Pymunk tutorial

Release 2019

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CHAPTER 1

Introduction

This tutorial shows how to make applications with the **2D physics** framework Pymunk in an object-oriented programming style.

1.1 About the naming of variables

Before we get started, get familiar with some conventions used in this tutorial. In order to make the programs simple and short, we will use short variable names.

- `b` stands for **Body**
- `c` stands for **Constraint**
- `s` stands for **Shape**

An important class is the `Vec2d` class which indicates either the absolute position of a point in space, or the direction vector between two points.

- `p` stands for **position**
- `v` stands for **vector**

We could define a vector as the difference between two points in space:

```
v = p1 - p0
```

A final `s` serves as a plural marker.

- `bs` is a list of **bodies**
- `ps` is a list of **positions**
- `vs` is a list of **vectors**

We can use the plural marker in a loop structure such as:

```
for b in bs:
    print(b)
```

The static body is used frequently, so we give it the short name `b0`

```
b0 = space.static_body
```

1.2 The abstract Body

The `Body` class describes the physical aspects of an objects. These aspects cannot be seen, but describe how it moves. Six properties describe the state of a body

- `mass` - how heavy it is
- `moment` - it's resistance to rotation
- `position` - it's spatial location
- `angle` - the current orientation
- `velocity` - how fast and in which direction it is moving
- `angular_velocity` - how fast in which direction it is rotatting

1.3 A bouncing ball

We start this tutorial with a simple bouncing ball simulation. The first thing we need to do is to import the `pymunk` and the `pygame` module:

```
import pymunk
import pymunk.pygame_util
import pygame
```

Then we initialize the Pygame module and define the `screen` surface where we are going to draw the simulation result. Pymunk comes with a simple draw option which can be used for quick prototyping:

```
pygame.init()
size = 640, 240
screen = pygame.display.set_mode(size)
draw_options = pymunk.pygame_util.DrawOptions(screen)
```

The 2D physics simulation takes place in a `Space` object. We define `space` as a global variable and assign it a gravity vector:

```
space = pymunk.Space()
space.gravity = 0, -900
```

To create a fixed ground for our object we create a `Segment` shape attached to the static body `b0`. In order to make the ball bounce, we give it an elasticity of 1:

```
b0 = space.static_body
segment = pymunk.Segment(b0, (0, 0), (640, 0), 4)
segment.elasticity = 1
```

Next, we create a dynamic body and give it a mass, moment and position:

```
body = pymunk.Body(mass=1, moment=10)
body.position = 100, 200
```

Then we create a `Circle` shape and attach it to the body:

```
circle = pymunk.Circle(body, radius=20)
circle.elasticity = 0.95
```

Finally we add the `body`, `circle` and `segment` to the `space`. Now we are ready for simulation:

```
space.add(body, circle, segment)
```

In the last part we start the Pygame event loop. The only event we are going to detect is the QUIT event:

```
running = True
while running:
    for event in pygame.event.get():
        if event.type == pygame.QUIT:
            running = False
```

In the latter part of the event loop we draw the obejcts. First we fill the screen with a gray background color. Then we draw the two objects with the `space.debug_draw()` function, call the display update function, and finally step the simulation forward by 0.01 time units:

```
    screen.fill(GRAY)
    space.debug_draw(draw_options)
    pygame.display.update()
    space.step(0.01)

pygame.quit()
```

`intro1.py`

1.4 Creating an App class

To simplfy the tutorial examples we will create a reusable `App` class which will run the simulation. This class will:

- initialize Pygame
- create a `screen` object

- create a space object
- set the draw option
- run the event loop
- draw the objects to the screen

Here is the class definition with the constructor method:

```
class App:
    def __init__(self):
        pygame.init()
        self.screen = pygame.display.set_mode((700, 240))
        self.draw_options = pymunk.pygame_util.DrawOptions(self.screen)
        self.running = True
```

The App class has a run() method which runs the Pygame event loop:

```
def run(self):
    while self.running:
        for event in pygame.event.get():
            if event.type == pygame.QUIT:
                self.running = False
                pygame.image.save(self.screen, 'intro.png')

        self.screen.fill((220, 220, 220))
        space.debug_draw(self.draw_options)
        pygame.display.update()
        space.step(0.01)

    pygame.quit()
```

intro.py

1.5 A ball rolling down slope

We can now import pymunk, space and the App class:

```
from intro import pymunk, space, App
```

Let's define an inclined segment and give it friction:

```
segment = pymunk.Segment(space.static_body, (20, 120), (400, 20), 1)
segment.elasticity = 0.5
segment.friction = 0.5
```

The circle shape also needs friction, in order to roll. Whithout friction it would just glide down the slope:

```
circle = pymunk.Circle(body, radius=20)
circle.elasticty = 0.5
circle.friction = 0.5
space.add(body, circle, segment)
```

Finally we instantiate the app and call the run() method:

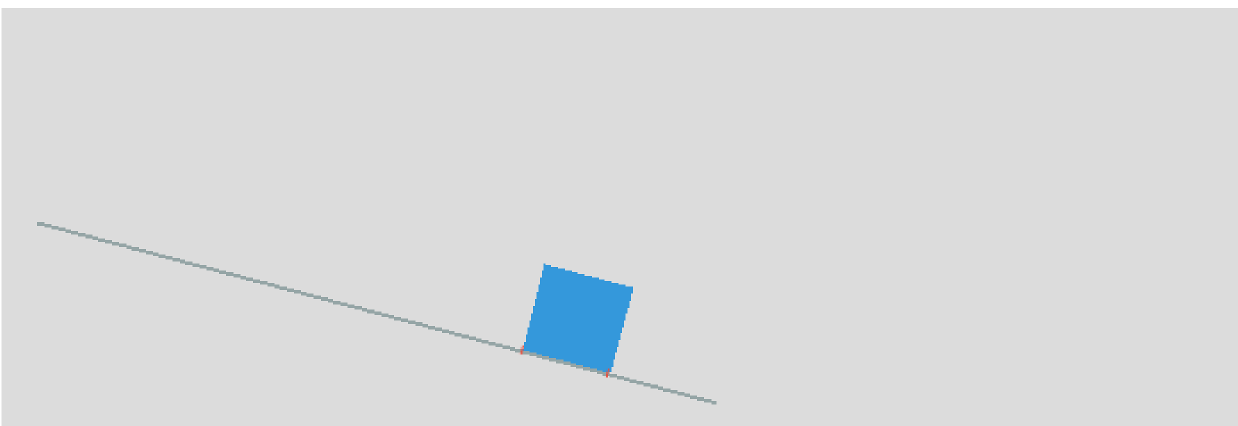
```
App().run()
```

intro2.py

1.6 A block sliding down a slope

The `Poly` class has a method to create box shapes. Without elasticity it slides down the slope:

```
box = pymunk.Poly.create_box(body, (50, 50))
space.add(body, box, segment)
```



intro3.py

1.7 A block tumbling down a slope

Now we add elasticity to the box shape. It tumbles down the slope:

```
box = pymunk.Poly.create_box(body, (50, 50))
box.elasticity = 0.95
space.add(body, box, segment)
```

intro4.py

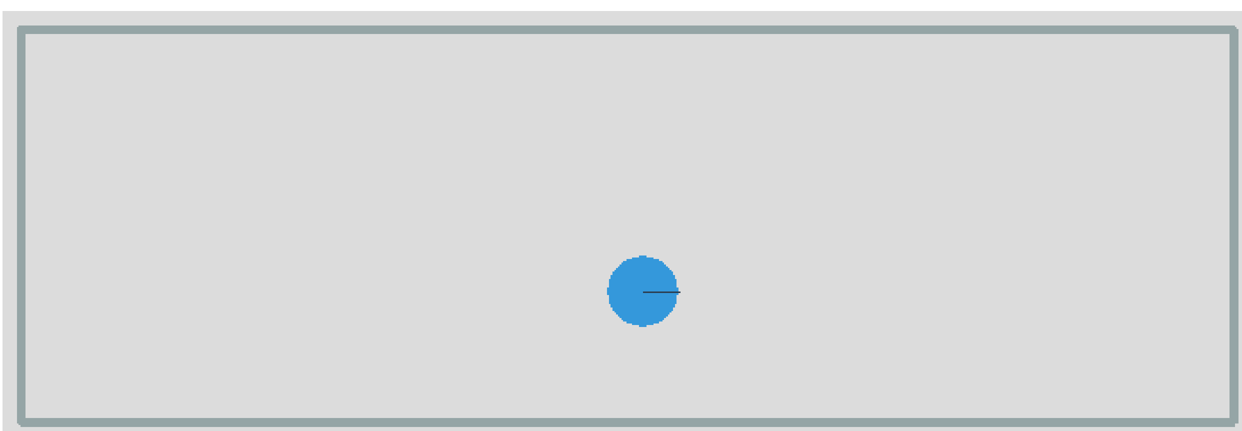
1.8 A ball inside a box

In order to draw a closed box where objects can bounce, we must get the 4 corner points. From those we can create 4 segments. We give them an elasticity of 0.999 as a value of 1 or larger can lead to an instable system:

```
pts = [(10, 10), (690, 10), (690, 230), (10, 230)]
for i in range(4):
    seg = pymunk.Segment(space.static_body, pts[i], pts[(i+1)%4], 2)
    seg.elasticity = 0.999
    space.add(seg)
```

In order to give the ball an inital lateral movement we apply an impulse vector of (100, 0) to it at initialization:

```
body = pymunk.Body(mass=1, moment=10)
body.position = (100, 200)
body.apply_impulse_at_local_point((100, 0))
```

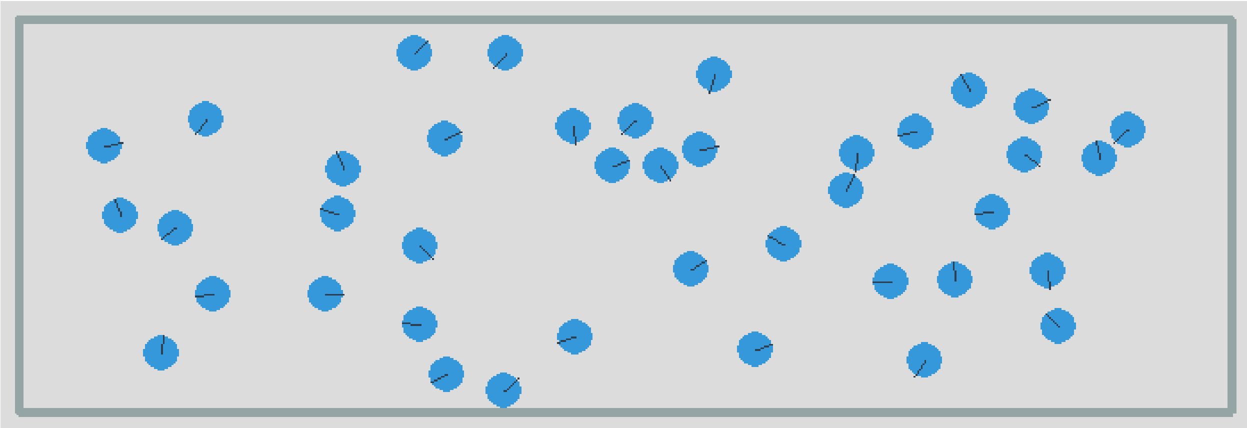


intro5.py

1.9 Many particles in a box

In order to simulate many particles in a box, we first turn off gravity. The we create a large number of particles at random location and give them random impulses as a starting movement:

```
space.gravity = 0, 0
for i in range(40):
    body = pymunk.Body(mass=1, moment=10)
    body.position = randint(40, 660), randint(40, 200)
    impulse = randint(-100, 100), randint(-100, 100)
    body.apply_impulse_at_local_point(impulse)
    circle = pymunk.Circle(body, radius=10)
    circle.elasticity = 0.999
    circle.friction = 0.5
    space.add(body, circle)
```



intro6.py

1.10 Pin joint

A PinJoint links two bodies with a solid link or pin. For all static points of attachement we use the same space.static_body which has its default position at (0, 0):

```
b0 = space.static_body
```

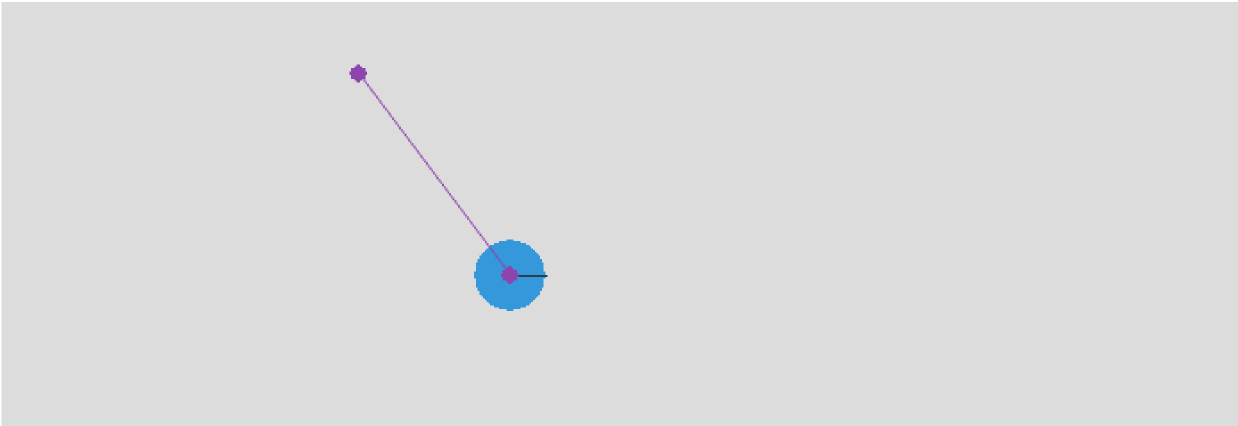
As the dynamic body we place a sphere at (100, 100):

```
body = pymunk.Body(mass=1, moment=10)
body.position = (100, 100)
circle = pymunk.Circle(body, radius=20)
```

The PinJoint methode takes 2 bodies and their local positions as argument. We place the static body b0's anchor at (200, 200) and leave the dynamic body at its default anchor of (0, 0). This creates a pin between static point (200, 200) and dynamic point (100, 100):

```
joint = pymunk.constraint.PinJoint(b0, body, (200, 200))
```

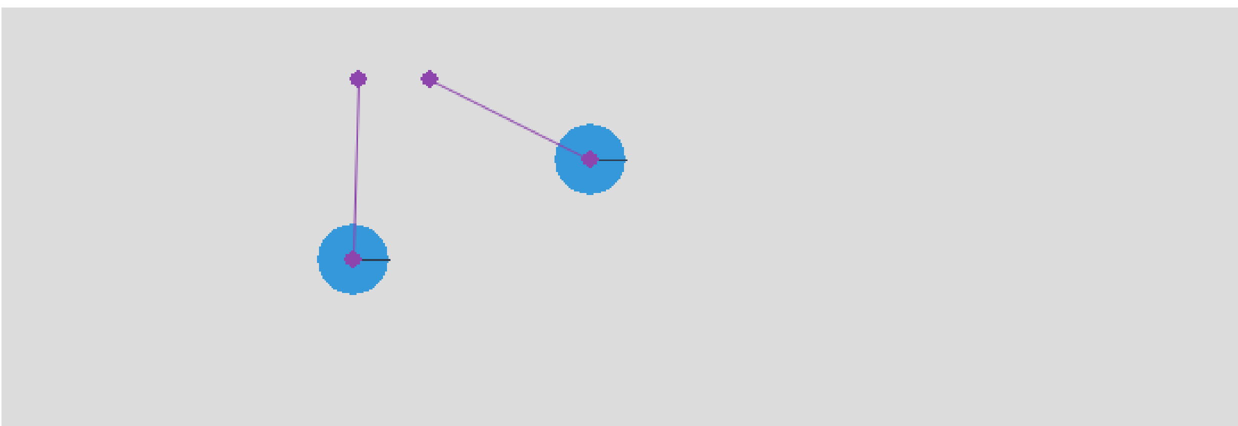
Due to gravity, the pendulum starts swinging.



intro7.py

1.11 Double pendulum

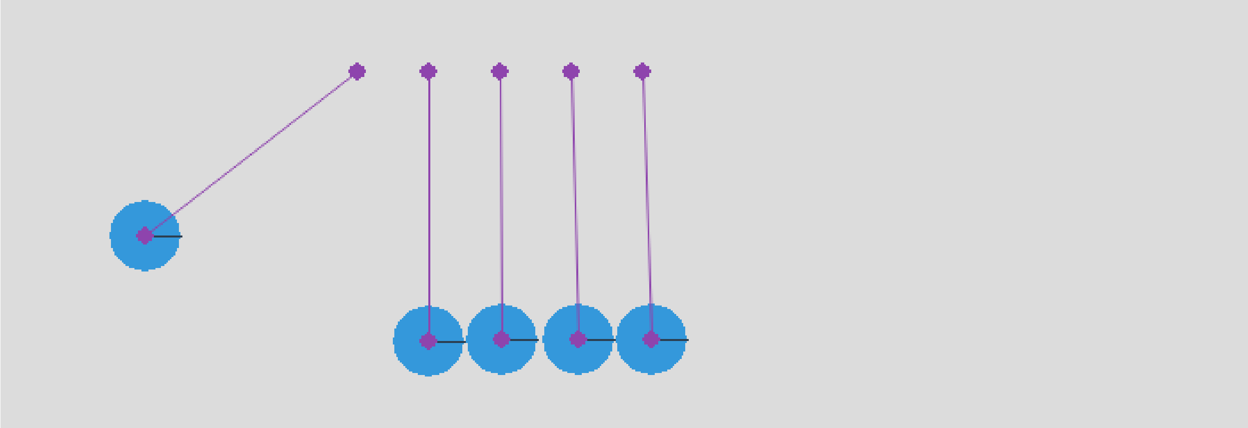
If a moving eleastic pendulum hits another pendulum of the same mass, the energy is entirely transferred to the second object.



intro8.py

1.12 Newton's cradle

Newton's cradle is a device that demonstrates conservation of momentum and energy using a series of swinging spheres.



intro9.py

CHAPTER 2

Shapes

In this section we look at different shapes. Shapes are attached to bodies. There are three basic shape classes:

- Circle
- Segment
- Poly

2.1 The Box class

Many of the simulations require a static box to contain the dynamic elements. So let's define the `Box` class which takes 2 diagonal end points to define a box:

```
class Box:
    def __init__(self, p0=(10, 10), p1=(690, 230), d=2):
        x0, y0 = p0
        x1, y1 = p1
        pts = [(x0, y0), (x1, y0), (x1, y1), (x0, y1)]
        for i in range(4):
            segment = pymunk.Segment(space.static_body, pts[i], pts[(i+1)%4], d)
            segment.elasticity = 1
            segment.friction = 1
            space.add(segment)
```

The new class library for this section can be found here:

`shape.py`

2.2 A simple compound shape

Two separate shapes can be attached to a body. To distinguish them we give them different colors.

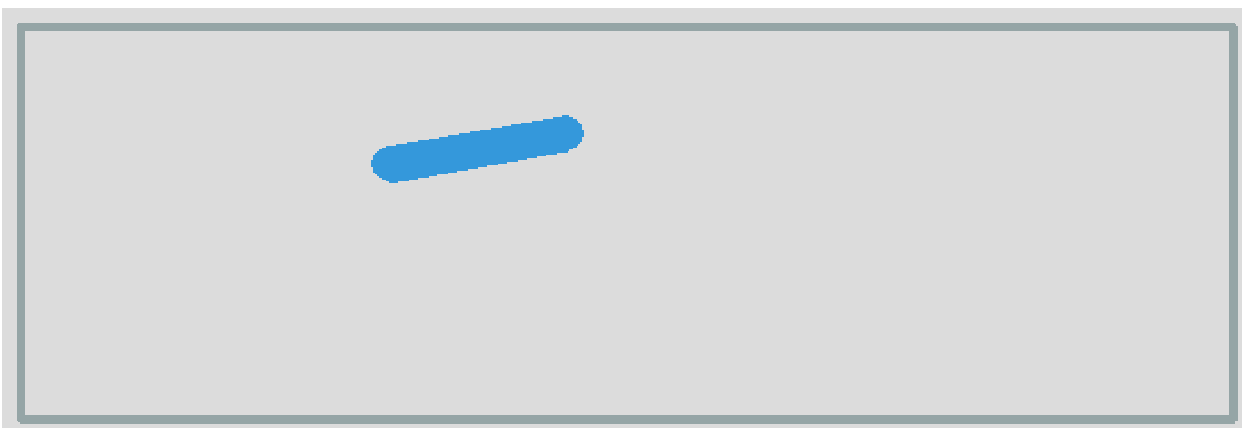
shape1.py

2.3 A moving segment

Segments are linear elements which have a radius. The following code represents a segment of length 100 with its center of gravity at the center:

```
body = pymunk.Body(mass=1, moment=1000)
body.position = (100, 200)
body.apply_impulse_at_local_point((100, 0), (0, 1))

shape = pymunk.Segment(body, (-50, 0), (50, 0), radius=10)
shape.elasticity = 0.999
space.add(body, shape)
```

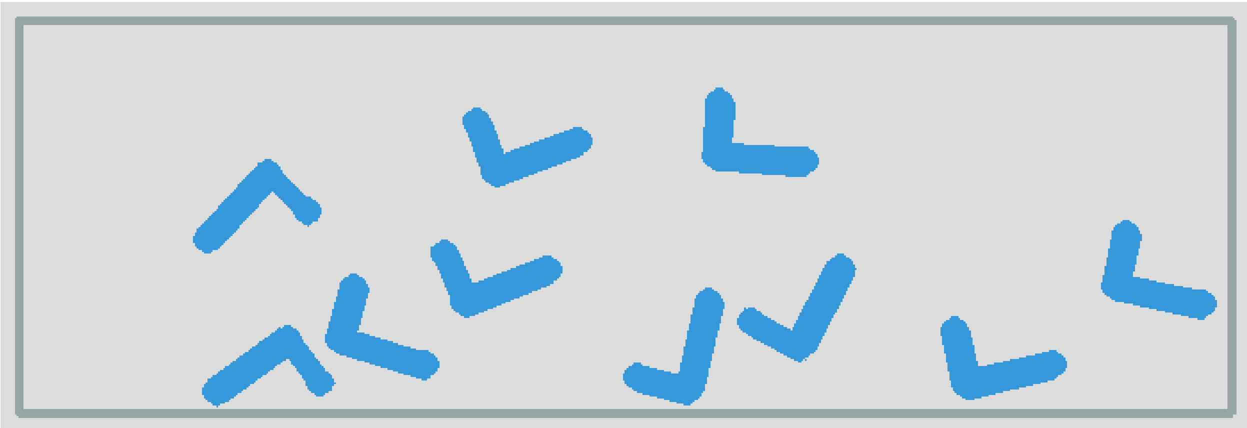


shape2.py

2.4 L-shaped segment

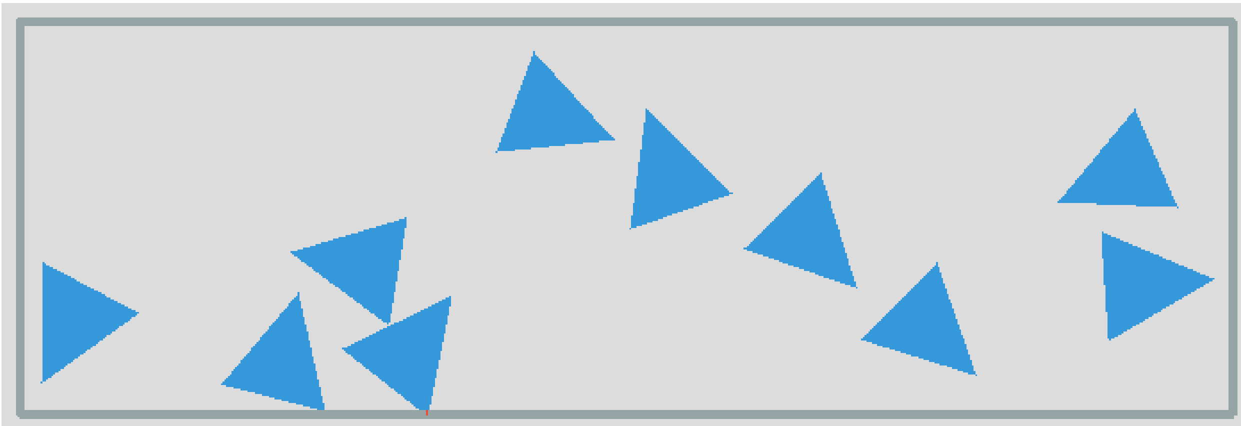
shape3.py

2.5 Multiple L-shaped segment



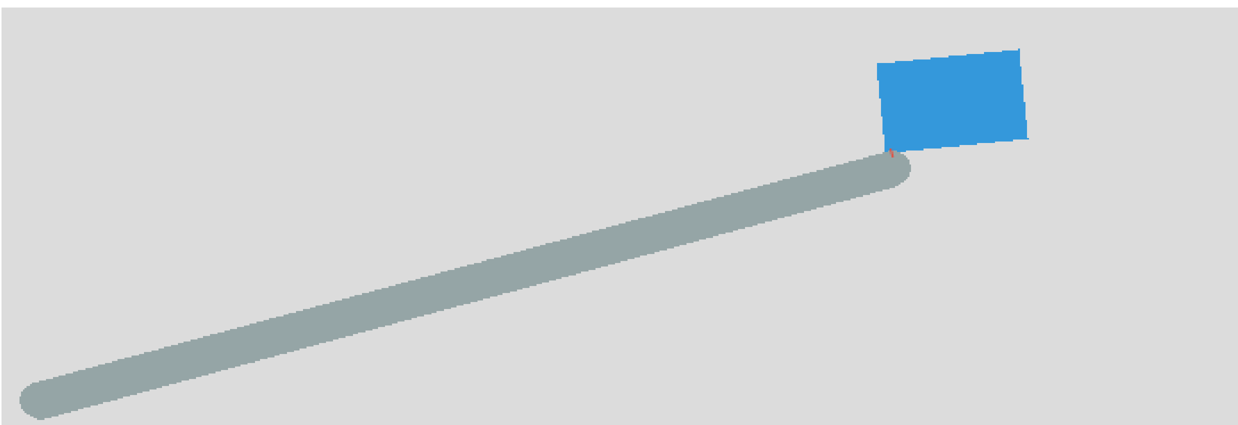
shape4.py

2.6 Triangles



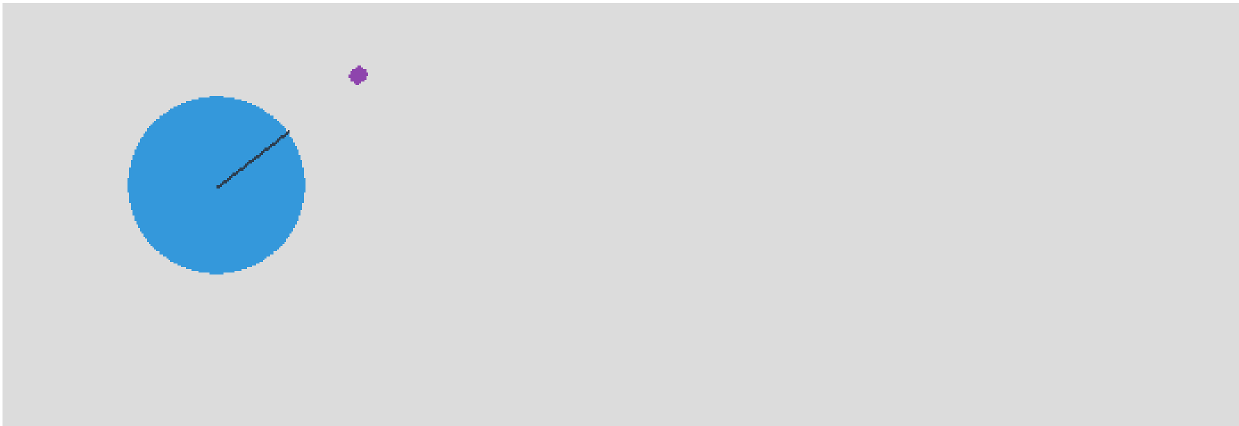
shape6.py

2.7 Conveyer belt



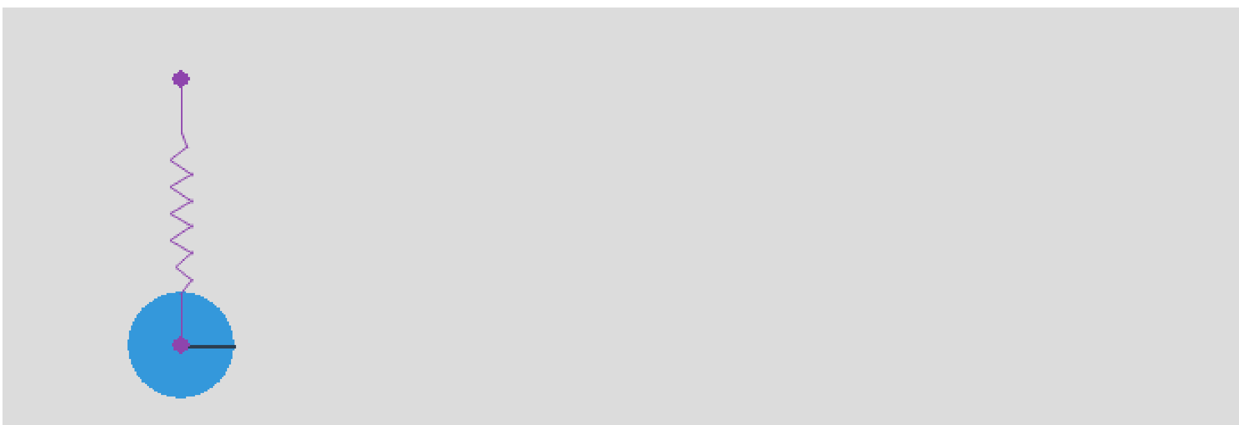
shape7.py

2.8 Pivot joint



shape8.py

2.9 Damped spring



shape9.py

CHAPTER 3

Constraints and joints

A constraint describes how two bodies interact with each other. Constraints can be simple joints, which allow bodies to pivot around each other, as well as springs, grooves or motors.

3.1 Pin joint

The pin joint links two bodies with a solid bar or pin.

We create a new PinJoint class which connects the two bodies b and b2 at their anchor points a and a2 via a pin joint. By adding the new joint directly to space, we save one line of code.

```
class PinJoint:
    def __init__(self, b, b2, a=(0, 0), a2=(0, 0)):
        joint = pymunk.constraint.PinJoint(b, b2, a, a2)
        space.add(joint)
```

We define the static body b0 which will be used for everything static:

```
b0 = space.static_body
```

We will label position points with p and vectors with v. The suspension point for the pendulum is p and the initial pin vector is v:

```
p = Vec2d(200, 190)
v = Vec2d(80, 0)
```

Now we can define the first circular body c and attach it with a pin joint to the static body b0 at position p:

```
c = Circle(p+v)
PinJoint(b0, c.body, p)
```

A second circular body c2 is placed at twice the vector distance:

```
c2 = Circle(p+2*v)
PinJoint(b0, c2.body, p)
```

The two pendulums swing at different frequencies.

pin1.py

```
# two pendulums of different length
from joint import *

p = Vec2d(200, 190)
v = Vec2d(80, 0)

c = Circle(p+v)
PinJoint(b0, c.body, p)

c2 = Circle(p+2*v)
PinJoint(b0, c2.body, p)

App().run()
```

3.2 Double pendulum

The double pendulum is a pendulum linked to another one. Together they execute a complicated chaotic movement.

The first segment is identical to the previous one:

```
c = Circle(p+v)
PinJoint(b0, c.body, p)
```

The second segment is attached to the first circular disc:

```
c2 = Circle(p+2*v)
PinJoint(c.body, c2.body)
```

The two pendulums create a complicated movement.

pin2.py

```
# double pendulum
from joint import *

p = Vec2d(200, 190 )
v = Vec2d(80, 0)

c = Circle(p+v)
PinJoint(b0, c.body, p)

c2 = Circle(p+2*v)
PinJoint(c.body, c2.body)

App().run()
```

3.3 Pivot joint

A pivot joint allows two objects to pivot about a single point.

We define a new `PivotJoint` class which connects the two bodies `b` and `b2` at their anchor points `a` and `a2` via a pivot joint. By adding the new joint directly to `space`, we save one line of code.

```
class PivotJoint:
    def __init__(self, b, b2, a=(0, 0), a2=(0, 0), collide=True):
        joint = pymunk.constraint.PinJoint(b, b2, a, a2)
        joint.collide_bodies = collide
        space.add(joint)
```

We define the first segment with its position point `p` and its direction vector `v`. Then we define a pivot joint in the static body `b0` located at position `p`:

```
segment = Segment(p, v)
PivotJoint(b0, segment.body, p)
```

A bit to the right, we create another segment, twice the length of the first:

```
segment = Segment(p+3*v, 2*v)
PivotJoint(b0, segment.body, p+3*v)
```

To this longer segment we attach a shorter one to create a double pendulum:

```
segment2 = Segment(p+5*v, v)
PivotJoint(segment.body, segment2.body, 2*v)
```

`joint1.py`

```
# pivot point
from joint import *

p = Vec2d(70, 190)
v = Vec2d(60, 0)

segment = Segment(p, v)
PivotJoint(b0, segment.body, p)

segment = Segment(p+3*v, 2*v)
PivotJoint(b0, segment.body, p+3*v)

segment2 = Segment(p+5*v, v)
PivotJoint(segment.body, segment2.body, 2*v)

App().run()
```

3.4 Rag doll

In a rag doll, the different elements of the body (torso, arm, forarm, leg) can cross, without creating collisions. This is possible when the shapes belong to the same group:

```
shape.filter = pymunk.ShapeFilter(group=1)
```

We define the torse by it's center point `p0` and the 4 vertices:

```
p0 = Vec2d(200, 150)
vs = [(-30, 50), (30, 50), (40, -50), (-40, -50)]
v0, v1, v2, v3 = vs
torso = Poly(p0, vs)
c = pymunk.Circle(torso.body, 20, (0, 70))
space.add(c)
```

Then we attach the left arm to the torso:

```
arm = Segment(p0+v0, -v)
PivotJoint(torso.body, arm.body, v0, (0, 0))
```

and then the left forearm to the upper arm:

```
forearm = Segment(p0+v0-v, -v)
PivotJoint(arm.body, forearm.body, -v, (0, 0))
```

We do the same on the right side, and finally attach the two legs:

```
leg = Segment(p0+v2, (20, -100))
PivotJoint(torso.body, leg.body, v2, (0, 0))
```

`joint2.py`

```
# rag doll
from joint import *

Box()

p = Vec2d(200, 120)
vs = [(-30, 40), (30, 40), (40, -40), (-40, -40)]
v0, v1, v2, v3 = vs
torso = Poly(p, vs)

c = pymunk.Circle(torso.body, 20, (0, 60))
space.add(c)

v = Vec2d(60, 0)
arm = Segment(p+v0, -v)
PivotJoint(torso.body, arm.body, v0, (0, 0))

forearm = Segment(p+v0-v, -v)
PivotJoint(arm.body, forearm.body, -v, (0, 0))

arm = Segment(p+v1, v)
PivotJoint(torso.body, arm.body, v1, (0, 0))

forearm = Segment(p+v1+v, v)
PivotJoint(arm.body, forearm.body, v, (0, 0))

leg = Segment(p+v2, (20, -100))
```

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```
PivotJoint(torso.body, leg.body, v2, (0, 0))

leg = Segment(p+v3, (-10, -100))
PivotJoint(torso.body, leg.body, v3, (0, 0))

App().run()
```

3.5 Motors

The `SimpleMotor` class keeps the relative angular velocity between two bodies at a constant rate.

```
class SimpleMotor:
    def __init__(self, b, b2, rate):
        joint = pymunk.constraint.SimpleMotor(b, b2, rate)
        space.add(joint)
```

In the following example code we have 3 constraints:

- a pivot joint makes a segment rotation around a point
- a pivot + motor joint, makes a rotation around a pivot point at a constant angular speed (10 radians/s)
- a motor joint, makes a freely moving segment follow the motor angle

This is the passive pivot joint:

```
p = 100, 120
v = 80,10
arm = Segment(p, v)
PivotJoint(b0, arm.body, p)
```

This is the motorized pivot joint:

```
p1 = 200, 120
arm = Segment(p1, v)
PivotJoint(b0, arm.body, p1)
SimpleMotor(b0, arm.body, 10)
```

This is the motor joint without a pivot:

```
p2 = 300, 120
arm = Segment(p2, v)
SimpleMotor(b0, arm.body, 10)
```

`joint3.py`

```
# motors
from joint import *
Box()

p = 100, 120
v = 60,10
arm = Segment(p, v)
PivotJoint(b0, arm.body, p)
```

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```
p1 = 200, 120
arm = Segment(p1, v)
PivotJoint(b0, arm.body, p1)
SimpleMotor(b0, arm.body, 10)

p2 = 300, 120
arm = Segment(p2, v)
SimpleMotor(b0, arm.body, 10)

App().run()
```

3.6 Motors moving at different speeds

In the following example 3 segments move at 3 different rotation rates. The first motor moves at speed 1:

```
arm = Segment(p, v)
PivotJoint(b0, arm.body, p)
SimpleMotor(b0, arm.body, 1)
```

The second motor moves at speed 3 and the last one at speed 6, which means about one rotation per second.

joint4.py

```
# different rotation speeds
from joint import *

p = 100, 100
v = 80, 0
arm = Segment(p, v)
PivotJoint(b0, arm.body, p)
SimpleMotor(b0, arm.body, 1)

p = 200, 100
arm = Segment(p, v)
PivotJoint(b0, arm.body, p)
SimpleMotor(b0, arm.body, 5)

p = 300, 100
arm = Segment(p, v)
PivotJoint(b0, arm.body, p)
SimpleMotor(b0, arm.body, 10)

App().run()
```

3.7 Wheeled car

To create a simplistic car we attach 2 wheels to a rectangular chassis, based on a central position point and a vertex list:

```
p = Vec2d(200, 150)
vs = [(-50, -30), (50, -30), (50, 30), (-50, 30)]
v0, v1, v2, v3 = vs
chassis = Poly(p, vs)
```

We place the wheels to the lower left and right corners of the chassis:

```
wheel1 = Circle(p+v0)
wheel2 = Circle(p+v1)
```

Both wheels are then motorized at the same speed:

```
PivotJoint(chassis.body, wheel1.body, v0, (0, 0))
SimpleMotor(chassis.body, wheel1.body, 5)
```

joint5.py

```
# car with pivot and motor joint
from joint import *

Box()

p = Vec2d(200, 150)
vs = [(-50, -30), (50, -30), (50, 30), (-50, 30)]
v0, v1, v2, v3 = vs
chassis = Poly(p, vs)

wheel1 = Circle(p+v0)
wheel2 = Circle(p+v1)

PivotJoint(chassis.body, wheel1.body, v0, (0, 0), False)
SimpleMotor(chassis.body, wheel1.body, 5)

PivotJoint(chassis.body, wheel2.body, v1, (0, 0), False)
SimpleMotor(chassis.body, wheel2.body, 5)

App().run()
```

3.8 Slide joint

A slide joint is like a pin joint, but instead of having a fixed distance, the distance between the two anchor points can vary between a minimum and maximum distance. First we define a rotating arm created from a `Segment`. The segment is placed at position `p0` and has a direction vector `v`:

```
p = Vec2d(200, 120)
v = Vec2d(80, 0)
arm = Segment(p, v)
```

In order to rotate the arm, we add to joints: a pivot joint and a simple motor joint:

```
PivotJoint(b0, arm.body, p)
SimpleMotor(b0, arm.body, 1)
```

The we create a ball from the `Circle` class and attach with a `SlideJoint` to the rotating arm:

```
ball = Circle(p+v+(40, 0), r)
SlideJoint(arm.body, ball.body, v, (-r, 0), min, max)
```

In this case the arm and the ball do collide. Now we create a second arm-and-ball mechanism, and this time don't allow bodies to collide:

```
ball = Circle(p+v+(40, 0), r)
SlideJoint(arm.body, ball.body, v, (-r, 0), min, max, False)
```

This is the simulation result. The first ball collides with the arm. The second ball does not collide with the moving arm.

joint6.py

3.9 Groove joint

GrooveJoint is similar to a PivotJoint, but with a linear slide. First we create a rotating arm:

```
arm = Segment(p, v)
PivotJoint(b0, arm.body, p)
SimpleMotor(b0, arm.body, 1)
```

Then we create a circle and attach it to a groove joint:

```
ball = Circle(p+v, 20)
GrooveJoint(arm.body, ball.body, (0, 0), v, (0, 0))
```

joint7.py

3.10 Damped rotary spring and rotary limit joint

To simplify its use we define again two new classes.

```
class DampedRotarySpring:
    def __init__(self, b, b2, angle, stiffness, damping):
        joint = pymunk.constraint.DampedRotarySpring(
            b, b2, angle, stiffness, damping)
        space.add(joint)
```

and

```
class RotaryLimitJoint:
    def __init__(self, b, b2, min, max, collide=True):
        joint = pymunk.constraint.RotaryLimitJoint(b, b2, min, max)
        joint.collide_bodies = collide
        space.add(joint)
```

Then we define a rotary segment:

```
arm = Segment(p0, v)
PivotJoint(b0, arm.body, p0)
SimpleMotor(b0, arm.body, 1)
```

We attache a second arm segment via a damped rotary spring:

```
arm2 = Segment(p0+v, v)
PivotJoint(arm.body, arm2.body, v, (0, 0))
DampedRotarySpring(arm.body, arm2.body, 0, 10000000, 10000)
```

joint8.py

3.11 Gear joint

A gear joint keeps the angular velocity ratio of a pair of bodies constant.

We define two wheels who touch:

```
p0 = Vec2d(200, 120)
r1, r2 = 40, 80
v = Vec2d(r1+r2, 0)
wheel1 = Circle(p0, r1)
wheel2 = Circle(p0+v, r2)
```

Then we motorize the first wheel, place a pivot on both bodies, and add a gear joint with a ratio of -r2/r1:

```
SimpleMotor(b0, wheel1.body, 5)
PivotJoint(b0, wheel1.body, p0)
PivotJoint(b0, wheel2.body, p0+v)
GearJoint(wheel1.body, wheel2.body, 0, -r2/r1)
```

joint10.py

3.12 Creating GIF images

We can use the PIL library to create an animated GIF.

```
    def make_gif(self):
        if self.gif > 0:
            strFormat = 'RGBA'
            raw_str = pygame.image.tostring(self.screen, strFormat, False)
            image = Image.frombytes(
                strFormat, self.screen.get_size(), raw_str)
            self.images.append(image)
            self.gif -= 1
            if self.gif == 0:
                self.images[0].save('joint.gif',
                                    save_all=True, append_images=self.images[1:],
                                    optimize=True, duration=1000//fps, loop=0)
                self.images = []
```

3.13 Complete source code

joint.py

```
import pymunk
from pymunk.pygame_util import *
from pymunk.vec2d import Vec2d

import pygame
from pygame.locals import *

import math
from PIL import Image

space = pymunk.Space()
space.gravity = 0, -900
b0 = space.static_body

size = w, h = 400, 200
fps = 30
steps = 10

BLACK = (0, 0, 0)
GRAY = (220, 220, 220)
WHITE = (255, 255, 255)


class PinJoint:
    def __init__(self, b, b2, a=(0, 0), a2=(0, 0)):
        joint = pymunk.constraint.PinJoint(b, b2, a, a2)
        space.add(joint)


class PivotJoint:
    def __init__(self, b, b2, a=(0, 0), a2=(0, 0), collide=True):
        joint = pymunk.constraint.PinJoint(b, b2, a, a2)
        joint.collide_bodies = collide
        space.add(joint)


class SlideJoint:
    def __init__(self, b, b2, a=(0, 0), a2=(0, 0), min=50, max=100, collide=True):
        joint = pymunk.constraint.SlideJoint(b, b2, a, a2, min, max)
        joint.collide_bodies = collide
        space.add(joint)


class GrooveJoint:
    def __init__(self, a, b, groove_a, groove_b, anchor_b):
        joint = pymunk.constraint.GrooveJoint(
            a, b, groove_a, groove_b, anchor_b)
        joint.collide_bodies = False
        space.add(joint)


class DampedRotarySpring:
    def __init__(self, b, b2, angle, stiffness, damping):
```

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```
        joint = pymunk.constraint.DampedRotarySpring(
            b, b2, angle, stiffness, damping)
        space.add(joint)


class RotaryLimitJoint:
    def __init__(self, b, b2, min, max, collide=True):
        joint = pymunk.constraint.RotaryLimitJoint(b, b2, min, max)
        joint.collide_bodies = collide
        space.add(joint)


class RatchetJoint:
    def __init__(self, b, b2, phase, ratchet):
        joint = pymunk.constraint.GearJoint(b, b2, phase, ratchet)
        space.add(joint)


class SimpleMotor:
    def __init__(self, b, b2, rate):
        joint = pymunk.constraint.SimpleMotor(b, b2, rate)
        space.add(joint)


class GearJoint:
    def __init__(self, b, b2, phase, ratio):
        joint = pymunk.constraint.GearJoint(b, b2, phase, ratio)
        space.add(joint)


class Segment:
    def __init__(self, p0, v, radius=10):
        self.body = pymunk.Body()
        self.body.position = p0
        shape = pymunk.Segment(self.body, (0, 0), v, radius)
        shape.density = 0.1
        shape.elasticity = 0.5
        shape.filter = pymunk.ShapeFilter(group=1)
        shape.color = (0, 255, 0, 0)
        space.add(self.body, shape)


class Circle:
    def __init__(self, pos, radius=20):
        self.body = pymunk.Body()
        self.body.position = pos
        shape = pymunk.Circle(self.body, radius)
        shape.density = 0.01
        shape.friction = 0.5
        shape.elasticity = 1
        space.add(self.body, shape)


class Box:
    def __init__(self, p0=(0, 0), p1=(w, h), d=4):
        x0, y0 = p0
        x1, y1 = p1
```

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```
        pts = [(x0, y0), (x1, y0), (x1, y1), (x0, y1)]
        for i in range(4):
            segment = pymunk.Segment(
                space.static_body, pts[i], pts[(i+1) % 4], d)
            segment.elasticity = 1
            segment.friction = 0.5
            space.add(segment)


class Poly:
    def __init__(self, pos, vertices):
        self.body = pymunk.Body(1, 100)
        self.body.position = pos

        shape = pymunk.Poly(self.body, vertices)
        shape.filter = pymunk.ShapeFilter(group=1)
        shape.density = 0.01
        shape.elasticity = 0.5
        shape.color = (255, 0, 0, 0)
        space.add(self.body, shape)


class Rectangle:
    def __init__(self, pos, size=(80, 50)):
        self.body = pymunk.Body()
        self.body.position = pos

        shape = pymunk.Poly.create_box(self.body, size)
        shape.density = 0.1
        shape.elasticity = 1
        shape.friction = 1
        space.add(self.body, shape)


class App:
    def __init__(self):
        pygame.init()
        self.clock = pygame.time.Clock()
        self.screen = pygame.display.set_mode(size)
        self.draw_options = DrawOptions(self.screen)
        self.running = True
        self.gif = 0
        self.images = []

    def run(self):
        while self.running:
            for event in pygame.event.get():
                self.do_event(event)

            self.draw()
            self.clock.tick(fps)

            for i in range(steps):
                space.step(1/fps/steps)

        pygame.quit()
```

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```
    def do_event(self, event):
        if event.type == QUIT:
            self.running = False

        if event.type == KEYDOWN:
            if event.key in (K_q, K_ESCAPE):
                self.running = False

            elif event.key == K_p:
                pygame.image.save(self.screen, 'joint.png')

            elif event.key == K_g:
                self.gif = 60

    def draw(self):
        self.screen.fill(GRAY)
        space.debug_draw(self.draw_options)
        pygame.display.update()

        text = f'fpg: {self.clock.get_fps():.1f}'
        pygame.display.set_caption(text)
        self.make_gif()

    def make_gif(self):
        if self.gif > 0:
            strFormat = 'RGBA'
            raw_str = pygame.image.tostring(self.screen, strFormat, False)
            image = Image.frombytes(
                strFormat, self.screen.get_size(), raw_str)
            self.images.append(image)
            self.gif -= 1
            if self.gif == 0:
                self.images[0].save('joint.gif',
                                    save_all=True, append_images=self.images[1:],
                                    optimize=True, duration=1000//fps, loop=0)
                self.images = []


if __name__ == '__main__':
    Box()
    p = 100, 180
    c = Circle(p)
    c.body.apply_impulse_at_local_point((10000, 0))
    App().run()
```

CHAPTER 4

Auto-geometry

The `autogeometry` module contains functions for automatic generation of geometry. This can be used to create a segment line or a polygon.

Lets give an example with a 7x7 pixel image:

```
img = """
.......
.xxx...
.xxx...
..xx...
..xxxx.
..xxxx.
.......
""".split()
```

Which produces this list:

```
['.......', '.xxx...', '.xxx...', '..xx...', '..xxxx.', '..xxxx.', '.......']
```

Then we prepare an empty segment list and define two functions needed for the segmentation algorithm:

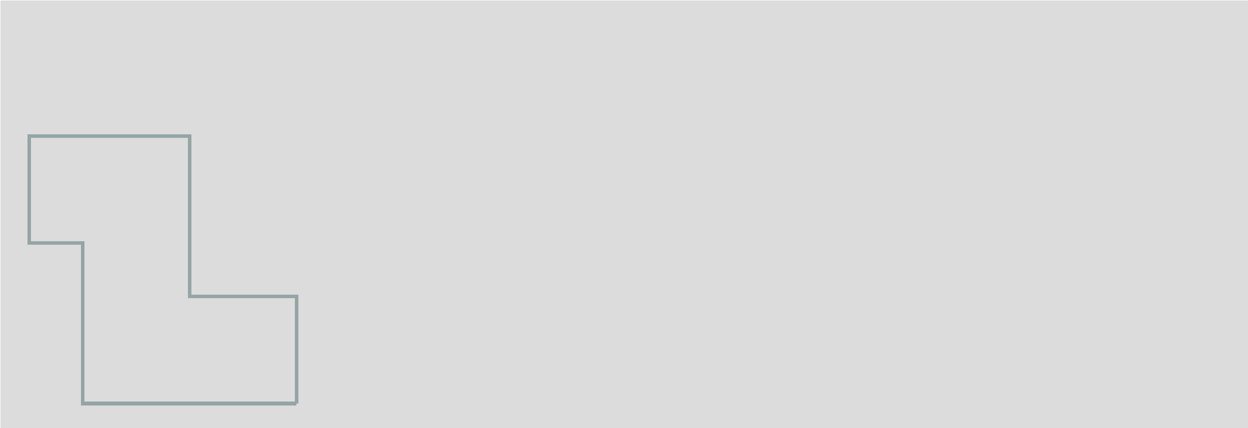
```
segments = []

def segment_func(p0, p1):
    segments.append((p0, p1))

def sample_func(point):
    x = int(point.x)
    y = 6-int(point.y)
    return 1 if img[y][x] == 'x' else 0
```

Now we can call the `march_hard` segmentation algorithm:

```
bb = pymunk.BB(0, 0, 6, 6)
threshold = 0.5
march_hard(bb, 7, 7, threshold, segment_func, sample_func)
```

The segment list can now be displayed either as segments or as polygon:

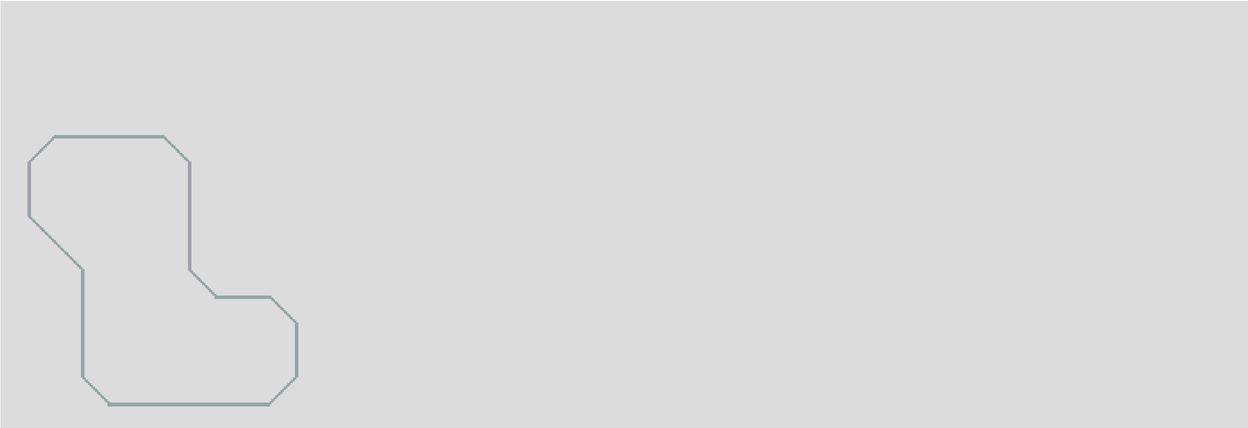
```
d = 30
for (a, b) in segments:
    segment = pymunk.Segment(space.static_body, d*a, d*b, 1)
    space.add(segment)
```



auto1.py auto.py

4.1 Soft contour

We can also trace an anti-aliased contour of an image by using the `march_soft` segmentation algorithm.



CHAPTER 5

Create an app

In this section we are looking how to make an interactive application using Pymunk.

```
class App:
    """Create a single-window app with multiple spaces (scenes)."""
    spaces = []
    current = None
    size = 640, 240

    def __init__(self):
        """Initialize pygame and the app."""
        pygame.init()
        self.screen = pygame.display.set_mode(App.size)
        self.running = True
        self.stepping = True

        self.rect = Rect((0, 0), App.size)
        self.draw_options = pymunk.pygame_util.DrawOptions(self.screen)
        self.dt = 1/50

        self.shortcuts = {
            K_a: 'Arrow(get_mouse_pos(self.screen), color=BLACK)',
            K_b: 'Rectangle(get_mouse_pos(self.screen), color=GREEN)',
            K_v: 'Rectangle(get_mouse_pos(self.screen), color=BLUE)',

            K_c: 'Circle(get_mouse_pos(self.screen), color=RED)',
            K_n: 'self.next_space()',

            K_q: 'self.running = False',
            K_ESCAPE: 'self.running = False',
            K_SPACE: 'self.stepping = not self.stepping',

            K_1: 'self.draw_options.flags ^= 1',
            K_2: 'self.draw_options.flags ^= 2',
            K_3: 'self.draw_options.flags ^= 4',
```

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```
            K_p: 'self.capture()',
            K_s: 'App.current.space.step(self.dt)',
            K_z: 'App.current.remove_all()',
            K_g: 'App.current.space.gravity = 0, 0',
        }

    def run(self):
        """Run the main event loop."""
        while self.running:
            for event in pygame.event.get():
                if event.type == QUIT:
                    self.running = False

                elif event.type == KEYDOWN:
                    self.do_shortcut(event)

                App.current.do_event(event)

            for s in App.current.space.shapes:
                if s.body.position.y < -100:
                    App.current.space.remove(s)

            self.draw()

            if self.stepping:
                App.current.space.step(self.dt)

        pygame.quit()

    def draw(self):
            self.screen.fill(App.current.color)

            for obj in App.current.objects:
                obj.draw()

            App.current.space.debug_draw(self.draw_options)
            self.draw_cg()
            App.current.draw()

            rect = App.current.sel_rect
            pygame.draw.rect(self.screen, GREEN, rect, 1)
            pygame.display.update()


    def draw_cg(self):
        """Draw the center of gravity."""
        screen = pygame.display.get_surface()
        for b in App.current.space.bodies:
            cg = b.position + b.center_of_gravity
            p = to_pygame(cg, screen)
            pygame.draw.circle(screen, BLUE, p, 5, 1)


    def do_shortcut(self, event):
        """Find the key/mod combination and execute the cmd."""
        k = event.key
```

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```
        m = event.mod
        cmd = ''
        if k in self.shortcuts:
            cmd = self.shortcuts[k]
        elif (k, m) in self.shortcuts:
            cmd = self.shortcuts[k, m]
        if cmd != '':
            try:
                exec(cmd)
            except:
                print(f'cmd error: <{cmd}>')

    def next_space(self):
        d = 1
        if pygame.key.get_mods() & KMOD_SHIFT:
            d = -1
        n = len(App.spaces)
        i = App.spaces.index(App.current)
        i = (i+d) % n
        App.current = App.spaces[i]
        pygame.display.set_caption(App.current.caption)

        for s in App.current.space.shapes:
            print(s, s.bb)


    def draw_positions(self):
        for body in App.current.space.bodies:
            print(body.mass)

    def capture(self):
        """Save a screen capture to the directory of the calling class"""
        name = type(self).__name__
        module = sys.modules['__main__']
        path, name = os.path.split(module.__file__)
        name, ext = os.path.splitext(name)
        filename = path + '/' + name + '.png'
        pygame.image.save(self.screen, filename)
```

5.1 Circle

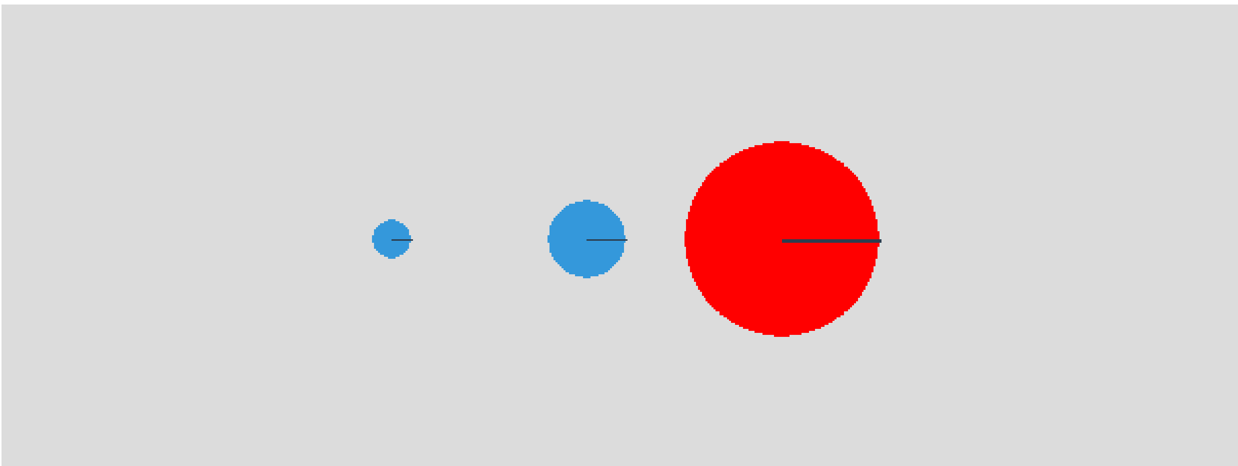
The `Circle` class creates a body with an attached circle shape.

```
class Circle:
    def __init__(self, p0, radius=10, color=None):
        self.body = pymunk.Body()
        self.body.position = p0
        shape = pymunk.Circle(self.body, radius)
        shape.density = 0.01
        shape.elasticity = 0.5
        shape.friction = 0.5
        if color != None:
            shape.color = color
        App.current.space.add(self.body, shape)
```

This is an exemple of three circles placed in a no-gravity space:

```
p0 = Vec2d(200, 120)
v = Vec2d(100, 0)

Space('Cercle', GRAY, gravity=(0, 0))
Circle(p0)
Circle(p0+v, 20)
Circle(p0+2*v, 50, RED)
```



app.py

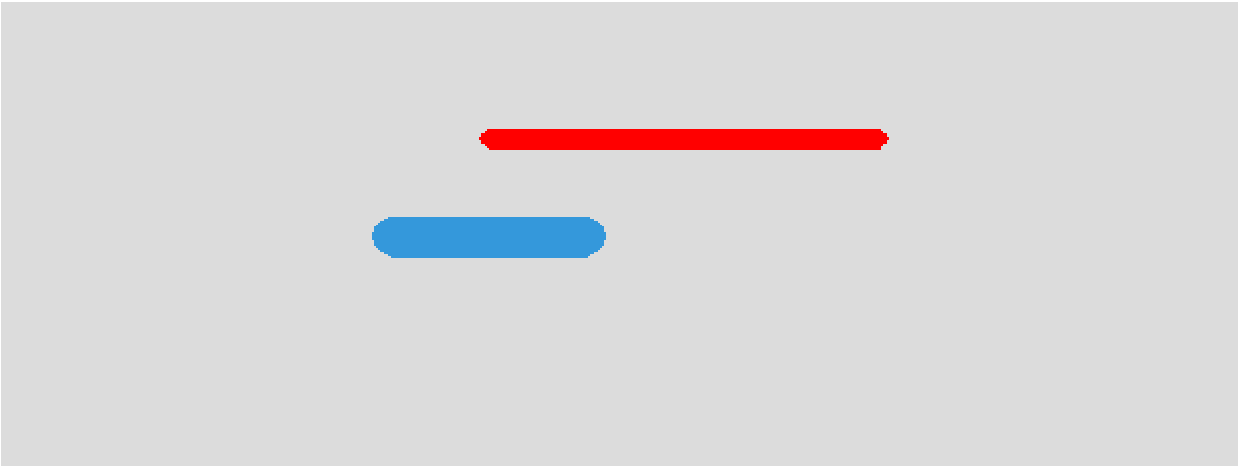
5.2 Segment

The `Segment` class creates a linear segment starting at position `p0` having a direction vector `v`, a radius and a color.

```
class Segment:
    def __init__(self, p0, v, radius=10, color=None):
        self.body = pymunk.Body()
        self.body.position = p0
        shape = pymunk.Segment(self.body, (0, 0), v, radius)
        shape.density = 0.01
        shape.elasticity = 0.5
        shape.friction = 0.5
        if color != None:
            shape.color = color
        App.current.space.add(self.body, shape)
```

This is an example of two segments of different radius, length and color:

```
Space('Segment', gravity=(0, 0))
Segment(p0, v)
Segment(p0+(50, 50), 2*v, 5, RED)
```



5.3 Poly

The `Poly` class creates a filled polygon placed at position `p0` with the vertices `v` given with a vertex list.

```
class Poly:
    def __init__(self, p0, vertices, color=None):
        self.body = pymunk.Body()
        self.body.position = p0
        self.shape = pymunk.Poly(self.body, vertices)
        self.shape.density = 0.01
        self.shape.elasticity = 0.5
        self.shape.friction = 0.5
        if color != None:
            self.shape.color = color
        App.current.space.add(self.body, self.shape)
```

This is an example of creating a triangle and a square polygon:

```
Space('Poly', gravity=(0, 0))
triangle = [(-30, -30), (30, -30), (0, 30)]
Poly(p0, triangle)
square = [(-30, -30), (30, -30), (30, 30), (-30, 30)]
Poly(p0+v, square)
```

CHAPTER 6

Using mouse and keyboard

In this section we look at using the mouse and keyboard to interact with shapes and bodies.

6.1 Starting file

Our starting point is a file which alreaday has the:

- `App` class to create the application
- `Box` class to draw a static rectangular segment box
- `Circle` class to create dynamic circles

The `Box` class takes 2 diagonal points `p0` and `p1` and creates 4 static segments. The default is to place a box around the screen.

```
class Box:
    def __init__(self, p0=(0, 0), p1=(w, h), d=4):
        x0, y0 = p0
        x1, y1 = p1
        ps = [(x0, y0), (x1, y0), (x1, y1), (x0, y1)]
        for i in range(4):
            segment = pymunk.Segment(b0, ps[i], ps[(i+1) % 4], d)
            segment.elasticity = 1
            segment.friction = 1
            space.add(segment)
```

The program reacts to the

- `QUIT` button to close the window
- `Q` and `ESCAPE` key to end the application
- `P` key to save a screen capture under the name `mouse.png`

```
    def do_event(self, event):
        if event.type == QUIT:
            self.running = False

        elif event.type == KEYDOWN:
            if event.key in (K_q, K_ESCAPE):
                self.running = False

            if event.key == K_p:
                pygame.image.save(self.screen, 'mouse.png')
```

This code at the end of the file creates an empty box and runs the app:

```
if __name__ == '__main__':
    Box()
    App().run()
```

mouse0.py

```
import pymunk
from pymunk.pygame_util import *
from pymunk.vec2d import Vec2d

import pygame
from pygame.locals import *
import random

space = pymunk.Space()
b0 = space.static_body
size = w, h = 700, 300

GRAY = (220, 220, 220)
RED = (255, 0, 0)


class Circle:
    def __init__(self, pos, radius=20):
        self.body = pymunk.Body()
```

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```
        self.body.position = pos
        shape = pymunk.Circle(self.body, radius)
        shape.density = 0.01
        shape.friction = 0.9
        shape.elasticity = 1
        space.add(self.body, shape)


class Box:
    def __init__(self, p0=(0, 0), p1=(w, h), d=4):
        x0, y0 = p0
        x1, y1 = p1
        ps = [(x0, y0), (x1, y0), (x1, y1), (x0, y1)]
        for i in range(4):
            segment = pymunk.Segment(b0, ps[i], ps[(i+1) % 4], d)
            segment.elasticity = 1
            segment.friction = 1
            space.add(segment)


class App:
    def __init__(self):
        pygame.init()
        self.screen = pygame.display.set_mode(size)
        self.draw_options = DrawOptions(self.screen)
        self.running = True

    def run(self):
        while self.running:
            for event in pygame.event.get():
                self.do_event(event)
            self.draw()
            space.step(0.01)

        pygame.quit()

    def do_event(self, event):
        if event.type == QUIT:
            self.running = False

        elif event.type == KEYDOWN:
            if event.key in (K_q, K_ESCAPE):
                self.running = False

            if event.key == K_p:
                pygame.image.save(self.screen, 'mouse.png')

    def draw(self):
        self.screen.fill(GRAY)
        space.debug_draw(self.draw_options)
        pygame.display.update()


if __name__ == '__main__':
    Box()
    App().run()
```

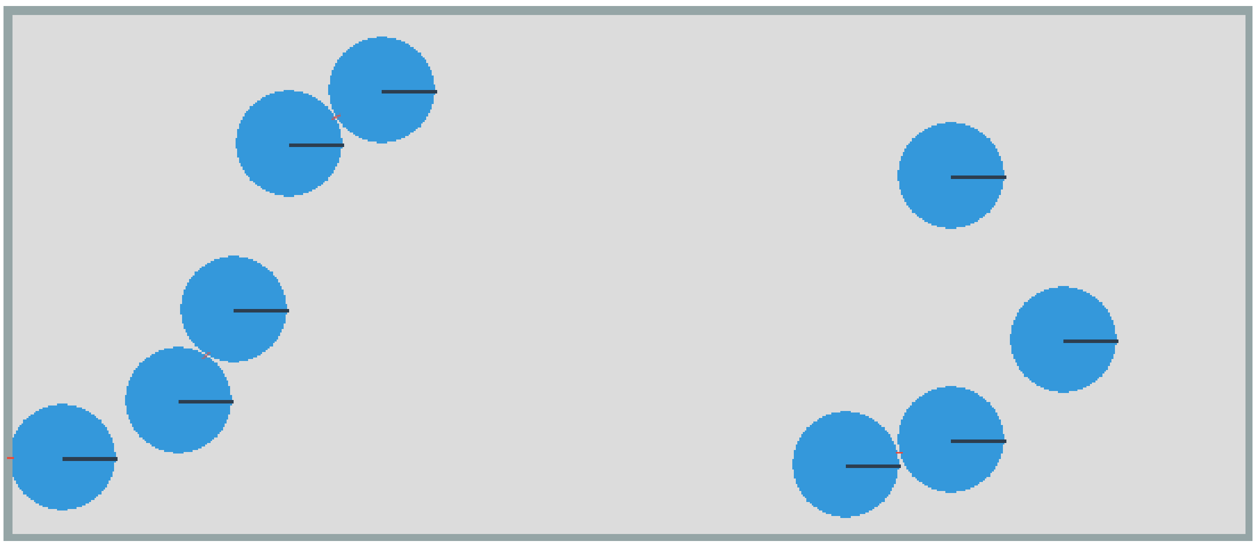
6.2 Create balls at random locations

We place 9 balls at random positions inside the box. In this example there is no gravity:

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

    r = 25
    for i in range(9):
        x = random.randint(r, w-r)
        y = random.randint(r, h-r)
        Circle((x, y), r)

    App().run()
```



6.3 Select a ball with the mouse

Now let's use a MOUSEBUTTONDOWN event to select an active shape with a mouse click. The two functions from_pygame and to_pygame allow us to change between

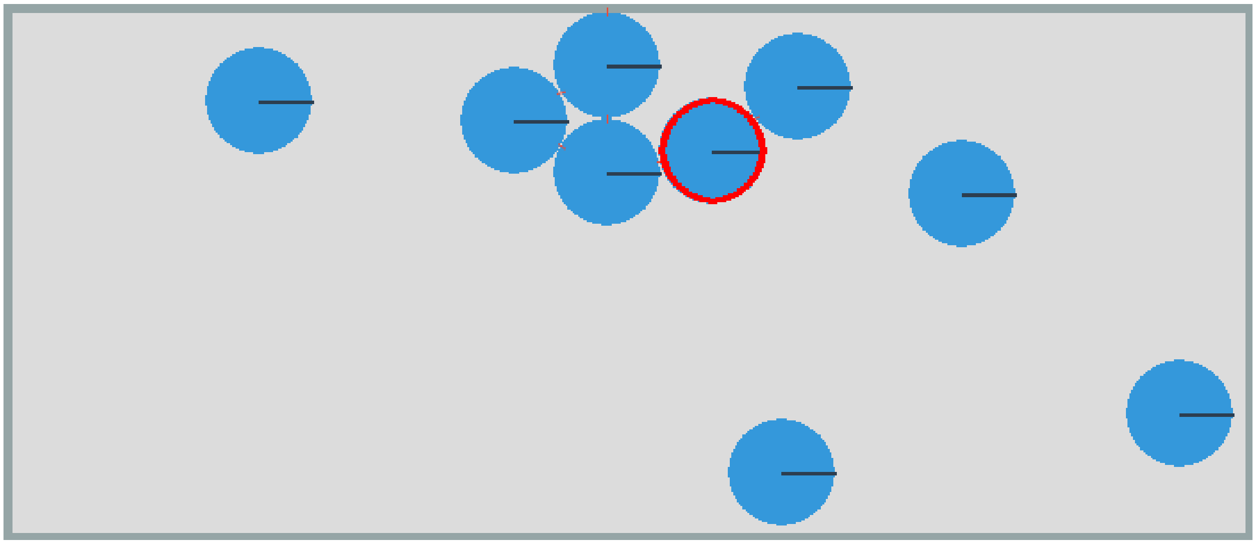
- pygame coordinates with the origin at the upper left
- pymunk coordinates with the origin at the lower left

The point_query(p) method checks if point p is inside the shape:

```
elif event.type == MOUSEBUTTONDOWN:
    p = from_pygame(event.pos, self.screen)
    self.active_shape = None
    for s in space.shapes:
        dist, info = s.point_query(p)
        if dist < 0:
            self.active_shape = s
```

When there is an active shape, we surround it with a red circle:

```
if self.active_shape != None:
    s = self.active_shape
    r = int(s.radius)
    p = to_pygame(s.body.position, self.screen)
    pygame.draw.circle(self.screen, RED, p, r, 3)
```



6.4 Move the active shape with keys

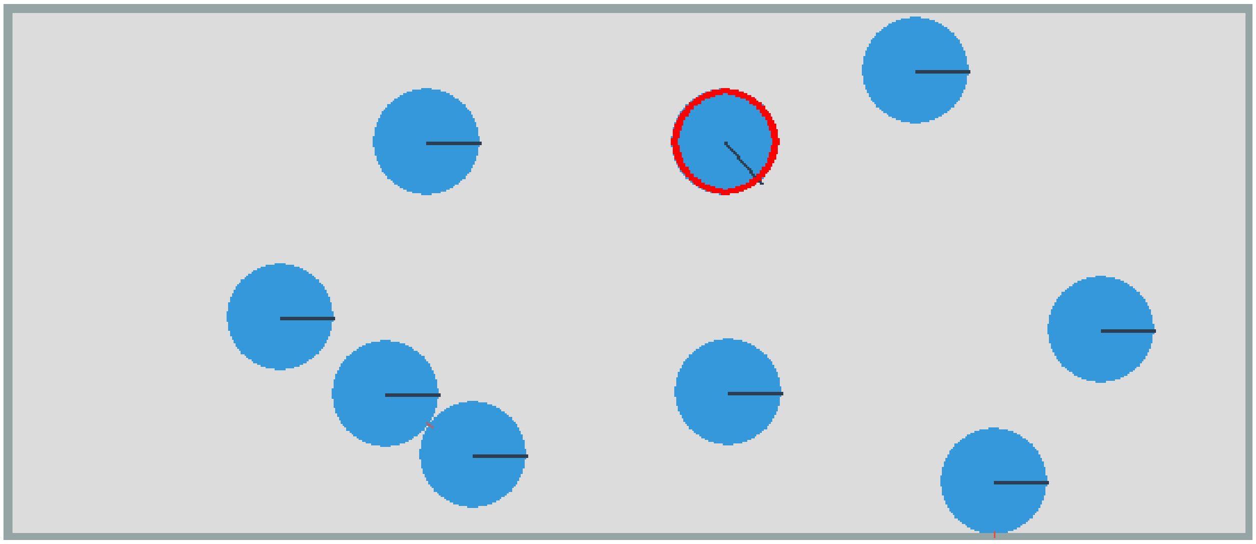
Let's use the arrow keys to move the active object. For this we define a dictionary where we association the 4 direction unit vectors with the 4 arrow keys. If the key pressed is an arrow key, we move the active shape 20 pixels into that direction:

```
keys = {K_LEFT: (-1, 0), K_RIGHT: (1, 0),
        K_UP: (0, 1), K_DOWN: (0, -1)}
if event.key in keys:
    v = Vec2d(keys[event.key]) * 20
    if self.active_shape != None:
        self.active_shape.body.position += v
```

6.5 Rotate an object with the mouse

We can use the mouse-click into an object to change its angle. All we need to add is this line of code in the `MOUSEBUTTONDOWN` section:

```
s.body.angle = (p - s.body.position).angle
```



6.6 Pull a ball with the mouse

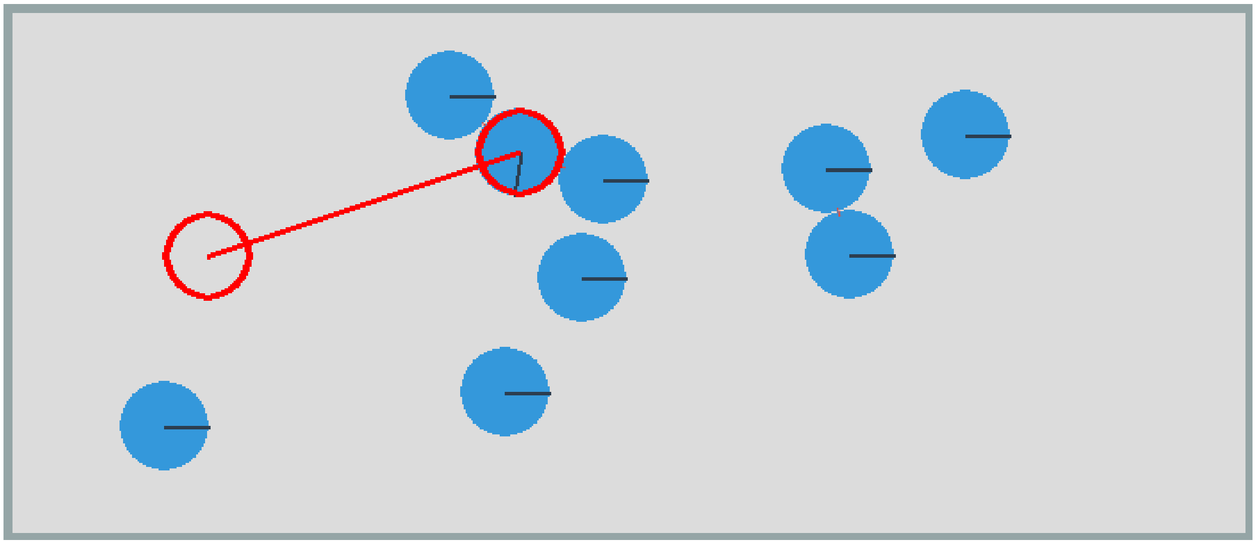
When releasing the mouse button, we take the mouse position and apply an impulse to the ball which is proportional to the red line drawn with the mouse, with `p0` being the object position and `p1` being the mouse position:

```
elif event.type == MOUSEBUTTONUP:
    if self.pulling:
        self.pulling = False
        b = self.active_shape.body
        p0 = Vec2d(b.position)
        p1 = from_pygame(event.pos, self.screen)
        impulse = 100 * Vec2d(p0 - p1).rotated(-b.angle)
        b.apply_impulse_at_local_point(impulse)
```

To draw the red line we add this to the drawing code:

```
if self.active_shape != None:
    b = self.active_shape.body
    r = int(self.active_shape.radius)
    p0 = to_pygame(b.position, self.screen)
    pygame.draw.circle(self.screen, RED, p0, r, 3)
    if self.pulling:
        pygame.draw.line(self.screen, RED, p0, self.p, 3)
        pygame.draw.circle(self.screen, RED, self.p, r, 3)
```

Which results in this

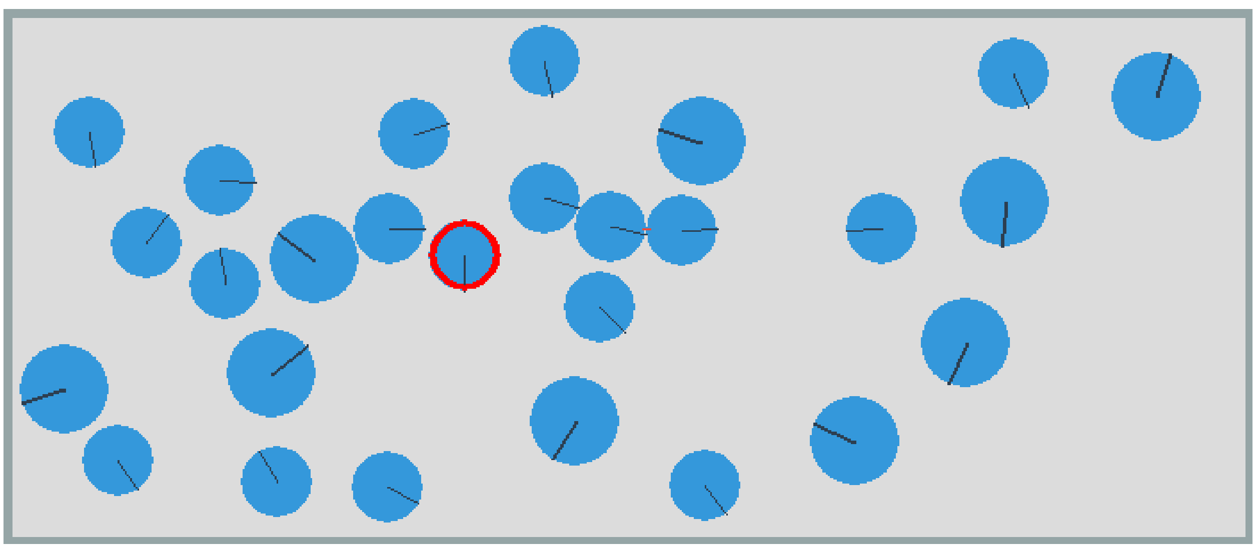


6.7 New objects at mouse position

Inside the `do_event()` section we add the following code:

```
if event.key == K_c:
    p = from_pygame(pygame.mouse.get_pos(), self.screen)
    Circle(p, radius=20)
```

This will add smaller circles at the mouse position.



6.8 Remove an object

To remove the active object we add the following code:

```
if event.key == K_BACKSPACE:
    s = self.active_shape
    if s != None:
        space.remove(s, s.body)
        self.active_shape = None
```

6.9 Add a bounding box (BB)

Inside the `MOUSEBUTTONDOWN` section if clicking inside a shape, we add the following test to add the shape to the current selection if the **cmd** key is pressed:

```
if pygame.key.get_mods() & KMOD_META:
    self.selected_shapes.append(s)
    print(self.selected_shapes)
else:
    self.selected_shapes = []
```

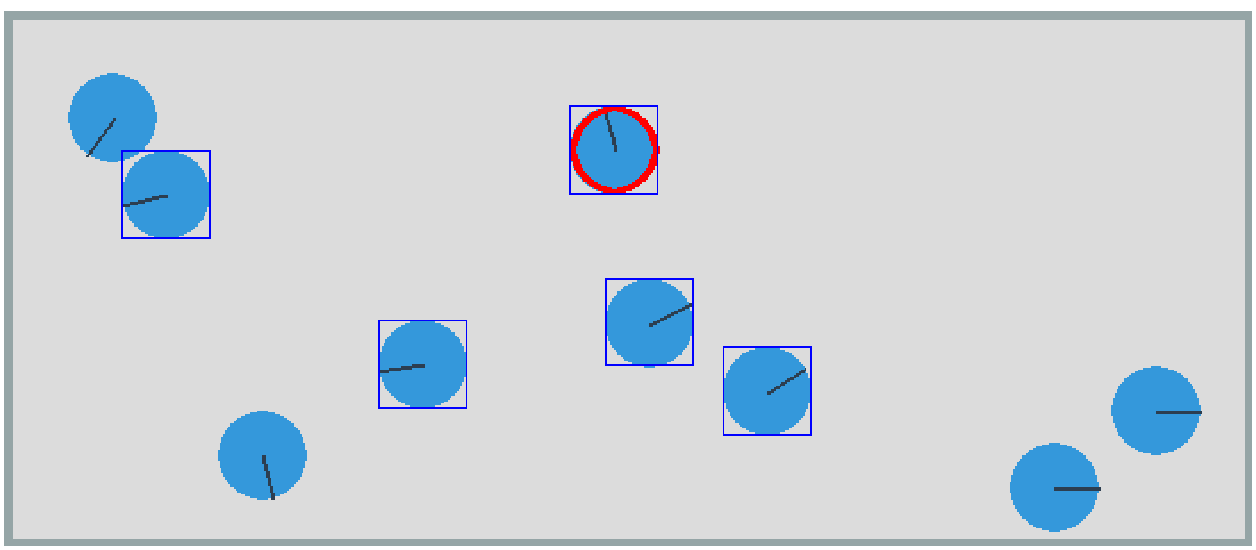
In order to draw a shape's bounding box (BB) we add the following method.

```
    def draw_bb(self, shape):
        pos = shape.bb.left, shape.bb.top
        w = shape.bb.right - shape.bb.left
        h = shape.bb.top - shape.bb.bottom
        p = to_pygame(pos, self.screen)
        pygame.draw.rect(self.screen, BLUE, (*p, w, h), 1)
```

In the App's `draw()` section we add:

```
for s in self.selected_shapes:
    self.draw_bb(s)
```

This shows the currently selected objects with a bounding box.

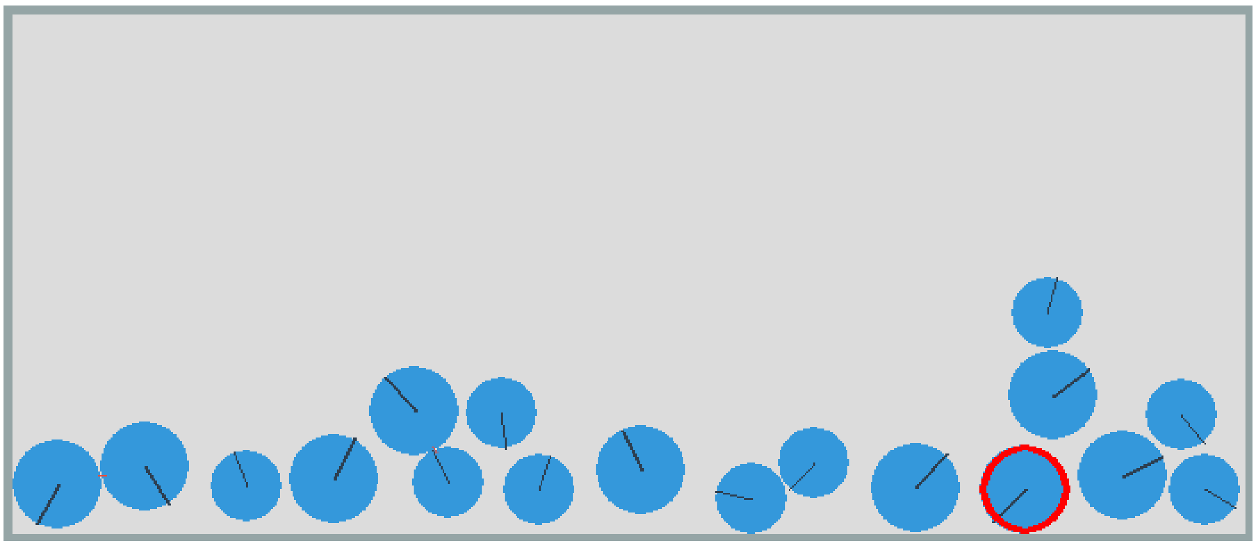


6.10 Toggle gravity

In order to turn on and off gravity we add the following code:

```
elif event.key == K_g:
    self.gravity = not self.gravity
    if self.gravity:
        space.gravity = 0, -900
    else:
        space.gravity = 0, 0
```

With gravity turned on, the circles fall to the ground.



6.11 Animated GIF

Balls under the influence of gravity.

Big and smalls balls.

6.12 Complete source code

Here is the complete file.

mouse.py

```
import pymunk
from pymunk.pygame_util import *
from pymunk.vec2d import Vec2d

import pygame
from pygame.locals import *
```

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```
import math
import random
from PIL import Image

space = pymunk.Space()
b0 = space.static_body
size = w, h = 700, 300

GRAY = (220, 220, 220)
RED = (255, 0, 0)
BLUE = (0, 0, 255)


class Segment:
    def __init__(self, p0, v, radius=10):
        self.body = pymunk.Body()
        self.body.position = p0
        shape = pymunk.Segment(self.body, (0, 0), v, radius)
        shape.density = 0.1
        shape.elasticity = 0.5
        shape.filter = pymunk.ShapeFilter(group=1)
        shape.color = (0, 255, 0, 0)
        space.add(self.body, shape)


class Circle:
    def __init__(self, pos, radius=20):
        self.body = pymunk.Body()
        self.body.position = pos
        shape = pymunk.Circle(self.body, radius)
        shape.density = 0.01
        shape.friction = 0.9
        shape.elasticity = 1
        space.add(self.body, shape)


class Box:
    def __init__(self, p0=(0, 0), p1=(w, h), d=4):
        x0, y0 = p0
        x1, y1 = p1
        ps = [(x0, y0), (x1, y0), (x1, y1), (x0, y1)]
        for i in range(4):
            segment = pymunk.Segment(b0, ps[i], ps[(i+1) % 4], d)
            segment.elasticity = 1
            segment.friction = 1
            space.add(segment)


class App:
    def __init__(self):
        pygame.init()
        self.screen = pygame.display.set_mode(size)
        self.draw_options = DrawOptions(self.screen)
        self.active_shape = None
        self.selected_shapes = []
        self.pulling = False
```

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```
        self.running = True
        self.gravity = False
        self.images = []
        self.image_nbr = 60

    def run(self):
        while self.running:
            for event in pygame.event.get():
                self.do_event(event)
            self.draw()
            space.step(0.01)

        pygame.quit()

    def do_event(self, event):
        if event.type == QUIT:
            self.running = False

        elif event.type == KEYDOWN:
            if event.key in (K_q, K_ESCAPE):
                self.running = False

            elif event.key == K_p:
                pygame.image.save(self.screen, 'mouse.png')

            keys = {K_LEFT: (-1, 0), K_RIGHT: (1, 0),
                    K_UP: (0, 1), K_DOWN: (0, -1)}

            if event.key in keys:
                v = Vec2d(keys[event.key]) * 20
                if self.active_shape != None:
                    self.active_shape.body.position += v

            elif event.key == K_c:
                p = from_pygame(pygame.mouse.get_pos(), self.screen)
                Circle(p, radius=20)

            elif event.key == K_BACKSPACE:
                s = self.active_shape
                if s != None:
                    space.remove(s, s.body)
                    self.active_shape = None

            elif event.key == K_h:
                self.gravity = not self.gravity
                if self.gravity:
                    space.gravity = 0, -900
                else:
                    space.gravity = 0, 0

            elif event.key == K_g:
                self.image_nbr = 60

        elif event.type == MOUSEBUTTONDOWN:
            p = from_pygame(event.pos, self.screen)
            self.active_shape = None
            for s in space.shapes:
```

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```
                dist, info = s.point_query(p)
                if dist < 0:
                    self.active_shape = s
                    self.pulling = True

                    s.body.angle = (p - s.body.position).angle

                    if pygame.key.get_mods() & KMOD_META:
                        self.selected_shapes.append(s)
                        print(self.selected_shapes)
                    else:
                        self.selected_shapes = []


        elif event.type == MOUSEMOTION:
            self.p = event.pos

        elif event.type == MOUSEBUTTONUP:
            if self.pulling:
                self.pulling = False
                b = self.active_shape.body
                p0 = Vec2d(b.position)
                p1 = from_pygame(event.pos, self.screen)
                impulse = 100 * Vec2d(p0 - p1).rotated(-b.angle)
                b.apply_impulse_at_local_point(impulse)

    def draw(self):
        self.screen.fill(GRAY)
        space.debug_draw(self.draw_options)

        if self.active_shape != None:
            s = self.active_shape
            r = int(s.radius)
            p = to_pygame(s.body.position, self.screen)
            pygame.draw.circle(self.screen, RED, p, r, 3)
            if self.pulling:
                pygame.draw.line(self.screen, RED, p, self.p, 3)
                pygame.draw.circle(self.screen, RED, self.p, r, 3)

        for s in self.selected_shapes:
            self.draw_bb(s)

        if self.image_nbr > 0:
            strFormat = 'RGBA'
            raw_str = pygame.image.tostring(self.screen, strFormat, False)
            image = Image.frombytes(strFormat, self.screen.get_size(), raw_str)
            self.images.append(image)
            self.image_nbr -= 1
            if self.image_nbr == 0:
                self.images[0].save('pillow.gif',
                    save_all=True, append_images=self.images[1:], optimize=False,␣
↪duration=40, loop=0)
                self.images = []

        pygame.display.update()

    def draw_bb(self, shape):
```

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```
        pos = shape.bb.left, shape.bb.top
        w = shape.bb.right - shape.bb.left
        h = shape.bb.top - shape.bb.bottom
        p = to_pygame(pos, self.screen)
        pygame.draw.rect(self.screen, BLUE, (*p, w, h), 1)


if __name__ == '__main__':
    Box()

    space.gravity = 0, -900
    r = 25
    for i in range(9):
        x = random.randint(r, w-r)
        y = random.randint(r, h-r)
        Circle((x, y), r)

    App().run()
```

CHAPTER 7

Demo examples

In this section we look at some games and examples inspired by the official Pymunk exemples (http://www.pymunk.org/en/latest/examples.html)

These are some of the topics to explore

- move a kinetic body with mouse/keys
- rotate a kinetic body with mouse/keys
- shoot balls in a specific direction
- make balls stick to objects
- make a player walk and jump
- make bricks disappear
- use mouse to give an impulse to a ball

CHAPTER 8

Angry Birds

This section shows how to make a simple and extensible version of Angry Birds using the 2D physics simulaiton package Pymunk and the Multi-media package Pygame.

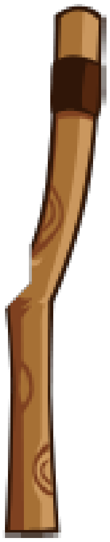
8.1 Resources

In this section you find the background music, the background images and the sprites used in this tutorial. Download them to your current folder.

`angry-birds.ogg`

`background.png`

bird.png

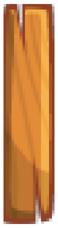


sling.png

sling2.png

pig.png

beam.png



column.png

The class definitions are here:

classes.py

8.2 First program

The first step will be to create the background image and the background music.

CHAPTER 9

Indices and tables

- genindex
- modindex
- search