éĆčäźĹä¡ääź§å¿Ůäÿ■åĹřäžžä¡Ţè¿ŞåĞžïijĹéŹď äžĘçÍŃåžŘåěŤæžČåď ŰïijL'ãĂĆ

18 éŹĎå¡ŢA

18.1 åIJÍçž£èţĎæžŘ

http://docs.python.org

åęĆæđIJä¡ăéIJĂèęĄæůśåĚěäžĘèğčæŐćçľ˝űèŕ■èÍĂåŠŇæÍąåİŮçŽĎçżĘèŁĆïijŇéĆčäźĹäÿ■å£Ěèŕť˝ïijŇPyth
3 çŽĎæŰĞæąčèĂŇäÿ■æŸŕäžěåL’■çŽĎèĂĄçL’ĹæIJň

http://www.python.org/dev/peps

åęĆæđIJä¡ăåŘŠçŘĘèğčäÿžpythonèŕ■èÍĂæůżåŁăæŰřçL’źæĂğçŽĎåŁÍæIJžäžěåŔŁåőđçŐřçŽĎçżĘèŁĆïijŇ
Enhancement ProposalsâĂŤ-PythonåijĂåŔŠçijŰçăĄèğĎèŇČïijL’çżİåŕźæŸŕéİđåÿÿåőİèť˝tçŽĎèţĎæžŘãĂĆåřď

http://pyvideo.org

è£ŹéĞŇæIJL’æİěèĞłæIJĂè£ŠçŽĎPyConåď˝ğäijŽãĂĄçŤÍæĹůçżĎèğĄéİćäijŽç■L’çŽĎåď˝ğéĞŔèğĘéćŚæi
3äÿ■æůżåŁăçŽĎçŽĎæŰřçL’źæĂğãĂĆ

http://code.activestate.com/recipes/langs/python

éŢ£æIJ§äžěæİěïijŇActiveStateçŽĎPythonçL’ĹåİŮåůšçżŔæĹŘäÿžäÿĂäÿłæL’¿åĹřæŢřäžěå■Čè őąçŽĎéŠĹ

http://stackoverflow.com/questions/tagged/python

Stack Overflow çŻőåL’■æIJL’èűĚè£Ğ175,000äÿłéŮőécŸècńæăĞèőřäÿžPythonçŻÿåĚşïijÍèĂŇåĚűäÿ■åď
3çŽĎïijL’ãĂĆår¡çőąéŮőécŸåŠŇåŻđç■ŤçŽĎèť˝íéĞŔäÿ■åŘŇïijŇä¡ĘæŸŕäż■çĎűèČ¡åŔŠçŐřå¿Ĺåď˝Žåě¡äijŸçğ

18.2 Pythonå■ęäźžääźęçś■

äÿŇéİćè£ŹäžŻäźęçś■æŔŘä¿ŻäžĘåŕźPythonçijŰçĺŇçŽĎåĚěéŮĺäżŇçż■ïijŇäÿŤéĞ■çĆźæŤ¿åIJĺäžĘPytho
3äÿŁãĂĆ

- *Learning Python*ïijŇçňňåŻŻçL’Ĺ ïijŇä¡IJèĂĚ Mark LutzïijŇ OâĂŹReilly & Associates åĞžçL’Ĺ (2009)ãĂĆ
- *The Quick Python Book*ïijŇä¡IJèĂĚ Vernon CederïijŇ Manning åĞžçL’Ĺ(2010)ãĂĆ
- *Python Programming for the Absolute Beginner*ïijŇçňňäÿL’çL’ĹïijŇä¡IJèĂĚ Michael DawsonïijŇCourse Technology PTR åĞžçL’Ĺ(2010).
- *Beginning Python: From Novice to Professional*ïijŇçňňäžŇçL’ĹïijŇ ä¡IJèĂĚ Magnus Lie HetâĂŘ landïijŇ Apress åĞžçL’Ĺ(2008).
- *Programming in Python 3*ïijŇçňňäžŇçL’ĹïijŇä¡IJèĂĚ Mark SummerfieldïijŇAddison-Wesley åĞžçL’Ĺ (2010).

18.3 énŸçžğäźęçś■

äÿŇéİćçŽĎè£ŹäžŻäźęçś■æŔŘä¿ŻäžĘæŻť˝åď˝ŽéńŸçžğçŽĎèŇČåŻť˝ïijŇäź§åŇĚåŘńPython
3æŰźéİćçŽĎåĘĚåőźãĂĆ

- *Programming Python*ïijŇçňňåŻŻçL'Ĺ, by Mark Lutz, OâĂŹReilly & Associates åĞžçL'Ĺ(2010).
- *Python Essential Reference*ïijŇçňňåŻŻçL'ĹïijŇä¡IJèĂĚ David Beazley, Addison-Wesley åĞžçL'Ĺ(2009).
- *Core Python Applications Programming*ïijŇçňňäÿL'çL'ĹïijŇä¡IJèĂĚ Wesley Chun, Prentice Hall åĞžçL'Ĺ(2012).
- *The Python Standard Library by Example* ïijŇ ä¡IJèĂĚ Doug HellmannïijŇAddison-Wesley åĞžçL'Ĺ(2011).
- *Python 3 Object Oriented Programming*ïijŇä¡IJèĂĚ Dusty Phillips, Packt Publishing åĞžçL'Ĺ(2010).
- *Porting to Python 3*ïijŇ ä¡IJèĂĚ Lennart RegebroïijŇCreateSpace åĞžçL'Ĺ(2011), http://python3porting.com.

19 åĚşäžŐèŕŚèĂĚ

åĚşäžŐèŕŚèĂĚ

- åğŞåŘ■ïijŽ çĘŁèČ¡
- å¿ő䣤ąïijŽ yidao620
- EmailïijŽ yidao620@gmail.com
- å■Žåőćïij Ž https://www.xncoding.com/
- GitHubïijŽ https://github.com/yidao620c

---

20 Roadmap

2014/08/10 - 2014/08/31:

```
|    githubéąźçŻőæŘ■åżžïijŇreadthedocsæŰĞæąčçŤ§æĹŘãĂĆ
|    æŢt'äÿłéąźçŻőçŽĎæąĘæđůåőŇæĹŘ
```

2014/09/01 - 2014/10/31:

```
|    åL'■4çńăç£żèŕŚåőŇæĹŘ
```

2014/11/01 - 2015/01/31:

```
|    åL'■8çńăç£żèŕŚåőŇæĹŘ
```

2015/02/01 - 2015/03/31:

```
|     åL’■9çńăç£żèŕŚåőŇæĹŘ
```

2015/04/01 - 2015/05/31:

```
|     10çńăç£żèŕŚåőŇæĹŘ
```

2015/06/01 - 2015/06/30:

```
|     11çńăç£żèŕŚåőŇæĹŘ
```

2015/07/01 - 2015/07/31:

```
|     12çńăç£żèŕŚåőŇæĹŘ
```

2015/08/01 - 2015/08/31:

```
|     13çńăç£żèŕŚåőŇæĹŘ
```

2015/09/01 - 2015/11/30:

```
|     14çńăç£żèŕŚåőŇæĹŘ
```

2015/12/01 - 2015/12/20:

```
|     15çńăç£żèŕŚåőŇæĹŘ
```

2015/12/21 - 2015/12/31:

```
|     åŕźåĚĺéČĺç£żèŕŚè£ŻèąŇæăąåŕźäÿĂæňą
```

2016/01/01 - 2016/01/10:

```
|     åŕźåd’ŰåĚňåijĂåŔŚåÿČåőŇæŢt’çL’Ĺ1.
↪0ïijŇåŇĚæŃňè¡ňæ■ćåŘŐçŽĎPDFæŰĞäżű
```