# Graphana - Operations and types

## Contents

# 1 Commands and graph operations

Every box in this section depicts one operation. The boxes are structured as follows:

**operationKey**

```
parameterName1:  ParameterType1
parameterName2:  ParameterType2
...
parameterNameN: ParameterTypeN
[...]
```
**returns** `ReturnType`

The operation's description text.

Default values are denoted with a `=` after the parameter type followed by the value. If a parameter has a default value then passing an argument is optional. Some operations have three dots at the end of their parameter lists. These operations can receive arguments of the type of the last parameter in the list at any number.

Besides operations, some subsections contain descriptions of terms. These are not written in boxes.

## 1.1 Graph creation

**Graph configuration:**
In *Graphana* a graph configuration is the combination of the properties *directed*, *weighted* and *simple forced*. If a graph is forced to be simple then no loops can be inserted.

**Graph library:**
*Graphana* can internally use different graph libraries. Which library is used influences performance and the set of available algorithms. The usage itself does not depend on the chosen library. So graph construction, graph loading etc. always works in the same way. In addition libraries can be converted into each other (either manually by calling **setLibrary** or automatically if a called algorithm is not compatible with the current library).

**createGraph**

```
directed:  Boolean = false
weighted:  Boolean = false
simpleForced:  Boolean = false
library:  String = 'KEEP'
```
**returns** `void`

Creates a graph with the given **graph configuration** and sets it as the current graph. With the parameter `library` a name of a **graph library** can be given. The graph will then internally be created as a graph of the respective library. If the argument is set to `KEEP` or omitted then the previously used library will be used. An already created graph will be completely deleted and recreated.

| **recreateGraph** |
|---|
| `directed: Boolean = false`<br>`weighted: Boolean = false`<br>`simpleForced: Boolean = false`<br>**returns** `void` |
| Recreates an already existing graph with the given **graph configuration**. The **graph library** remains the same.<br>The operation is equal to a call of **createGraph**(`directed`,`weighted`,`simpleForced`,'KEEP'); |

## 1.2 Graph loading

| **loadGraph** |
|---|
| `filename: ExistingFile`<br>**returns** `void` |
| Sets the current graph by loading a DIMACS or a dot file. Depending on the given file format, the operation does either the same as **loadDIMACS** or **loadDot**. |

| **loadDIMACS** |
|---|
| `filename: ExistingFile`<br>`directed: Boolean = false`<br>`weighted: Boolean = false`<br>`simpleForced: Boolean = false`<br>**returns** `void` |
| Loads the given DIMACS **File**.<br>If the graph is directed then every edge in the file is seen as an directed edge and vice versa. So if the graph is undirected, there can only be one edge per vertex pair even if there are two in the file. If the graph is unweighted then the weights within the file will be ignored. If the graph is forced to be simple then loops in the file will be ignored . For huge files the number of lines to read can be limited using 'MaxLines'. |

| **loadDot** |
|---|
| `filename: ExistingFile`<br>`ignoreWeights: Boolean = false`<br>`ignoreLayoutAttributes: Boolean = false`<br>**returns** `void` |
| Loads the given dot **File**.<br>Since a dot file directly contains information of whether the graph is directed or not, the resulting graph will be directed if and only if it is directed in the dot file. If the graph is unweighted then the weights within the file will be ignored. If the graph is forced to be simple then loops in the file will be ignored . |

## 1.3 Graph libraries

| **setLibrary** |
|---|
| `libraryName: String`<br>**returns** `void` |
| Sets the current **graph library**. The graph will be converted into the given graph library. Initially, the JUNG2 library is set. |

| **getLibrary** |
| --- |
| **returns** `String` |
| Returns the name of the current graph library as a **String**. |

| **getAvailableLibraries** |
| --- |
| **returns** `Set` |
| Returns the names of all available graph libraries as a **Set** of **String**. Each of the given names is a valid library input for the **setLibrary** operation or the **createGraph** operation. |

## 1.4 Graph editing

| **resolveVertexNameClashes** |
| --- |
| `resolve: Boolean`<br>**returns** `void` |
| If `resolve` is `true` then name clashes will be automatically resolved when adding a vertex (e.g. with **addVertex**) with an identifier which is already used by an existing vertex of the graph. Initially name clashes are not resolved. |

| **addVertex** |
| --- |
| `identifier: String = ”`<br>**returns** `Vertex` |
| Adds a vertex with the given name to the current graph. The added vertex is then identified by the given `identifier`. If auto-resolving of name clashes is activated (see **resolveVertex-NameClashes**) then underscores will be added to the given identifier until there is no vertex with the same identifier. If not and there is a name clash then no vertex will be added. If no identifier is given, a default identifier will be used (default identifiers are enumerated).<br>The new or the already existing vertex is returned. |

| **addVertices** |
| --- |
| `identifier: String`<br>`...`<br>**returns** `void` |
| Adds multiple vertices. With every given `identifier` the operation adds a vertex just as **addVertex** does |

| **addVertexRow** |
| --- |
| `amount: PositiveInteger`<br>`startIndex: Integer = 0`<br>`prefix: String = ’v’`<br>`Cluster: Boolean = false`<br>**returns** `void` |
| Adds overall `amount` vertices. The operation enumerates the added vertices, starting at `startIndex`. The name of an added vertex will be the `prefix` concatenated with the number. If `cluster` is set to `true` then all added vertices are connected with each other. |

| **addEdge** |
|---|
| `startVertex: Vertex` |
| `endVertex: Vertex` |
| `weight: Float = 1.0f` |
| **returns** `void` |
| Adds an edge between the two given vertices (see **Vertex**). A weight can be given, but will be ignored, if the graph is unweighted. |

| **setEdgeWeight** |
|---|
| `edge: Edge` |
| `weight: Float = 1.0f` |
| **returns** `void` |
| Sets the weight of the given **Edge**. An error is returned if the graph is unweighted. |

| **removeVertex** |
|---|
| `vertex: Vertex` |
| `...` |
| **returns** `void` |
| Removes the given **Vertex** or the given vertices, respectively, from the graph. That means one ore more vertices can be given. |

| **removeVertexSet** |
|---|
| `vertices: Iterable` |
| `...` |
| **returns** `void` |
| Removes all vertices of the given **Iterable**. |

| **removeEdge** |
|---|
| `edge: Edge` |
| `...` |
| **returns** `void` |
| Removes the given **Edge** or the given edges, respectively, from the graph. That means one or more edges can be given. |

| **removeEdgeSet** |
|---|
| `edges: Iterable` |
| `...` |
| **returns** `void` |
| Removes all edges of the given **Iterable**. |

| **clearGraph** |
|---|
| **returns** `void` |
| Removes all vertices from the graph. |

| **deleteLoops** |
|---|
| **returns** `void` |
| Deletes all loops from the graph in order that the graph is simple after this operation. However, loops can be inserted afterwards. To disallow this, see **forceSimple**. |

| **forceSimple** |
|---|
| **returns** `void` |
| Deletes all loops from the graph. Furthermore, loops cannot be inserted afterwards. |

| **allowLoops** |
|---|
| **returns** `void` |
| After the call of this operation, loops can be added into the graph. |

| **mergeGraph** |
|---|
| `sourceGraph: Graph`<br>**returns** `void` |
| Merges the graph with the given `sourceGraph`. Every vertex and edge of the given graph will be added to the graph as deep copies. Only dates of the vertices and edges, if existing, are not copied deep. |

| **graphGUI** |
|---|
| `deleteGraph: Boolean = false`<br>`drawWindowWidth: PositiveInteger = 640`<br>`drawWindowHeight: PositiveInteger = 640`<br>`frameRate: PositiveInteger = 0`<br>**returns** `void` |
| Opens a **visualization window** with the standard grid layout with the purpose of editing the graph visually. If `deleteGraph` is set to `true` then all vertices are deleted before editing and the graph as well as the visualization window is empty. |

## 1.5 Getting graph information

| **isDirected** |
|---|
| **returns** `Boolean` |
| Returns `true`, if and only if the graph is directed. |

| **isWeighted** |
|---|
| **returns** `Boolean` |
| Returns `true`, if and only if the graph is weighted. |

| **isSimple** |
|---|
| **returns** `Boolean` |
| Returns `true`, if and only if the graph does not contain any loops. |

| **isSimpleForced** |
|---|
| **returns** `Boolean` |
| Returns `true`, if and only if the graph is simple and it is not possible to add loops into the graph. |

## 1.6 Graph conversions

| **setGraphConfig** |
|---|
| `directed: Boolean`<br>`weighted: Boolean`<br>`forceSimple: Boolean`<br>**returns** `void` |
| Converts the current graph into a graph with the given **graph configuration** whereas the graph library remains the same. If the given graph configuration is forbidden in the respective graph library then an error will be returned. |

| **asDirected** |
|---|
| **returns** `Graph` |
| Returns an equivalent directed graph. The returned graph contains the same vertices as the original graph. For every undirected edge in the original graph two directed edges are created in the returned graph. If the original graph is already directed then the graph is returned without any changes. |

| **toDirected** |
|---|
| **returns** `void` |
| Converts the current graph into a directed graph. The converted graph contains the same vertices as the original graph. For every undirected edge in the original graph two directed edges are created in the converted graph.<br>If the current graph is already directed then nothing happens. |

| **asWeighted** |
|---|
| **returns** `Graph` |
| Returns an equivalent weighted graph. The returned graph contains the same vertices as the original graph. For every unweighted edge of the original graph, an edge with the weight 1 is created in the returned graph. In the returned graph, edge weights can be set.<br>If the original graph is already weighted then the graph is returned without any changes. |

| **toWeighted** |
|---|
| **returns** `void` |
| Converts the current graph into a weighted graph. The converted graph contains the same vertices as the original graph. For every unweighted edge of the original graph an edge with the weight 1 is created in the converted graph. After this call, edge weights can be set in the current graph.<br>If the current graph is already weighted then nothing happens. |

| **graphAsDIMACS** |
|---|
| **returns** `String` |
| Returns a **String** containing the DIMACS representation of the graph. |

## 1.7 Program configuration

| **getCurrentGraph** |
| --- |
| `deepCopy: Boolean = false`<br>**returns** `Graph` |
| Returns the current graph. The returned **Graph** can be stored in a variable for example. |

| **setCurrentGraph** |
| --- |
| `graph: Graph`<br>**returns** `void` |
| Sets the given graph as the current graph. |

| **setAlgorithmTimeout** |
| --- |
| `timeOutMillis: PositiveInteger`<br>**returns** `void` |
| Sets the maximum computation time for an algorithm. If an algorithm which is executed afterwards exceeds the given time then the computation will be aborted and a timeout error will be returned.<br>The timeout is given in milliseconds, so a timeout of 1000 means one second. Initially, the timeout is set to 10000. |

| **setPrintWarnings** |
| --- |
| `printWarnings: Boolean = true`<br>**returns** `void` |
| Calling this method enables or disables the output of warnings. |

| **setCaching** |
| --- |
| `enableCaching: Boolean`<br>**returns** `void` |
| This operation can be used to enable or disable caching of algorithm results. Some algorithms save their (interim) results to reuse them when called repeatedly or to provide them to other algorithms to increase the overall program performance.<br>Initially, caching is enabled. There are circumstances under which caching is automatically disabled, for example if the runtime of an algorithm is measured. |

## 1.8 System operations

| **import** |
| --- |
| `Class: ExistingFile`<br>**returns** `String` |
| Imports the given **ExistingFile** into the program. The file must be a java class which is compatible with *Graphana*. After importing, the operations that are defined within the class are available in the program. |

| **sleep** |
| --- |
| `milliseconds: PositiveInteger`<br>**returns** `void` |
| Causes the program to sleep. The duration is given in milliseconds, so for example `1000` means one second. |

## 1.9 Time and date

| **getTime** |
| --- |
| `format: String = 'HH:mm:ss'`<br>**returns** `String` |
| Returns the current system time as formatted **String** in the given format. |

| **millisToString** |
| --- |
| `milliseconds: PositiveInteger`<br>**returns** `String` |
| Converts the given `milliseconds` into a formatted **String**. |

| **getTimeMillis** |
| --- |
| **returns** `Integer` |
| Returns the current system time in milliseconds where 0 is 00:00. |

| **getDate** |
| --- |
| `format: String = 'yyyy/MM/dd'`<br>**returns** `String` |
| Returns the current system date as formatted **String** in the given format. |

## 1.10 Counters

| **startCounter** |
| --- |
| **returns** `void` |
| Starts the global counter. Every time this operation is called, the global counter will be reset. |

| **getCounter** |
| --- |
| **returns** `Integer` |
| Returns the time difference between the call of startCounter and the current time in milliseconds. This operation does not stop the counter. |

**Algorithm timer:**
The algorithm timer can be used to measure the runtimes of algorithms. It increases whenever an algorithm is running. So the timer is more accurate than the normal counter because only the runtime of the algorithm itself is measured, ignoring for example compatibility checks. Nevertheless, interferences with the java garbage collector may occur.
The algorithm timer is used via **startAlgorithmTimer** and **getAlgorithmTime**.

| **startAlgorithmTimer** |
| --- |
| **returns** `void` |
| Starts/restarts the **algorithm timer**. That means, that its value is set to 0. |

| **getAlgorithmTime** |
| --- |
| **returns** `Integer` |
| Returns the current algorithm timer as **Integer** in milliseconds. The algorithm timer keeps running after calling this operation. |

## 1.11 Execution

| **script** |
| --- |
| `file: ExistingFile`<br>`statements: ANY = ''`<br>`...`<br>**returns** `ANY` |
| Executes the given **ExistingFile** as batch. The script must contain source code in *Graphana* syntax. The additional arguments are ignored and can be used to set up global variables which are used within the script for example. |

| **executeString** |
| --- |
| `statement: String`<br>**returns** `ANY` |
| Executes the given **String** and returns the result of the execution. The given string must be source code in *Graphana* syntax. The additional arguments are ignored and can be used to set up global variables which are used within the statement for example. If the statement shall be executed multiple times it is recommended to use **parse** and **executeTree** instead of this command. |

| **parse** |
| --- |
| `source: String`<br>**returns** `ParseTree` |
| Parses the given **String** and returns a **ParseTree**. The given `source` must be source code in *Graphana* syntax. |

| **parseScript** |
| --- |
| `script: ExistingFile`<br>**returns** `ParseTree` |
| Parses the given **ExistingFile** and returns a **ParseTree**. The script must be source code in *Graphana* syntax. |

| **executeTree** |
| --- |
| `tree: ParseTree`<br>**returns** `ANY` |
| Executes the given **ParseTree** and returns the result of the execution. The execution of a parse tree is much faster than the execution of a **String** with **executeString**. |

## 1.12 System alerts

| **error** |
|---|
| `message: String`<br>**returns** `void` |
| Throws an error with the given text message and stops the execution of the statement and, if executed in a script, of the script. |

| **warning** |
|---|
| `message: String`<br>**returns** `void` |
| Prints a warning with the given text together with some meta data. |

| **alert** |
|---|
| `message: String`<br>`title: String = 'Message'`<br>**returns** `void` |
| Shows a message dialogue containing the given text. The dialogue window will be titled with the given `title`. |

## 1.13 File output

| **setOutputFile** |
|---|
| `file: File`<br>`autoWriteConsoleOutput: Boolean = false`<br>`autoWriteConsoleInput: Boolean = false`<br>**returns** `void` |
| Sets the current output file. After the output file is set, every `WRITE` call will write into the chosen file.<br>If the given file does not exist, it will be created. Otherwise it will be overwritten. If `autoWriteConsoleOutput` is set to true then nearly every console output, including `PRINT` calls, errors and warnings, will be written into the file automatically. If `autoWriteConsoleInput` is set to true then also console inputs will be written into the file. |

| **flushOutput** |
|---|
| **returns** `void` |
| Flushes the current output file without closing it. So the file will be visible and up to date in the file system. |

| **closeOutput** |
|---|
| **returns** `void` |
| Closes the current output file. So the file will be visible and up to date in the file system and can be used by other programs. After closing the file it is not allowed to call `WRITE` until a new output file is set using **setOutputFile**. |

| **writeWholeFile** |
|---|
| `file: File`<br>`object: ANY`<br>**returns** `void` |
| Creates a text file which contains the string representation of the given **Object**. The file will be automatically closed after writing. |

## 1.14 File input

| **readWholeFile** |
|---|
| `file: ExistingFile`<br>**returns** `String` |
| Reads the whole given (text) file and returns the content as one **String**. |

| **getFiles** |
|---|
| `directory: String`<br>`acceptedExtensions: Vector =`<br>**returns** `Set` |
| Returns all files of the given directory as a set of **File**. Instead of a directory, a filename can be given alternatively. In this case, a set, which only contains the given file, will be returned. |

## 1.15 Graph visualization

**Visualization window:**
Every graph visualization and **algorithm visualization** is done in a visualization window which can be minimized, maximized and closed. Within the window, the following actions can be performed:

Left click on a vertex: moving vertex.
Right click on empty space: adding a vertex.
Middle click and drag: scrolling through the view.
Mouse wheel: zoom in and out.
Right click and hold on a vertex and release on another vertex: creating an edge from the first vertex to the second or delete the respective edge, if it already exists.

Modifying the graph only works in the standard visualization and only if it is allowed (for example it is not possible in algorithm visualizations). So the right mouse button may have no effect.

Every window has a certain frame rate which determines, how often the graph is repainted per second. Repainting is necessary to make changes in the dates and states of the vertices and edges visible. If the frame rate is set to zero, then the graph must be repainted manually using **repaintGraph**.

**Layout:**
The layout determines how the vertices are positioned in a **visualization window**. The layout

is chosen for example as the first argument of the **showGraph** operation.

The following layouts are available in *Graphana*:
GRID
CYCLE
TREE
JUNG.CYCLE
JUNG.ISOM

For directed graphs, a root vertex must be given when using the TREE layout by writing a colon and the vertex identifier, for example TREE:v1.

| **showGraph** |
|---|
| `layout: String = 'GRID'`<br>`windowTitle: String = ''`<br>`width: PositiveInteger = 640`<br>`height: PositiveInteger = 640`<br>`enableModification: Boolean = true`<br>`frameRate: PositiveInteger = 10`<br>**returns** `void` |
| Visualizes the graph in the **visualization window** with the given `title`. If no such window exists, a new one will be created. The **layout** is set by passing the respective layout keyword (e.g. "Jung$ISOM","TREE" ...).<br>With `width` and `height` the dimensions of the window can be set.<br>If `allowModification` is set to `false` then the graph cannot be modified within the visualization window, so right click will not have any effect.<br>The parameter `frameRate` sets the frame rate of the visualization window. If zero is given then the window will not update frequently. |

| **repaintGraph** |
|---|
| `windowTitle: String = 'Graph'`<br>**returns** `void` |
| Refreshes the graph visualization in the **visualization window** with the given title. |

| **closeGraphView** |
|---|
| `windowTitle: String = 'Graph'`<br>**returns** `void` |
| Closes the graph **visualization window** with the given title. |

**Algorithm visualization:**
Some algorithms support algorithm visualization, which is a step-by-step algorithm output. If algorithm visualization is enabled and a respective algorithm is executed, the visualization starts automatically. Depending on the algorithm, the graph or multiple graphs are visualized in one or more **visualization window**(s) after every important step of the algorithm. One can iterate through the steps by pressing enter in the console. To abort the visualization, 'fin' can be typed in.
The algorithm visualization blocks **caching** and the **algorithm timer**. Algorithm visualization can be enabled or disabled using **setAlgorithmOutput**. Initially, algorithm visualization

is disabled.

| **setAlgorithmVisualization** |
| --- |
| `showOutput: Boolean`<br>**returns** `void` |
| This operation enables or disables **algorithm visualization**. |

| **setAlgorithmVisualizationParams** |
| --- |
| `layout: String = 'GRID'`<br>`width: PositiveInteger = 640`<br>`height: PositiveInteger = 640`<br>**returns** `void` |
| Sets the visualization parameters for the **algorithm visualization**, which can be enabled using **setAlgorithmOutput**. The parameters have the same meaning as the respective parameters in the **showGraph** operation. |

## 1.16 Histogram creation

| **newHistogram** |
| --- |
| `estimatedValues: PositiveInteger = 64`<br>**returns** `Histogram` |
| Creates a new empty **Histogram**. The returned **Histogram** can be filled with values using **setHistogramValue** or **incHistogramValue**. Initially, a value is zero. With the parameter `estimatedValues` the initial memory allocation can be set. The capacity is nearly unlimited - `estimatedValues` only has a slight effect on performance. |

| **setHistogramValue** |
| --- |
| `histogram: Histogram`<br>`index: PositiveInteger`<br>`value: Float`<br>**returns** `void` |
| Sets the value associated with the given index in the given histogram. |

| **incHistogramValue** |
| --- |
| `histogram: Histogram`<br>`index: PositiveInteger`<br>`incValue: Float = 1.0f`<br>**returns** `void` |
| Increments the value associated with the given index in the given **Histogram** by the given `incValue`, which may be negative, too. |

| **csvToHistogram** |
| --- |
| `csv: String`<br>`separator: String = ':'`<br>**returns** `Histogram` |
| Converts a CSV string into a **Histogram** which then can be used for example for visualization. |

## 1.17 Histogram visualization

| **showHistogram** |
|---|
| `histogram: Histogram`<br>`titleKey: String = 'Histogram'`<br>`clearPrevious: Boolean = true`<br>`width: Integer = 640`<br>`height: Integer = 480`<br>**returns** `void` |
| Visualizes the given **Histogram** using the window with the given title. If no such Window is shown, a new one will be created. If `clearPrevious` is set to `false` then previously shown histograms of the window won't be deleted. The dimension of the output window can be set by the parameters `width` and `height`'. |

| **addHistogramToView** |
|---|
| `histogram: Histogram`<br>`titleKey: String = 'Histogram'`<br>**returns** `void` |
| Does the same as **showHistogram** with `ClearPrevious` set to false. |

| **setHistogramViewMode** |
|---|
| `LinesMode: Boolean`<br>`BoldLines: Boolean = true`<br>**returns** `void` |
| Configures histogram visualization in general. This will influence every histogram visualization which is done after this operation.<br>If `linesMode` is set to `true` then lines will be drawn instead of bars. With `boldLines` set to true the lines have a width of 3px instead of 1px. |

| **refreshHistogramView** |
|---|
| `titleKey: String = 'Histogram'`<br>**returns** `void` |
| Refreshes the visualization of histograms associated with the given title. This operation must be called after changing **Histogram** values to make the changes visible to the user. |

| **setHistogramViewColors** |
|---|
| `color: Color`<br>`...`<br>**returns** `void` |
| Configures the colors of the bars or lines of all histogram visualization which is called after this operation. The first given **Color** is used for the first added **Histogram** of a visualization, the second **Color** for the second one and so on. If there are more histograms to output than colors given then it restarts with the first **Color**. |

| **clearHistogramView** |
|---|
| `titleKey: String = 'Histogram'`<br>**returns** `void` |
| Removes all the histograms of a visualization associated with the given title. The visualization window remains visible. |

| **getHistogramFromView** |
|---|
| `titleKey: String = 'Histogram'`<br>`index: PositiveInteger = 0`<br>**returns** `Histogram` |
| Extracts the **Histogram** with the given index from a visualization associated with the given title. The indices of the histograms are set by the order they were added into the visualization. |

## 1.18 Colors

| **color** |
|---|
| `red: PositiveInteger`<br>`green: PositiveInteger`<br>`blue: PositiveInteger`<br>`alpha: PositiveInteger = 255`<br>**returns** `Color` |
| Returns the color created with the given RGBA-values. The values must be numbers between 0 and 255. |

| **fColor** |
|---|
| `red: Float`<br>`green: Float`<br>`Blue: Float`<br>`Alpha: Float = 1.0f`<br>**returns** `Color` |
| Returns the color created with the given RGBA-values. The values must be numbers between 0 and 1. |

| **gray** |
|---|
| `value: PositiveInteger`<br>**returns** `Color` |
| Returns a gray color with the given brightness. The brightness must be a value between 0 (black) and 255 (white) |

| **fGray** |
|---|
| `value: Float`<br>**returns** `Color` |
| Returns a gray color with the given brightness. The brightness must be a value between 0 (black) and 1 (white) |

## 1.19 User interactions

| **ask** |
|---|
| `question: String = ''`<br>**returns** `String` |
| Pauses the execution, waits for a user input and returns the **String** which was entered by the user. |

| **pause** |
|---|
| `message: String = 'Press Enter...'`<br>**returns** `void` |
| Pauses the execution until the user presses enter. A message can be given. This message will be printed before the execution pauses. |

## 1.20 Variables

| **typeOf** |
|---|
| `variable: ANY`<br>**returns** `String` |
| Returns the type name of the given value. |

| **removeVariable** |
|---|
| `identifier: String`<br>**returns** `Boolean` |
| Removes the variable with the given `identifier`. The value will be deleted from memory and calling `defined` on the variable afterwards will return `false`. |

## 1.21 Assertions

| **assert** |
|---|
| `condition: Boolean`<br>`message: ANY = ''`<br>**returns** `void` |
| Does nothing, if the given **Boolean** is true. Otherwise, an error is thrown together with a message that can be given. |

| **assertEq** |
|---|
| `value1: ANY`<br>`value2: ANY`<br>`message: ANY = ''`<br>**returns** `void` |
| Does nothing, if the two given values are equal. Otherwise, an error is thrown together with a message that can be given. |

## 1.22 Bounds

| **newInterval** |
| --- |
| `lowerBound: Float`<br>`upperBound: Float`<br>**returns** `Interval` |
| Creates and returns a new **Interval** with the given bounds. |

| **getLowerBound** |
| --- |
| `bounds: Interval`<br>**returns** `Float` |
| Returns the lower bound of the given **Interval**. |

| **getUpperBound** |
| --- |
| `bounds: Interval`<br>**returns** `Float` |
| Returns the upper bound of the given **Interval**. |

## 1.23 Converting primitives

| **asFloat** |
| --- |
| `integer: Integer`<br>**returns** `Float` |
| Converts an **Integer** into a **Float**. This can be used for example to enforce float division when dividing two integers. |

| **parseInt** |
| --- |
| `string: String`<br>**returns** `Integer` |
| Converts a **String** into an **Integer** by parsing the string. |

| **parseFloat** |
| --- |
| `string: String`<br>**returns** `Float` |
| Converts a **String** into a **Float** by parsing the string. |

| **parseBool** |
| --- |
| `string: String`<br>**returns** `Boolean` |
| Converts a **String** into a **Boolean** by parsing the string. The strings ”`true`” and ”`1`” result in `true` and the strings ”`false`” and ”`0`” result in `false`. The strings are not case-sensitive. |

## 1.24 String operations

| **toString** |
|---|
| `object: ANY`<br>**returns** `String` |
| Returns the **String** representation of the given `object` which can be of any type. |

| **split** |
|---|
| `string: String`<br>`regex: String = '\n'`<br>`trim: Boolean = true`<br>**returns** `Vector` |
| Splits the given **String** at the given regular expression and returns multiple strings as a **Vector**. |

| **startsWith** |
|---|
| `string: String`<br>`prefix: String`<br>**returns** `Boolean` |
| Returns `true` iff the given **String** starts with `prefix`. |

| **endsWith** |
|---|
| `string: String`<br>`postfix: String`<br>**returns** `Boolean` |
| Returns `true` iff the given **String** ends with `postfix`. |

## 1.25 Complex type operations

| **getSize** |
|---|
| `iterable: Iterable`<br>**returns** `PositiveInteger` |
| Returns the number of elements in the given **Iterable**. |

| **getVectorSize** |
|---|
| `vector: Vector`<br>**returns** `PositiveInteger` |
| Returns the number of entries of the given **Vector**. |

| **setVectorSize** |
|---|
| `vector: Vector`<br>`newSize: PositiveInteger`<br>**returns** `void` |
| Sets the number of entries of the given **Vector** to the given number. The values of the vector remain the same. |

| **getSetCardinality** |
| --- |
| `set: Set`<br>**returns** `PositiveInteger` |
| Returns the cardinality of the given **Set**. |

| **setInsert** |
| --- |
| `set: Set`<br>`value: ANY`<br>**returns** `void` |
| Inserts the given element into the given **Set**. The element is inserted even if an equal element exists in the given set. |

## 1.26 Math functions

| **round** |
| --- |
| `number: Float`<br>**returns** `Integer` |
| Converts a **Float** into an **Integer** by rounding the given value. |

| **random** |
| --- |
| `lowerBound: Integer`<br>`upperBound: Integer`<br>**returns** `Integer` |
| Returns a random **Integer** which is bigger or equal to `lowerBound` and smaller or equal to `upperBound`. |

| **sqrt** |
| --- |
| `x: Float`<br>**returns** `Float` |
| Returns the square root of the given value. |

| **sqr** |
| --- |
| `x: Float`<br>**returns** `Float` |
| Returns the square of the given value. |

| **pow** |
| --- |
| `base: Float`<br>`exp: Float`<br>**returns** `Float` |
| Returns `base` to the power of `exp`. |

| **sin** |
| --- |
| `x: Float`<br>**returns** `Float` |
| Returns the sine of the given value. |

| cos |
|---|
| `x: Float`<br>**returns** `Float` |
| Returns the cosine of the given value. |

| tan |
|---|
| `x: Float`<br>**returns** `Float` |
| Returns the tangent of the given value. |

| cotan |
|---|
| `x: Float`<br>**returns** `Float` |
| Returns the cotangent of the given value. |

# 2 Algorithms

In the explanaitions of this section, $G$ is the given graph, $V$ its vertices and $E$ its edges. When a runtime is given then $n$ is the number of vertices, $m$ the number of edges and $\Delta(G)$ is the sum of both.

Every box in this section depicts one algorithm. The boxes are structured as follows:

| **algorithmKey** |
|---|
| `parameterName1:  ParameterType1`<br>`parameterName2:  ParameterType2`<br>`...`<br>`parameterNameN: ParameterTypeN`<br>`[...]`<br>**returns** `ReturnType` |
| The algorithm's description text.<br><br>For some algorithms:<br>**Runtime:** The algorithms runtime in $O$-notation<br>**Graph preconditions:** List of preconditions<br>**Compatible libraries:** List of supported graph libraries |

Parameters are handled in the same way as they were explained in the previous section. The **algorithm timer** only counts if one of the algorithms of this section is called.

Algorithms which support **algorithm visualization** are marked with a * after the algorithm key.

## 2.1 General graph properties

| **vertexCount** |
|---|
| **returns** `Integer` |
| Returns the number of vertices. |

| **edgeCount** |
|---|
| **returns** `Integer` |
| Returns the number of edges. |

| **graphSize** |
|---|
| **returns** `Integer` |
| Returns the sum of the vertex count and edge count. |

## 2.2 Vertex degrees

| **averageDegree** |
| --- |
| **returns** `Float` |
| Returns the average degree of all vertices.<br><br>**Graph preconditions:** not empty |

| **maxDegree** |
| --- |
| **returns** `Integer` |
| If the graph is undirected then the degree of the vertices with the largest number of neighbors is returned. Otherwise the maximum of **maxIngoingDegree** and **maxOutgoingDegree** is returned.<br><br>**Graph preconditions:** not empty |

| **maxIngoingDegree** |
| --- |
| **returns** `Integer` |
| Returns the ingoing edge count of the vertices with the largest number of ingoing edges.<br>If the graph is undirected then the returned value is equal to the **maxDegree** return value.<br><br>**Graph preconditions:** not empty |

| **maxOutgoingDegree** |
| --- |
| **returns** `Integer` |
| Returns the outgoing edge count of the vertices with the largest number of outgoing edges.<br>If the graph is undirected then the returned value is equal to the **maxDegree** return value.<br><br>**Graph preconditions:** not empty |

| **degreeDistribution** |
| --- |
| **returns** `Histogram` |
| Returns a **Histogram** with a mapping from vertex degrees to the amount of vertices that have the respective degree.<br><br>**Graph preconditions:** undirected, not empty |

| **ingoingDegreeDistribution** |
| --- |
| **returns** `Histogram` |
| Returns a **Histogram** with a mapping from vertex degrees to the amount of vertices that have the respective ingoing degree.<br>If the graph is undirected then the returned histogram is equal to the **degreeDistribution** return value.<br><br>**Graph preconditions:** not empty |

| **outgoingDegreeDistribution** |
| --- |
| **returns** `Histogram` |
| Returns a **Histogram** with a mapping from vertex degrees to the amount of vertices that have the respective outgoing degree.<br>If the graph is undirected then the returned histogram is equal to the **degreeDistribution** return value.<br><br>**Graph preconditions:** not empty |

| **hIndex** |
| --- |
| **returns** `Integer` |
| The *h-index* is the largest number $n$ in order that $n$ nodes have at least $n$ neighbors.<br><br>**Runtime:** $O(n + \Delta(G))$<br>**Graph preconditions:** not empty |

**k-degenerate:**
A graph is *k-degenerate* if and only if there is an induced subgraph which contains a vertex with a degree at most $k$.

| **degeneracy** |
| --- |
| **returns** `Integer` |
| The *degeneracy* is the smallest number $k$ in order that the graph is **k-degenerate**.<br><br>**Runtime:** $O(m)$<br>**Graph preconditions:** undirected, not empty, simple |

| **distanceDistribution** |
| --- |
| **returns** `Histogram` |
| Returns a mapping of $d$ to the number of vertices that have the distance $d$.<br><br>**Graph preconditions:** not empty<br>**Compatible libraries:** JUNG2 |

## 2.3 Flows

| **maxFlow** |
| --- |
| `source: Vertex`<br>`sink: Vertex`<br>**returns** `Float` |
| Returns the max flow between the two given vertices (see **Vertex**).<br><br>**Graph preconditions:** not empty<br>**Compatible libraries:** JUNG2, JGraphT |

| **minCut** |
| --- |
| `source: Vertex`<br>`sink: Vertex`<br>**returns** `Vector` |
| Returns the min cut between the two given vertices (see **Vertex**).<br><br>**Graph preconditions:** not empty<br>**Compatible libraries:** JUNG2 |

**Gomory-Hu-Tree:**
The *Gomory-Hu-Tree* $T = (V, E_T)$ of a graph $G = (V, E_G)$ is a tree in order that every pair $(v, w) \in V$ has the same max flow as in $G$.

| **gomoryHuTree *** |
| --- |
| `ignoreWeights: Boolean = false`<br>**returns** `Graph` |
| Returns the **Gomory-Hu-tree** of the graph.<br><br>**Runtime:** $O(n^2 + m^2)$<br>**Graph preconditions:** undirected, not empty, simple<br>**Compatible libraries:** JUNG2 |

## 2.4 Connected Components

| **getConnectedComponentCount *** |
| --- |
| **returns** `PositiveInteger` |
| Returns the number of connected components. |

| **getConnectedComponent *** |
| --- |
| `componentIndex: PositiveInteger`<br>**returns** `Graph` |
| Returns the connected component with the given index. The index must be a value between 0 and the connected component count (see getConnectedComponentCount) minus one. The indices are given internally.<br>The returned graph is a deep copy of the respective connected component.<br><br>**Graph preconditions:** undirected, not empty |

| **getConnectedComponentByVertex *** |
| --- |
| `vertex: String`<br>**returns** `Graph` |
| Returns the connected component in which the given vertex is contained.<br>The returned graph is a deep copy of the respective connected component.<br><br>**Graph preconditions:** undirected, not empty |

## 2.5 Trees

**Tree:**
A *tree* is an acyclic graph.

**Feedback edge set size:**
The *feedback edge set size* is the minimum number of edge deletions that are necessary in order that the graph becomes a **tree**.
The feedback edge set size for a connected component is $|E| + 1 - |V|$.

| **isTree *** |
|---|
| **returns** `Boolean` |
| Checks, whether the graph is a **tree**.<br><br>**Graph preconditions:** undirected |

| **feedbackEdgeSetSize *** |
|---|
| **returns** `Integer` |
| Returns the **feedback edge set size**.<br><br>**Graph preconditions:** undirected |

## 2.6 Treewidth

| **setTreewidthUpperBoundHeuristics** |
|---|
| `heuristic: String`<br>`...`<br>**returns** `void` |
| Since the computation of the treewidth is NP-complete, *Graphana* uses some heuristics for this problem. The heuristics are implemented in `LibTW` from `www.treewidth.com` .<br>The heuristics which are to be used are passed as **String**s. If multiple heuristics are given then every heuristic will be executed and the best result will be returned .<br><br>The following **String**s are valid treewidth upper bound heuristic keys:<br>`GREEDYFILLIN`<br>`GREEDYDEGREE`<br>`ALLSTARTLEXBFS`<br><br>By default, `GREEDYFILLIN` is set. For informations on the different heuristics, see `www.treewidth.com` .<br><br>The chosen treewidth upper bound heuristics influence the following algorithms: **treewidthUpperBound**, **treewidthBounds**, **treewidthExact**. |

| setTreewidthLowerBoundHeuristics |
|---|
| `heuristic: String`<br>`...`<br>**returns** `void` |
| Since the computation of the treewidth is NP-complete, *Graphana* uses some heuristics for this problem. The heuristics are implemented in `LibTW` from `www.treewidth.com` .<br>The heuristics which are to be used are passed as **String**s. If multiple heuristics are given then every heuristic will be executed and the best result will be returned .<br><br>The following **String**s are valid treewidth lower bound heuristic keys:<br>`MAXMINDEGREEPLUSLEASTC`<br>`MAXCARDSEARCH`<br>`RAMACHANDRAMURTHI`<br>`ALLSTARTMAXCARDSEARCH`<br>`MAXMINDEGREE`<br>`MAXMINDEGREEPLUSMAXD`<br>`MAXMINDEGREEPLUSMIND`<br>`ALLSTARTMAXMINDEGREE`<br>`ALLSTARTMAXMINDEGREEPLUSLEASTC`<br>`ALLSTARTMINORMINWIDTH`<br>`MINORMINWIDTH`<br>`MINDEGREE`<br><br>By default, `MAXMINDEGREEPLUSLEASTC` is set. For informations on the different heuristics, see `www.treewidth.com` .<br><br>The chosen treewidth lower bound heuristics influence the following algorithms: **treewidthLowerBound**, **treewidthBounds**. |

| treewidthUpperBound |
|---|
| **returns** `Integer` |
| Returns an upper bound of the treewidth. The heuristics which are to be used can be set with **setTreewidthUpperBoundHeuristics**.<br><br>**Graph preconditions:** not empty<br>**Compatible libraries:** LibTW |

| treewidthLowerBound |
|---|
| **returns** `Integer` |
| Returns a lower bound of the treewidth. The heuristics which are to be used can be set with **setTreewidthLowerBoundHeuristics**.<br><br>**Graph preconditions:** not empty<br>**Compatible libraries:** LibTW |

| **treewidthExact** |
| --- |
| **returns** `Integer` |
| Returns the treewidth using the 'TreewidthDP' algorithm from `www.treewidth.com`. The algorithm has a NP runtime. Before the actual computation starts, an upper bound is established by using one or more heuristics. Which heuristics are to be used for this can be set with **setTreewidthUpperBoundHeuristics**.<br>For further information on the algorithm, see `www.treewidth.com`.<br><br>**Graph preconditions:** not empty<br>**Compatible libraries:** LibTW |

## 2.7 Connectivity

| **largestKConnected *** |
| --- |
| `k: Integer`<br>**returns** `Integer` |
| Returns the cardinality of a maximum $V' \subset V$ in order that $V'$ is k-edge-connected depending on the parameter `k`.<br><br>**Graph preconditions:** undirected, not empty, simple<br>**Compatible libraries:** JUNG2 |

| **edgeConnectivityDistribution *** |
| --- |
| **returns** `Histogram` |
| Returns a mapping from $k$ to **largestKConnected**($k$) as a **Histogram**. The first value is $k = 0$. The last value is the largest $k$ where **largestKConnected**($k$) does not return `0`.<br><br>**Graph preconditions:** not empty<br>**Compatible libraries:** JUNG2 |

## 2.8 Clusters

**Cluster:**
A *cluster* is a connected component in which all vertices are connected with each other.

**Cluster graph:**
A *cluster graph* is a graph which consists only of clusters (see **Cluster**).

| **isClusterGraph *** |
| --- |
| **returns** `Boolean` |
| Returns `true` if and only if the graph is a **Cluster graph**.<br><br>**Graph preconditions:** undirected |

## 2.9 Cluster vertex deletion

**CVD:**
Abbrevation for "cluster vertex deletion"

**Cluster vertex deletion set:**
A set $C \subseteq V$ in order that $(V \backslash C, E_C)$ is a **cluster graph** (the set of edges $E_C \subseteq E$ contains all edges which are not incident to any vertex in $C$).

**CVD-set:**
Abbrevation for **Cluster vertex deletion set**

**CVD-heuristics:**
Since finding a **CVD-set** is NP-complete, *Graphana* supports several heuristics for this problem which differ in runtime and cardinality of the resulting set.
Which heuristic(s) shall be used, can be set with **setCVDHeuristics**. A CVD-heuristic consists of two parts: the search strategy to search for nodes which may be deleted and the delete strategy to delete one or more vertex of the found candidates. In *Graphana* there are two search strategies and three delete strategies. So in combination, there are six heuristics.

The search strategies are:
**Successive (key: "SUCC"):**
The candidates are found by regarding each vertexes neighbors. This strategy is recommended for very sparse graphs.
**Runtime:** $O(n \cdot m)$**Connected components (key: "CC"):**
The candidates are found by recursively splitting the graph into connected components. This strategy is especially recommended for dense graphs. In most cases the runtime is better than the runtime of the "Successive" strategy.

**Runtime:** $O((n+m) + |C| \cdot (n+m) \cdot \Delta(G) + |C| \cdot (\Delta(G))^2)$
Where $|C|$ is the cardinality of the CVD set.

The delete strategies are:
**All (key: "ALL"):** Deletes all found candidates. This strategy ensures, that the cardinality of the resulting CVD-set is not more than three times as large as the cardinality of an optimal solution.
**First (key: "FIRST"):**
Deletes the candidate which was found first.
**Maximum degree (key: "MAX")**
Deletes a candidate with the highest **degree**.

| **setCvdHeuristics** |
|---|
| `heuristic: String`<br>`...`<br>**returns** `void` |
| Sets the **CVD-heuristics** which shall be used when computing a **CVD-set**. The heuristics are given as **String**s containing the key of search strategy and the key of the deletion strategy, separated by a minus character. So for example "CC-MAX" is a valid string. More than one heuristic can be set by passing them within one call. A new call of setCVDHeuristics resets the heuristics. If multiple heuristics are given, then the respective algorithms will execute all of them and return the best result. So the computation time increases but the results are getting more accurate.<br><br>The chosen cvd heuristics influence the following algorithms: **cvdSet**, **cvdSize**, **cvdBounds**, **toClusterGraph**, **maximumIndependentSetByCVD** |

| **toClusterGraph** |
|---|
| **returns** `void` |
| Deletes vertices in order that the graph becomes a **cluster graph**. The number of deleted vertices may not be optimal (see **CVD-heuristics**).<br><br>**Graph preconditions:** undirected, not empty, simple |

| **getMaximumIndependentSetByCVD** |
|---|
| **returns** `List` |
| Computes the maximum independent set with a parameterized algorithm which uses a **CVD-set** as parameter.<br><br>**Graph preconditions:** undirected, not empty, simple |

## 2.10 Other graph parameters

**vertex cover:**
A *vertex cover* $S$ is a set of vertices in order that every edge $e \in E$ has at least one endpoint in $V$. The vertex cover size is the cardinality of a minimum vertex cover.

| **vertexCoverSize** |
|---|
| `useGreedy: Boolean = true`<br>**returns** `Integer` |
| The vertex cover can be computed with two different heuristics: If `useGreedy` is set to `true` then a *nlogn* - approximation is used. Otherwise a 2-approximation is used. The greedy heuristic delivers better results in many practical cases.<br><br>**Runtime:** $O(n+m)$<br>**Graph preconditions:** undirected, not empty<br>**Compatible libraries:** JGraphT |

| **vertexCoverSizeBothHeuristics** |
| --- |
| **returns** `Integer` |
| Calls both heuristics of **vertexCoverSize** and returns the minimum of both results.<br><br>**Runtime:** $O(n + m)$<br>**Graph preconditions:** undirected, not empty<br>**Compatible libraries:** JGraphT |

| **feedbackVertexSet** * |
| --- |
| **returns** `Set` |
| Computes the *feedback vertex set* for an undirected graph with no loops. The feedback vertex set is returned as a set of vertices and can for example be used to make the graph acyclic by calling **removeVertexSet** with the returned set.<br><br>**Runtime:** $O(m + nlogn)$<br>The algorithm is an implementation of the 2-approximation modified greedy algorithm of Becker and Geiger.<br>**Graph preconditions:** undirected |

| **feedbackVertexSetSize** * |
| --- |
| **returns** `PositiveInteger` |
| A call to this algorithm is equivalent to **getSize**(**feedbackVertexSet**()).<br><br>**Graph preconditions:** undirected, simple |

# 3 Types

Every box in this section depicts one type. The boxes are structured as follows:

| **TypeName** |
|---|
| The type's description text.<br><br>**Samples:**<br>sample1<br>sample2<br>...<br>sampleN |

## 3.1 Primitive types

| **Integer** |
|---|
| An integral number with the range -2,147,483,648 to 2,147,483,647.<br><br>**Samples:**<br>8<br>-10<br>0 |

| **PositiveInteger** |
|---|
| Essentially the same as **Integer** but with the range 0 to 2,147,483,647.<br><br>**Samples:**<br>3<br>0 |

| **Boolean** |
|---|
| A truth value with two possible values.<br><br>**Samples:**<br>true<br>false |

| **Float** |
|---|
| A floating point number with the range 1.40129846432481707e-45 to 3.40282346638528860e+38 (positive and negative).<br><br>**Samples:**<br>4.6<br>-2.0<br><br>An **Integer** is automatically converted into a Float, if it is necessary. |

| **String** |
| --- |
| A string of characters. Constant strings can either be written in quotation marks or in tick marks. When using quotation marks, tick marks can be written inside the string and vice versa without escaping.<br>See **Escape characters** to get a list of supported escape characters.<br><br>**Samples:**<br>'word'<br>"long text"<br>"A string with\n\t'tick marks' and\n\t\"quotation marks\"" |

| **Character** |
| --- |
| A single character.<br>See **Escape characters** to get a list of supported escape characters.<br><br>**Samples:**<br>'A'<br>'\n' |

**Escape characters:**
Within constant **String**s or **Character**s, the following expressions are valid escape characters:

| | |
| --- | --- |
| \n | Line break |
| \t | Tab |
| \\ | Backslash |
| \" | Quotation marks |
| \' | Tick mark |

## 3.2 Graph types

| **Graph** |
| --- |
| A graph including vertices, edges, configuration, vertex- and edge data, name and algorithm cache.<br><br>**Sample:** getCurrentGraph() |

| **Vertex** |
| --- |
| A single vertex of a graph. A constant vertex can be written with `$[vertex identifier]`. This will deliver the vertex with the given identifier of the respective graph. If no such vertex exists, an error will occur.<br><br>**Samples:**<br>$v2<br>getVertexByIdent('v2') |

| Edge |
| --- |
| A single edge of a graph. An edge can be identified by the two incident vertices (in directed graphs by their ordering, too).<br>An edge can for example be delivered using *vertex1 −− vertex2* in undirected and *vertex1 -> vertex2* in directed graphs.<br><br>**Samples:**<br>getEdge($v0,$v2)<br>$v0 −− $v2 |

## 3.3 Complex types

| Vector |
| --- |
| A vector holds multiple ordered values and can be of any size. An entry of the vector can be of any individual type (also Vector again). The particular entries can be accessed with *vector*[*index*] where *index* is an **Integer** beginning at `0`.<br>Vectors can be used in foreach-loops (see 'graphana_manual.pdf').<br><br>**Samples:**<br>(1,2,3,4)<br>()<br>((2.4,4.2,6.4),(-5.6,7,10.2),(3,2.1,0))<br><br>See **Complex type operations** for a list of operations on vectors. |

| Set |
| --- |
| A set holds multiple unordered values and can be of any size. An element of the set can be of any individual type (also Set again).<br>Sets can be used in foreach-loops (see 'graphana_manual.pdf').<br><br>**Samples:**<br>{1,2,3,4}<br>{}<br>{"A string",$aVertex,{2.3,8.5,-6}}<br><br>See **Complex type operations** for a list of operations on sets. |

| Iterable |
| --- |
| An Iterable cannot be created directly. An argument of an operation call is casted into an Iterable if it is a **Vector** or a **Set**. |

## 3.4 File types

| File |
| --- |
| Files are given as **String**s containing the relative or absolute filename. The file does not have to exist.<br><br>**Samples:**<br>"C:/absolute/path/file.ext"<br>"relative/path/file.ext" |

| ExistingFile |
| --- |
| Nearly similar to **File** but the file must exist.<br><br>**Sample:** "path/to/an/existing/file.ext" |

## 3.5 Miscellaneous types

| Histogram |
| --- |
| A histogram contains a mapping from integral numbers to float numbers. Every entry can be accessed in particular.<br><br>**Samples:**<br>createHistogram(30)<br>degreeDistribution()<br><br>See **Histogram creation** for a list of operations on histograms. |

| Interval |
| --- |
| An interval has a minimum and a maximum value ("bounds"). The bounds can be extracted using **getLowerBound** and **getUpperBound**<br><br>**Samples:**<br>newInterval(-3,7)<br>cvdBounds() |

| ParseTree |
| --- |
| A **String** can be parsed and converted into a parse tree. This tree can then be executed any number of times and does not need to be parsed again, which improves performance. Note that the execution of a tree may return different results depending on global variables for example. So if a script shall be executed very often, it makes sense to convert it into a parse tree once using **parse**, assign it to a variable and execute it repeatedly (for example within a loop) using **executeTree**.<br><br>**Sample:** parse("2 + x*(3+y)") |