Chair of
Software Engineering

Visualizing graphs with Vision2

Semester Thesis

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Computer Science

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Table of Contents

1 Introduction

This report gives a short description of the “Graph Widget” project. This chapter describes the objectives of the project. The second chapter provides an overview over the final system, while the third chapter is a summary of the most difficult problems that occurred during development. In the forth chapter, a list of possible options for future extensions and improvements is given, and this is then followed by the conclusion. Appendix A contains the full documentation of the project's classes at the time of submission

1.1 Objectives

The objective of the project was to create an Eiffel-Vision2 (http://docs.eiffel.com/eiffelstudio/libraries/vision2/index.html) widget that uses the GraphViz (www.graphviz.org) library to layout graphs and allows the user to modify these layouts in an intuitive way. The widget had to be able to render graphs using a subset of the graphical primitives provided by GraphViz, in particular, the widget had to be able to render a graph containing node shapes that are not part of this subset using a default representation. Besides the graph widget, the project also had to contain a sample application demonstrating the functionality of the widget.

2 The Graph Widget

The final system - the “Graph Widget” - uses the GraphViz library only for a very limited set of operations (see section 3 for reasons). All of the data concerning the graph layout and the component's state is kept strictly in the C structs maintained by GraphViz since the library does not support any other means of communication. Therefore, most of the Eiffel features interfacing to the GraphViz library are simple struct access methods to get data from the C objects or write updated data back to them.

2.1 Object Mapping

Once GraphViz has loaded a graph from a DOT file, a pointer to the “root graph” is returned to Eiffel. The Graph Widget then begins to wrap each element of the primary structure on the C side into the corresponding object on the Eiffel side (see “Figure 1”). GraphViz employs the concept of a “meta graph” to store the sub-graph structure of a graph. Each sub-graph (including the root graph) has a corresponding meta node in the meta graph and the hierarchy between the sub-graphs is modeled by meta edges. This concept has been dropped in the Graph Widget for simplicity.

2.2 Layout Data

The layout information is attached to each graph, node and edge on the C side and has to be kept up to date with modifications on the Eiffel side at all times since the GraphViz renderers depend on this layout information to generate their output. To avoid inconsistencies between the Eiffel and the C layer, almost all layout information only exists in C space and their information is only accessed indirectly through C calls in Eiffel (in contrast to the nodes and edges which also have a pure Eiffel representation).

For further information about implementation details, please see appendix A.

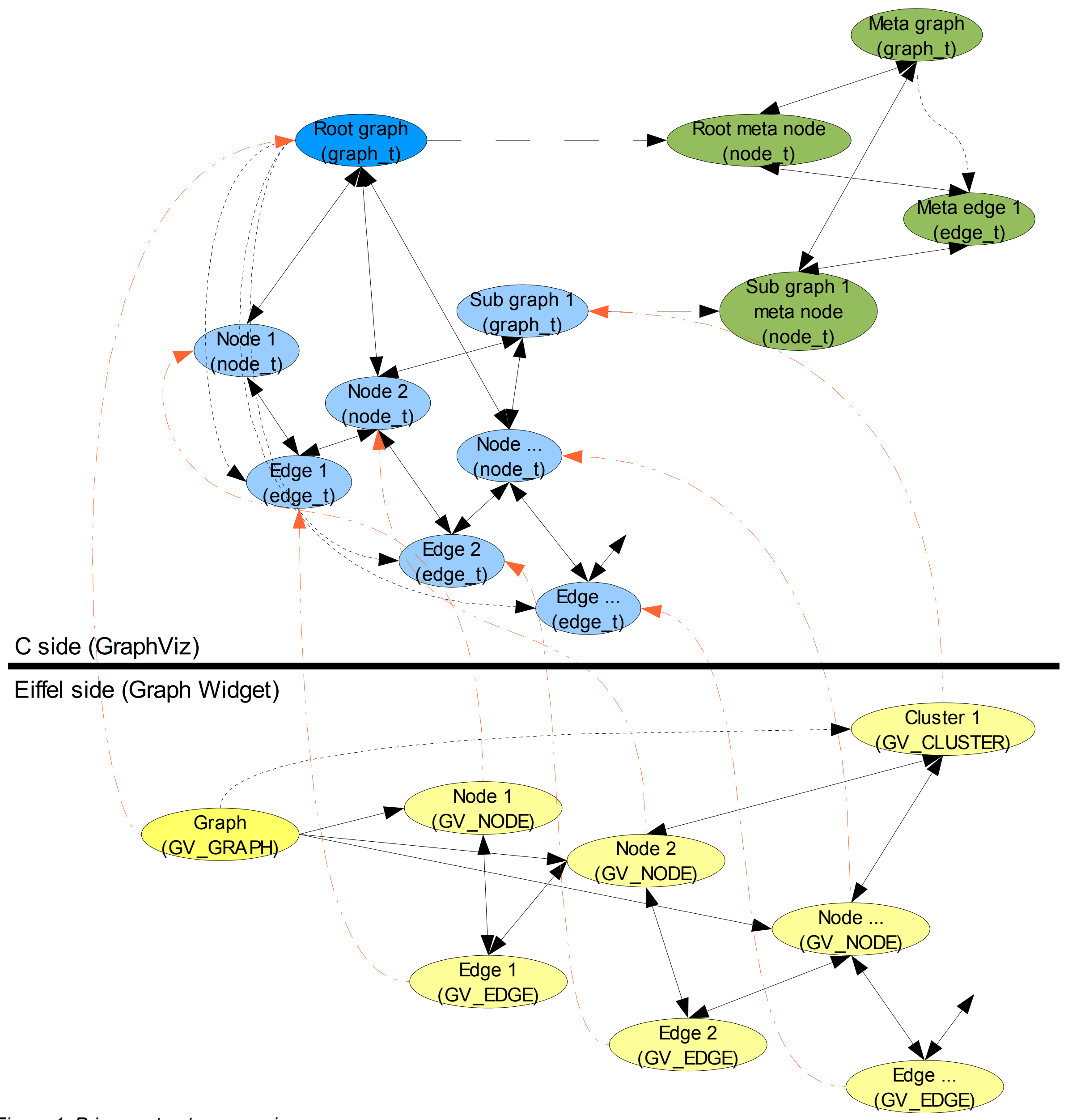


Figure 1: Primary structure mapping

3 Problems

Most of the problems that occurred during the development of the graph widget were caused by the GraphViz documentation. It seems that most of the (during development time) available GraphViz documentation was either grossly outdated or referred to the version of GraphViz that was under development at that time (the graph widget project is based on GraphViz version 2.8 since version 2.9 was far from stable). The GraphViz library has been, and still is, under heavy development and the library API is changing constantly. Therefore, most of the available tutorials either don't work at all or don't give the expected results using version 2.8. For that reason, most of the research involved going through the GraphViz header files with a fine-tooth comb, and since source code level documentation was mostly missing too, it also involved a lot of guessing what the library functions might actually do.

Another problem is, that the GraphViz library is written in C and is therefore anything but object oriented. Most “modules” such as the layout algorithms, can only be accessed as a whole and interesting sub-components (for example the algorithm used to calculate edges) are either hidden from the library user or don't work in any other context than the one they were originally designed in. As a result, the only GraphViz components accessed by the Graph Widget are:

- Layout algorithms (only for complete graphs)
- Load / store functions
- Output renderers to create PNGs, JPGs or other output

Probably the most irritating problem is, that GraphViz has no possibility to incorporate modified layout data into a subsequent layout operation. This means that during every layout operation, GraphViz overwrites all the layout attributes, which makes it amazingly difficult to maintain layout modifications during manipulations on the graph's primary structure. (This is solved in the Graph Widget by storing layout data to “string attributes” attached to the graph elements and restoring the modified layout from there after every application of a layout algorithm.)

4 Future Work

Some possibilities for future extensions and improvements:

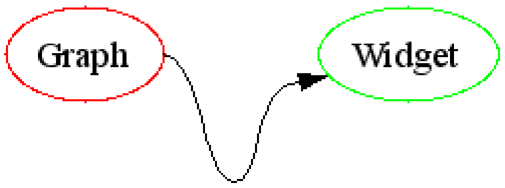
- Implementing the rest of the node shapes that are supported by GraphViz (see "http://www.graphviz.org/doc/info/shapes.html"
- Since the API of the GraphViz library is constantly changing, the graph widget probably won't work properly with new versions of the library without some modifications to the interface code. So, once a newer stable version of the library becomes available, this might be worth looking into.
- Extending the graph widget to enable the user to modify graph attributes like the node shape, shape color, node label and other layout related attributes directly with the widget instead of changing the DOT file.

5 Conclusion

Although the problems that occurred during development were not particularly simple, they have been solved without compromising the system's overall design. Working with a non object oriented library may not be very enjoyable for somebody who is used to work with object oriented software, but it certainly is instructive. The final widget does what it is supposed to do according to the problem specification and it even has some nice usability features, so all in all the project can be considered a complete success.

Appendix A

Appendix A contains the complete documentation of the Graph Widget project for the source code revision 280 (revision number of the Subversion revision). This documentation is also available on line at http://graphvision.origo.ethz.ch/.



Visualizing graphs with Vision2

Introduction

The *Graph Widget* provides a graphical user interface to layout graphs. It is based on the *GraphViz* library (see References), which loads graphs (from DOT files), creates an initial layout and saves the edited graph as an image or an attributed DOT file.

Installation

- **Installation**
  Getting started with the *GraphViz Widget*

Graph Widget Documentation

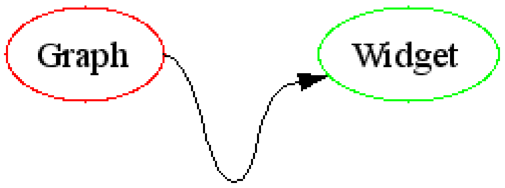
- **User Documentation**
  User documentation for the *Graph Widget*
- **Developer Documentation**
  Developer documentation for the *Graph Widget* library API

Graph Widget Test Application

- **Overview**
  This gives an overview over the *Graph Widget* test application and its UI elements.

References

- **References**
  References to other documents such as thesis reports and web pages



Installation Guide

You can use the *Graph Widget* either as precompiled executable of the demo application (for Windows users) or you can use it as an Eiffel library using the source code of the demo application as a starting point. In the latter case you will need to download and install the *GraphViz* binaries from the download page

Demo Application Binary

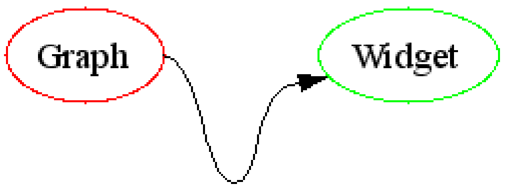
Download the *Graph Widget* archive from the download page, extract the "demo_application.exe" (Win32 binary) and run the executable.

Using the Graph Widget as a Library

First you have to install the *GraphViz* version 2.8 binaries and download the *Graph Widget* archive from the download page. Installable *GraphViz* packages are available under www.graphviz.org for several operating systems.

Next, you have to create a new environment variable "GRAPHVIZ" pointing to your *GraphViz* installation directory. In Windows, this is done by right-clicking "My Computer" -> Properties -> Advanced Tab -> Environment Variables (Linux users usually know how to do this sort of stuff on their operating system ;). After that, you extract the "graph_widget" folder from the *Graph Widget* archive to your *GraphViz* directory.

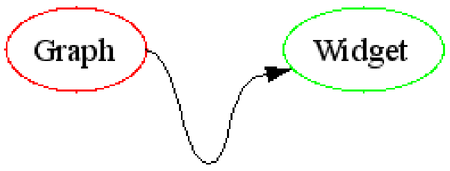
As the last step, extract the "demo_application" folder from the *Graph Widget* archive to a location of your choosing. Start your EiffelStudio and compile the project by opening the ACE file in the demo application folder. If everything went as planned, you have now a working demo application to get you started.



Graph Widget User Guide

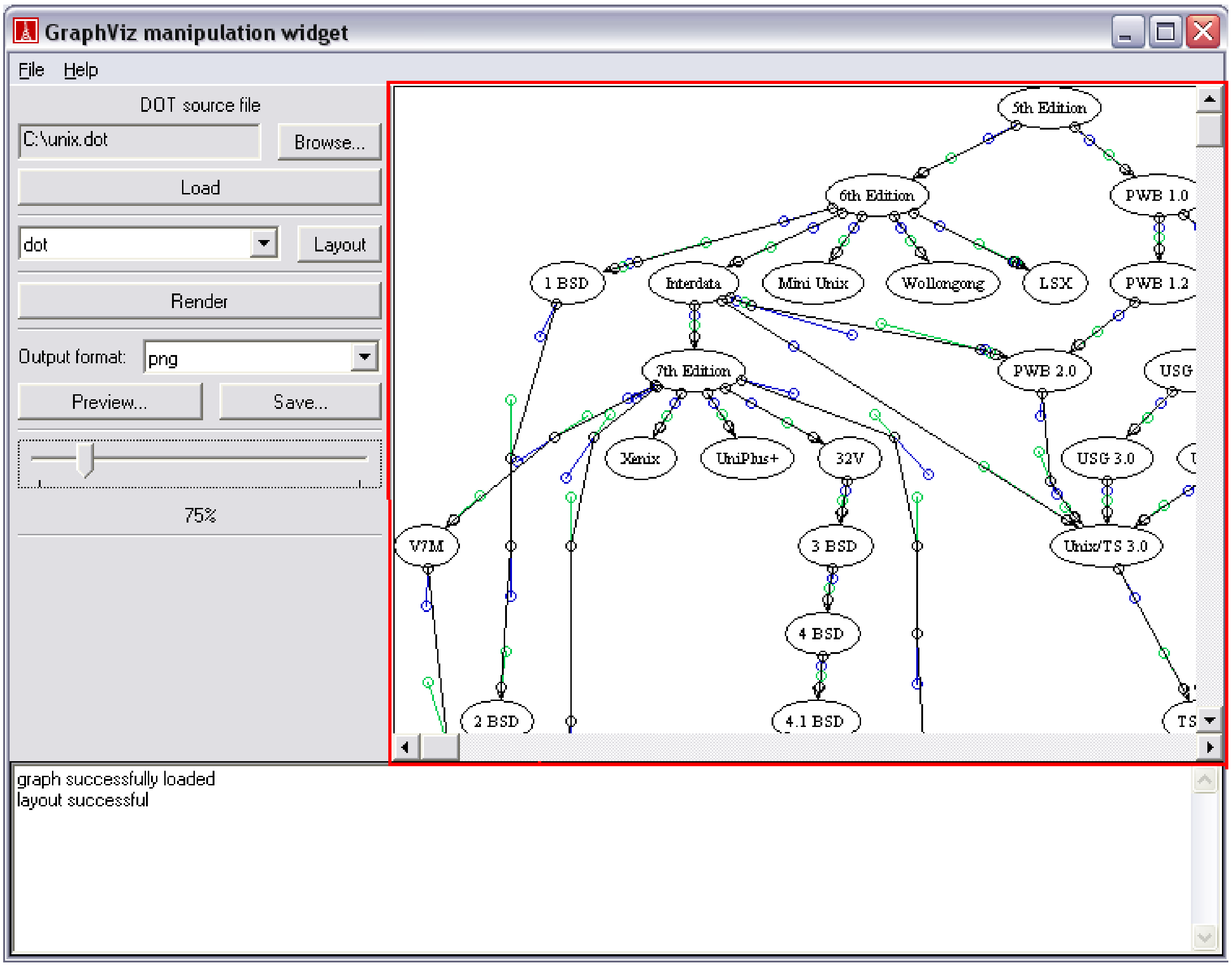
The *Graph Widget* allows easy manipulation of graph layouts and provides methods to perform basic graph manipulations (insert / delete edges and nodes)

This section is structured as follows:



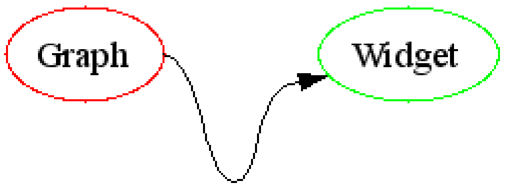
Graph Widget User Guide

The picture below shows the *Graph Widget* test application, the actual Graph Widget is the right part where the graph is displayed (red border). Although the *Graph Widget* allows manipulating most of the "important" aspects of the graph, its manipulation options do not include all of the options that *GraphViz* provides. If you need more than the *Graph Widget* provides, you can always manipulate the DOT file (see The DOT Language and Graph Attributes for more information)



C:\unix.dot
dot
png
75%

graph successfully loaded
layout successful



Graph Widget User Guide

A graph as shown in the figure of the introduction section contains the following elements that can be created/deleted/edited through context menus provided by the *Graph Widget*

Clusters

Clusters are subsections of the graph marked by a rectangle surrounding the nodes included in the cluster (the whole graph is also a cluster).

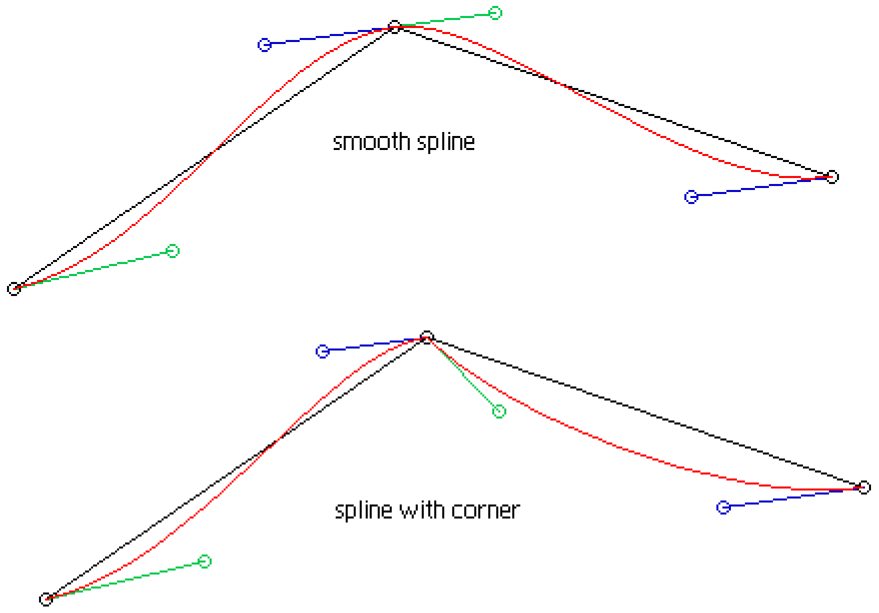
- Context Menu:
  - "create node..." : Creates a new node in the selected cluster (centered at the mouse position during the right click).

Nodes

- Moving: Click on a node of the displayed graph with the left mouse button and drag the node around while keeping the left mouse button pressed.
- Context Menu:
  - "create edge to..." : Creates a new edge to the node that will be clicked next.
  - "delete node" : Removes the node (and all associated edges) from the graph.

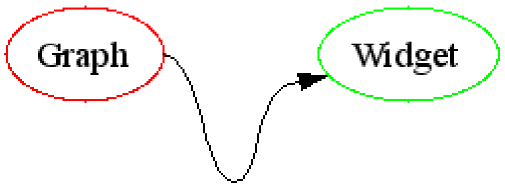
Edges

In *GraphViz* edges are represented as bezier splines, but the *Graph Widget* doesn't draw them as such, instead the splines are represented as start/end points and their control points.



The spline starts in the top right corner (black circle) and ends in the lower left corner (other black circle) while the blue and green circles represent the control points. The red line is what *GraphViz* draws. It takes some getting used to, but it's actually quite easy to manipulate the splines. Since a spline can have more than one segment, the colors blue and green are used to mark outgoing and incoming control points. They are connected because a smooth transition between two spline segments requires that the incoming and outgoing control point form a straight line with their spline point.

- Moving: Simply drag one of the little circles from a spline or control point. Start and end points are a special topic. Since they are each attached to a node, they can't be dragged away from those nodes, instead they stay attached to the border of the nodes they belong to.
- Context Menu (depends on what kind of point you click on):
    - "insert point after" : Inserts a new spline point (including control points) after the currently selected spline point.
    - "insert point before" : Inserts a new spline point (including control points) before the currently selected spline point.
    - "remove point" : Removes the spline point and all associated control points from the edge.
    - "delete edge" : Deletes the edge from the graph.



GraphViz Widget Developer Guide

This section consists of a description of the intention and use of the *Graph Widget library* with a description of each class and its simplified interface.

The Widget

- **Overview**
  Gives an overview of the classes surrounding the actual graph widget
- **Classes**
  Describes the two widget classes of the *Graph Widget*

GraphViz Wrapper

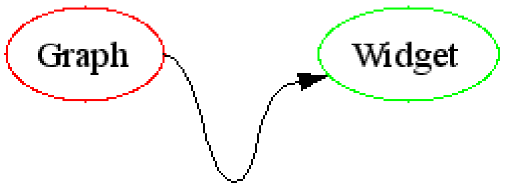
- **Overview**
  Gives an overview over the Eiffel representations of the *GraphViz* structs and access methods.
- **Classes**
  Describes each class that has a counterpart in the *GraphViz* library.
- **Externals**
  Gives a short description of the C externals used by the *Graph Widget*

Visual Aspects

- **Overview**
  Describes the overall structure of the graphical aspects of the *Graph Widget*
- **Interfaces**
  Describes the DRAWABLE and MOVABLE deferred classes that are used to draw graphs on the screen.
- **Points and Rectangles**
  Gives a short description of the geometry classes used for visual representation
- **Node Shapes**
  Describes how node shapes are represented and how one could create additional node shapes.

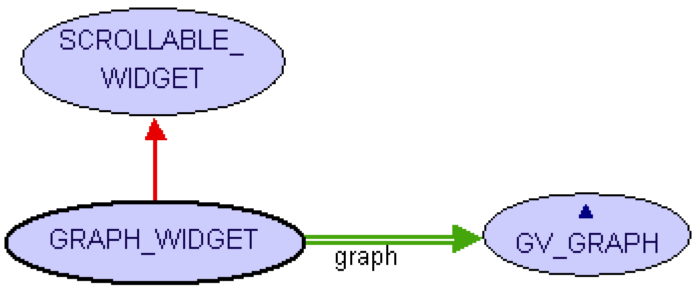
Miscellaneous Classes

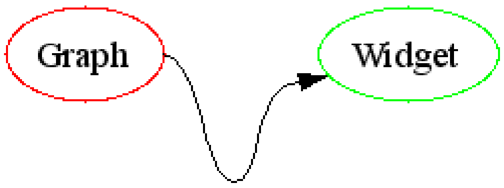
- **Classes**
  Gives a description of the *Graph Widget* helper classes that are not really important in the great scheme of things and could not be assigned to any other category.



Widget Overview

The GRAPH_WIDGET class is one of the key classes in the library since it provides a graphical user interface to manipulate the GV_GRAPH object. It inherits from the SCROLLABLE_WIDGET class which - as the name suggests - enables the GRAPH_WIDGET to scroll. For most actions that can be performed on a GV_GRAPH object and its components (nodes, edges, ...) there is an example in the GRAPH_WIDGET code (if you care to find it ;) but you will find more about that in the next chapter. The GRAPH_WIDGET class is the "master" class of library; although it is technically only a client of the GV_GRAPH class, it "knows" everything about the wrapper classes (the ones starting with GV_) and their structure. This is of course necessary since it has to manipulate these classes to provide the implemented functionality to the end user.





Widget Classes

The widget classes (there are only two that fall in this category) provide the basic functionality to visualize a graph and allow the user to manipulate its layout.

- SCROLLABLE_WIDGET
- GRAPH_WIDGET

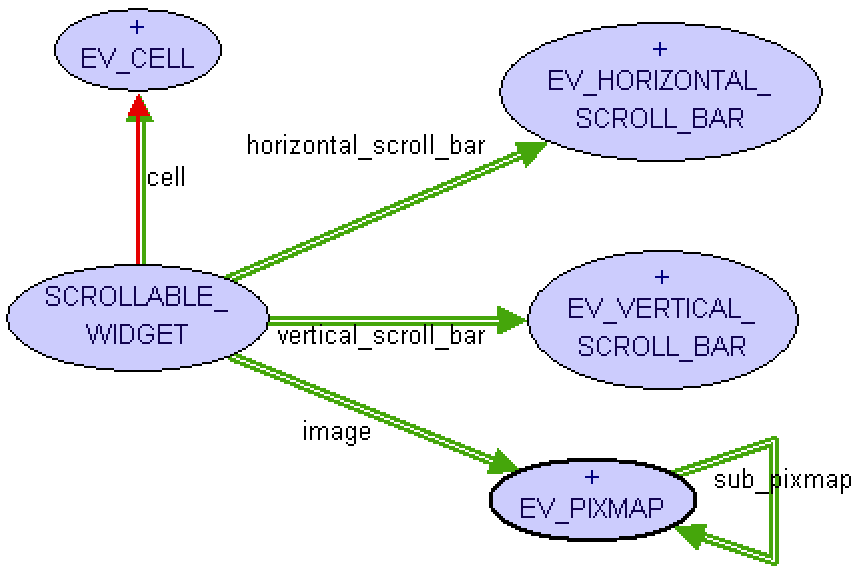
SCROLLABLE_WIDGET
Requirements:

none

Description

The SCROLLABLE_WIDGET is basically just an EV_CELL containing two scrollbars and a pixmap filling that part of the cell that is not filled by the two scroll bars. using the set_scrollable_size feature you can set the virtual size of the component that will be drawn on the pixmap. The rest of the class is pretty much straight forward (mostly access features to the used widgets).

Class overview



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GRAPH_WIDGET
Requirements:

SCROLLABLE_WIDGET

Description

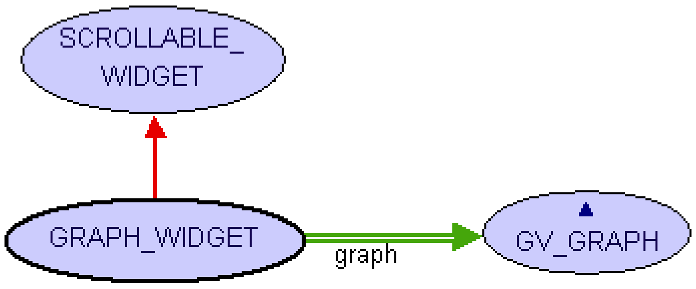
The GRAPH_WIDGET lets the user view and manipulate graphs. Its main access methods are private action handlers that get invoked during user interaction with the widget which therefore are not part of the public API.

The main public features are

- layout_graph which creates an initial layout for the loaded graph using one of the *GraphViz* layout algorithms.
- render_graph which renders the graph (if it has a layout) onto the image of the SCROLLABLE_WIDGET.
- can_preview which determines whether for a given format there is a preview available or not.
- preview which creates a preview of the selected format (if available).

You can access the current graph via graph and set it using set_graph (this will not refresh the displayed image call render_graph for this).

Class overview



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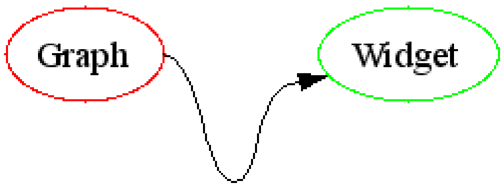


GraphViz Wrappers Overview

The *GraphViz* wrappers are a set of classes that serve as a link to the *GraphViz* data structures that represent the loaded graph.

How a Graph is loaded by GraphViz

In *GraphViz*, a graph is loaded from a DOT file by recreating the graphs primary structure (nodes, edges) as C structs. Some other structs that will later contain the layout information are allocated as well, but initially there is no data in them. The attributes from the dot file are attached to these structs in their original (string) form and most of them are NEVER loaded into the corresponding C structs. This is one of the many problems of *GraphViz* since there is no possibility to load the string attributes into the C structures besides parsing the strings yourself and setting the values in the layout structs (which has been done in this library).

The graph's secondary structure (clusters, sub-graphs) is loaded into a second set of the same C structs as the primary structure. In this meta graph, clusters are nodes and edges specify the hierarchy of the clusters. (This structure is only partially loaded in the *Graph Widget* library)

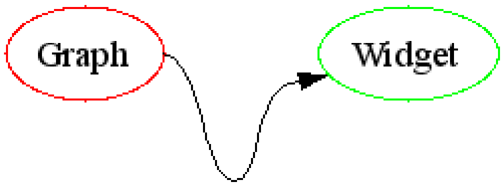
After the graph has been loaded, the user of the *GraphViz* library can apply any of the *GraphViz* layout engines to the graph. Each of these layout algorithms then store their layout data in the C layout structs, overwriting any previous modifications to these structures. Some of the algorithms even overwrite some of the string attributes that have been loaded from the DOT file (which they are not supposed to do) which makes it pretty hard to preserve any kind of layout information.

Eiffel Wrappers and Externals

Each wrapper class (classes starting with the prefix GV_) takes a pointer to one of the many C structs and provides some methods to access and modify this struct. All the Eiffel externals are grouped in the *_OPERATIONS classes in the "externals" cluster of the *Graph Widget* library. I would love to refer you to the *GraphViz* documentation for further details on the C structures and methods, but most of the available documentation was (at the time this was written) either speculative (referring to future versions) or horribly outdated. Therefore, I added a little one or two sentence summary on every external feature in the externals section of this document.

Common Functionalities

All wrapper classes have some basic functionality in common: First, they are all DRAWABLE which means they have a graphical representation which can be rendered on a EV_DRAWABLE. The drawing is recursive, which means that drawing the graph will draw the sub clusters, will draw the nodes and so on. Some of the wrappers are also MOVABLE which allows the GRAPH_WIDGET to do drag and drop layout of the graph. The last common functionality is the load_attributes feature. Like drawing, this is also a recursive feature and it allows to load the string attributes of the graph into the C layout structures (this is the trick that allows the graph widget to load a previously saved layout that has been modified by the user). This is the most important feature. Without it, saving layout information for later use would be quite useless since it would be impossible to load it again.



GraphViz Wrappers Classes

The wrapper classes each have a C struct counterpart. At the core, there is always a pointer to one of these C structs and manipulations on the Eiffel class are propagated back to the C struct since that is the only way to communicate with *GraphViz*.

- **GV_GRAPH**
- **GV_CLUSTER**
- **GV_NODE**
- **GV_EDGE**
- **GV_SPLINE**

GV_GRAPH

Requirements:

GV_CLUSTER

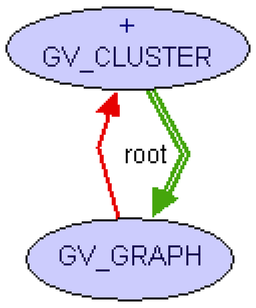
Description

GV_GRAPH wraps the root "Agraph_t" struct in the "graph.h" header of the *GraphViz* library. It is basically a GV_CLUSTER with some enhanced functionality to create (do_layout) graph layouts using one of the *GraphViz* layout engines and render these layouts to an image file.

To create an instance of the GV_GRAPH class, pass the path to a DOT file to the make feature. On creation, the complete graph structure including its meta graph is loaded and the corresponding wrapper classes are created; this is in fact the only class that a user of this library has to create on his own.

The purpose of the feature set delete_node, create_node, delete_edge and create_edge should be fairly obvious. They are located in this particular class, because *GraphViz* requires the pointer to the root graph for this sort of operation.

Class overview



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GV_CLUSTER

Requirements:

COMMON_OPERATIONS, CLUSTER_OPERATIONS, GRAPH_OPERATIONS, NODE_OPERATIONS, EDGE_OPERATIONS, DRAWABLE

Description

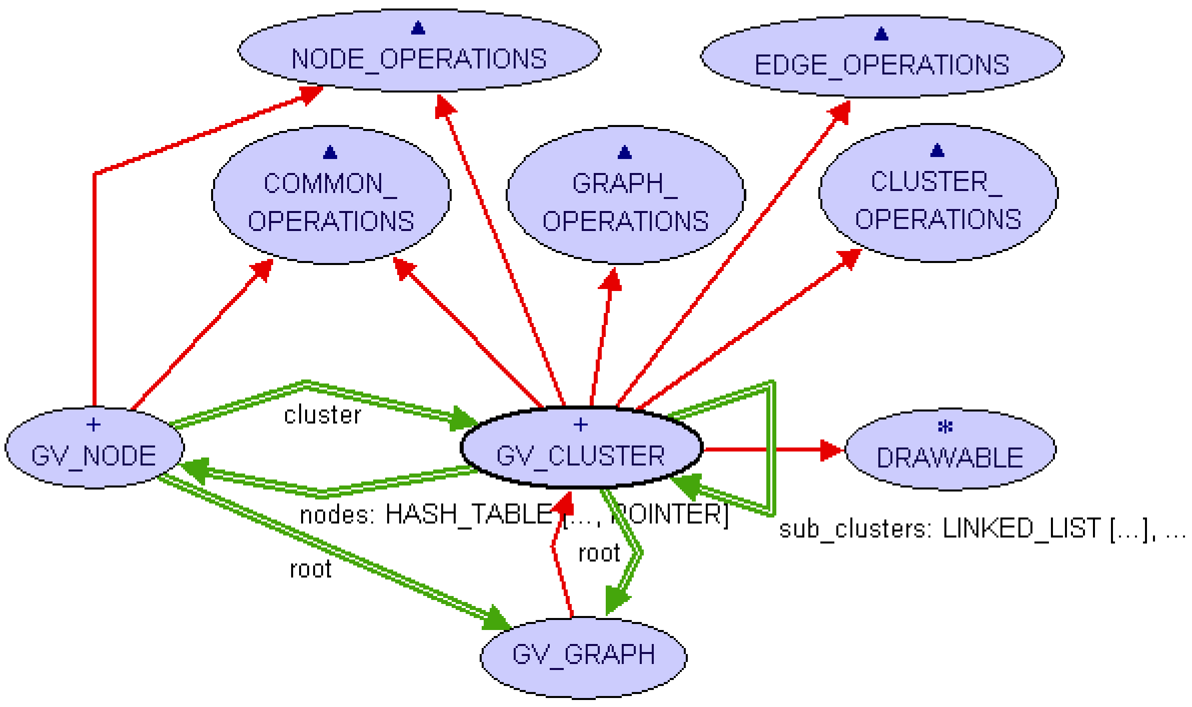
GV_CLUSTER wraps the "Agraph_t" struct in the "graph.h" header of the *GraphViz* library. From the *GraphWiz* documentation it is unclear what its real purpose is, besides giving the graph a more hierarchical structure. In the wrapper it acts as a container for nodes, where every cluster contains the nodes of all its sub clusters as well as the direct child nodes of the cluster itself.

Apart from that, the GV_CLUSTER is a rectangle representing its bounds. To create one, pass make_cluster a pointer to a "Agraph_t" structure representing the cluster, the parent cluster (to create the tree structure) and the root graph.

There are three special features in the GV_CLUSTER class:

- pick_cluster picks the cluster at the given coordinates which is furthest down in the tree structure.
- recalc_bb recalculates the bounding box rectangle to fit all the nodes contained in the cluster (useful, if you move nodes around).
- preload_attributes is actually the fix for a *GraphViz* bug. When performing a layout operation on a graph, GraphViz overrides the "bb" (bounding box) string attribute of the root graph, which it is NOT supposed to do. To prevent this from affecting the program, the preload_attributes feature has to be called before any layout operation. It stores the string attribute in a class variable, so when the actual load_attributes call happens, it can restore the original bounding box, and not the one calculated by GraphViz.

Class overview



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GV_NODE

Requirements:

COMMON_OPERATIONS, NODE_OPERATIONS, MOVABLE

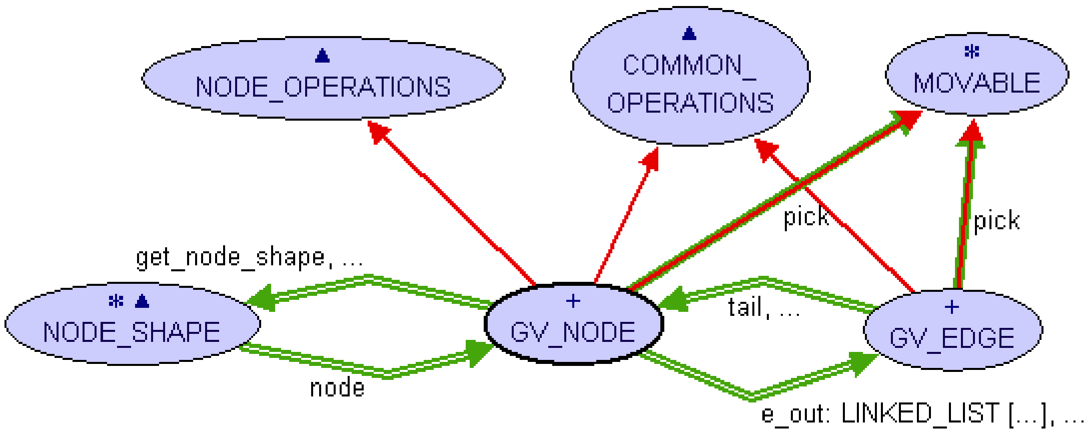
Description

GV_NODE wraps the "Agnode_t" struct in the "graph.h" header of the *GraphViz* library. Its main purpose (the drawing of the node's shape) is actually defined in another set of classes, namely NODE_SHAPE and its descendants. What remains is a collection of position (x, set_x, y and set_y) and size (width, height, ...) attributes that define the nodes appearance (

Of course there is the mandatory node attribute that is a pointer to the "Agnode_t" struct that is passed to the creation procedure along with the node's direct parent cluster (clusters are arranged in a hierarchical structure).

The graphical representation of the node is stored in the shape attribute. The actual shape instance is created the first time the shape is accessed since *GraphViz* does not create the shape struct until the graph is laid out by one of the layout engines. The feature get_node_shape (exported to NONE) creates the instance of the required node shape. This feature needs to be updated to accommodate for new shape types.

Class overview



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GV_EDGE
Requirements:

COMMON_OPERATIONS, EDGE_OPERATIONS, MOVABLE

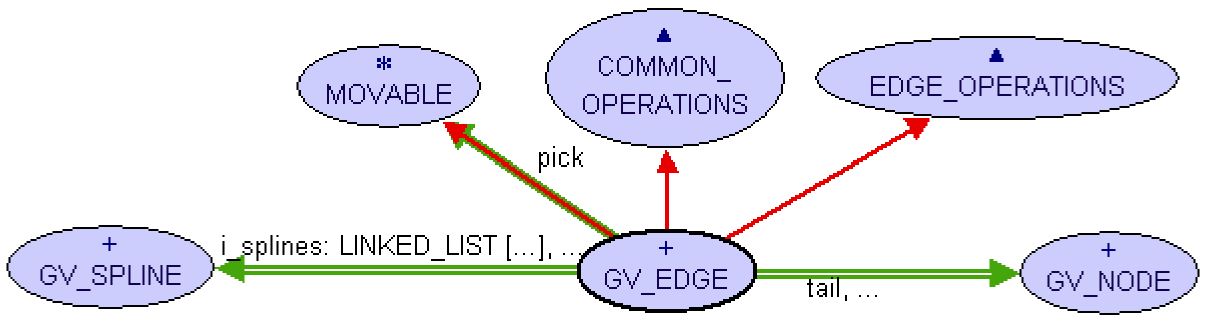
Description

GV_EDGE wraps the "Agedge_t" struct in the "graph.h" header of the *GraphViz* library. It consists of a reference to its head and tail nodes (head, tail) and a list of splines. Although there could in theory be more than one spline for an edge, I have never found such an instance and I am not sure how useful it would be.

To create an instance of GV_EDGE, pass a pointer to an "Agedge_t" struct and the parent GV_GRAPH to the make creation feature. At this point, the GV_GRAPH already needs to have a complete list of nodes in the graph (or at least the nodes this edge is connected to). The edge will try to get the head and tail nodes from the graph (and will fail if they are not available).

The pick and the draw operations are passed along to the GV_SPLINE instances of the edge. The pick operation is special: Edges cannot be moved as a whole (they are attached to nodes), single spline and control points, however, can. Since moving control points can be somewhat tricky, the pick operation on a GV_SPLINE instance creates a SPLINE_POINT which can represent a simple spline point, a spline point that is attached to a node or a control point. Calling the move feature on a GV_EDGE passes the call on to the SPLINE_POINT which adapts the actions to this particular kind of spline point. The insert/remove operations (insert_before_current, insert_after_current and remove_current) are also passed on to the SPLINE_POINT.

Class overview



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GV_SPLINE

Requirements:

SPLINE_OPERATIONS, DRAWABLE

Description

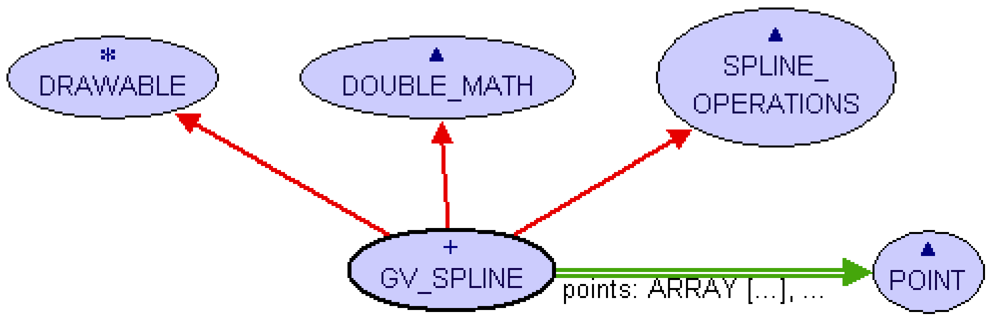
GV_SPLINE is a wrapper for the "bezier" struct in the "types.h" header of the *GraphViz* library. A GV_SPLINE can have a head and/or a tail (has_head, has_tail and head, tail respectively) where an arrowhead will be drawn.

The creation procedure (make) of GV_SPLINE takes a pointer to a bezier struct and a pointer to its parent edge as arguments. After creation the spline can be drawn via the draw feature.

There is also a set of spline manipulation features:

- insert_point_before inserts a new spline point (and two control points) after a given spline point.
- insert_point_after inserts a new spline point (and two control points) before a given spline point.
- remove_point removes a given spline point and the one or two control points associated with it.

Class overview



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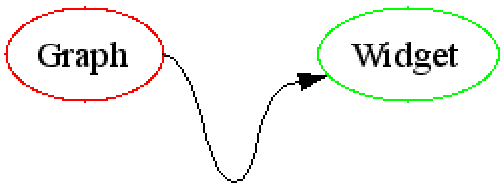


Graph Widget Externals

These classes provide the communication channel to the *GraphViz* C library. The C functions are grouped into classes according to the class they belong to most (actually most of the functions "belong" to more than one class, since C is not object oriented). The wrapper classes then inherit from the external classes to gain access to the operations they need.

COMMON_OPERATIONS

- get_attribute (obj: POINTER; name: STRING) : STRING

C Name	
Header File	
Description	gets the string representation of the attribute with the given *name*

- c_agget (p, s: POINTER) : POINTER

C Name	agget
Header File	gvc.h
Description	gets the attribute specified by its name *s* from the graph, node or edge *p*

- c_agset (p, n, v: POINTER) : INTEGER

C Name	agset
Header File	gvc.h
Description	sets the attribute *n* of graph, node or edge *p* to value *v*

- c_agdelete (g, p: POINTER)

C Name	agdelete
Header File	gvc.h
Description	removes the graph, node or edge *p* from the graph with root *g*

GRAPH_OPERATIONS

- c_gvContext : POINTER

C Name	gvContext
Header File	gvc.h
Description	gets a gv context (used to create layouts)

- c_gvLayout (gvc, g, layout: POINTER) : INTEGER

C Name	gvLayout
Header File	gvc.h
Description	applies the layout algorithm *layout* to the graph *g* using the gv context *gvc*

- c_gvFreeLayout (gvc, g: POINTER) : INTEGER

C Name	gvFreeLayout
Header File	gvc.h
Description	releases the layout from graph *g* (resets all layout related structs)

- c_gvRender (gvc, g, output, file: POINTER) : INTEGER

C Name	gvRender
Header File	gvc.h
Description	renders the graph *g* to the file *file* using *output* as file format

- c_agread (file: POINTER) : POINTER

C Name	agread
Header File	gvc.h
Description	reads the next graph from *file* and returns a pointer to it

- c_agclose (g: POINTER)

C Name	agclose
Header File	gvc.h
Description	closes the graph *g* (frees the resources associated with *g*)

- c_attach_attrs (g: POINTER)

C Name	attach_attrs
Header File	gvc.h
Description	attaches all layout related attributes to the string attributes (overwriting existing ones)

- c_meta_graph (g: POINTER) : POINTER

Struct Access	g->meta_node->graph
Header File	gvc.h
Description	gets the pointer to the meta graph of root graph *g*

CLUSTER_OPERATIONS

- c_bb_ll_x (p: POINTER) : INTEGER

Struct Access	p->u.bb.LL.x
Header File	gvc.h
Description	gets the x coordinate of the lower left corner of the bounding box of *p*

- c_bb_ll_y (p: POINTER) : INTEGER

Struct Access	p->u.bb.LL.y
Header File	gvc.h
Description	gets the y coordinate of the lower left corner of the bounding box of *p*

- c_bb_ur_x (p: POINTER) : INTEGER

Struct Access	p->u.bb.UR.x
Header File	gvc.h
Description	gets the x coordinate of the upper right corner of the bounding box of *p*

- c_bb_ur_y (p: POINTER) : INTEGER

Struct Access	p->u.bb.UR.y
Header File	gvc.h
Description	gets the y coordinate of the upper right corner of the bounding box of *p*

- c_set_bb_ll_x (p: POINTER; v: INTEGER)

Struct Access	p->u.bb.LL.x

Header File	gvc.h
Description	sets the x coordinate of the lower left corner of the bounding box of *p*

- c_set_bb_ll_y (p: POINTER; v: INTEGER)

Struct Access	p->u.bb.LL.y
Header File	gvc.h
Description	sets the y coordinate of the lower left corner of the bounding box of *p*

- c_set_bb_ur_x (p: POINTER; v: INTEGER)

Struct Access	p->u.bb.UR.x
Header File	gvc.h
Description	sets the x coordinate of the upper right corner of the bounding box of *p*

- c_set_bb_ur_y (p: POINTER; v: INTEGER)

Struct Access	p->u.bb.UR.y
Header File	gvc.h
Description	sets the y coordinate of the upper right corner of the bounding box of *p*

- c_agfstnode (g: POINTER) : POINTER

C Name	agfstnode
Header File	gvc.h
Description	returns a pointer to the first node in *g*

- c_agnxtnode (g, n: POINTER) : POINTER

C Name	agnxtnode
Header File	gvc.h
Description	returns the node in *g* following the node *n*

- c_agfindsubg (p, name: POINTER) : POINTER

C Name	agfindsubg
Header File	gvc.h
Description	returns a pointer to a subgraph of *p* given its name

- c_meta_node (g: POINTER) : POINTER

Struct Access	g->meta_node
Header File	gvc.h
Description	gets the pointer to the meta node of graph *g*

NODE_OPERATIONS

- c_agnode (g, n: POINTER) : POINTER

C Name	agnode
Header File	gvc.h
Description	creates a new node with name *n* in the subgraph pointed to by *g* and returns said node pointer

- c_agfstout (g: POINTER; n: POINTER) : POINTER

C Name	agfstout
Header File	gvc.h
Description	returns a pointer to the first outgoing edge of *n*

- c_agnxtout (g: POINTER; e: POINTER) : POINTER

C Name	agnxtout
Header File	gvc.h
Description	returns a pointer to the next outgoing edge after *e*

- c_get_name (n: POINTER) : POINTER

Struct Access	n->name
Header File	gvc.h
Description	returns a pointer to a C string containing the name of the node *n*

- c_get_u_coord_x (p: POINTER) : INTEGER

Struct Access	p->u.coord.x
Header File	gvc.h
Description	gets the x coordinate of the center of node *p*

- c_set_u_coord_x (p: POINTER; v: INTEGER)

Struct Access	p->u.coord.x
Header File	gvc.h
Description	sets the x coordinate of the center of node *p*

- c_get_u_coord_y (p: POINTER) : INTEGER

Struct Access	p->u.coord.y
Header File	gvc.h
Description	gets the y coordinate of the center of node *p*

- c_set_u_coord_y (p: POINTER; v: INTEGER)

Struct Access	p->u.coord.y
Header File	gvc.h
Description	sets the y coordinate of the center of node *p*

- c_get_width (p: POINTER) : DOUBLE

Struct Access	p->u.width
Header File	gvc.h
Description	gets the width (in inches) of the node *p*

- c_set_width (p: POINTER; v: DOUBLE)

Struct Access	p->u.width
Header File	gvc.h
Description	sets the width (in inches) of the node *p*

- c_get_height (p: POINTER) : DOUBLE

Struct Access	p->u.height
Header File	gvc.h
Description	gets the height (in inches) of the node *p*

- c_set_height (p: POINTER; v: DOUBLE)

Struct Access	p->u.height
Header File	gvc.h
Description	sets the height (in inches) of the node *p*

- c_get_shape_name (p: POINTER) : POINTER

Struct Access	p->u.shape->name
Header File	gvc.h
Description	gets the name of the shape of node *p*

EDGE_OPERATIONS

- c_agedge (g, t, h: POINTER) : POINTER

C Name	agedge
Header File	gvc.h
Description	creates a new edge from node *t* to node *h* and returns a pointer to it

- c_get_head (e: POINTER) : POINTER

Struct Access	e->head
Header File	gvc.h
Description	returns a pointer to the node at the head end of edge *e*

- c_get_tail (e: POINTER) : POINTER

Struct Access	e->tail
Header File	gvc.h
Description	returns a pointer to the node at the tail end of edge *e*

- c_get_spline_count (e: POINTER) : INTEGER

Struct Access	e->u.spl->size
Header File	gvc.h
Description	returns the number of bezier structs associated with edge *e*

- c_get_spline_list (e: POINTER) : POINTER

Struct Access	e->u.spl->list
Header File	gvc.h
Description	returns a pointer to an array of bezier structs representing the splines associated with edge *e*

- c_get_ith_spline (s: POINTER; i: INTEGER) : POINTER

C Name	i_th_spline
Header File	gv_edge.h
Description	returns a pointer to the *i*-th bezier struct in the array pointed to by *s*

- c_reset_edge (e: POINTER; x1, y1, x2, y2: INTEGER)

C Name	reset_edge
Header File	gv_edge.h
Description	resets the edge *e* to a straight line from point (*x1*,*y1*) to point (*x2*,*y2*)

- c_reset_edge_load (e: POINTER; count: INTEGER)

C Name	reset_edge_load
Header File	gv_edge.h
Description	resets the edge to a state where it has only one spline associated with it which has *count* points (the points are NOT initialized). This is used to load edges from string attributes.

SPLINE_OPERATIONS

- c_get_point_count (b: POINTER) : INTEGER

Struct Access	b->size
Header File	gvc.h
Description	returns the number of points (regular and control points) in the spline *b*

- c_get_point_list (b: POINTER) : POINTER

Struct Access	b->list
Header File	gvc.h
Description	returns a pointer to the first point in the array of points of the spline *b*

- c_get_ith_point (p: POINTER; i: INTEGER) : POINTER

C Name	i_th_point
Header File	spline.h
Description	returns a pointer to the *i*-th point in the array of points pointed to by *p*

- c_get_sflag (b: POINTER) : BOOLEAN

Struct Access	b->sflag
Header File	gvc.h
Description	returns true if spline *b* has an arrow tail, false otherwise

- c_set_sflag (b: POINTER; v: BOOLEAN)

Struct Access	b->sflag
Header File	gvc.h
Description	sets the flag indicating an arrow tail to *v*

- c_get_eflag (b: POINTER) : BOOLEAN

Struct Access	b->eflag
Header File	gvc.h
Description	returns true if spline *b* has an arrow head, false otherwise

- c_set_eflag (b: POINTER; v: BOOLEAN)

Struct Access	b->eflag
Header File	gvc.h
Description	sets the flag indicating an arrow head to *v*

- c_get_sp (p: POINTER) : POINTER

C Name	bezier_sp
Header File	spline.h
Description	returns a pointer to the pointy end of the arrow tail

- c_get_ep (p: POINTER) : POINTER

C Name	bezier_ep
Header File	spline.h
Description	returns a pointer to the pointy end of the arrow head

- c_insert_point (b: POINTER; index: INTEGER)

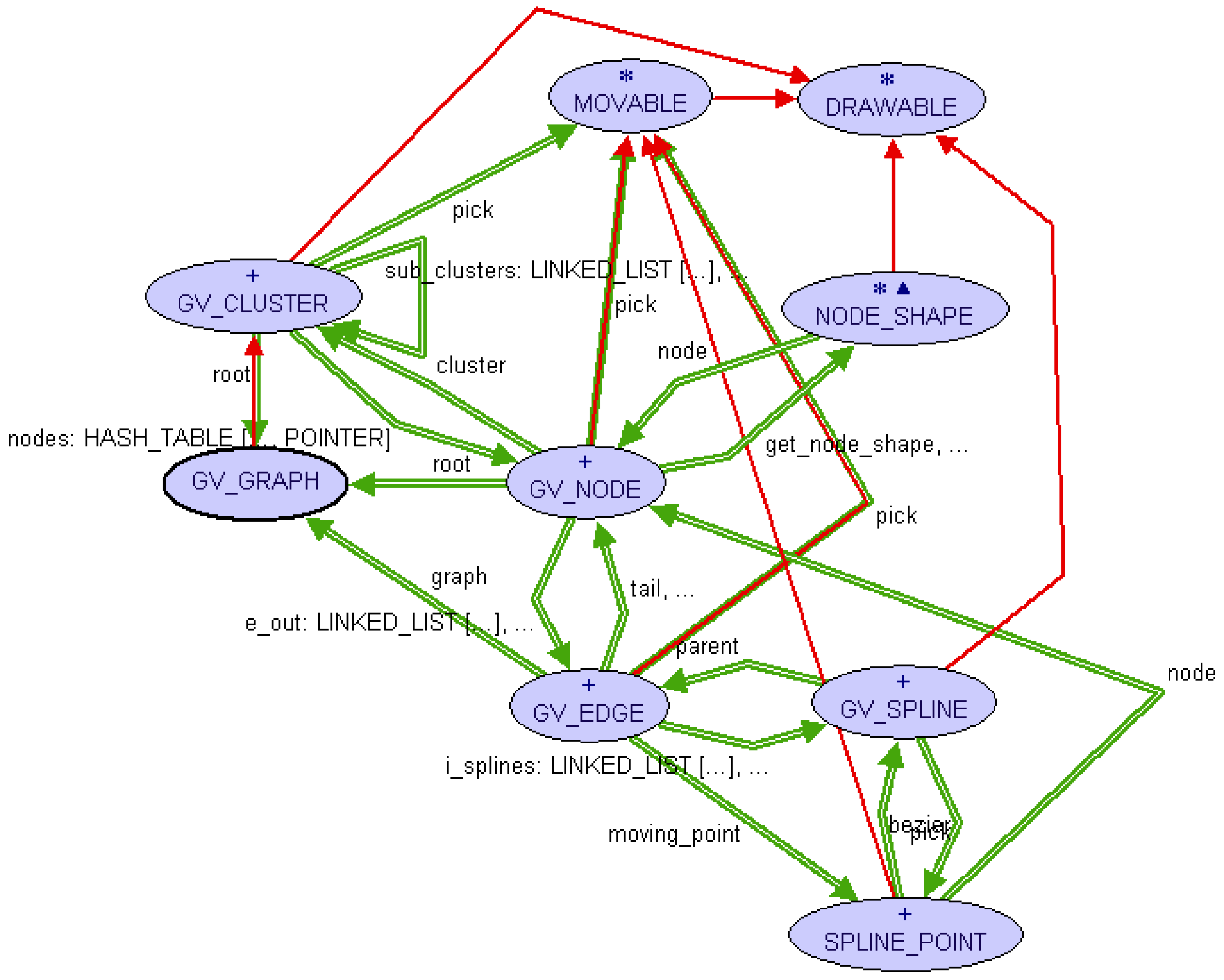
C Name	insert_point
Header File	spline.h
Description	creates a new spline point and one or two control points at *index* in splie *b*

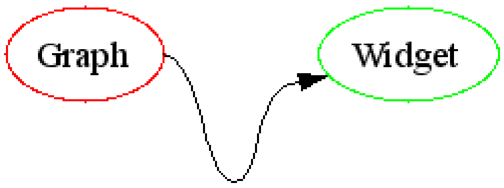
- c_delete_point (b: POINTER; index: INTEGER)

C Name	delete_point
Header File	spline.h
Description	deletes the spline point at *index* (and its control points) from spline *b*

Visual Aspects Overview

A graph is a simple hierarchical structure: In the case described here, the graph (which is a cluster) contains sub clusters and nodes as children. The nodes have edges as children and the edges have splines. When a graph is drawn, the draw command is passed down this hierarchy and thus the image of the graph is created. The figure below shows this hierarchical structure.





Interfaces

This section describes the two deferred classes that build the basis for the visualization of the graph objects.

- DRAWABLE
- MOVABLE

DRAWABLE

Requirements:

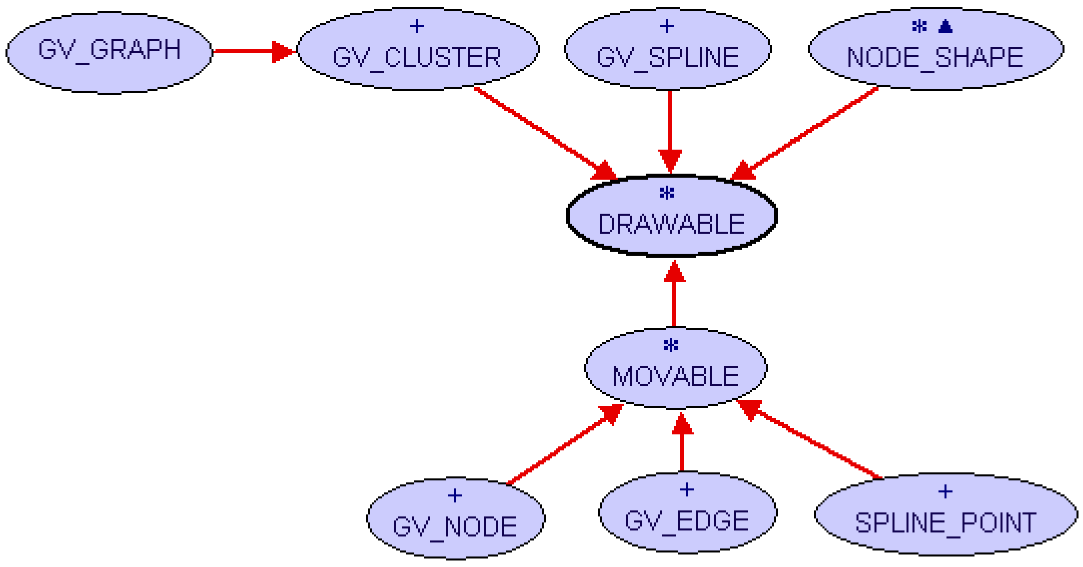
none

Description

Every drawable object has a primary color (color, set_color) and a deferred draw (rect: RECT; offset: POINT; zoom: DOUBLE; image: EV_DRAWABLE) feature. To decide whether or not the object should be drawn at all, the *rect* parameter defines a rectangular region in graph space (not image pixel space!) that should be drawn. The *offset* defines the distance from the top left corner of the image to the top left corner of the rectangle in image space; that is the x and y offset that has to be added to every draw operation on the image. The zoom parameter specifies the scaling factor for the graphical primitive and triggers different transformations for each drawable object.

The DRAWABLE interface is implemented in every *Graph Widget* class that is used for the graph representation (which includes almost every class in the library). To get a better idea of how it works, please refer to the source code of one of the implementations.

Class overview



top

MOVABLE

Requirements:

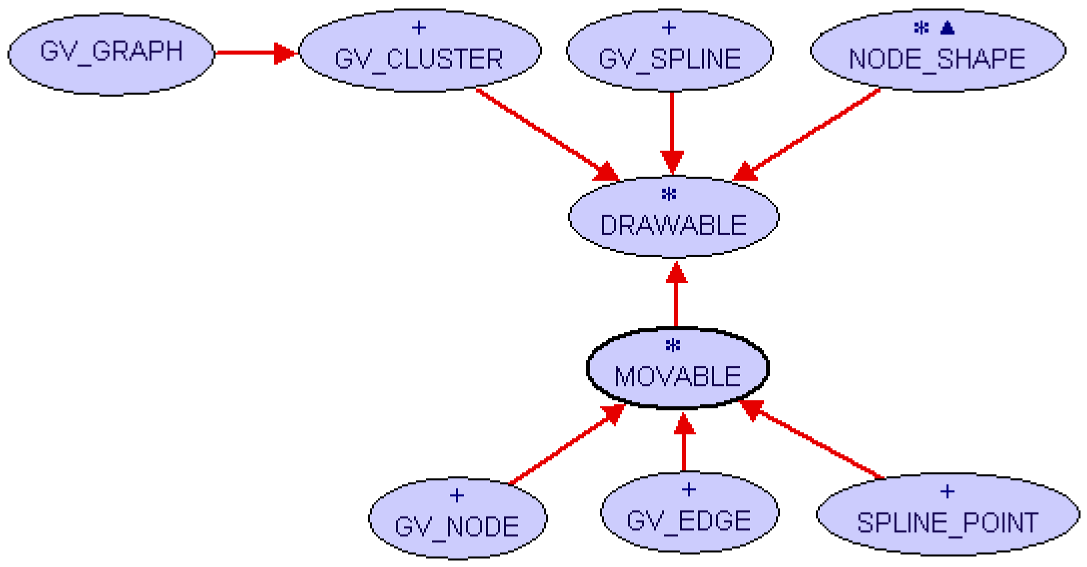
DRAWABLE

Description

MOVABLE is the deferred base class for graphical objects that can be moved. The actual movement is mostly done by dragging the object with the mouse, but it could also be done by the program itself (move). Since it is mostly used for dragging, there are some features directly related to that. Instead of redrawing the entire visible graph over and over again each time the mouse moves, the implementation takes another approach: When a drag operation is initiated, the static part of the graph (all parts that are not currently dragged around) is drawn onto an off screen surface and every time the mouse moves, this image is copied to the main image and the moving parts are drawn as an overlay (using a different color).

To create the static off screen image, the movable parts have to be prevented from being drawn (disable) and later on they have to be drawn manually (manual_draw) to create the overlay. This is why the MOVABLE class provides a standard implementation for the draw feature of DRAWABLE while introducing the new deferred draw_impl. Once the drag operation has been completed, the movable object is re-enabled and everything is back to normal.

Class overview



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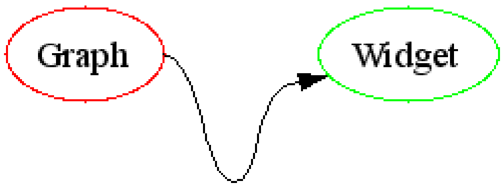


Points and Rectangles

This section describes the classes that provide geometry information to the *Graph Widget* components.

- **POINT**
- **RECT**
- **SPLINE_POINT**

POINT
Requirements:

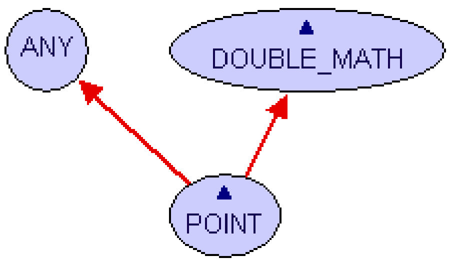
none

Description

The POINT class has two purposes in the *Graph Widget* library. First, when created via the make feature, it serves as a simple two dimensional point or vector (access using x, y, set_x and set_y) with support for transformations like translate or scale. It also allows to measure distances to other points. This first version of POINT is mostly used to transform the graph for drawing. Second, if created via make_from_c_pointer all transformations from above are available with the added advantage that all changes to the x and y coordinates are propagated back to the C point passed as argument to the creation feature.

Since *GraphViz* coordinates have their origin in the lower left corner of the graph, the coordinates are converted to a (for computer graphics) "normal" top-left coordinate system. That is the reason for providing the set_true_x and set_true_y features, that circumvent this transformations.

Class overview



top
RECT
Requirements:

none

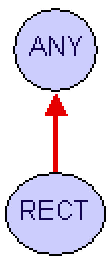
Description

The main purpose of the rectangle is to determine which other primitives (points - contains, lines - intersects_line, other rectangles - intersects) intersect it in order to decide which parts of the graph have to be drawn.

A RECT can be created by giving a left, top, right and bottom coordinate with make or by giving two points and a margin using make_from_points.

Like in the POINT class, there are also features to transform the rectangle (mostly used in the drawing features). They are: expand, rescale and translate. There is also a feature to extend the rectangle to include a specific point, which is especially useful for cluster resizing.

Class overview



top

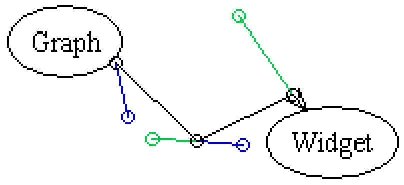
SPLINE_POINT

Requirements:

MOVABLE

Description

Spline points are the points displayed with little circles around them (see figure below). They can be dragged by the user, but some of these drag operations have constraints (they cannot be moved freely) and those constraints are enforced by the SPLINE_POINT class.



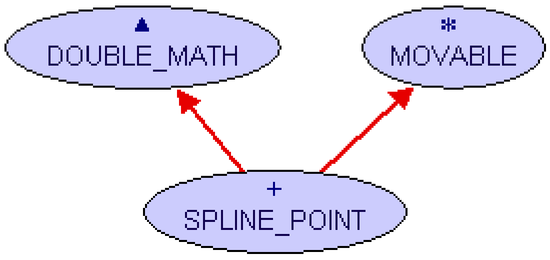
There exist four sub types of spline points that are all encapsulated in this one class to simplify their handling.

- Simple spline points are displayed with black circles that are not directly connected to a node or part of an arrow head/tail. When a point like this is moved, the SPLINE_POINT ensures, that the two control points connected to this simple spline point are moved as well (their distance and direction from the simple spline point remain constant).
- Connected spline points are directly connected to a node (displayed as black circles as well). When connected points are moved, they remain on the border line of the node they are connected to.
- Connected arrow heads work like connected spline points (they remain near the border line of the node they are attached to), only that internally they are two points; the one with the circle and the pointy end of the arrow which are moved as one unit.
- Spline control points (with blue or green circles) can also be moved freely, but if they are connected to a simple spline point (which have two control points), the other control point is always kept in a straight line with the moved control point and the simple spline point. This ensures that the resulting spline (as drawn by *GraphViz*) will always appear smooth (the outgoing line from a simple spline point to a control point defines the tangent for the simple point).

The first and forth sub types are created using the make_simple creation feature which decides on its own whether it is confronted with case one or four. The other two cases each have their own creation feature make_connected (case two) and make_arrowhead (case three). Since SPLINE_POINT implements MOVABLE it has a move feature. This is where all the actual work of satisfying the constraints is done.

As explained in the description of the GV_SPLINE class, the features insert_point_after, insert_point_before and remove are called by the spline the point belongs to and are never called by anybody else. The "is_" features reflect the sub type of the spline point and are used by the graph widget to determine what options the context menu of a spline point should contain (obviously inserting a point before the first point of the spline does not make that much sense). Their meaning should be obvious, except maybe is_point which returns true if the point is a spline point (simple, connected or arrowhead) and returns false if it is a control point.

Class overview



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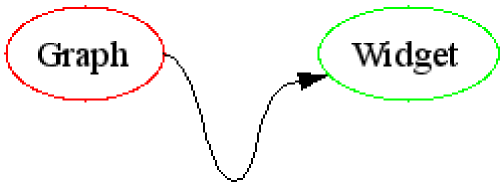


Node Shapes

The NODE_SHAPE class

Since dragging spline end points along the border of a node is not as easy as it looks, the concept of a node shape is encapsulated in a separate (deferred) class and its descendants.

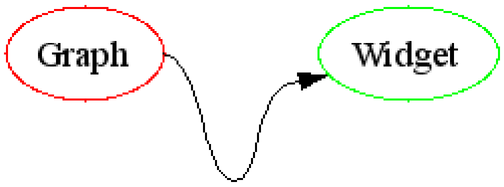
The NODE_SHAPE class houses the common functionalities for all node shapes:

- A creation feature that gets the pointers to the needed C structs called make which should be listed as a creation feature in every descendant of NODE_SHAPE
- font gets the EV_FONT that should be used to draw the label of the node
- label_text gives you the nodes label

Then there are the two features get_port_to_node and get_port_to_point: The idea is to implement get_port_to_point either in a parametric way that gives a point on the nodes border line for each possible parameter or to create actual "ports" that serve as entry/exit points for edges (for example, to implement a node shape that has only four points where edges start or end).

The descendants of NODE_SHAPE

Since everything has to end eventually (even my semester project), I only implemented a couple of exemplary node shapes (a subset of the node shapes used by *GraphViz*). To create a new node, create a new class that inherits from NODE_SHAPE and implement the two features get_port_to_point from NODE_SHAPE and draw from DRAWABLE. Although this can be quite time consuming, it is actually not that difficult to do. To get an idea how it works exactly, take a look at the implemented node shapes in the "node_shapes" cluster of the graph widget library.



Miscellaneous Classes

This entire section is devoted to the most unimportant classes of the *Graph Widget* project. Feel free to skip it right away.

- **EDGE_LINE**
- **NAME_DIALOG**

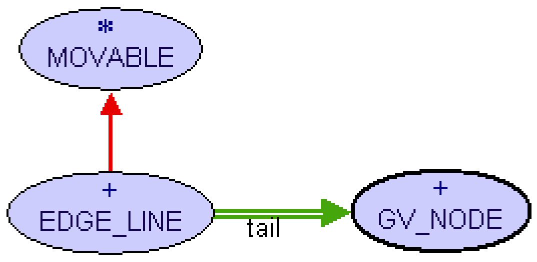
EDGE_LINE
Requirements:

MOVABLE

Description

The EDGE_LINE is used by the GRAPH_WIDGET as a trick to visualize the process of creating a new edge in the graph. When the user right clicks a node and selects the option "create edge to..." a new EDGE_LINE is created with the selected node as anchor. A line from the center of this node to the current mouse position is drawn to indicate the edge that will be created. Once the user clicks on a second node, a new edge is created and the EDGE_LINE is destroyed.

Class overview



top
NAME_DIALOG
Requirements:

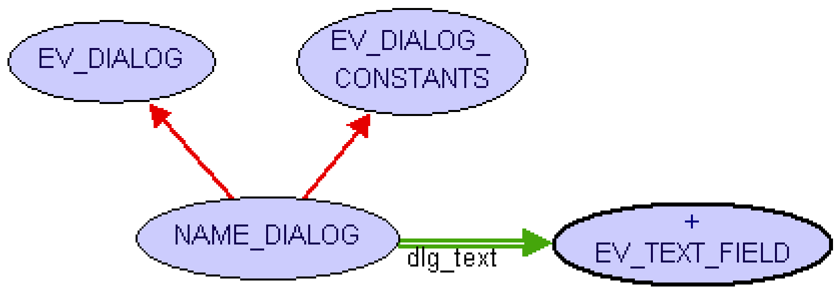
EV_DIALOG, EV_DIALOG_CONSTANTS

Description

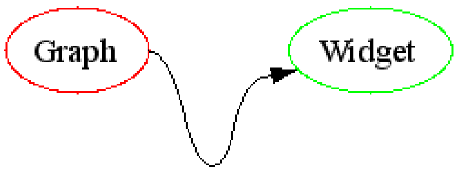
The NAME_DIALOG is a one to one copy of the EV_MESSAGE_DIALOG class with the addition of one EV_TEXT_FIELD where the user can enter a text.

It is used by the GRAPH_WIDGET to ask the user to enter a name for a new node.

Class overview

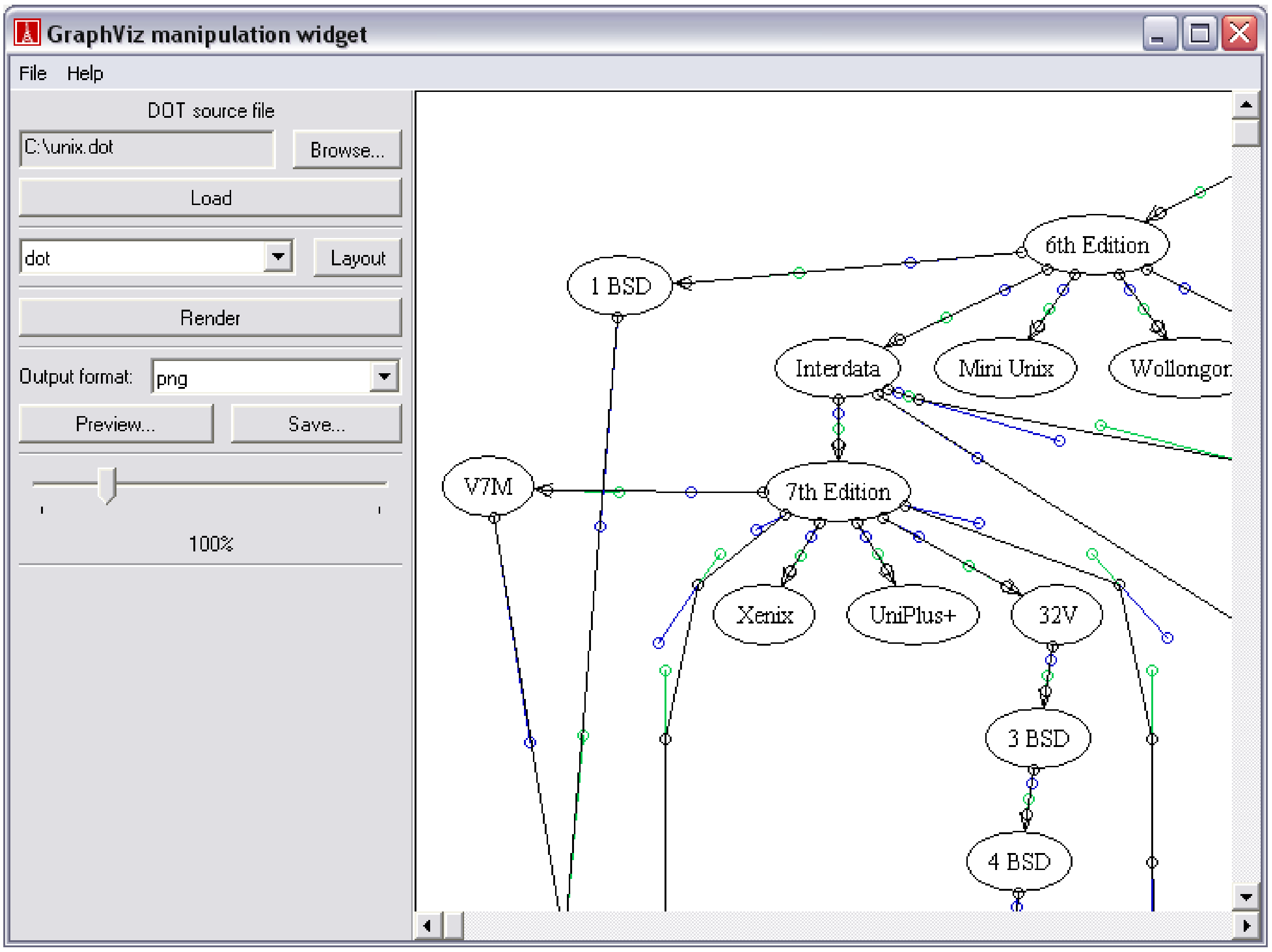

EV_DIALOG
EV_DIALOG_
CONSTANTS
NAME_DIALOG
dlg_text
+
EV_TEXT_FIELD

top



Graph Widget Test Application Overview

The *Graph Widget* test application offers a graphical user interface element for almost all features that the GRAPH_WIDGET and GV_GRAPH provide.

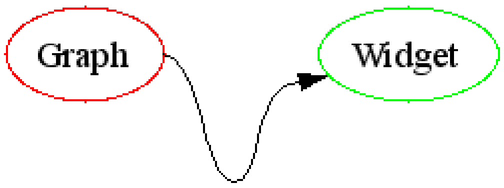


Via the "Browse..." button you can select the DOT file to manipulate with the graph widget. Once you press the "Load" button, the program checks whether the loaded DOT file already contains layout information or not. If the DOT file has a layout, the "Render" button is enabled along with the "Layout" button (otherwise only the "Layout" button is enabled.

Using the output format combo box and the "Preview..." and "Save" buttons, you can take a look at the preview of certain formats or save your graph in the selected format. To save your layout for later use, you have to select "dot" as output format, to be able to load it again (reconstruction of a graph from a png file would be a tad difficult).

The zoom of the *Graph Widget* has still a minor graphical bug (drawing of multiple lines when the zoomed graph is scrolled), but this can always be corrected by pressing the "Render" button that redraws the whole graph. Apart from that, the zoom feature works just fine and this concludes this little tour of the test application.

For a description of the graph widget features, see Graph Widget User Documentation



References

GraphViz

Main page of the *GraphViz* project.
  http://www.graphviz.org/

Download page for *GraphViz*.
  http://www.graphviz.org/Download.php

GraphViz documentation index.
  http://www.graphviz.org/Documentation.php

EiffelVision 2

EiffelVision 2 online documentation.
  http://docs.eiffel.com/eiffelstudio/libraries/vision2/index.html