Rian

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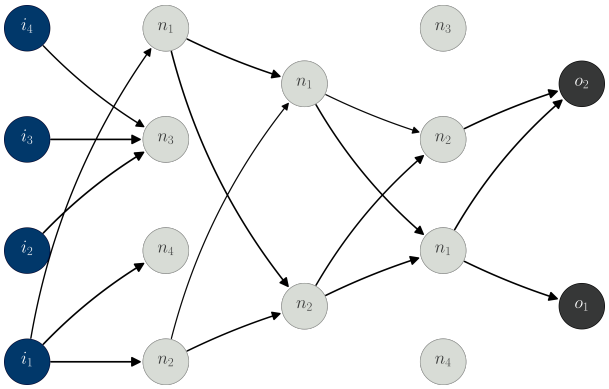
Contents

CHAPTER 1

Introduction

In many domains of enterprise and scientific data analysis the lack of structural knowledge encourages the use of machine intelligence methods, which surpass the structural flexibility of classical statistical methods. Since this approach, however, generally is paid by high mathematical uncertainty, it is indispensable to properly select and adapt the method to it's respective application. This requires a close cooperation between enterprise analytics and data science.



Rian is a data analysis framework for collaborative data science and enterprise application. The key goal of the project is to provide a long-term data analysis framework, which seemingly integrates into existing enterprise data environments and thereby supports collaborative data science. To achieve this goal rian orchestrates established frameworks like TensorFlow® and SQLAlchemy and dynamically extends their capabilities by community driven algorithms for probabilistic graphical modeling [PGM], machine learning [ML] and structured data-analysis [SDA].

1.1 Components

Rian is open source and based on the Python programming language. It provides:

- A transparent DW architecture for the seamless integration of existing SQL databases, flat data from laboratory measurement devices or data generators.
- A versatile and fast data modeling and data analysis framework.

CHAPTER 2

Install

Rian requires Python 3.7 or later. If you do not already have a Python environment configured on your computer, please see the instructions for installing the full scientific Python stack.

Note: If you are using the Windows platform and want to install optional packages (e.g., *scipy*), then it may be useful to install a Python distribution such as: Anaconda, Enthought Canopy, Python(x,y), WinPython, or Pyzo. If you already use one of these Python distributions, please refer to their online documentation.

Below it is assumed, that you have the default Python environment configured on your computer and you intend to install Rian inside of it. If you want to create and work with Python virtual environments, please follow instructions on venv and virtual environments.

2.1 Install the latest distributed package

You can install the latest distributed package of Rian by using *pip*:

```
$ pip install rian
```

2.2 Install the development branch

The installation requires that you have Git installed on your system. Under this prerequisite the first step is to clone the GitHub repository of Rian:

```
$ git clone https://github.com/frootlab/rian.git
```

Thereupon the development branch can locally be installed by using *pip*:

```
$ cd rian
$ pip install -e .
```

The `pip install` command allows you to follow the development branch as it changes by creating links in the right places and installing the command line scripts to the appropriate locations.

2.3 Update the development branch

Once you have cloned the Rian GitHub repository onto a local directory, you can update it anytime by running a `git pull` in this directory:

```
$ git pull
```

2.4 Testing the development branch

Rian uses the Python builtin package unittest for testing. Since the tests are not included in the distributed package you are required to install the Rian development branch. Thereupon you have to switch to the repository directory and run:

```
$ python3 tests
```

2.5 Required packages

Note: Some required packages (e.g., *numpy*) may require compiling C or C++ code. If you have difficulty installing these packages with *pip*, it is highly recommended to review the instructions for installing the full scientific Python stack.

By using the `pip install` the required packages should by installed automatically. These packages include:

```
- `numpy <https://www.numpy.org/>`_ (>= 1.15.0)
- `NetworkX <https://networkx.github.io/>`_ (>= 2.1)
- `Matplotlib <https://matplotlib.org/>`_ (>= 2.2.2)
- `AppDirs <https://github.com/ActiveState/appdirs>`_ (>= 1.1.0)
```

CHAPTER 3

rian

3.1 rian package

3.1.1 Subpackages

rian.base package

Submodules

rian.base.array module

rian.base.nbase module

Module contents

rian.core package

Subpackages

rian.core.ui package

Submodules

rian.core.ui.shell module

Module contents

Submodules

rian.model package

Subpackages

rian.model.analysis package

Submodules

rian.model.analysis.bayes module

rian.model.analysis.generic module

rian.model.analysis.hybrid module

rian.model.analysis.markov module

Module contents

rian.model.builder package

Submodules

rian.model.builder.base module

Module contents

rian.model.classes package

Submodules

rian.model.classes.base module

Module contents

rian.model.evaluation package

Submodules

rian.model.evaluation.ann module

rian.model.evaluation.base module

rian.model.evaluation.dbn module

rian.model.evaluation.rbm module

3.1.2 Submodules

rian.typing module

3.1.3 Module contents

CHAPTER 4

Glossary

4.1 Math Glossary

4.1.1 Norms and Metrices

1-Norm The *1-norm* provides a length measure for the interpretation of vector spaces as orthogonal lattices. For a vector space of dimension *n*, the norm is given by:[1]

$$\|\vec{x}\|_1 := \sum_{i=1}^{n} |x_i|$$

The 1-norm specifies the *p-norm* for the case $p = 1$ and induces the *Manhattan distance* to the underlying vector space. When applied to a random sample, the Manhattan distance is also known as the *sum of absolute differences*.

References

Chebyshev Distance The *Chebyshev Distance* generates the *Chebyshev Metric*. For a vector space of dimension *n*, the Chebyshev distance is given by:[2]

$$d_\infty(\vec{x}, \vec{y}) := \max_i (|y_i - x_i|)$$

The Chebyshev distance is induced by the *Maximum norm* and specifies the *Minkowski distance* for the transition $p \to \infty$.

Euclidean Distance The *Euclidean Distance* corresponds to the natural geometric interpretation of a vector space. For an underlying vector space of dimension *n*, the Euclidean distance is given by:[3]

$$d_2(\vec{x}, \vec{y}) := \left(\sum_{i=1}^{n} |y_i - x_i|^2 \right)^{1/2}$$

[1] https://en.wikipedia.org/wiki/Taxicab_geometry
[2] https://en.wikipedia.org/wiki/Chebyshev_distance
[3] https://en.wikipedia.org/wiki/Euclidean_distance

The Euclidean distance is induced by the *Euclidean norm* and specifies the *Minkowski distance* for the case $p = 2$. With respect to regression analysis the Euclidean distance endows the components of a random sample with a discrepancy measure, between observed an estimated realizations. This discrepancy measure is commonly referred as *Residual sum of squares* (RSS) and provides the foundation for the method of least squares.[4]

Euclidean Norm The *Euclidean norm* provides the fundamental length measure for natural geometric interpretations of vector spaces. For a vector space of dimension *n*, the Euclidean norm is given by:[5]

$$\|\vec{x}\|_2 := \left(\sum_{i=1}^{n} |x_i|^2 \right)^{1/2}$$

The Euclidean norm equals the *p-norm* for $p = 2$ and induces a the *Euclidean distance* to it's domain.

Frobenius Distance The *Frobenius Distance* is a distance measure for matrices. For a vector space of dimension $n \times m$, the Frobenius distance is defined by:[6]

$$d_F(A,\, B) := \left(\sum_{i=1}^{m} \sum_{j=1}^{n} |b_{ij} - a_{ij}|^2 \right)^{1/2}$$

The Frobenius distance is induced by the *Frobenius norm* and specifies the *pq-distance* for the case $p = q = 1$.

Frobenius Norm The *Frobenius norm* is a matrix norm, which is derived by the consecutive evaluation of the *Euclidean norm* for the rows and columns of a matrix. For an underlying vector space of dimension $n \times m$, the Frobenius norm is given by:[7]

$$\|A\|_F := \left(\sum_{i=1}^{m} \sum_{j=1}^{n} |a_{ij}|^2 \right)^{1/2}$$

The Frobenius norm specifies the *pq-norm* for the case $p = q = 2$.

Hölder Mean The *Hölder means* generalize the *Arithmetic mean* and the *Geometric mean*, in the same way as the *p-norm* generalizes the *Euclidean norm* and the *1-norm*. For a positive real number *p* and a vector space of dimension *n*, the Hölder mean for absolute values is given by:[8]

$$M_p(\vec{x}) := \left(\frac{1}{n} \sum_{i=1}^{n} |x_i|^p \right)^{1/p}$$

By it's definition it follows, that for $p \geq 1$ the Hölder means for absolute values are linear related to the p-norms:

$$M_p(\vec{x}) = \left(\frac{1}{n} \right)^{1/p} \|\vec{x}\|_p$$

As a consequence for $p \geq 1$ the Hölder means of absolute values are norms and thus induce distances to their underlying domains. These are occasionally referred as *power mean difference*.

The Hölder means and their respective distances, have important applications in regression analysis. When applied to the components of a random sample, the Hölder means of absolute values are known as the absolute sample moments and their induces metrices provide normalized measures of statistical dispersion.

[4] https://en.wikipedia.org/wiki/Least_squares
[5] https://en.wikipedia.org/wiki/Euclidean_norm
[6] https://en.wikipedia.org/wiki/Frobenius_norm
[7] https://en.wikipedia.org/wiki/Frobenius_norm
[8] https://en.wikipedia.org/wiki/Power_mean

Manhattan Distance The *Manhattan Distance* corresponds to the interpretation of vector spaces as orthogonal lattices. For a vector space of dimension *n*, the Manhattan distance is given by:[9]

$$d_1(\vec{x}, \vec{y}) := \sum_{i=1}^{n} |y_i - x_i|$$

The Manhattan distance is induced by the *1-norm* and specifies the *Minkowski distance* for $p = 1$. When applied to a fixed set of outcomes of a random variable, the Minkowski distance is a measure of *discrepancy measure* and referred as *Sum of Absolute Differences*.

Maximum Norm The *Maximum norm* provides a length measure for vector spaces. For a vector space of dimension *n*, the Maximum norm is given by:[10]

$$\|\vec{x}\|_\infty := \max_i (|x_i|)$$

The Maximum norm specifies the *p-norm* for the case $p \to \infty$ and induces the *Chebyshev distance* to it's domain.

Mean Absolute The *Mean Absolute* provides a normalized length measure for the interpretation of vector spaces as orthogonal lattices. For a vector space of dimension *n*, it is given by:

$$M_1(\vec{x}) := \frac{1}{n} \sum_{i=1}^{n} |x_i|$$

The Mean Absolute specifies the *Hölder mean* of absolute values for the case $p = 1$ and is linear dependent to the *1-norm*:

$$M_1(\vec{x}) = \frac{\|\vec{x}\|_1}{n}$$

Due to this linear relationship the Mean Absolute is a valid vector space norm and thus induces a distance to it's underlying domain, which is referred as *mean absolute difference*.

Mean Absolute Difference The *Mean Absolute Difference* (MD) is a normalized distance measure for the interpretation of vector spaces as orthogonal lattices. For a vector space of dimension *n*, this distance is given by:

$$\mathrm{MD}_1(\vec{x}, \vec{y}) := \frac{1}{n} \sum_{i=1}^{n} |y_i - x_i|$$

The mean absolute difference is induced by the *mean absolute* and specifies the *power mean difference* for the case $p = 1$. Furthermore the mean absolute difference is linear dependent to the *Manhattan distance*:

$$\mathrm{MD}_1(\vec{x}, \vec{y}) = \frac{d_1(\vec{x}, \vec{y})}{n}$$

The term 'mean absolute difference' is frequently associated with it's application to sampled values[11]. In regression analysis it provides a consistent and unbiased estimator for the *mean absolute error* of a predictor.

Minkowski Distance The class of *Minkowski Distances* provides different geometric interpretations of vector spaces. For a real number $p \geq 1$ and a vector space of dimension *n*, the Minkowski distance is given by:[12]

$$d_p(\vec{x}, \vec{y}) := \left(\sum_{i=1}^{n} |y_i - x_i|^p \right)^{1/p}$$

The class of Minkowski distances is induced by the *p-norm* and comprises the *Euclidean distance* the *Manhattan distance* and the *Chebyshev distance*

[9] https://en.wikipedia.org/wiki/Taxicab_geometry
[10] https://en.wikipedia.org/wiki/Maximum_norm
[11] https://en.wikipedia.org/wiki/Mean_absolute_difference
[12] https://en.wikipedia.org/wiki/Minkowski_distance

p-Norm The *p-norms* provide length measures for different geometric interpretations of vector spaces. For a real number $p \geq 1$ and a vector space of dimension *n*, the p-norm is given by:[13]

$$\|\vec{x}\|_p := \left(\sum_{i=1}^{n} |x_i|^p \right)^{1/p}$$

For $0 \leq p < 1$ an evaluation according to the p-norm does not satisfy the triangle inequality and yields a quasi-norm.

The p-norms generalize the *1-Norm*, the *Euclidean Norm* and the *Maximum Norm*. The class of distances, induced by the p-norms are referred as *Minkowski distance*.

pq-Distance The *pq-Distances* are matrix distances, which are derived by an elementwise application of the *p-norm* to the rows of two matrices, followed by an elementwise application of another p-norm to the columns. For real numbers $p,\ q \geq 1$ and an underlying vector space of dimension $n \times m$, the pq-distance is given by:[14]

$$d_{p,q}(A,\ B) := \left(\sum_{j=1}^{m} \left(\sum_{i=1}^{n} |a_{ij} - b_{ij}|^p \right)^{q/p} \right)^{1/q}$$

For the case $p = q = 2$, the pq-distance is also referred as *Frobenius distance*.

pq-Norm The *pq-Norms* are matrix norms, which are derived by an elementwise application of the *p-norm* to the rows of a matrix, followed by an elementwise application of another p-norm to the columns. For real numbers $p,\ q \geq 1$ and an underlying vector space of dimension $n \times m$, the pq-norm is given by:[15]

$$\|A\|_{p,q} := \left(\sum_{j=1}^{m} \left(\sum_{i=1}^{n} |a_{ij}|^p \right)^{q/p} \right)^{1/q}$$

For the case $p = q = 2$, the pq-norm is also referred as *Frobenius norm*.

Power Mean Difference The *Power Mean Differences* are normalized distance measures for different geometric interpretations of vector spaces. For a real number $p \geq 1$ and a vector space of dimension *n*, the power mean difference is given by:

$$\mathrm{MD}_p(\vec{x},\ \vec{y}) := \left(\frac{1}{n} \sum_{i=1}^{n} |y_i - x_i|^p \right)^{1/p}$$

The power mean differences are induced by the *Hölder mean* for absolute values and linear related to the *Minkowski distance*:

$$\mathrm{MD}_p(\vec{x},\ \vec{y}) = \left(\frac{1}{n} \right)^{1/p} d_p(\vec{x},\ \vec{y})$$

When applied to the components of a random sample, the Power-Mean differences are normalized measures of statistical dispersion.

Quadratic Mean The *Quadratic Mean* is a normalized length measure for the geometric interpretation of vector spaces. For a vector space of dimension *n*, it is given by:[16]

$$M_2(\vec{x}) := \left(\frac{1}{n} \sum_{i=1}^{n} |x_i|^2 \right)^{1/2}$$

[13] https://en.wikipedia.org/wiki/P_norm
[14] https://en.wikipedia.org/wiki/Matrix_norm#L2,1_and_Lp,q_norms
[15] https://en.wikipedia.org/wiki/Matrix_norm#L2,1_and_Lp,q_norms
[16] https://en.wikipedia.org/wiki/Quadratic_mean

The quadratic mean specifies the *Hölder mean* for $p = 2$ and is linear dependent to the *Euclidean norm*:

$$M_2(\vec{x}) = \frac{\|\vec{x}\|_2}{\sqrt{n}}$$

Due to this linear relationship the quadratic mean is a valid vector space norm and thus induces a distance to it's underlying domain, which occasionally is referred as the *quadratic mean difference*. When applied to the components of a random sample, the quadratic mean norm is a sample statistic, which is referred as *Root-Mean-Square error*.

Quadratic Mean Difference The *Quadratic Mean Difference* is a normalized distance measure for the natural geometric interpretation of vector spaces. For a vector space of dimension *n*, the distance is given by:

$$\mathrm{MD}_2(\vec{x},\, \vec{y}) := \left(\frac{1}{n} \sum_{i=1}^{n} |y_i - x_i| \right)^{1/2}$$

The quadratic mean difference is induced by the *quadratic mean* and specifies the *power mean difference* for $p = 2$. Furthermore the quadratic mean difference is linear dependent to the *Euclidean distance*:

$$\mathrm{MD}_2(\vec{x},\, \vec{y}) = \frac{d_2(\vec{x},\, \vec{y})}{\sqrt{n}}$$

When applied to individual components of a random sample, the quadratic mean difference is a measure of statistical dispersion and referred as *Root-Mean-Square Error*.

4.1.2 Statistics

Association Measure *Association measures* refer to a wide variety of coefficients, that measure the statistical strength of relationships between the variables of interest. These measures can be directed / undirected, signed / unsigned and normalized or unnormalized. Examples for association measures are the Pearson correlation coefficient, Mutual information or Statistical Interactions.

Discrepancy Measure *Discrepancy measures* are binary functions in spaces of random variables, that induce a semi-metric to the underlying space.[17] In regression analysis discrepancies are used to assess the accuracy of a predictor, by quantifying the expected deviation between observed and predicted realizations. By minimizing a discrepancy with respect to parameters, it serves as an objective function for parameter and model selection.

Mean Absolute Error The *Mean Absolute Error* (MAE) is a *discrepancy measure*, that assesses the accuracy of a predictor. For an observable random variable Y and a corresponding predictor $\hat{Y}$ the MAE is given by:

$$\mathrm{MAE} := \mathrm{E}\left[|Y - \hat{Y}| \right]$$

The MAE has a consistent and unbiased estimator, given by the *mean absolute difference* of observations and predictions. For *n* observations $\mathbf{y}$ with corresponding predictions $\hat{\mathbf{y}}$ the MAE is estimated by:

$$\mathrm{MD}_1(\mathbf{y},\, \hat{\mathbf{y}}) \xrightarrow{n \to \infty} \mathrm{MAE}$$

Due to this transition, the MAE adopts all required properties from the mean absolute difference, to induce a valid metric to the space of random variables.

Mean Squared Error The *Mean Squared Error* (MSE) is a *discrepancy measure*, that assesses the accuracy of a predictor. For an observable random variable Y and a corresponding predictor $\hat{Y}$ the MSE is given by:

$$\mathrm{MSE} := \mathrm{E}\left[(Y - \hat{Y})^2 \right]$$

[17] https://en.wikipedia.org/wiki/discrepancy_function

The MSE has a consistent and unbiased estimator, given by the squared *quadratic mean difference* of observations and predictions. For *n* observations $\mathbf{y}$ with corresponding predictions $\hat{\mathbf{y}}$ the MSE is estimated by:

$$\mathrm{MD}_2(\mathbf{y}, \hat{\mathbf{y}})^2 \xrightarrow{n\to\infty} \mathrm{MSE}$$

In difference to the *Root-Mean-Square Error*, the MSE does not satisfy the triangle inequality and therefore does not define a valid distance measure. Since the MSE, however, is positive definite and subhomogeneous, it induces a semi-metric to the underlying space of random variables.

Residual Sum of Squares The *Residual Sum of Squares* (RSS) is a *discrepancy measure*, that assesses the accuracy of a predictor with respect to a fixed (finite) set of observations. For an observable random variable Y with *n* fixed observations $\mathbf{y}$ and a predictor $\hat{Y}$ with corresponding predictions $\hat{\mathbf{y}}$ the RSS is given by:

$$\mathrm{RSS}(\mathbf{y}, \hat{\mathbf{y}}) := \sum_{i=1}^{n} (y_i - \hat{y}_i)^2$$

The RSS equals the squared *Euclidean distance*, which does not satisfy the triangle inequality and therefore does not define a valid distance measure. Since the RSS, however, is positive definite and subhomogeneous, it induces a semi-metric to the underlying space of random variables.

Root-Mean-Square Error The *Root-Mean-Square Error* (RMSE) is a *discrepancy measure*, that assesses the accuracy of a predictor. For an observable random variable Y and a corresponding predictor $\hat{Y}$ the RMSE is given by:

$$\mathrm{RMSE} := \mathrm{E}\left[(Y - \hat{Y})^2\right]^{1/2}$$

The RMSE has a consistent and unbiased estimator, given by the *quadratic mean difference* of observations and predictions. For *n* observations $\mathbf{y}$ with corresponding predictions $\hat{\mathbf{y}}$ the RMSE is estimated by:

$$\mathrm{MD}_2(\mathbf{y}, \hat{\mathbf{y}}) \xrightarrow{n\to\infty} \mathrm{RMSE}$$

Due to this transition, the RMSE adopts all required properties from the quadratic mean difference, to induce a valid metric to the space of random variables.

Sum of Absolute Differences The *Sum of Absolute Differences* (SAD) is a *discrepancy measure*, that assesses the accuracy of a predictor with respect to a fixed (finite) set of observations. For an observable random variable Y with *n* fixed observations $\mathbf{y}$ and a predictor $\hat{Y}$ with corresponding predictions $\hat{\mathbf{y}}$ the RSS is given by:

$$\mathrm{SAD}(\mathbf{y}, \hat{\mathbf{y}}) := \sum_{i=1}^{n} |y_i - \hat{y}_i|$$

The SAD equals the *Manhattan distance* and therefore is also a valid distance measure within the underlying space of random variables. The SAD is effectively the simplest possible distance, that takes into account every observation of a fixed finite set. This makes SAD an extremely fast distance measure.

4.2 API Glossary

4.2.1 Basic Parameters and Formats

Field Identifier *Field Identifiers* uniquely identify fields within objects. Since objects may comprise fields, given by it's attributes, items or / and other accessing mechanisms, the identification mechanism of the fields depends on the domain type of the object:

objects For the domain type `object` fields are identified by attribute names, and therefore required to be valid identifiers as specified in **PEP 3131**. Additionally the functions in the module `rian.base.operator` accept the usage of dots, for the identification of arbitrary sub-objects within object hierarchies.

mappings For the domain type `dict` (or any subclass of the `Mapping class`) fields are identified by the keys of the mappings and therefore required to be hashable. Additionally the functions in the module `rian.base.operator` require, that the field identifiers are not given by tuples.

sequences For the domain type `tuple` (or any subclass of the `Sequence class`) the fields are identifiers are not the names of fields, but their position within the sequence (starting with 0) and therefore required to be non-negative integers.

Domain Like *Domain Like* parameters are used to specify the *type* and the *frame* of the domain and the target (codomain) of an operator. Thereby the format, which is used for the specification depends an the respective type:

Domain types that use named *field identifiers* (like `object` or `dict`) do not require the specification of a frame. In this case the parameter format is given by a single term *<type>*, where *<type>* may ether be a supported `type` of the respective parameter or None, for the default behavior of the respective function.

Domain types that use positional field identifiers (like `tuple` or `list`) require the specification of a frame, to map variable names to their positions within the frame. In this case the parameter format is given by a tuple *(<type>, <frame>)*, where the term *<frame>* is required to be a tuple of valid field identifiers in the domain type.

Variable Definition *Variable Definition* parameters are used to specify the mapping of fields to variables. For a variable that represents a named field (e.g. group keys in grouped sequences, etc.), it is sufficient to only provide the *identifier* of the field. If the underlying domain type, however, does not support named fields or the variable name shall be different to the field identifier, then the variable name has to be included in the definition by *(<field>, <name>)*, where *<name>* is required to be a valid identifier.

For a variable that only depends on a single named field, but is not identical identical to the field, the mapping from the field to the variable has to be specified by an operator (e.g. an *aggregation function*), which has to be included within the definition by *(<field>, <operator>)*. If the underlying domain type, does not support named fields or the variable name is required to be different to the field identifier, then the definition has to be given by the format *(<field>, <operator>, <name>)*.

For a variable that depends on multiple fields the definition has to be given in the format *(<fields>, <operator>, <name>)*, where *<fields>* is a tuple of valid field identifiers in the domain type and *<operator>* an operator, which accepts the specified fields as arguments.

4.2.2 Parameters and Formats used in Data Warehousing

Row Like *Row like* data comprises different data formats, which are used to represent table records. This includes tuples, mappings and instances of the `Record class`. The `Table class` accepts these data types for appending rows by `insert()` and for retrieving rows by `select()`.

Cursor Mode The *cursor mode* defines the *scrolling type* and the *operation mode* of a cursor. Internally the respective parameters of the `Cursor class` are identified by binary flags. The public interface uses a string representation, given by the space separated names of the scrolling type and the the operation mode. Supported scrolling types are:

forward-only The default scrolling type of cursors is called a forward-only cursor and can move only forward through the result set. A forward-only cursor does not support scrolling but only fetching rows from the start to the end of the result set.

scrollable A scrollable cursor is commonly used in screen-based interactive applications, like spreadsheets, in which users are allowed to scroll back and forth through the result set. However, applications should use scrollable cursors only when forward-only cursors will not do the job, as scrollable cursors are generally more expensive, than forward-only cursors.

random Random cursors move randomly through the result set. In difference to a randomly sorted cursor, the rows are not unique and the number of fetched rows is not limited to the size of the result set. If the method `fetch()` is called with a zero value for size, a CursorModeError is raised.

Supported operation modes are:

dynamic A **dynamic cursor** is built on-the-fly and therefore comprises any changes made to the rows in the result set during it's traversal, including new appended rows and the order of it's traversal. This behavior is regardless of whether the changes occur from inside the cursor or by other users from outside the cursor. Dynamic cursors are thread-safe but do not support counting filtered rows or sorting rows.

indexed Indexed cursors (aka Keyset-driven cursors) are built on-the-fly with respect to an initial copy of the table index and therefore comprise changes made to the rows in the result set during it's traversal, but not new appended rows nor changes within their order. Keyset driven cursors are thread-safe but do not support sorting rows or counting filtered rows.

static Static cursors are buffered and built during it's creation time and therefore always display the result set as it was when the cursor was first opened. Static cursors are not thread-safe but support counting the rows with respect to a given filter and sorting the rows.

Aggregation Function *Aggregation Functions* are `callable` objects, that transform sequences of objects of a given domain into a single value. Examples include `len()`, `sum()`, `min()` or `max()`, but depending on the domain, many out-of-the-box aggregators are shipped with the standard library package `statistics` or with third party packages like `numpy`.

CHAPTER 5

License

Rian is distributed with the GNU General Public License v3 [GPLV3].

```
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Version 3, 29 June 2007

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general-purpose computers, but in those that do, we wish to avoid the
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effectively proprietary.  To prevent this, the GPL assures that patents
cannot be used to render the program non-free.

The precise terms and conditions for copying, distribution and modification
follow.

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0. Definitions.

"This License" refers to version 3 of the GNU General Public License.

"Copyright" also means copyright-like laws that apply to other kinds of
works, such as semiconductor masks.

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To "modify" a work means to copy from or adapt all or part of the work in a
fashion requiring copyright permission, other than the making of an exact
copy.  The resulting work is called a "modified version" of the earlier work
or a work "based on" the earlier work.

A "covered work" means either the unmodified Program or a work based on the
Program.
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To "propagate" a work means to do anything with it that, without permission,
would make you directly or secondarily liable for infringement under
applicable copyright law, except executing it on a computer or modifying a
private copy.  Propagation includes copying, distribution (with or without
modification), making available to the public, and in some countries other
activities as well.

To "convey" a work means any kind of propagation that enables other parties
to make or receive copies.  Mere interaction with a user through a computer
network, with no transfer of a copy, is not conveying.

An interactive user interface displays "Appropriate Legal Notices" to the
extent that it includes a convenient and prominently visible feature that
(1) displays an appropriate copyright notice, and (2) tells the user that
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view a copy of this License.  If the interface presents a list of user
commands or options, such as a menu, a prominent item in the list meets this
criterion.

1. Source Code.

The "source code" for a work means the preferred form of the work for making
modifications to it.  "Object code" means any non-source form of a work.

A "Standard Interface" means an interface that either is an official
standard defined by a recognized standards body, or, in the case of
interfaces specified for a particular programming language, one that is
widely used among developers working in that language.

The "System Libraries" of an executable work include anything, other than
the work as a whole, that (a) is included in the normal form of packaging a
Major Component, but which is not part of that Major Component, and (b)
serves only to enable use of the work with that Major Component, or to
implement a Standard Interface for which an implementation is available to
the public in source code form.  A "Major Component", in this context, means
a major essential component (kernel, window system, and so on) of the
specific operating system (if any) on which the executable work runs, or a
compiler used to produce the work, or an object code interpreter used to run
it.

The "Corresponding Source" for a work in object code form means all the
source code needed to generate, install, and (for an executable work) run
the object code and to modify the work, including scripts to control those
activities.  However, it does not include the work's System Libraries, or
general-purpose tools or generally available free programs which are used
unmodified in performing those activities but which are not part of the
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between those subprograms and other parts of the work.

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You may convey a work based on the Program, or the modifications to produce
it from the Program, in the form of source code under the terms of section
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4, provided that you also meet all of these conditions:

a) The work must carry prominent notices stating that you modified it, and
giving a relevant date.

b) The work must carry prominent notices stating that it is released under
this License and any conditions added under section 7.  This requirement
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A compilation of a covered work with other separate and independent works,
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legal rights of the compilation's users beyond what the individual works
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You may convey a covered work in object code form under the terms of
sections 4 and 5, provided that you also convey the machine-readable
Corresponding Source under the terms of this License, in one of these ways:

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a physical distribution medium), accompanied by the Corresponding Source
fixed on a durable physical medium customarily used for software
interchange.

b) Convey the object code in, or embodied in, a physical product (including
a physical distribution medium), accompanied by a written offer, valid for
at least three years and valid for as long as you offer spare parts or
customer support for that product model, to give anyone who possesses the
object code either (1) a copy of the Corresponding Source for all the
software in the product that is covered by this License, on a durable
physical medium customarily used for software interchange, for a price no
more than your reasonable cost of physically performing this conveying of
source, or (2) access to copy the Corresponding Source from a network server
at no charge.

c) Convey individual copies of the object code with a copy of the written
offer to provide the Corresponding Source.  This alternative is allowed only
occasionally and noncommercially, and only if you received the object code
with such an offer, in accord with subsection 6b.
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d) Convey the object code by offering access from a designated place (gratis
or for a charge), and offer equivalent access to the Corresponding Source in
the same way through the same place at no further charge.  You need not
require recipients to copy the Corresponding Source along with the object
code.  If the place to copy the object code is a network server, the
Corresponding Source may be on a different server (operated by you or a
third party) that supports equivalent copying facilities, provided you
maintain clear directions next to the object code saying where to find the
Corresponding Source.  Regardless of what server hosts the Corresponding
Source, you remain obligated to ensure that it is available for as long as
needed to satisfy these requirements.

e) Convey the object code using peer-to-peer transmission, provided you
inform other peers where the object code and Corresponding Source of the
work are being offered to the general public at no charge under subsection
6d.

A separable portion of the object code, whose source code is excluded from
the Corresponding Source as a System Library, need not be included in
conveying the object code work.

A "User Product" is either (1) a "consumer product", which means any
tangible personal property which is normally used for personal, family, or
household purposes, or (2) anything designed or sold for incorporation into
a dwelling.  In determining whether a product is a consumer product,
doubtful cases shall be resolved in favor of coverage.  For a particular
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or common use of that class of product, regardless of the status of the
particular user or of the way in which the particular user actually uses, or
expects or is expected to use, the product.  A product is a consumer product
regardless of whether the product has substantial commercial, industrial or
non-consumer uses, unless such uses represent the only significant mode of
use of the product.

"Installation Information" for a User Product means any methods, procedures,
authorization keys, or other information required to install and execute
modified versions of a covered work in that User Product from a modified
version of its Corresponding Source.  The information must suffice to ensure
that the continued functioning of the modified object code is in no case
prevented or interfered with solely because modification has been made.

If you convey an object code work under this section in, or with, or
specifically for use in, a User Product, and the conveying occurs as part of
a transaction in which the right of possession and use of the User Product
is transferred to the recipient in perpetuity or for a fixed term
(regardless of how the transaction is characterized), the Corresponding
Source conveyed under this section must be accompanied by the Installation
Information.  But this requirement does not apply if neither you nor any
third party retains the ability to install modified object code on the User
Product (for example, the work has been installed in ROM).

The requirement to provide Installation Information does not include a
requirement to continue to provide support service, warranty, or updates for
a work that has been modified or installed by the recipient, or for the User
Product in which it has been modified or installed.  Access to a network may
be denied when the modification itself materially and adversely affects the
operation of the network or violates the rules and protocols for
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communication across the network.

Corresponding Source conveyed, and Installation Information provided, in
accord with this section must be in a format that is publicly documented
(and with an implementation available to the public in source code form),
and must require no special password or key for unpacking, reading or
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<program>  Copyright (C) <year>  <name of author> This program comes with
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```

CHAPTER 6

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6.1 Publications

6.2 Links

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[IEEE754] https://ieeexplore.ieee.org/document/4610935/

[ML] https://en.wikipedia.org/wiki/Machine_learning

[MIME] http://www.iana.org/assignments/media-types/

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Index

Symbols

A

C

D

E

F

H

M

P

Q

R

S

V