
Rian

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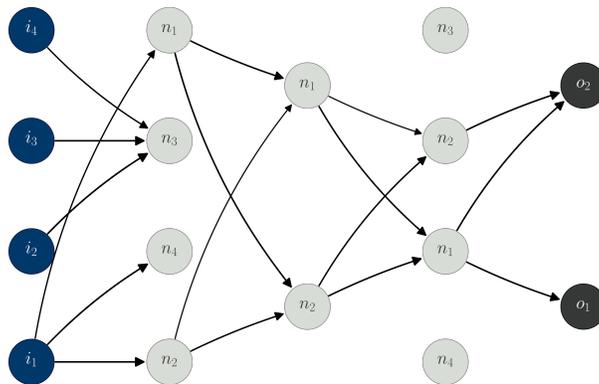
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In many domains of enterprise and scientific data analysis the lack of structural knowledge encourages the use of machine intelligence methods, which surpass the structural flexibility of classical statistical methods. Since this approach, however, generally is paid by high mathematical uncertainty, it is indispensable to properly select and adapt the method to its 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.

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 be 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)
```

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.core.cli module

rian.core.dcmeta module

rian.core.log module

rian.core.session module

rian.core.tty module

rian.core.ws module

Module contents

rian.dataset package

Subpackages

rian.dataset.builder package

Submodules

rian.dataset.builder.plain module

Module contents

rian.dataset.classes package

Submodules

rian.dataset.classes.base module

Module contents

rian.dataset.common package

Subpackages

rian.dataset.common.labels package

Submodules

rian.dataset.common.labels.gene module

Module contents

Module contents

rian.dataset.exports package

Submodules

rian.dataset.exports.archive module

rian.dataset.exports.image module

rian.dataset.exports.text module

Module contents

rian.dataset.imports package

Submodules

rian.dataset.imports.archive module

rian.dataset.imports.text module

Module contents

Module contents

rian.math package

Submodules

rian.math.curve module

rian.math.graph module

rian.math.matrix module

rian.math.regress module

rian.math.stat module

rian.math.test module

rian.math.vector module

Module contents

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

Module contents

rian.model.exports package

Submodules

rian.model.exports.archive module

rian.model.exports.image module

Module contents

rian.model.imports package

Submodules

rian.model.imports.archive module

Module contents

rian.model.morphisms package

Submodules

rian.model.morphisms.ann module

rian.model.morphisms.base module

rian.model.morphisms.dbn module

rian.model.morphisms.rbm module

Module contents

Module contents

rian.network package

Subpackages

rian.network.builder package

Submodules

rian.network.builder.layer module

Module contents

`rian.network.classes` package

Submodules

`rian.network.classes.base` module

`rian.network.classes.layer` module

Module contents

`rian.network.exports` package

Submodules

`rian.network.exports.archive` module

`rian.network.exports.graph` module

`rian.network.exports.image` module

Module contents

`rian.network.imports` package

Submodules

`rian.network.imports.archive` module

`rian.network.imports.graph` module

`rian.network.imports.text` module

Module contents

Module contents

`rian.plot` package

Submodules

`rian.plot.heatmap` module

`rian.plot.histogram` module

rian.plot.network module

rian.plot.scatter module

Module contents

rian.session package

Subpackages

rian.session.classes package

Submodules

rian.session.classes.base module

Module contents

Module contents

rian.system package

Subpackages

rian.system.classes package

Submodules

rian.system.classes.ann module

rian.system.classes.base module

rian.system.classes.dbn module

rian.system.classes.rbm module

Module contents

rian.system.common package

Submodules

rian.system.common.links module

rian.system.common.units module

Module contents

rian.system.exports package

Submodules

rian.system.exports.archive module

Module contents

rian.system.imports package

Submodules

rian.system.imports.archive module

rian.system.imports.text module

Module contents

Module contents

rian.workspace package

Subpackages

rian.workspace.classes package

Submodules

rian.workspace.classes.base module

Module contents

rian.workspace.imports package

Submodules

rian.workspace.imports.text module

Module contents

Module contents

3.1.2 Submodules

rian.typing module

3.1.3 Module contents

4.1 Math Glossary

4.1.1 Norms and Metrics

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 $p \rightarrow \infty$.

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 and estimated realizations. This discrepancy measure is commonly referred to 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 the *Euclidean distance* to its 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 its 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 to 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 induced metrics 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 $p \rightarrow \infty$ 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:

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

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*:

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

The term 'mean absolute difference' is frequently associated with it's application to sampled values¹¹. 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:

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

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

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

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 its 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:

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

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*:

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

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:

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

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:

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

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:

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

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:

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

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:

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

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:

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

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:

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

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:

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

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 on 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 either 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 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`.

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CHAPTER 6

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6.1 Publications

6.2 Links

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- [PGM] https://en.wikipedia.org/wiki/Graphical_model
- [TGN] <http://www.getty.edu/research/tools/vocabulary/tgn/>
- [UAX31] <http://unicode.org/reports/tr31/>
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