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1 Introduction

The program is a graph editor developed for the mathematical field of graph theory. The program is created on request of Klas Markström at the mathematical department in Umeå University as a Bachelor thesis project.

1.1 Purpose

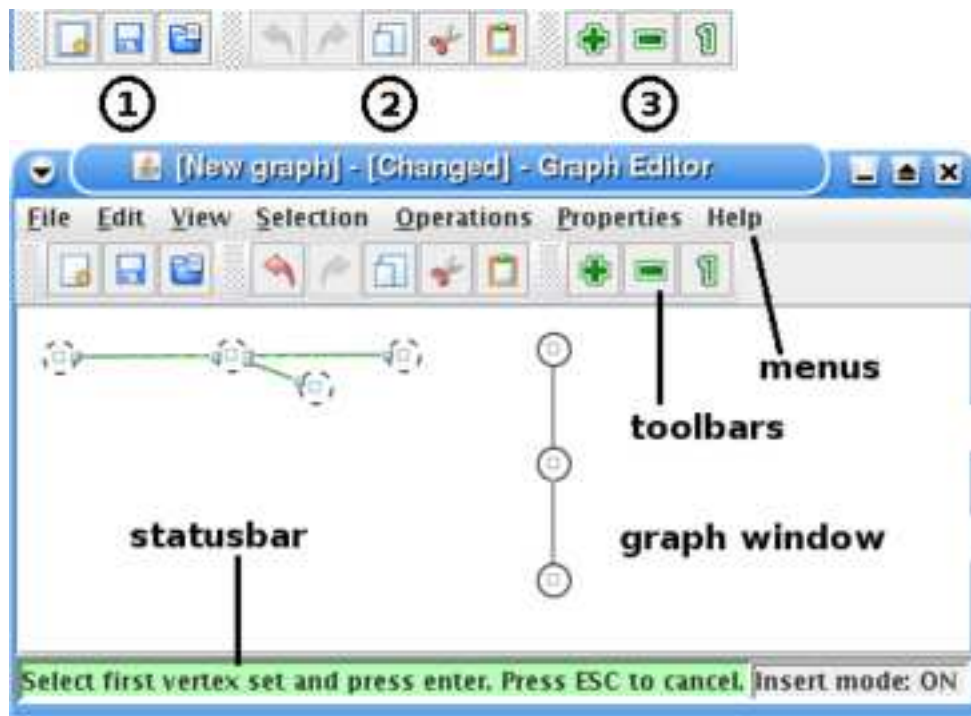
The main purpose of the graph editor is to make it easy to edit and create graphs that are used to illustrate theories and ideas in the mathematical field of graph theory. Many graph editors exist but just a few are developed with graph theory in mind and of them almost none are updated. Therefore there is a gap that this editor tries to fill.

1.2 Main functions and features

The program's main functionality is to *edit*, *save* and open *graphs*. This is described in the help section* *editing graphs*. Other features are for example, graph operations and automatic embedding algorithms etc. The functions are summarized in the following list:

- Functions for copying and pasting part of the graph
- Functions for unlimited undo and redo editing commands
- View functions for zooming in and out the view of the graph and to center the current graph
- Selection function to select parts of the graphs depending on the current selection (e.g. select neighbours)
- Graph operations and other graph manipulation functions
- Export functions to export the graph to other graph file formats:
 - Graphviz dot-file format
 - GraphML
 - Graph Modeling Language (GML)
 - File format compatible with Mathematica Combinatorica software
 - JPEG image file format
 - PNG image file format
 - *Mathematica* compatible file format
 - Neighbor lists
 - EPS image file format
- Import functions to import graphs from other file formats:
 - Random graph importer that creates a random graph from a number of vertices and a number of edges.
 - Mathematica compatible graph file format

2 Main window and toolbars

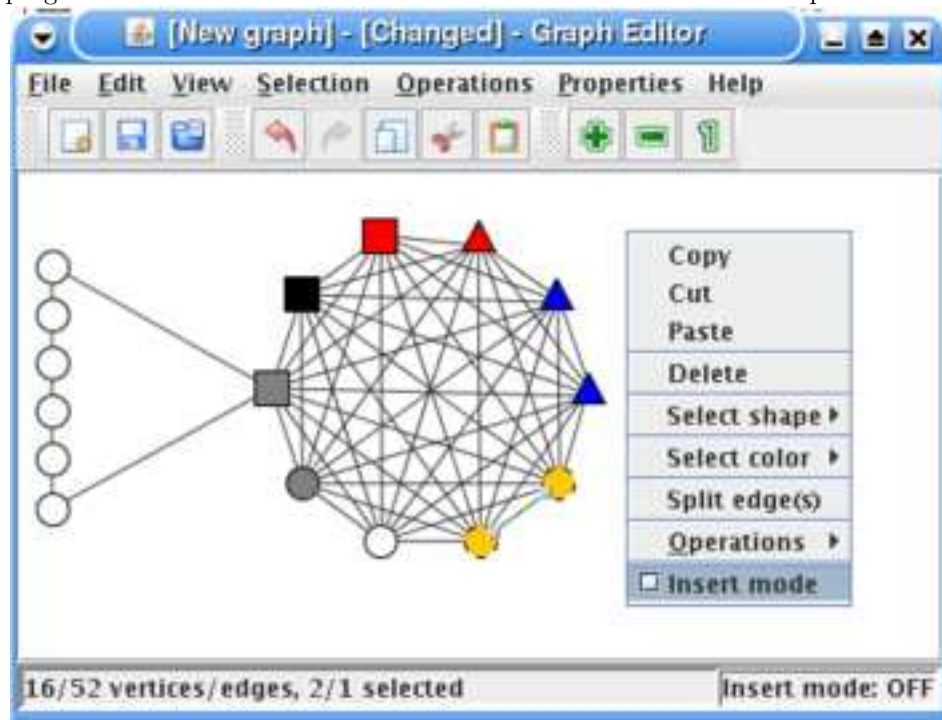


The main window has four head components that are marked in the figure above. They are described in the list below:

- The **graph window** is the place where graphs are edited and displayed. How editing is performed is described in more detail in the section* called *editing graphs* .
- The **menubar** contains a number of menus to choose operations from. They are described in more detail in the section* called *Menus and their operations*.
- The **toolbars** are used to fast access operations that are also in the menus. You can choose to hide the toolbars by using the *show toolbars* menu that is under the properties menu. The descriptions below correspond to the toolbar with the same number in the picture of the toolbars above.
 1. The file toolbar is used for some basic file operations. There are buttons on it to create a new graph, save the current graph and to open a graph from a file.
 2. The edit toolbar is used for some basic edit operations that also exists under the edit menu. The edit commands in the toolbar are for undo, redo, copy, cut and paste.
 3. With the view toolbar you can zoom in/out and set the zoom-level to the default.
- The **statusbar** is used to give varying information to the user. As default the number of vertices and edges and selected vertices and edges in the graph are displayed. The status bar is also used to give hints to the user of how to interact with the program. In the picture above the status bar contains a hint to the user during a graph operation that requires several interaction steps.

3 Introduction to editing

When the program starts it displays an empty graph in the *graph window* . The *graph window* is the component in the program window that is located in the center of the screen. The computer mouse is used



to edit the graph.

3.1 Editing modes

There are two editing modes, one is called *insert mode on* and another is *insert mode off* . The current is indicated in the right corner of the status bar at the bottom of the window. The *insert mode on* is typically used to insert vertices and edges into the graph. The *insert mode off* is typically used to move vertices.

3.2 Ways to switch editing mode

The easiest to switch editing mode is to use the *space* key on the keyboard. You can also click on the edit menu and select insert modeH or right click in the editing window to get a menu where it is possible to change editing mode. Holding down the **A** -key wil temporarily change and it will only stay as long as you hold down the key. The **A** -key is intended for situation when you only want to do something fast in the other editing mode and after that go back to the original

3.3 Selection and related commands

nMany of the commands that can be performed on the graph are dependent on which part of the graph is selected. To select one edge or vertex click on the vertex or edge you want to select. To select all vertices and edges in an area you can press the mouse button in one corner of the area and move it to the opposite corner and then release it. Press the control button on the keyboard to keep the selection when you are selecting more edges or vertices.

3.4 Delete vertices and edges

To delete vertices or edges, first select the vertices and edges you want to delete, then use the delete or backspace key on the keyboard. You can also delete by using the delete menu item in the menu that comes up when you right click in the graph window.

4 To edit in insert mode

The intention of the insert mode is to make it easy and intuitive to put in vertices and edges in the graph.

The only action that is needed to put in a new vertex is to click with the mouse on the position where you want the vertex. The position where you click needs to be empty if it is not the object at the place you click will be selected and no new vertex will be created. To create an edge between two vertices, press the mouse button in the middle of one of the vertices and drag the mouse with the mouse button down, until the mouse pointer is in the middle of the other vertex and then release the mouse button.

To get a menu with commands click with the second mouse button in the graph window. The commands are different depending on the selection of vertices and edges.

5 Not insert mode

The intention of *not insert mode* (or *insert mode off*) is to make it easy to move vertices and modify a currently existing graph without adding new vertices and edges. It is also possible to add vertices in this mode but it is much less intuitive than in the *insert mode* . To add vertices click with the right mouse button on an empty area and select *Insert vertex*.

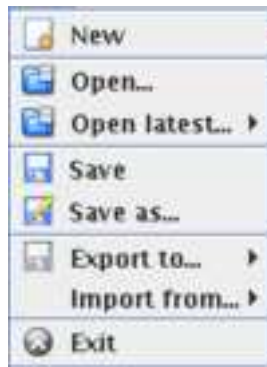
To move vertices in this mode it is just to press the mouse button when the mouse pointer is in the middle of a vertex and drag the mouse with the mouse button down until the mouse pointer is at the position where you want to place it.

To get a menu with commands click with the second mouse button in the graph window. The commands are different depending on the selection of vertices and edges.

5.1 Merge vertices

It is possible to merge two vertices in the not insert mode so that the resulting vertex is neighbour to all vertices that the vertices in the merging are neighbours to. To merge two vertices press the mouse button in the center of a vertex and drag the mouse so that the mouse pointer is at the center of the vertex you want to merge it.

6 The file menu and its content



The file menu contains operations that has to do with files. The operations in the menu are described in the list below. The list is ordered in the same order as the menu items in the file menu.

1. The **New** command opens a new window with an empty graph.
2. The **Open...** command opens a file chooser dialog to open a file from.
3. The **Open latest...** menu item has a sub menu which contains a list of recently used files. The list is ordered with the latest used file in the top of the list. If you click on one of them a new window with the corresponding file will be opened.
4. The **Save** command saves the graph if it is already associated with a file. If it is not associated with a file a dialog box where it is possible to select a file to save to will be displayed.
5. The **Save as...** command will show a dialog box where it is possible to select a file to save the graph to.
6. The **Export to...** menu item will show a menu with file formats it is possible to export the graph to. For more information see the section* about export.
7. The **Import from...** shows a list of possible import alternatives. For more information see the section* about import.

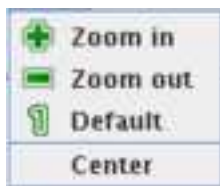
7 The edit menu and its operations



The edit menu contains operations that are used for the editing or effect the editing in some way. The operations in the menu are described in the list below. The list is in the same order as the menu items in the menu.

1. The **undo** command makes the last operation undone. The number of undo commands that is possible to perform is unlimited.
2. The **redo** command cancels the last undo command.
3. The **cut** command first saves all selected graph objects so they can be pasted with the paste command later and then removes them.
4. The **copy** command makes a copy of the selected objects in the graph so they can be pasted with the paste command
5. The **paste** command paste the saved object from the cut or copy commands in the graph window. It is possible to paste parts of graphs that have been copied or cut from other graph windows.
6. The **Insert mode** alternative can be set to on and off below and not insert mode for more information.

8 The view menu and its content

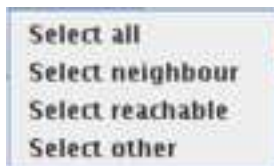


The view menu contains operations that change the view of the graph in some way.

The operations that are in the menu are described in the list below. The list is ordered in the same way as the menu items.

1. The **Zoom in** command zoom the current graph. This means that the size of everything is increased. If you want to expand the graph so that the distance of the vertices increases but still have the same size of the vertices and edges then look at the *expand selected by factor* command in the operations menu.
2. The **Zoom out** command is the opposite of the *zoom in* command. It decreases the size of the graph.
3. The **Default** command sets the zoom level to the default.
4. The **Center** command centers the graph in the middle of the window. The center of the graph is the center of least bounding rectangle that contains all vertices.

9 The selection menu and its content

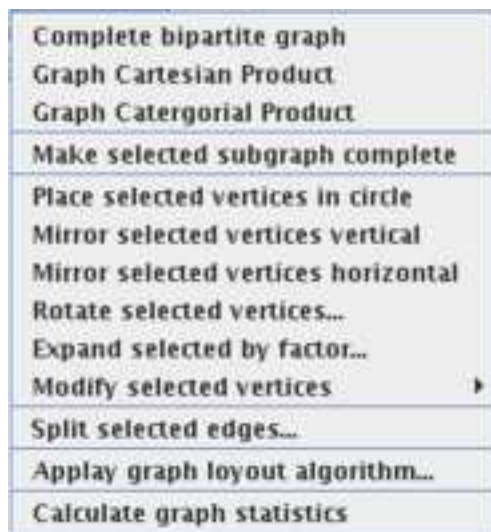


The selection menu contains operations that are used to select different parts of the graph. All commands except the *select all* requires that at least one vertex is selected. Therefore they are disabled when no vertex is selected.

The operations in the menu are described below. The list is ordered in the same order as the menu items in the selection menu.

1. The **Select all** command selects all vertices in the graph.
2. The **Select neighbour** command selects all neighbour vertices to the currently selected vertices.
3. The **Select reachable** command selects all vertices that are reachable by only *walking* on the edges from the selected vertices.
4. The **Select other** command unselects all selected vertices and selects all previously not selected vertices.

10 The operations menu and its content



This menu is also available under the menus that come up when you click with the right mouse button in the *graph window*. The menu contains commands that perform some kind of operation on the graph. Most operations change the graph, but there is also one command that traverses the graph to take information from it, namely *Calculate graph statistics*. The commands have been divided by lines in the menu into categories. All menu items in the same category are similar to each other in some way. That has been done to make it easier to find a certain command. The description of the menu commands below is also divided in the same way. The description marked with the number one describes the first category from the top of the menu and so on.

1. The first category contains operations or graph products that need two subgraphs. They are selected by the user in two steps:

When a command has been started by a click on a menu item in the category the statusbar in the bottom of the window displays a message. The message tells the user to select the vertices that is in the first subgraph and then press *enter*. When *enter* is pressed the user can select the second subgraph in the same way. Because the operations need two disjoint vertex sets it is not possible to select vertices in the first set when the second is being selected. They are therefore marked with a red cross. To cancel a started operation the user can press the *escape* key.

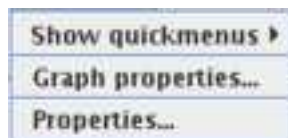
The operations in this category is:

- The **Complete bipartite graph** operation creates a complete bipartite graph of two vertex sets. The operation does not remove edges that are already there. A complete bipartite graph made up by two vertex sets A with n vertices and B with m vertices is denoted by $K_{m,n}$ and is a graph where every vertex in A is connected to all vertices in B and every vertex in B is connected to all vertices in A.
 - The **Graph Cartesian Product** operation creates a graph that is the *Graph Cartesian Product* of two graphs G1 and G2. The resulting graph is placed to the left under the original graph in the *graph window*. For a definition of the Graph Cartesian Product please see, <http://mathworld.wolfram.com/GraphCartesianProduct.html>.
 - The **Graph Categorical Product** operation creates a graph that is the *Graph Categorical Product* of two graphs G1 and G2. The resulting graph is placed to the left under the original graph in the *graph window*. For a definition of the *Graph Categorical Product* please see, <http://mathworld.wolfram.com/GraphCategoricalProduct.html>.
2. This category contains operations that only use one graph as operand. The operand is the graph created by the selected vertex set. The menu item in this category is only enabled if one or more vertices is selected. At the moment there is only one operation in this category. The **Make selected subgraph complete** operation makes the subgraph created by the selected vertex set to a complete subgraph by adding edges so every vertex is neighbour to every other vertex in the vertex set.
 3. This category contains operations that modify the position of selected vertices. The menu items is only enabled if any vertices are selected. The operations in this category is listed below with an explanation of what they do:
 - The **Place selected vertices in circle** operation reorganize the selected vertices so they are placed in the edge of a circle with the same distance between each vertex. The circle's diameter is equal to the greatest of the width and the height of the least bounding rectangle of the selected vertices. The circle's center is in the center of the bounding box.
 - The **Mirror selected vertices vertical** operation mirror all selected vertices over the x-axis through the center of the least bounding rectangle of all selected vertices. To mirror a vertex over a vertical axis is to change its horizontal position so it is on equal distance from the axis but on the opposite side.
 - The **Mirror selected vertices horizontal** does the same thing as *Mirror selected vertices vertical* does but over the horizontal axis instead of the vertical.
 - The **Rotate selected vertices** operation brings up a rotation dialog where it is possible to select a rotation angle for the selected vertices. When the angle is changed in the dialog the graph is instantly updated. To keep the new angle press the *ok* button and use the *cancel* button to cancel the changes. The vertices is rotated around the center of the least bounding rectangle for the selected vertices.
 - The **Expand selected by factor...** command brings up a dialog. In the dialog it is possible to select a decimal expand factor. There are two buttons. A *cancel button* that closes the dialog and an *expand button* that expand or shrink the selected vertices by the expand factor. The name of the command is misleading in the way that it can not only be used to expand but also to shrink. When the *expand button* is pressed the vertical and horizontal distances between vertices is multiplied with the expand factor.
 - The **Modify selected vertices** menu item brings up a submenu where it is possible to change the color and the shape of selected vertices.
 4. This category contains edge operations. Items in this category is only enabled when one or more edges are selected. The **Split selected edges...** command brings up a dialog where you can select a number of vertices to input for each selected edge. When the *ok button* is pressed every selected edge

is removed and then the number of vertices that have been chosen is inserted between all the vertices that previously were neighbours. New edges are also created between the newly inserted vertices and the vertices that was previously neighbours so a path with the length (number of inserted vertices + 1) are created between all vertices that previously were neighbours.

5. The **Apply graph layout algorithm...** command brings up a dialog where you can select a number of graph layout algorithms that you can execute on the graph. You can select to execute most of the algorithms on selected vertices or all vertices.
6. The **Calculate graph statistics** command first traverses the graph to catch some information from it and then displays a dialog with information about the current graph.

11 The properties menu and its content



The properties menu contains menu items used to change the properties of the program and the graph. The **Show quickmenus** alternative shows a submenu where it is possible to select which quickmenus that are displayed.

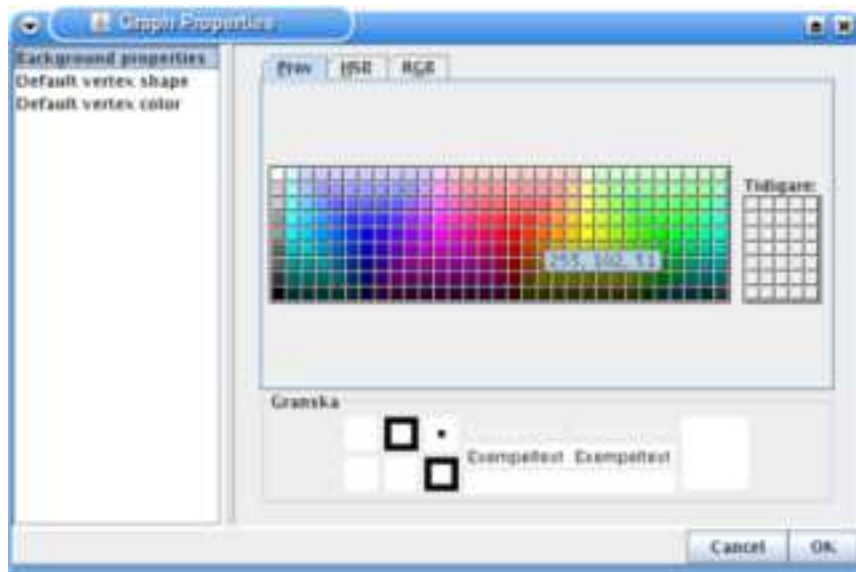
The dialogs that comes up when **Graph properties...** and the **Properties...** alternatives have been chosen, are described in the two next section*s.

11.1 The graph properties dialog

This dialog comes up when you select the **Graph properties...** alternative. In this dialog it is possible to select settings that is directly related to the graph. The settings is saved to the graph file when you save a graph and loaded when you open a graph from a file.

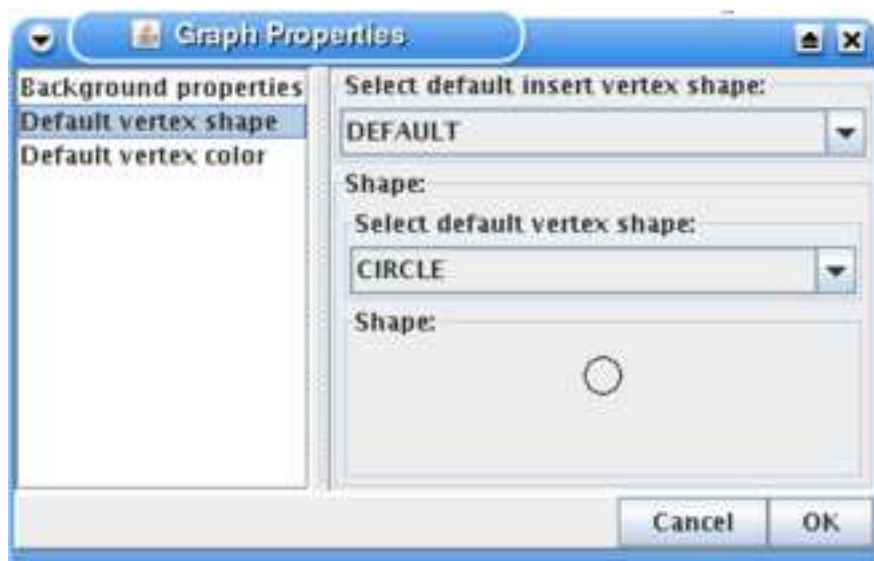
The dialog is divided in two parts. One is the list that is to the left. The list contains a number of names of settings modules. To the right, the currently selected settings module is displayed. To switch between settings module click on the name of the settings module that you want to change. To save all changed settings that have been done in the different settings modules click on the ok button in the bottom right corner. If you don't want to save the changes click on the cancel button. The different settings modules are described in the section*s below.

11.1.1 Background properties



Here the background color of the graph is selected.

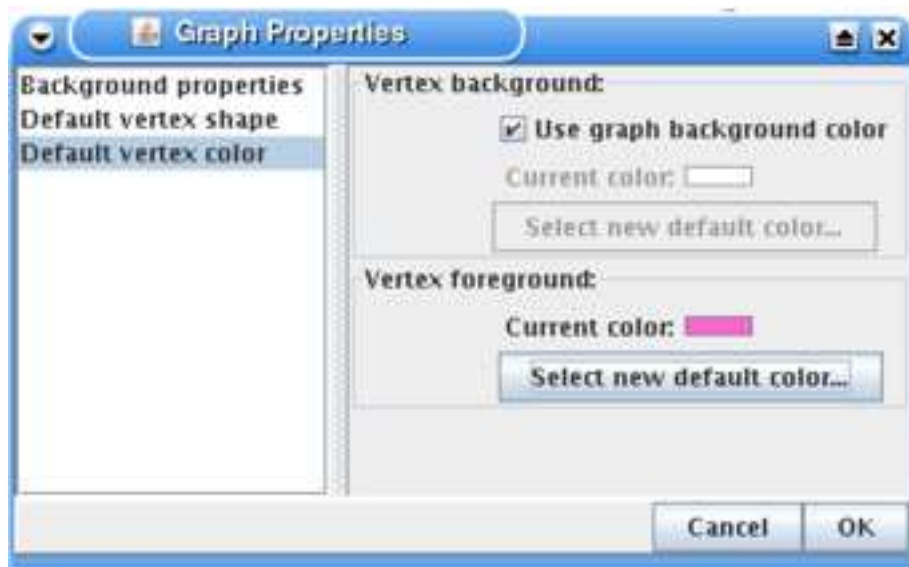
11.1.2 Default vertex shape



In this module you can select the default vertex shape. The default vertex shape is the shape of the vertex that is inserted when you insert vertices. The shape that you select in the drop down menu in the top of the module is displayed under it.

There exists one shape called *DEFAULT* that is different from the others. The *DEFAULT* shape can be any of the other shape. Therefore when you select the *DEFAULT* shape it is also possible to select which shape that shall be set as the *DEFAULT* at the moment. If you have inserted vertices with the *DEFAULT* shape it is possible to change them afterward by changing the actual shape of the *DEFAULT* shape.

11.1.3 Default vertex color



Here it is possible to select the default vertex color. That is the color of the vertices created with insert commands like clicking in the *graph window* when insert mode is on. The module is divided into two parts.

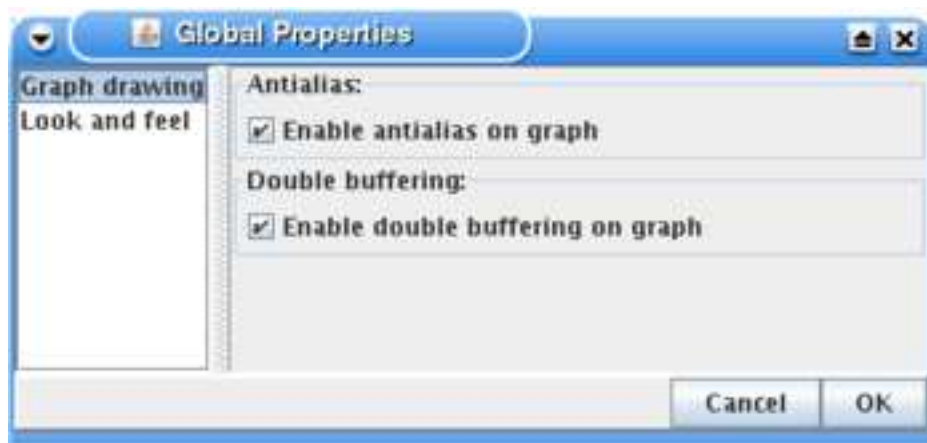
In the upper part you can select the background color of vertices. That is the color inside the selected shape that has borders with the foreground color. One option is to use the graph background color of the graph as the background color for vertices. If you unselect that option it is possible to choose a background color by clicking on the *Select new default color...* button.

You can select the default vertex foreground color in the lower part. The foreground color is the border of the shape that the vertex is made up by.

11.2 The global properties dialog

The global properties is the program properties that is used for all opened programs. The global properties is saved in the file *.grapheditor/properties.xml* that is placed in the user home directory. The user home directory is the directory given by the *java system* as the home directory. The dialog's structure is the same as in the *graph properties dialog*. The different settings modules in it are described in the section*s below.

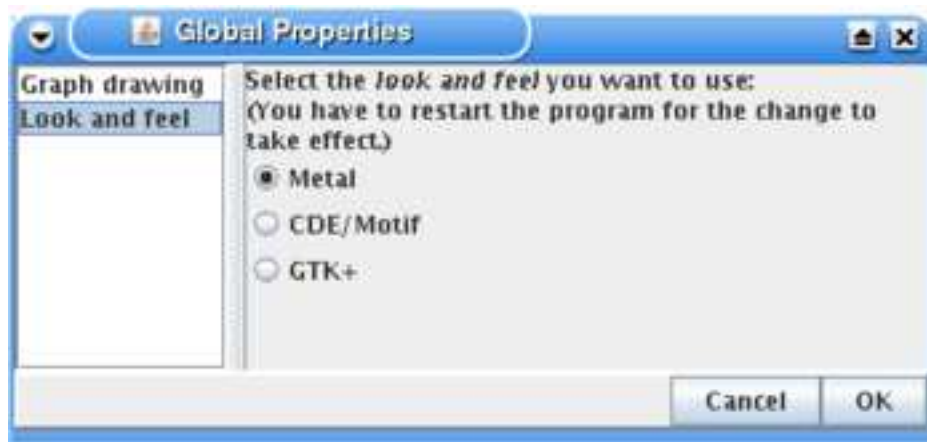
11.2.1 Graph drawing



Here you can change some drawing alternatives for the graph.

- If the **Antialias** alternative is selected the graph will be drawn with antialiasing. That means that lines and shapes get smoother edges. Turn this off if the program runs slowly
- If the **Double buffering** alternative is selected the graph will be drawn with the *double buffering* technique which means that the images is first drawn to an off screen buffer and then to the on screen buffer. This will remove flicker effects but can possible make the program consume more processor cycles and memory.

11.2.2 Look and feel



In this module you can select the *look and feel* for the program. A *look and feel* is a collection of settings that decide how the user interface will look and behave. Which *look and feel* s that is available depend on the java version the program is running on.

12 Export

The file menu contains a submenu with a number of different file formats that it is possible to export the graph to. The submenu is under the menu item called *Export to...* . Bellow are the different file formats

described with references to webpages where it is possible to find more information.

12.1 Graphviz dot-file format

This format can be used with the Graphviz tools produced in the Graphviz project. The Graphviz tools can create images of graphs from simple graph descriptions. The generated file is a description of a undirected graph created from the current graph. See the Graphviz documentation for information of how to change the files and configure the output. Bellow is an example of a command that produces a PNG-image file with a graph drawn from the description in the test.dot file:

```
neato test.dot -Teps > test.eps
```

<http://www.graphviz.org>

12.2 GraphML

GraphML is an XML based file format for describing all types of graph structures. Among other things it has support for both undirected and directed graphs. The generated file is a description of an undirected graph. <http://graphml.graphdrawing.org>

12.3 Graph Modeling Language (GML)

GML was created to make a universal graph file format that could be used in all types of graph programs. It is possible to attach all kind of data to the graph objects. <http://www.infosun.fim.uni-passau.de/Graphlet/GML>

12.4 File format compatible with Mathematica Combinatorica software

This file format is a simple neighbour list with position information for vertices. It can be opened with the Mathematica software.

Each row in the file format represents a vertex. The first number on each line is a vertex identification. The two floating point number next on the line is the horizontal and vertical coordinates of the vertex. The numbers coming after that is the identifications of the vertices that are neighbours to the vertex.

<http://www.wolfram.com>

12.5 Neighbourlist

The files exported by this exporter are exactly the same as files that are exported by the *Mathematica* exporter except that they do not contain vertex position information.

12.6 JPEG image file format

When you export to a JPEG (Joint Photographic Experts Group) image the graph is exported exactly as it looks like in the *graph window* except that the selection is cleared. This means that if you zoom in the graph the exported image will be bigger. The image exported is the same size as the least bounding rectangle of all vertices plus an empty border with 5 pixels. <http://www.jpeg.org>

12.7 PNG image file format

The PNG (Portable Network Graphics) export export is similar to the JPEG export but produces a PNG image. <http://www.w3.org/Graphics/PNG>

12.8 EPS image file format

The EPS (Encapsulated PostScript) image files produced by this exporter uses vector graphics which makes the images scalable. It is a very popular file format for images included in e.g. scientific reports. <http://www.prepressure.com/formats/eps/fileformat.htm>

13 Import

The file menu contains a submenu with different import alternatives. The submenu is under the menu item called *Import from...*. Below are the different import alternatives described.

13.1 Random graph importer

The random importer imports a graph with a random structure. A dialog is displayed when you choose this option. In the dialog, it is possible to select a number of vertices and a number of edges. The edges is randomly connected from one vertex to another until all edges has been connected somewhere. The vertices are placed in the circumference of a circle. It is also possible to change the distance between vertices in the dialog.

13.2 Mathematica compatible graph file format

The Mathematica compatible file format importer imports graphs from a graph file format that can be exported from Mathematica. This format is a simple neighbor list with vertex position information. See the information about *Mathematica compatible graph file format* under the section* about exporters for more information.

14 Used libraries

The program uses a lot of third part libraries. In the table below they are listed with information about which license they uses and where you can find more information. The program also uses java standard class library but it is not listed below.

Name	License	Website
JGraph	LGPL	http://www.jgraph.com
JGraphT	LGPL	http://www.jgrapht.org
JGraphpad CE	GPL	http://sourceforge.net/projects/jgraph
XStream	Modified BSD license	http://xstream.codehaus.org
EPS Graphics Library	GPL	http://www.abeel.be/epsgraphics
JavaHelp System	GPL with the class path exception	http://javahelp.dev.java.net
BrowserLauncher2	LGPL	http://browserlaunch2.sourceforge.net

The icons used in the program is created by David Vignoni. They are licensed under the LGPL license and can be downloaded from <http://icon-king.com>