A 3-DIMENSIONAL GRAPH EDITOR IN HASKELL

by

O. Halabieh
N. Liu
W. S. Tan
L. Zhao

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Supervised by Dr. Kahl
Department of Computing and Software

McMaster University
Hamilton, Ontario L8S 4K1
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ABSTRACT & SUMMARY

As the title suggests, this project deals with viewing and editing 3-dimensional graphs.

Although most graph editors available in the market handle 2-dimensional graphs, there are a limited number of 3-dimensional graph editing tools. However, none of the existing tools are written in Haskell, so they fail to interface with other software written in that language thus our motivation to develop such a tool. Our work involved, therefore, creating an interactive editing environment for 3-dimensional graphs in Haskell using HOpenGL. This project also involved developing a library for such graphs so that components of this library may be reused in other Haskell programs.

This project was done for Dr.Wolfram Kahl, associate professor of software engineering at McMaster University, who is interested in such tool since he has many other programs which generate 3-dimensional graphs and he would like to view and edit them. In addition he is also keen on Haskell, thus our requirement to use that language.

This project was done by Omar Halabieh, Ning Liu, Wern Sern Tan and Lei Zhao in collaboration with Jun Wu, a graduate student at McMaster University supervised by Dr. Kahl. We would like to take this opportunity to thank Jun Wu for her contribution into the implementation of this tool, Gordon Uszkay who helped us throughout the work with his expertise in project management, Dr. Anand and Dr. Zucker for their efforts in coordinating this course, and last but not least our supervisor Dr.Kahl for his continuous support and belief in us.

The project was completed successfully and was demonstrated to work for graphs with small number of nodes and edges. However, the tool has proven too slow on larger graphs (more than twenty nodes). A number of areas in which performance might be improved were identified, and these would form a good project for a subsequent group.

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1 REQUIREMENTS ANALYSIS

1.1 Background

Despite the fact that there are many graph editor software out there in the market, most of them are two dimensional. While visualization of graphs in two dimensions can be very useful, visualization in three dimensions can open up new applications and new ways of interacting with old applications.

In addition to the relatively low amount of 3-dimensional graph editors out there, there are no existing 3-dimensional graph editors that have been developed in Haskell. This poses a problem as many Haskell applications out there will not be able to interface with these existing non-Haskell graph editors when needed to.

Thus our motivation for working on this project is to present a 3-dimensional graph editor developed in Haskell using HOpenGL which enables other Haskell developers to adapt or reuse this software according to their needs.

Finally, the main objective of this project consists of creating a toolkit and library implementing a comprehensive interface for exposing 3-dimensional graph visualization and interaction, in Haskell, in a way that can be used for diverse applications.

1.2 Functional Requirements

The approach adapted to gather and analyse the requirements is based on that discussed in Dr. Khedri's Software Requirements Activities courseware [Khe03].

Before discussing the functional requirements, it would be helpful to define some terminology that will be used. A graph is a set of nodes connected by edges. The layout of a graph describes the positioning of the nodes and edges in the space. A view of a graph is a point in space from where we are looking at the graph and a direction vector along which we are viewing. Finally, a node or an edge attribute are physical properties of the object such as color, shape, thickness...

We will give the functional requirements for the Haskell 3-D graph library accompanying the software first, and then those of the graph editor tool. The requirements are similar to those presented in the extended project proposal with few minor changes, such as rephrasing them; in addition a new requirement for undoing/redoing graph changes has been introduced. These changes can be tracked via issues CZJ18 and CZJ29 in figure (2).

Functional requirements for the Haskell 3-D graph library:

1.2.1 File Management

Graphs with layout information will be associated with files. There will also be view files associated with each graph which contain different views for that graph. These files can be opened and saved, and new files can be created.

1.2.2 Graph Nodes Manipulation

Nodes can be added to or removed from a graph. Nodes can also be moved to different positions in the graph and their attributes (color, label, stacks, slices, radius) can be modified. Any such changes to the graph should be reflected in all existing views of that graph.

1.2.3 Graph Edges Manipulation

Edges can be added to or removed from a graph. Edges can also be bent and their attributes (color, label, stacks, slices, radius) can be modified. Any such changes to the graph should be reflected in all existing views of that graph.

1.2.4 Graph View Manipulation

A view of a graph can be rotated and also can be zoomed in from or out of.

1.2.5 Graph Manipulation

A graph can be rotated around a given axis(X,Y,Z) and can be scaled by a certain scalar factor. Any such changes to the graph should be reflected in all existing views of that graph.

Functional requirements for the graph editor tool:

1.2.6 Close Graph Scenario

If the user wishes to close the existing graph, he selects the appropriate option in the menu and the program will close the current graph.

1.2.7 Open Graph Scenario

If the user wishes to load an existing graph, he selects the appropriate option in the menu and the program will ask the user for the graph file location together with its file name. If the file exists and is of valid type, the graph is loaded into the editor with the default view. If the graph file does not exist or is of invalid type nothing is done.

1.2.8 Save Graph Scenario

If the user wishes to save the current graph, he selects the appropriate option in the menu and he is asked for the location together with the name of the file he wishes to save the graph into. If the specified file already exists, the program will ask the user for permission to overwrite that file. Otherwise, the specified file will be created and the graph will be saved into it.

1.2.9 New View Scenario

If the user wishes to add another view of the graph, he selects the appropriate option in the menu and the program will then open another window with the same view as the default one. The user can then edit the view in that new window.

1.2.10 Save View File Scenario

If the user wishes to save the view(s) of an opened graph, he selects the appropriate option in the menu and he is asked for the location together with the name of the file he wishes to save the view into. If the specified file already exists, the program will ask the user for permission to overwrite that file. Otherwise, the specified file will be created and the view will be saved into it.

1.2.11 Close View Scenario

If the user wishes to close an opened view of an opened graph, he selects the appropriate option in the menu and the associated window is closed.

1.2.12 Open View File Scenario

If the user wishes to open a certain view file for an opened graph, he selects the appropriate option in the menu and the program will ask the user for the view file location and its file name. If the file exists and is of valid type the graph will be displayed in the different views specified by the files. Otherwise, nothing is done.

1.2.13 Add Node Scenario

If the user wishes to add a node, he selects the appropriate option in the menu and the program will add a node with default shape, color and size in the location pointed to by the pointing device, given that no node is already present there.

1.2.14 Remove Node Scenario

If the user wishes to remove an edge, he selects the appropriate option in the menu with the desired node and chooses to delete it. The node is then removed from the graph and all incident edges on that node are also removed.

1.2.15 Add Edge Scenario

If the user wishes to add an edge, he selects the appropriate option in the menu together with the node upon which the edge is to be incident. The edge is then inserted in such a way that it does not coincide with another edge.

1.2.16 Remove Edge Scenario

If the user wishes to remove an edge, he selects the appropriate option in the menu together with the desired edge and then chooses to remove it. The edge is then deleted from the graph.

1.2.17 Bend Edge Scenario

If the user wishes to bend an edge, he selects the appropriate option in the menu and drags the edge using his pointing device. The edge will stay connected with its nodes while being bent. Before the bending occurs the resulting movement is checked for collision, if no collision is detected then the edge is bent.

1.2.18 Move Node Scenario

If the user wishes to move a node, he selects the appropriate option in the menu together with the desired node and drags it to the desired location using his pointing device. Before the moving occurs the resulting movement is checked for collision, if no collision is detected then the node is moved.

1.2.19 Edit Edge/Node Attribute Scenario

If the user wishes to edit an edge's/node's attribute (color, label, slices, stacks, radius), he selects the appropriate option in the menu after which he selects the edge/node and chooses the attribute he wishes to change and enters its new value. The attribute of the edge/node is then updated.

1.2.20 Rotate Graph Around Axis Scenario

If the user wishes to rotate the graph around a given axis (X,Y or Z), he selects the appropriate option in the menu together with the appropriate rotation mode and axis and then he rotates the graph.

1.2.21 Rotate View Scenario

If the user wishes to rotate the view , he selects the appropriate option in the menu and then rotates the view.

1.2.22 Zoom View Scenario

If the user wishes to zoom into or out of the graph, he selects the appropriate option in the menu and zooms. There will be a limit on how much the user can zoom into or out of the graph. The view is then updated.

1.2.23 Scaling Graph Scenario

If the user wishes to scale the graph by some scalar factor, he selects the appropriate option in the menu and scales the graph. There will be a limit on how much the user can scale the graph by. The graph is then updated.

1.2.24 Undo/Redo Scenario

If the user wishes to undo/redo changes done to the graph, he selects the appropriate option in the menu which will enable him to undo/redo the latest changes done to the graph. This requirement was added at a later stage and can be tracked via issues CZJ18 and CZJ29 in figure (2).

1.2.25 Exit Scenario

If the user wishes to exit the program , he selects the appropriate option in the menu . After that, the program will exit.

1.3 Non-Functional Requirements

1.3.1 Look and Feel requirements

The graph window shall occupy the majority of the user's screen in order to offer him a true 3-dimensional experience. Menus and controls shall not intrude into the user's working space.

1.3.2 Usability Requirements

a) Ease of use

The product shall be easy for anyone to use. The controls shall be intuitive and provided through easy-to-navigate menus.

b) Ease of learning

The product shall be easy to learn by anyone. If necessary, the user's manual can be consulted for help.

1.3.3 Performance Requirements

a) Speed requirements

Reasonable response time is required on a recent machine even if that compromises the detail of the graph to be displayed.

b) Capacity requirements

The product is required to handle graphs comprising hundreds of nodes gracefully. Performance for large graphs should be optimized as much as possible given both the time constraint of the project and the hardware used.

We failed to meet this requirement. We tried to do profiling on the application to see where the slow downs are happening due to large graphs, however some of the packages being used, namely WxHaskell and HaXml do not support profiling by default. We strongly suspect that the slow down is caused by the numerous interactions with the graph data structure (read and update), as it was not implemented with performance in mind. This issue be tracked via issue CZJ30 in figure (2).

1.3.4 Operational Requirements

a) Partner applications

The product shall interface with other programs/applications written in Haskell.

1.3.5 Maintainability and Portability Requirements

a) How easy must it be to maintain this product?

The product shall be maintained by its end-users (programmers/developers) who are familiar with the Haskell programming language and the HOpenGL interface. Upgrades to the existing features of the product are expected to be relatively easy. Moreover, the addition of new functionality shall only necessitate the addition of new modules and possibly some very minor changes in the existing implementation. To ensure this requirement is satisfied, the principles of modularization, encapsulation and separation of concerns will be used wherever appropriate. The extensive documentation together with the literate program style will contribute in the same direction.

b) Portability requirements

The product is required to run under the Linux operating system. However, it should not use any functionality that is platform specific so that it may run on other operating systems as well. To ensure this requirement is met, all hardware access shall be handled through the published interfaces of Haskell and HOpenGL.

1.3.6 User Documentation

The implementation shall be produced in the shape of a literate program that will help programmers and developers maintain/update the existing implementation. In addition, three layers of documentation, each targeting a specific audience will be provided.

a) User manual

The first layer of documentation will serve as a user manual for the interactive portion of the software. Its purpose is to teach the user how to use the tool and its different functionalities. This document will include screen shots and detailed textual descriptions about the graphical user interface (GUI).

b) Introduction to interface documentation

The second layer of documentation, intended to be used by developers/ programmers, will serve as an introduction to the interface documentation accompanying the Haskell library.

c) Interface documentation

Finally, the third layer of documentation, namely the interface documentation, will be used by developers/programmers as mentioned above to assist them in using the functionality provided by the library.

2 HIGH LEVEL DESIGN

The specification of the system to be used for development are as follows:

CPU: Intel Pentium 4 Processor or AMD Athlon 1.4 Ghz

Operating System: Linux Redhat 8-9

Software Requirements:

a) A Haskell Compiler (Preferably GHC 6.2 with OpenGL enabled)
b) WxHaskell package
c) HaXml package

Memory: 512 MB RAM

Video: A 3D accelerator video card with support for OpenGL and at least 64 MB of video memory is required.

The target platform should have similar specifications as the development system or better.

Given the stringent non-functional requirements elicited above in what concerns maintainability and modifiability, a heavily modularized design is a must. After analyzing the system, the following decomposition into modules has been reached. Each module will be described in terms of what are the details(secrets) that it hides and the functionality(services) that it offers. The module description, serves as a general overview of the project and the work done.
Jun Wu contributed in the project by providing us the data structure that will be used to store the graph, a set of functions to manipulate it and an interface to read from/write to GXL files [Wu03]. Some additional functions have been introduced to manipulate the graph data structure as we will see in the module description to follow.

This high-level design was revised after the extended project proposal was submitted mainly due to the fact that our understanding of the problem became much clearer after our work on the proof of concept. These changes can be tracked via issue CZJ28 in figure (2).

a) Module Graph Data Structure

Secret: The internal data structure used to represent the graph.

Service: The following interface is offered:

In addition to the functions described below, there are also a set of functions used from Jun's implementation of the GXL graphset which are listed in her documentation instead [Wu03].

getItemStacks: This function is called to get the number of stacks of an item in the graph (node or edge).

getItemSlices: This function is called to get the number of slices of an item in the graph (node or edge).

getItemRadius: This function is called to get the radius of an item in the graph (node or edge).

bendEdgeMidPoint: This function is called before we bend an edge, in case it is straight we add a midpoint for it to serve as a control point. Then in any case we return that control Point.

defaultNoMidPoint: This constant function is called so that we can tell if the edge is bent or not.

getNode: This function returns the information necessary to draw a given node.

getEdgeQuadricStyle: This function returns the information necessary to draw a given edge.

getItemLabel: This function is called to get the label of an item in the graph (node or edge).

getListOfNodes: This function is called to get the list of the id's of nodes in the graph.

getListOfEdges: This function is called to get the list of the id's of edges in the graph.

getItemColor4: This function is called to get the color of an item in the graph (node or edge).

getEdgeMidPoint: This function is called to get the control point of an edge.

getToNode: This function is called to get the node id that the edge is origination from.

getFromNode: This function is called to get the node id that the edge is terminating into.

getDirectedOrNot: This function is called to distinguish whether the edge is directed or not.

b) Module Graph Manipulation

Secret: Algorithms involved in manipulating the graph.

Service: The following interface is offered:

scaleGraph: This function is called to scale the graph.

graphRotationButtonDown: This function is called to rotate the graph around the vertical and horizontal axis.

addNode: This function is called to add a node to a graph at a specified location with default attributes.

moveNodeButtonDown: This function is called to move a node in the vertical and horizontal directions.

moveNodeWheelUp: This function is called to move a node in depth inwards.

moveNodeWheelDown: This function is called to move a node in depth outward.

addEdge: This function is called to add an edge to a graph to connect two nodes with default attributes.

bendEdgeWheelUp: This function is called to bend an edge in depth inwards.

bendEdgeWheelDown: This function is called to bend an edge in depth outward.

bendEdgeButtonDown: This function is called to bend an edge in the vertical and horizontal directions.

removeItem: This function is called to remove an item (node or edge) from a graph.

colorChange: This function is called to change the color of an item (node or edge) of a graph.

radiusChange: This function is called to change the radius of an item (node or edge) of a graph.

stacksChange: This function is called to change the number of stacks of an item (node or edge) of a graph.

slicesChange: This function is called to change the number of slices of an item (node or edge) of a graph.

labelChange: This function is called to change the label of an item (node or edge) of a graph.

c) Module Graph File Manager

Secret: The file format used to hold the graph.

Service: The following interface is offered:

saveGraph: This function is called to save the current graph into a GXL file specified by the user.

openGraph: This function is called to load a graph from a GXL file specified by the user into the program.

closeGraph: This function is called to close the current graph.

d) Module Layout

Secret: Algorithm used to generate the layout.

Service: The following interface is offered:

generateLayout: This function is called to generate a layout for the current graph if this information is partial or not present.

e) Module Collision

Secret: Algorithm used to detect collisions.

Service: The following interface is offered:

addNodeCollision: This function is called to see if the node to be added creates a collision.

bendEdgeCollision: This function is called to see if the edge that is being bent will create a collision in its new position.

newEdgeCollision: This function is called to see if the edge to be added creates a collision.

moveNodeCollision: This function is called to see if the node that is being moved will create a collision in its new position.

f) Module Undo Data Structure

Secret: The data structure used to be able to undo and redo.

Service: The following interface is offered:

initUndoDataStructure: This function is called to initialize the undo data structure to an empty one.

newUndoDataStructure: This function is called to create a new undo data structure.

updateGraphDataStructure: This function is called when we need to update the current graph so that we keep a copy of the old one thus enabling us to undo and redo.

undo: This function is called to undo the latest change made to the graph.

redo: This function is called to redo the latest change that was undone.

g) Module Draw Graph

Secret: The method used to extract the information from the current graph and display it.

Service: The following interface is offered:

displayGraph: This function is called to display the current graph on the screen from a certain view and under certain settings.

h) Module View Data Structure

Secret: Internal representation of the views.

Service: The following interface is offered:

getHorizontal: This function is called to give us the horizontal component of the point we are looking to the graph from.

getVertical: This function is called to give us the vertical component of the point we are looking to the graph from.

getCameraDistance: This function is called to give us the depth component of the point we are looking to the graph from.

changeHorizontal: This function is called to change the horizontal component of the point we are looking to the graph from.

changeVertical: This function is called to change the vertical component of the point we are looking to the graph from.

changeCameraDistance: This function is called to change the depth component of the point we are looking to the graph from.

initView: This function is called to initialize the view to the default value.

i) Module View File Manager

Secret: File format used to store views.

Service: The following interface is offered:

openView: This function is called to load a view from a view file specified by the user into the program.

saveView: This function is called to save the current view into a view file specified by the user.

closeView: This function is called to close the current view.

j) Module View Manipulation

Secret: Algorithms used to manipulate views.

Service: The following interface is offered:

rotateViewButtonDown: This function is called to rotate the view around the vertical and horizontal axis.

rotateViewWheelUp: This function is called to zoom the view into the graph.

rotateViewWheelDown: This function is called to zoom the view out of the graph.

k) Module Settings Data Structure

Secret: Internal representation of the settings.

Service: The following interface is offered:

initSettingsDataStructure: This function is called to initialize the settings data structure to the default one.

newSettingsDataStructure: This function is called to create a new settings data structure.

getNumOfCylinders: This function is called to get the number of cylinders being used to render a bent edge.

getCollisionOn: This function is called to see if collision detection is on or not.

getAxisOn: This function is called to see if the user wants the axis displayed or not.

changeCylinderNumber: This function is called to prompt the user for new number of cylinders to be used and set it accordingly.

changeCollisionDetection: This function is called to prompt the user to toggle collision detection and set it accordingly.

changeAxisDisplay: This function is called to prompt the user to toggle axis rendering and set it accordingly.

updateNumOfCylinders: This function is called to change the number of cylinders being used to render a bent edge.

updateCollisionOn: This function is called to toggle collision detection.

updateAxisOn: This function is called to toggle axis rendering.

l) Module Settings File Manager

Secret: File format used to store settings.

Service: The following interface is offered:

openSettings: This function is called to load settings from a settings file specified by the user into the program.

saveSettings: This function is called to save the current settings into a settings file specified by the user.

l) Module Main

Secret: The way the program is setup and run.

Service: The following interface is offered:

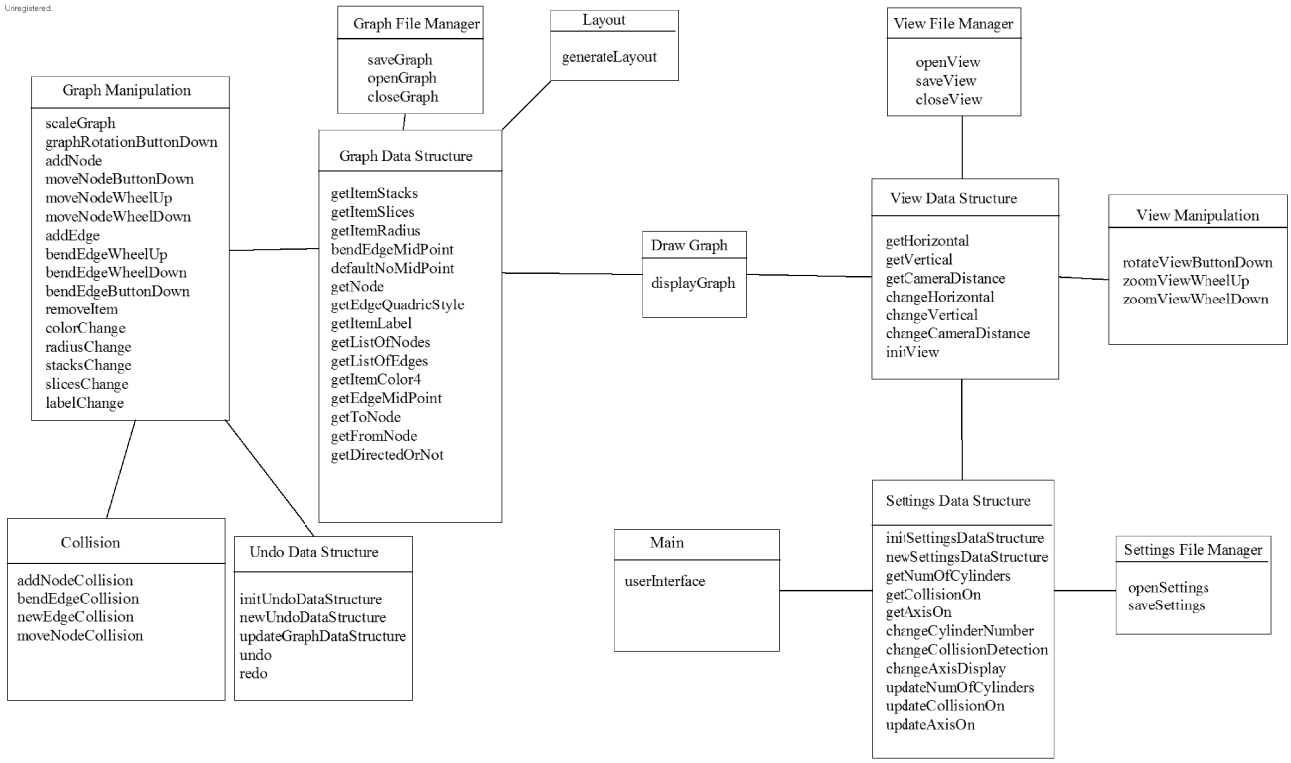
userInterface: This function is called to open a new view of the current view.

Figure (1) summarizes the different modules that compose the design. Modules that interact with each other are connected with a straight line. A simplification was made so that the diagram is not cluttered with lines, module Main is supposed to be connected to the following modules:

- Module Undo Data Structure
- Module Graph Data Structure
- Module Graph Manipulation
- Module Graph File Manager
- Module Draw Graph
- Module View File Manager
- Module View Data Structure
- Module View Manipulation
- Module Settings Data Structure
- Module Settings File Manager

For further information on detailed design decisions, please refer to the documented source files.

Figure 1: Module Diagram



3 IMPLEMENTATION

The specifications of the system used to build the tool can be found in the high level design section 1.3.

The programming language used to develop the tool is Haskell, the compiler used is GHC 6.2 with HOpenGL enabled. Several references were used to learn Haskell in great depth [Hud00] [Dav92] and to learn OpenGL [SWND03] [Len03] [Hil00].

Two additional packages were used: HaXml, a package to manipulate XML files from Haskell which was used when dealing with GXL files and WxHaskell, a GUI development package which was used for several purposes namely handling file dialogs and input dialogs.

Instructions to build the tool can be found in section A.1.

Implementation was done in teams of two, where Omar Halabieh and Tan Wern Sern formed one team and Ning Liu and Lei Zhao formed the other.

In this project, no advanced algorithms or methods were used. This is because the focus was on developing all the required functionalities, so no specific attention was given to a particular aspect where an advanced algorithm would be used to optimize the functionality in question.

For example, for collision detection, to detect collision between two nodes, we check the distance between their two centers as they are spheres and compare it with the sum of the radius of each. To detect collision for edges, we fill the cylindrical edge with spheres of small radius and treat the collision similar to a node to node collision as done above.

Another example, is rendering bent edges. What is done here is that a bent edge is treated as a series of smaller straight edges. So a bent edge is a sequence of straight edges connecting the two nodes.

We will try to outline how we went about implementing the tool after the design was laid out. Rather then using the prototype developed for the proof of concept as a throw away prototype, we adapted the approach of an adaptive prototype. That is, we made the proof of concept the starting point of implementation and carried on from there, adapting rather an iterative scheme where by each iteration would add a new feature/functionality to the existing implementation. Therefore we would test each functionality in isolation and only integrate it into the existing implementation if it fulfilled its requirements [Khe03].

In addition, the issue tracking system, Scarab, was extensively used during this phase (Figure (2)) to facilitate and document communication among the different team members and reporting issues relating to the functionality. A schedule was also maintained to make sure that we were on track in regards to time management. A copy of the schedule is included in appendix D.

An important aspect of the project was the data structure used to hold the graph, this data structure was developed by Jun Wu and supplied us with an interface to enable us to read from/write to GXL files as well as to edit the data structure [Wu03]. We collaborated with Jun to curtail the data structure interface to our needs in addition to the changes and additions we made to the data structure ourselves.

The module/file association is as follows:

Module View File Manager is implemented by the file ViewFileManager.lhs

Module Settings File Manager is implemented by the file SettingsFileManager.lhs

Module Graph File Manager is implemented by the file GraphFileManager.lhs

Module Graph Manipulation is implemented by the following files: Node.lhs, NodeManipulation.lhs, EdgeManipulation.lhs, ItemManipulation.lhs and GraphManipulation.lhs

Module View Data Structure is implemented by the file: ViewDataStructure.lhs

Module View Manipulation is implemented by the file ViewManipulation.lhs

Module Settings Data Structure is implemented by the file SettingsDataStructure.lhs

Module Undo Data Structure is implemented by the file UndoDataStructure.lhs

Module Graph Interface is implemented by the file GraphInterface.lhs

Module Draw Graph is implemented by the file DrawGraph.lhs

Module Layout is implemented by the file Layout.lhs

Module Collision is implemented by the file Collision.lhs

Module Main is implemented by the file Main.lhs

The source code was written in a literate fashion and the literate code follows. The code has been extensively documented with all the implementation details/decisions at both the module level and the function level.

3.1 Literate Code

Module Collision, as the name indicates, provides us with functions to determine if there collision between objects in the graph. The functions are named according to the user's actions. Collision detection is implemented for the following actions, adding node, bending edge, adding edge and moving node, hence the four appropriately named functions in the interface. The secret of the module is that it hides how collision is detected between various objects in the graph and what method is used to resolve a collision. The collision detection algorithms that are implemented are not sophisticated ones but rather the straightforward obvious ones. Collision detection may not be efficient due to this in the case of more than tens of nodes.

```
module Collision(addNodeCollision,bendEdgeCollision,newEdgeCollision, moveNodeCollision) where

import Text.XML.HaXml.Xml2Haskell
import Gxl_1_0_1_DTD
import GXL_DTD
import INIT
import Utils
import Interface
import Data.Set
import Data.FiniteMap
import Additional
import Data.IORef
import Graphics.Rendering.OpenGL.GL
import Graphics.Rendering.OpenGL.GLU
import Graphics.Rendering.OpenGL.GLU.Quadrics
import Graphics.UI.GLUT
import Graphics.UI.WX hiding (WxcTypes.Id,KeyUp,KeyDown,color,motion,WXCore.WxcTypes.Size,
Classes.position,Attributes.get)
import Graphics.UI.WXCore.Frame
import Node
import GxlGraphSetManage
import GxlGraphSetXml
import Text.XML.HaXml.OneOfN
import SettingsDataStructure
import GraphInterface
```

Here we define the default radius for adding new edges between nodes.

```
--Default new edge radius
defaultNewEdgeRadius = 0.3
```

The collision module is designed by exhausting the types of collisions that can happen in the graph. So in the graph editor that we currently have, the possible objects for collision are nodes, straight edges and bent edges. Therefore we classify each of the collision cases this way, node to node collision, bent edge to node collision, straight edge to node collision, straight edge to straight edge collision, etc. As seen above in the interface, the functions supplied are addNodeCollision, bendEdgeCollision, newEdgeCollision and moveNodeCollision. For each of them, there are several types of collisions to be checked, for example, adding a node, we have to check node to node collision, node to straight edge collision and node to bent edge collision. So all of this functions are implemented by smaller functions which we will discuss below.

It is important to state that, all the methods used in this module just basically reduces a problem we have into a problem of detecting collision between a node and a node. For example, in an edge, the edge is simulated by a sequence of spheres(nodes) and then node to node collision is performed on it, similarly with bent edges.

Firstly we start with the simplest collision, which is node to node collision. The method of determining collision here is just by calculating whether the distance between the nodes is smaller than the sum of their radiuses. If it is, then we know collision has occurred.

For node to node collision, several possibilities of actions may cause it. Such as moving a node and adding a node. Therefore we separated these two cases to be handled by two separate functions. Function nodeToNode does the calculation of the collision detection and returns true if collision was detected, otherwise false. It takes in two node ids and the position of the first node. The purpose of the node ids is so that we can get its radius through getItemRadius and in the case of the second node, its position too. Once all the proper information is extracted about the nodes, the distances are calculated and the result is returned as a boolean value. Note that if the two node id's are the same, it will return false and is handled seperately.

```
nodeToNode :: IORef GxlGraphSet -> Id -> Id ->Vector3 GLfloat -> IO (Prelude.Bool)
nodeToNode dataStructure nodeA nodeB newPosA = do
  if (nodeA==nodeB)
   then do return (False)
   else do myNodeA <- getNode nodeA dataStructure
           nodeARadius <- getItemRadius nodeA dataStructure
           myNodeB <- getNode nodeB dataStructure
           let nodeBLayout = extractLayout myNodeB
           nodeBRadius <- getItemRadius nodeB dataStructure
           return ((((realToFrac $ distance newPosA nodeBLayout)::GLdouble) < (nodeARadius + nodeBRadius)) )

-- The distance function that is used above to calculate the distance between two three dimensional coordinates
distance :: Vector3 GLfloat -> Vector3 GLfloat -> GLfloat
distance a b = sqrt( (xcoord a - xcoord b)^2 + (ycoord a - ycoord b)^2 + (zcoord a - zcoord b)^2)
```

The above function deals with one node collision with one node, if the user moves a node in a graph with 10 nodes, we need to detect collision for the moved node with all the existing nodes. Therefore this function below serves this purpose. nodeToNodeCollision takes in the graphset, the new node and the list of nodes in the graphset, and the new position of the moved node. This function then recursively goes through all of the nodes in the list by checking collision for each one of them with the moved node.

```
nodeToNodeCollision :: IORef GxlGraphSet -> Id -> [Id] -> Vector3 GLfloat -> IO (Prelude.Bool)
nodeToNodeCollision dataStructure myItem (x:xs) newPosA = do
  result <- nodeToNode dataStructure myItem x newPosA
  if (result==True)
   then return(True)
   else nodeToNodeCollision dataStructure myItem xs newPosA

nodeToNodeCollision _ _ _ _ = return (False)
```

However, moving a node is not the only way to get a node to node collision, addition of a node is also a problem. Therefore a function is seperately done to take care of this case. The above function could be combined to handle both, but for simplicity and easier understanding, seperate functions with appropriate names are used. newNodeToNode is the function which handles collision of addition of new nodes. It is similar with the above case except that the posA argument is the new position where the node is to be placed instead of where it is to be moved.

```
newNodeToNode :: IORef GxlGraphSet -> Id ->Vector3 GLfloat ->GLdouble -> IO (Prelude.Bool)
newNodeToNode dataStructure nodeB posA radiusA = do
  myNodeB <- getNode nodeB dataStructure
  let nodeBLayout = extractLayout myNodeB
  nodeBRadius <- getItemRadius nodeB dataStructure
  return ((((realToFrac $ distance posA nodeBLayout)::GLdouble) < (radiusA + nodeBRadius)) )
```

As in the moving node collision case, the below function compares all the nodes in the graph with the new added node.

```
newNodeToNodeCollision :: IORef GxlGraphSet -> [Id] -> Vector3 GLfloat -> GLdouble -> IO (Prelude.Bool)
newNodeToNodeCollision dataStructure (x:xs) newPosA radius = do
  result <- newNodeToNode dataStructure x newPosA radius
  if (result==True)
    then return(True)
    else newNodeToNodeCollision dataStructure xs newPosA radius

newNodeToNodeCollision _ _ _ _ = return (False)
```

Now that node to node collisions are taken care of in both the moving node and adding node case, node with straight edge collision is handled below. The method that is used to detect collision between nodes and straight edges is by using the node to node collision. The straight edges are simulated by a sequence of nodes and this simplifies the problem into a one node to many-node collision. As above, node to straight edge collisions can happen in two ways, when the node is moved, when a node is added or when a straight edge is added.

Below is the case of a moved node with straight edge connected.

The nodeToStraightEdge function below does the collision detection by simulating a straight edge as a sequence of connected nodes or spheres. The parameters a and a_rad represents the node position and node radius currently involved in the detection and b,c and edge_rad represents the two nodes that form the edge with radius edge_rad. By getting the edge radius and the to and from nodes, we are able to construct a sequence of nodes from one end to another for this detection.

```
nodeToStraightEdge :: Vector3 GLfloat -> GLdouble -> Vector3 GLfloat -> Vector3 GLfloat -> GLdouble -> Prelude.Bool
nodeToStraightEdge a a_rad b c edge_rad =
          if (acos ((d1^2+d2^2-d3^2)/(2*d1*d2)) > ( pi/2 )) then
                  False
          else if (acos ((d3^2+d2^2-d1^2)/(2*d3*d2)) > ( pi/2 )) then
                  False
          else if ((realToFrac$sin(acos ((d1^2+d2^2-d3^2)/(2*d1*d2)))* d1:: GLdouble) > a_rad+edge_rad) then
                  False
          else    True
          where d1 = distance a b
                d2 = distance b c
                d3 = distance c a
```

Since the function above takes care of one simple case, the function below generalizes it to include all the edges in the graph, nodeToStraightEdgeCollision takes in the list of edges, the node to be compared with, its position and the graphset.

```
nodeToStraightEdgeCollision :: IORef GxlGraphSet -> Id -> [Id] -> Vector3 GLfloat -> IO (Prelude.Bool)
nodeToStraightEdgeCollision dataStructure myItem (x:xs) newPosA = do
  myNodeA <- getNode myItem dataStructure
  let nodeALayout = extractLayout myNodeA
  nodeARadius <- getItemRadius myItem dataStructure
  edgeRadius <- getItemRadius x dataStructure
  myGraphSet <- readIORef dataStructure
  let listOfGraphId = getGxlGraphs myGraphSet
  --Get the position of the node connected on one end of the edge with edge id x.
  let nodeB = to myGraphSet (head (listOfGraphId)) x
  myNodeB <- getNode nodeB dataStructure
```

```
  let nodeBLayout = extractLayout myNodeB
  --Get the position of the node connected on the other end of the edge with edge id x.
  let nodeC = from myGraphSet (head (listOfGraphId)) x
  myNodeC <- getNode nodeC dataStructure
  let nodeCLayout = extractLayout myNodeC
  --Calculate the collision detection result
  let result = nodeToStraightEdge nodeALayout nodeARadius nodeBLayout nodeCLayout edgeRadius
  --If there was a collision and the node involved in the comparison isn't connected to the edge
  --then return true else continue with the next edge.
  if ((result==True) && (myItem/=nodeB)&&(myItem/=nodeC))
   then return(True)
   else nodeToStraightEdgeCollision dataStructure myItem xs newPosA

nodeToStraightEdgeCollision _ _ _ _ = return (False)
```

Here the second case is handled, which is a new added node with straight edges. When a new node is added, this function is called to detect if it is colliding with any straight edges in the graph. It is similar as the above, but again for simplicity, two seperate functions are used for both of them.

```
newNodeToStraightEdgeCollision :: IORef GxlGraphSet -> [Id] -> Vector3 GLfloat -> GLdouble -> IO (Prelude.Bool)
newNodeToStraightEdgeCollision dataStructure (x:xs) newPosA radius = do
  edgeRadius <- getItemRadius x dataStructure
  myGraphSet <- readIORef dataStructure
  let listOfGraphId = getGxlGraphs myGraphSet
  let nodeB = to myGraphSet (head (listOfGraphId)) x
  let nodeC = from myGraphSet (head (listOfGraphId)) x
  myNodeB <- getNode nodeB dataStructure
  let nodeBLayout = extractLayout myNodeB
  myNodeC <- getNode nodeC dataStructure
  let nodeCLayout = extractLayout myNodeC
  let result = nodeToStraightEdge newPosA radius nodeBLayout nodeCLayout edgeRadius
  if (result==True)
   then return(True)
   else newNodeToStraightEdgeCollision dataStructure xs newPosA radius

newNodeToStraightEdgeCollision _ _ _ _ = return (False)
```

Now that nodes to straight edge collision is taken care of, the next step is to resolve straight edge to straight edge collisions. This collision only occurs in two cases, when a straight edge is added or when a node with a straight edge connected to it is moved. There are again, handled by two different functions, one is sedgeTosedgeCollision which is for the case of movement of a node with a connected edge, and the other is newEdgeCollision which is explained further on. The method of detecting collision for straight edge to straight edge is similar to node to straight edge. So the below function takes in two edge id's and the new position of the node newPosA is the new position of the node with a straight edge connected to it, myNode is the node id of the node that is currently being moved. sedgeTosedge is called in the below function for the actual calculation of detection between two edges.

```
sedgeTosedgeHandler:: IORef GxlGraphSet -> Vector3 GLfloat -> Id ->Id ->Prelude.Int -> Id -> IO(Prelude.Bool)
sedgeTosedgeHandler dataStructure  newPosA edgeId1 edgeId2 step myNode = do
```

Acquire the radiuses of the 2 edges.

```
edgeRadius1 <- getItemRadius edgeId1 dataStructure
edgeRadius2 <- getItemRadius edgeId2 dataStructure
```

Get the 'to' node or target node of edge with edgeId1 which is the edge that is connected to the node that is currently being moved.

```
myGraphSet <- readIORef dataStructure
let listOfGraphId = getGxlGraphs myGraphSet
let nodeA = to myGraphSet (head (listOfGraphId)) edgeId1
```

There are two possibilities if a node is moved and we are checking for straight edge to straight edge collision. Whether the node that is moved is the node that is the source of the edge or is the target of the edge. If the node the is moved is the target of the edge, then it is handled in this if block, otherwise it is handled in the else block.

```
if (myNode==nodeA)
 then do let nodeB = from myGraphSet (head (listOfGraphId)) edgeId1
         let nodeC = to myGraphSet (head (listOfGraphId)) edgeId2
         let nodeD = from myGraphSet (head (listOfGraphId)) edgeId2
         myNodeB <- getNode nodeB dataStructure
         let nodeBLayout = extractLayout myNodeB
         myNodeC <- getNode nodeC dataStructure
         let nodeCLayout = extractLayout myNodeC
         myNodeD <- getNode nodeD dataStructure
         let nodeDLayout = extractLayout myNodeD
         let result = sedgeTosedge newPosA nodeBLayout edgeRadius1 nodeCLayout nodeDLayout edgeRadius2 step
         return(result)
 else do
```

This section is similar to the above except that nodeB now is the target node instead of the source node.

```
         let nodeB = to myGraphSet (head (listOfGraphId)) edgeId1
         let nodeC = to myGraphSet (head (listOfGraphId)) edgeId2
         let nodeD = from myGraphSet (head (listOfGraphId)) edgeId2
         myNodeB <- getNode nodeB dataStructure
         let nodeBLayout = extractLayout myNodeB
         myNodeC <- getNode nodeC dataStructure
         let nodeCLayout = extractLayout myNodeC
         myNodeD <- getNode nodeD dataStructure
         let nodeDLayout = extractLayout myNodeD
         let result = sedgeTosedge newPosA nodeBLayout edgeRadius1 nodeCLayout nodeDLayout edgeRadius2 step
         return(result)
```

Notice that it calls the nodeToStraightEdge function, it simulates the edge fo be compared with with a sequence of nodes, and then reduces it to be problem of straight edge to node collision. The function below calculates the collision detection by simulating an edge with a series of spheres and calling nodeToStraightEdge. Step is how many spheres would be fitted from one end of the edge to another. The sedgeToEdge function below does all the calculation of collision between two individual edges. It recursively calculates collision between one of the nodes fitted into the edge with the edge involved in the movement of the node until it exhausts all of the nodes fitted to simulate the edge. If none reports a collision, then no collision is detected.

```
sedgeTosedge :: Vector3 GLfloat -> Vector3 GLfloat -> GLdouble ->Vector3 GLfloat ->Vector3 GLfloat -> GLdouble
-> Prelude.Int -> Prelude.Bool
sedgeTosedge a b rad1 c d rad2 0
          = nodeToStraightEdge b rad1 c d rad2
sedgeTosedge a b rad1 c d rad2 step
          = (nodeToStraightEdge a rad1 c d rad2) || (sedgeTosedge (Vector3 x y z) b rad1 c d rad2 (step-1))
```

```
            where x= xcoord a +((xcoord b - xcoord a)/(fromIntegral step))
                  y= ycoord a +((ycoord b - ycoord a)/(fromIntegral step))
                  z= zcoord a +((zcoord b - zcoord a)/(fromIntegral step))
```

The function below is the main function which utilizes the sedgeTosedgeHandler above. It is noted that 100 is the default step size, which is how many spheres are used to simulate a straight edge. This function is called with an edge, which is the edge that is moving, or the edge that is new, the position of on of the nodes that it is connected to(newPosA) and the list of edges in the graph.

```
sedgeTosedgeCollision :: IORef GxlGraphSet -> Id -> [Id] -> Vector3 GLfloat -> Id ->  IO (Prelude.Bool)
sedgeTosedgeCollision dataStructure myEdge (x:xs) newPosA myNode= do
result <- sedgeTosedgeHandler dataStructure newPosA myEdge x 100 myNode

if ((result==True) && (myEdge/=x))
then return(True)
else sedgeTosedgeCollision dataStructure myEdge xs newPosA myNode
sedgeTosedgeCollision _ _ _ _ _ = return (False)
```

Now that straight edge to straight edge collision is handled for the case of moving a node. The case of adding a new edge is handled below. This function compares a list of edges in the graph and the added edge. newEdgeToEdgeCollision takes in the source node and target node for the new edge, the list of edges already existing in the graph and determines if a collision would occur if the new edge is added.

```
newEdgeToEdgeCollision :: IORef GxlGraphSet -> [GXL_DTD.Id] -> Id -> Id -> Prelude.Int
-> IORef SettingsDataStructure -> IO(Prelude.Bool)
newEdgeToEdgeCollision dataStructure (x:xs) sourceNode targetNode step settings = do
  myGraphSet <- readIORef dataStructure
  let listOfGraphId = getGxlGraphs myGraphSet
  source <- getNode sourceNode dataStructure
  target <- getNode targetNode dataStructure
  -- Get number of cylinders
  mySettings <- readIORef settings
  myNumOfCylindersIORef <- getNumOfCylinders mySettings
  myNumOfCylinders <- readIORef myNumOfCylindersIORef
  -- Get the layout of the edge to be added
  let sourceLayout = extractLayout source
  let targetLayout = extractLayout target
  --- Get the layout of one of the edge in the list of edges
  let fromNode = from myGraphSet (head (listOfGraphId)) x
  let toNode  = to myGraphSet (head (listOfGraphId)) x
  myFromNode <- getNode fromNode dataStructure
  myToNode <- getNode toNode dataStructure
  let fromNodeLayout = extractLayout myFromNode
  let toNodeLayout = extractLayout myToNode
  (bentEdges,straightEdges) <- getListOfSeperateEdges dataStructure (x:xs) ([],[])
  -- Get the midPoint of one of the edge in the list of edges
  midPointVertex <- getEdgeMidPoint x myGraphSet
  let midPoint = vertexToVector midPointVertex
  edgeRadius <- getItemRadius x dataStructure
```

Since we are extracting the source node and target node information for each edge in the list of edges already existing, when comparing all the edges of the graph with the new edge, we must dismiss the case where the source node or target node of the new edge is compared to itself or to its opposite.

```
  if ( (sourceNode/=fromNode) && (targetNode/=fromNode) && (sourceNode/=toNode) && (targetNode/=toNode) )
   then
```

Since this function handles the addition of new edge collision in a general way, it will compare the added edge with all the existing edges in the graph whether straight or bent. If the edge compared to is bent, then sedgeTobedge will be called to do this. This function will be discussed later in the collisions involving bent edges section. If the edge compared to is not bent, then the function explained above sedgeTosedge is used.

```
    if (isMember x bentEdges)
      then do let result = sedgeTobedge sourceLayout targetLayout (defaultNewEdgeRadius) fromNodeLayout midPoint
                                        toNodeLayout edgeRadius myNumOfCylinders
              if (result==True)
               then return(True)
               else newEdgeToEdgeCollision dataStructure (xs) sourceNode targetNode step settings
              else do let result = sedgeTosedge fromNodeLayout toNodeLayout edgeRadius sourceLayout targetLayout
                                                (defaultNewEdgeRadius) step
                      if (result==True)
                       then return(True)
                       else newEdgeToEdgeCollision dataStructure (xs) sourceNode targetNode step settings
              else newEdgeToEdgeCollision dataStructure (xs) sourceNode targetNode step settings


newEdgeToEdgeCollision dataStructure [] sourceNode targetNode step settings = return(False)
```

When a new edge is added, it needs to be checked against all the nodes in the graph and all the edges in the graph, from above edge to edge collision is done for addition of new edges, in the function below, it will detect if collision will occur against nodes upon addition of the new edge. It calls the nodeToStraightEdge function from above which we defined to compare each node in the list of nodes in the graph with the new edge. If the new edge fails collision detection, it will not be added.

```
newEdgeToNodeCollision :: IORef GxlGraphSet -> [GXL_DTD.Id] -> Id -> Id -> IORef SettingsDataStructure
-> IO(Prelude.Bool)
newEdgeToNodeCollision dataStructure (x:xs) sourceNode targetNode settings = do
  source <- getNode sourceNode dataStructure
  target <- getNode targetNode dataStructure
  currentNode <- getNode x dataStructure
  let sourceLayout = extractLayout source
  let targetLayout = extractLayout target
  let currentNodeLayout = extractLayout currentNode
  currentNodeRadius <- getItemRadius x dataStructure
```

Here the actual collision checking is done by calling nodeToStraightEdge. If there is a collision and the nodes that were checked against were not the edge's own nodes, then return true, else continue checking with the rest of the nodes in the graph.

```
  let result = nodeToStraightEdge currentNodeLayout currentNodeRadius sourceLayout targetLayout
                                  (defaultNewEdgeRadius)
  if ((result==True) && (x/=sourceNode) && (x/=targetNode))
      then return(True)
      else newEdgeToNodeCollision dataStructure xs sourceNode targetNode settings

newEdgeToNodeCollision dataStructure [] sourceNode targetNode settings = return (False)
```

The below function is the main function for checking collision of addition of new edges, it joins the previous edge collision functions into one main function which is called whenever an edge is to be added.

```
newEdgeCollision::IORef GxlGraphSet -> [ GXL_DTD.Id] -> [GXL_DTD.Id] -> Id -> Id -> Prelude.Int
-> IORef SettingsDataStructure -> IO(Prelude.Bool)
newEdgeCollision dataStructure myListOfNodes myListOfEdges sourceNode targetNode step settings = do
  mySettings <- readIORef settings
  myNumOfCylindersIORef <- getNumOfCylinders mySettings
  myNumOfCylinders <- readIORef myNumOfCylindersIORef
  result1 <- newEdgeToNodeCollision dataStructure myListOfNodes sourceNode targetNode settings
  result2 <- newEdgeToEdgeCollision dataStructure myListOfEdges sourceNode targetNode step settings
  return(result1||result2)
```

Addition of new nodes must also be handled in the same fashion, compare the new node with the other nodes in the graph, compare the new node with all the straight edges in the graph and compare the new node with all the bent edges in the graph. If none of these fail collision detection, then there is no collision. From above, node to node and node to straight edge collisions are already done. Below defines the collision detection for addition of new nodes against bent edges in the graph.

```
newNodeToBentEdgeCollision :: IORef GxlGraphSet -> [Id] -> Vector3 GLfloat -> GLdouble
-> Prelude.Int -> IO (Prelude.Bool)
newNodeToBentEdgeCollision dataStructure (x:xs) newPosA radius numOfCylinders = do
  myGraphSet <- readIORef dataStructure
  edgeRadius <- getItemRadius x dataStructure
  midPointVertex <- getEdgeMidPoint x myGraphSet
  let midPoint = vertexToVector midPointVertex
  myGraphSet <- readIORef dataStructure
  let listOfGraphId = getGxlGraphs myGraphSet
  let nodeB = to myGraphSet (head (listOfGraphId)) x
  let nodeC = from myGraphSet (head (listOfGraphId)) x
  myNodeB <- getNode nodeB dataStructure
  let nodeBLayout = extractLayout myNodeB
  myNodeC <- getNode nodeC dataStructure
  let nodeCLayout = extractLayout myNodeC
```

Actual collision detection is done here by the function nodeToBentEdge which takes in a node, which in this case is the node to be added and the bent edge's information.

```
 let result = nodeToBentEdge newPosA radius nodeBLayout midPoint nodeCLayout edgeRadius numOfCylinders
 if (result==True)
  then return(True)
  else newNodeToBentEdgeCollision dataStructure xs newPosA radius numOfCylinders

newNodeToBentEdgeCollision _ _ _ _ _ = return (False)
```

Finally to merge it all together, all the checks are done at once in one function called addNodeCollision as defined below. If one of the tests fail, then collision is concluded to have occured for the addition of that node.

```
addNodeCollision::IORef GxlGraphSet -> [GXL_DTD.Id] -> [GXL_DTD.Id] -> Vector3 GLfloat -> GLdouble
->IORef SettingsDataStructure -> IO(Prelude.Bool)
addNodeCollision dataStructure myListOfNodes myListOfEdges newNodeLayout defaultRadius settings = do
```

seperatedList is a tuple of bent edge ids and straight edge ids, it helps seperate the bent edges and straight edges so the collision functions would be more efficient. For example, when node to straight edge collision is needed to be used, we can reduce the comparisons done on the edges on the graph to only the straight edges, instead of going through every edge in the graph. Therefore, node to straight edge collision uses the second component of seperatedList which is the list straight edges and node to bent edge collision uses the first component of seperatedList which is the list bent edges.

```
  seperatedList <- getListOfSeperateEdges dataStructure myListOfEdges ([],[])
  result1 <- newNodeToNodeCollision dataStructure myListOfNodes newNodeLayout defaultRadius
  result2 <- newNodeToStraightEdgeCollision dataStructure (snd(seperatedList)) newNodeLayout defaultRadius
  mySettings <- readIORef settings
  myNumOfCylindersIORef <- getNumOfCylinders mySettings
  myNumOfCylinders <- readIORef myNumOfCylindersIORef
  result3 <- newNodeToBentEdgeCollision dataStructure (fst(seperatedList)) newNodeLayout
                                        defaultRadius myNumOfCylinders
  return((result1||result2||result3))
```

For moving a node, it is possible to move a node and collide with a bent edge, from above, the cases where it collides with a straight edge or a node is handled, the function below outlines the method used to detect collision between a node and a bent edge in the case of node movement. The deepest part of the calculation of the collision detection for nodes against bent edges will be discussed here. Here is where the method of determining whether collision occurs for nodes against bent edges. Basically, a bent edge is a bunch of straight edges drawn through an interpolated curve through some mid point. So the idea to detect if collision occured between a node and a bent edge is by simulating the bent edge by a sequence of spheres through the curve and comparing each sphere with the node. The number of spheres used to simulate the bent edge is same as the number of cylinders used to draw the edge. Below is the function which does this generally, it takes in one node and compares it with all the bent edges in the graph.

```
nodeToBentEdgeCollision :: IORef GxlGraphSet -> Id -> [Id] -> Vector3 GLfloat -> Prelude.Int -> IO (Prelude.Bool)
nodeToBentEdgeCollision dataStructure myItem (x:xs) newPosA numOfCylinders = do
  myGraphSet <- readIORef dataStructure
  myNodeA <- getNode myItem dataStructure
  let nodeALayout = extractLayout myNodeA
  nodeARadius <- getItemRadius myItem dataStructure
  edgeRadius <- getItemRadius x dataStructure
  midPointVertex <- getEdgeMidPoint x myGraphSet
  let midPoint = vertexToVector midPointVertex
  myGraphSet <- readIORef dataStructure
  let listOfGraphId = getGxlGraphs myGraphSet
  let nodeB = to myGraphSet (head (listOfGraphId)) x
  let nodeC = from myGraphSet (head (listOfGraphId)) x
  myNodeB <- getNode nodeB dataStructure
  let nodeBLayout = extractLayout myNodeB
  myNodeC <- getNode nodeC dataStructure
  let nodeCLayout = extractLayout myNodeC
```

nodeToBentEdge is the function of importance here, it will be discussed after, it does what was stated above to a node and an edge. If a collision was detected, and the edges we are comparing with are not associated with the node that is currently being moved, then it can be concluded that collision did occur.

```
  let result = nodeToBentEdge newPosA nodeARadius nodeBLayout midPoint nodeCLayout edgeRadius numOfCylinders
  if ((result==True) && (myItem/=nodeB)&&(myItem/=nodeC))
    then return(True)
    else nodeToBentEdgeCollision dataStructure myItem xs newPosA numOfCylinders

nodeToBentEdgeCollision _ _ _ _ _ = return (False)


getListOfSeperateEdges:: IORef GxlGraphSet -> [Id] -> ([Id],[Id]) -> IO(([Id],[Id]))
getListOfSeperateEdges dataStructure (x:xs) (bentEdges,straightEdges) = do
myGraphSet <- readIORef dataStructure
midPointVertex <- getEdgeMidPoint x myGraphSet
if (midPointVertex /= defaultNoMidPoint )
then getListOfSeperateEdges dataStructure xs ((x:bentEdges),(straightEdges))
else getListOfSeperateEdges dataStructure xs ((bentEdges),(x:straightEdges))
getListOfSeperateEdges dataStructure [] result = return result
```

The inner workings of the node to bent edge collision mechanism is defined below. fx, fy and fz are the interpolation functions. interp applies these functions to the coordinates desired.

```
fx :: Vector3 GLfloat -> Vector3 GLfloat -> Vector3 GLfloat -> GLfloat -> GLfloat
fx a b c t = (1.0-t)^2*(xcoord a) + 2.0*t*(1.0-t)*(xcoord b) + t^2 * (xcoord c)

fy :: Vector3 GLfloat -> Vector3 GLfloat -> Vector3 GLfloat -> GLfloat -> GLfloat
fy a b c t = (1.0-t)^2*(ycoord a) + 2.0*t*(1.0-t)*(ycoord b) + t^2 * (ycoord c)

fz :: Vector3 GLfloat -> Vector3 GLfloat -> Vector3 GLfloat -> GLfloat -> GLfloat
fz a b c t = (1.0-t)^2*(zcoord a) + 2.0*t*(1.0-t)*(zcoord b) + t^2 * (zcoord c)

interp :: (Vector3 GLfloat -> Vector3 GLfloat -> Vector3 GLfloat -> GLfloat -> GLfloat) -> Vector3 GLfloat
-> Vector3 GLfloat -> Vector3 GLfloat -> [GLfloat] -> [GLfloat]
interp f a b c list = map (f a b c) list
```

nodeToBentEdge is the main function which takes in the list of coordinates needed to interpolate and applies detection1 to it. detection1 function is same as the function which draws the bent edge by interpolation, only in this case, a sphere is simulated instead of a cylinder and nodeToStraightEdge is called each time against the node that is being moved for the collision detection.

```
nodeToBentEdge :: Vector3 GLfloat -> GLdouble -> Vector3 GLfloat -> Vector3 GLfloat -> Vector3 GLfloat
-> GLdouble -> Prelude.Int ->Prelude.Bool
nodeToBentEdge a a_rad c d e e_rad numOfCylinders =
        detection1 a a_rad xlist ylist zlist e_rad
        where xlist = interp fx c d e (tFunction numOfCylinders)
              ylist = interp fy c d e (tFunction numOfCylinders)
              zlist = interp fz c d e (tFunction numOfCylinders)

detection1 :: Vector3 GLfloat -> GLdouble -> [GLfloat] -> [GLfloat] -> [GLfloat] -> GLdouble -> Prelude.Bool
```

```
detection1 node node_rad [] [] [] _ = False
detection1 node node_rad (x1:[]) (y1:[]) (z1:[]) _ = False
detection1 node node_rad (x1:x2:xlist) (y1:y2:ylist) (z1:z2:zlist) edge_rad =
               ((nodeToStraightEdge node node_rad (Vector3 x1 y1 z1) (Vector3 x2 y2 z2) edge_rad)
                 || (detection1 node node_rad (x2:xlist) (y2:ylist) (z2:zlist) edge_rad))
```

When moving a node, the edge connected to it may also move, therefore collision is checked on the edges of that node. edgeLoop does exactly that, it compares every edge with every other edge in the graph for collision. This function seperates the list of edges into straight edges and bent edges, and calls the four appropriate functions with them depending on whether its comparing bent edge to bent edge, bent edge to straight edge, straight edge to bent edge and straight edge to straight edge.

```
edgeLoop :: IORef GxlGraphSet -> Id -> [Id] -> ([Id],[Id]) -> Vector3 GLfloat
-> Prelude.Int -> IO (Prelude.Bool)
edgeLoop dataStructure myNode edgeList edgePairList newPosA numOfCylinders= do
  edgesConnected <- getEdgesConnected dataStructure myNode (edgeList) []
  seperatedList <- getListOfSeperateEdges dataStructure edgesConnected ([],[])
  -- Compare bent to bent
  result4 <- bentEdgeToBentEdgeRecursion dataStructure (fst edgePairList) (fst seperatedList) newPosA
                                         numOfCylinders myNode
  -- Compare bent to straight
  result3 <- bentEdgeTosedgeRecursion dataStructure (snd edgePairList) (fst seperatedList) newPosA
                                      numOfCylinders myNode
  -- Compare straight to bent
  result2 <- sedgeToBentEdgeRecursion dataStructure (snd seperatedList) (fst edgePairList) newPosA
                                      numOfCylinders myNode
  -- Compare sTraight to straight
  result <- sedgeTosEdgeRecursion dataStructure (snd seperatedList) (snd edgePairList) newPosA
                                  myNode
  return (result||result2||result3||result4)
```

The function below, sedgeToBentEdgeRecursion recursively goes through all the straight edges and calls sedgeTobedgeCollision on each of them with the list of bent edges in the graph. This is called specifically by edgeLoop for when a node is moved. This compares all the straight edges in the graph with all the bent edges in the graph to see if collision has occured.

```
sedgeToBentEdgeRecursion :: IORef GxlGraphSet -> [Id] -> [Id] -> Vector3 GLfloat -> Prelude.Int
-> Id -> IO (Prelude.Bool)
sedgeToBentEdgeRecursion dataStructure (x:xs) edgeList newPosA numOfCylinders myNode = do
  value <- sedgeTobedgeCollision dataStructure x edgeList newPosA numOfCylinders myNode
  if (value==True) then return(True)
                   else sedgeToBentEdgeRecursion dataStructure xs edgeList newPosA numOfCylinders myNode

sedgeToBentEdgeRecursion dataStructure [] edgeList newPosA numOfCylinders myNode = return(False)
```

The function sedgeTobedgeCollision used above to compare the straight edge with a list of bent edges is defined below. It calls the handler defined above for the individual one edge to one edge comparison, while it recursively goes through the list of bent edges.

```
sedgeTobedgeCollision :: IORef GxlGraphSet -> Id -> [Id] -> Vector3 GLfloat ->  Prelude.Int
-> Id -> IO (Prelude.Bool)
```

```
sedgeTobedgeCollision dataStructure myEdge (x:xs) newPosA numOfCylinders myNode = do
  result <- sedgeTobedgeHandler dataStructure newPosA myEdge x numOfCylinders myNode
  if ((result==True) && (myEdge/=x))
    then return(True)
    else sedgeTobedgeCollision dataStructure myEdge xs newPosA numOfCylinders myNode

sedgeTobedgeCollision _ _ _ _ _ _ = return (False)
```

bentEdgeTosedgeRecursion recursively goes through all the bent edges and calls bentEdgeTosedgeCollision on each of them with the list of straight edges in the graph.

```
bentEdgeTosedgeRecursion :: IORef GxlGraphSet -> [Id] -> [Id] -> Vector3 GLfloat -> Prelude.Int
-> Id -> IO (Prelude.Bool)
bentEdgeTosedgeRecursion dataStructure (x:xs) edgeList newPosA numOfCylinders myNode = do
  value <- bentEdgeTosedgeCollision dataStructure x edgeList newPosA numOfCylinders myNode
  if (value==True) then return(True)
                   else bentEdgeTosedgeRecursion dataStructure xs edgeList newPosA numOfCylinders myNode

bentEdgeTosedgeRecursion dataStructure [] edgeList newPosA numOfCylinders myNode = return(False)
```

Here we explain the bentEdgeTosedgeCollision function. This takes in one bent edge and the list of straight edges, and recursively goes through all of the straight edges and determines if the bent edge collides with any of them. This is done through calling the bedgeTosedgeHandler which compares one bent edge to one straight edge.

```
bentEdgeTosedgeCollision :: IORef GxlGraphSet -> Id -> [Id] -> Vector3 GLfloat ->  Prelude.Int
-> Id -> IO (Prelude.Bool)
bentEdgeTosedgeCollision dataStructure myEdge (x:xs) newPosA numOfCylinders myNode = do
  result <- bedgeTosedgeHandler dataStructure newPosA myEdge x numOfCylinders myNode
  if ((result==True) && (myEdge/=x))
    then return(True)
    else bentEdgeTosedgeCollision dataStructure myEdge xs newPosA numOfCylinders myNode

bentEdgeTosedgeCollision _ _ _ _ _ _ = return (False)
```

bentEdgeToBentEdgeRecursion recursively goes through all the bent edges in the graph and calls bentEdgeToBentEdgeCollision on it. Which then calls the bentEdgeToBendEdgeToHandler function which compares specfically one bent edge to another one bent edge.

```
bentEdgeToBentEdgeRecursion :: IORef GxlGraphSet -> [Id] -> [Id] -> Vector3 GLfloat -> Prelude.Int
-> Id -> IO (Prelude.Bool)
bentEdgeToBentEdgeRecursion dataStructure (x:xs) edgeList newPosA numOfCylinders myNode = do
  value <- bentEdgeToBentEdgeCollision dataStructure x edgeList newPosA numOfCylinders myNode
  if (value==True) then return(True)
                   else bentEdgeToBentEdgeRecursion dataStructure xs edgeList newPosA numOfCylinders myNode

bentEdgeToBentEdgeRecursion dataStructure [] edgeList newPosA numOfCylinders myNode = return (False)
```

sedgeTosEdgeRecursion performs similarly as above, it goes through all the straight edges in the graph and for each straight edge, it calls sedgeTosedgeCollision with on it together with the list of all straight edges in the graph.

```
sedgeTosEdgeRecursion :: IORef GxlGraphSet -> [Id] -> [Id] -> Vector3 GLfloat -> Id -> IO (Prelude.Bool)
sedgeTosEdgeRecursion dataStructure (x:xs) edgeList newPosA myNode = do
  value <- sedgeTosedgeCollision dataStructure x edgeList newPosA myNode
  if (value==True) then return(True)
                   else sedgeTosEdgeRecursion dataStructure xs edgeList newPosA myNode

sedgeTosEdgeRecursion dataStructure [] edgeList newPosA myNode = return(False)
```

This function is used by edgeLoop to acquire the list of bent edges and straight edges and seperate them in a tuple of lists. The first component of the tuple represents the bent edges while the second component represents the straight edges.

```
getEdgesConnected :: IORef GxlGraphSet -> GXL_DTD.Id -> [ItemId] -> [ItemId] -> IO([ItemId])
getEdgesConnected currentGraphSet id (edge:edges) result = do
  myGraphSet <- readIORef currentGraphSet
  let listOfGraphId = getGxlGraphs myGraphSet
  if ( (to myGraphSet (head (listOfGraphId)) edge==id) || (from myGraphSet (head (listOfGraphId)) edge==id) )
   then do getEdgesConnected currentGraphSet id  edges (edge:result)
   else do getEdgesConnected currentGraphSet id  edges result

getEdgesConnected currentGraphSet id []  result            = return (result)
```

Now that all the needed functions for node movement collision are properly defined, it can all be merge and used in one main function, defined below. When moving a node, all types of collision can happen. Below is the function which put all of the functions we have implemented above to its real use. When a node is moved(myNode), 4 checks are done on it, which is if it is colliding with another node, a straight edge, a bent edge or its own edge colliding with any other object in the graph(edgeLoop). The names that are used explain the type of collision they are handling clearly and therefore need not be explained further. If any one of these detections fail, this function will return false, therefore signifying a collision for the movement of the node.

```
moveNodeCollision dataStructure myListOfNodes myListOfEdges myNode newNodeLayout settings = do

  seperatedList <- getListOfSeperateEdges dataStructure myListOfEdges ([],[])
  mySettings <- readIORef settings
  myNumOfCylindersIORef <- getNumOfCylinders mySettings
  myNumOfCylinders <- readIORef myNumOfCylindersIORef
  result1 <- nodeToStraightEdgeCollision dataStructure myNode (snd(seperatedList)) newNodeLayout
  result2 <- nodeToNodeCollision dataStructure myNode myListOfNodes newNodeLayout
  result3 <- edgeLoop dataStructure myNode myListOfEdges seperatedList newNodeLayout myNumOfCylinders
  result4 <- nodeToBentEdgeCollision dataStructure myNode (fst(seperatedList)) newNodeLayout myNumOfCylinders
  return((result1||result2||result3||result4))
```

Collision detection for addition of nodes, addition of edges and movement of nodes are already done. One major part that is left in the collision module is when the user bends an edge. When the user bends an edge, the bended edge must be checked against all the nodes and edges (other than itself) in the graph. Starting from the simplest case, bent edge against other nodes, we will explain how all these cases are merged in the end for a bending edge collision function. Below we define the function bentEdgeToNodeCollision which handles collision detection for edges that are bent and nodes. It takes in a list of nodes in the graph, and a bent edge, and reports whether a collision has occured between them or not. The important function in it is nodeToBentEdge, which was defined and explained above.

```
bentEdgeToNodeCollision :: IORef GxlGraphSet -> [Id] -> Id -> Vertex3 GLfloat
-> IORef SettingsDataStructure -> IO(Prelude.Bool)
bentEdgeToNodeCollision dataStructure (x:xs) edgeId newMidPoint settings = do
  myGraphSet <- readIORef dataStructure
  let listOfGraphId = getGxlGraphs myGraphSet
  mySettings <- readIORef settings
  myNumOfCylindersIORef <- getNumOfCylinders mySettings
  myNumOfCylinders <- readIORef myNumOfCylindersIORef
  -- Retrieve the layout of source and target nodes for the bent edge
  let fromNode = from myGraphSet (head (listOfGraphId)) edgeId
  let toNode  = to myGraphSet (head (listOfGraphId)) edgeId
  myFromNode <- getNode fromNode dataStructure
  myToNode <- getNode toNode dataStructure
  let fromNodeLayout = extractLayout myFromNode
  let toNodeLayout = extractLayout myToNode
  -- Retrive the layout of current node
  currentNode <- getNode x dataStructure
  let currentNodeLayout = extractLayout currentNode
  -- Retrieve Current node's radius that is to be compared with
  nodeRadius <- getItemRadius x dataStructure
  -- Retrieve the bent edge's radius
  edgeRadius <- getItemRadius edgeId dataStructure
  -- Convert future edge midpoint to vector
  let midPoint = vertexToVector newMidPoint
  let result = nodeToBentEdge currentNodeLayout nodeRadius fromNodeLayout midPoint toNodeLayout edgeRadius
                              myNumOfCylinders
  if ((result==True) && (x/=fromNode) && (x/=toNode) )
     then return(True)
     else bentEdgeToNodeCollision dataStructure (xs) edgeId newMidPoint settings

bentEdgeToNodeCollision dataStructure [] edgeId newMidPoint settings = return (False)
```

Below, we define bentEdgeToStraightEdgeCollision, the function which handles collision detection between the bended edge and the straight edges in the graph. It takes in the new mid point which is specified by the mouse in the user's bending edge action, the edge id of the edge the user is bending and the list of straight edges in the graph.

```
bentEdgeToStraightEdgeCollision :: IORef GxlGraphSet -> [Id] -> Prelude.Int -> Id -> Vertex3 GLfloat
-> IORef SettingsDataStructure -> IO(Prelude.Bool)
bentEdgeToStraightEdgeCollision dataStructure (x:xs) step myItem newMidPoint settings = do
  myGraphSet <- readIORef dataStructure
  let listOfGraphId = getGxlGraphs myGraphSet
  mySettings <- readIORef settings
  myNumOfCylindersIORef <- getNumOfCylinders mySettings
  myNumOfCylinders <- readIORef myNumOfCylindersIORef
  -- Retrieve the layout of source and target nodes for the bent edge
  let fromNode = from myGraphSet (head (listOfGraphId)) myItem
  let toNode  = to myGraphSet (head (listOfGraphId)) myItem
  myFromNode <- getNode fromNode dataStructure
  myToNode <- getNode toNode dataStructure
  let fromNodeLayout = extractLayout myFromNode
  let toNodeLayout = extractLayout myToNode
```

```
  -- Retrieve the layout of source and target nodes for the bent edge
  let currentFromNode = from myGraphSet (head (listOfGraphId)) x
  let currentToNode  = to myGraphSet (head (listOfGraphId)) x
  myCurrentFromNode <- getNode currentFromNode dataStructure
  myCurrentToNode <- getNode currentToNode dataStructure

  let fromCurrentNodeLayout = extractLayout myCurrentFromNode
  let toCurrentNodeLayout = extractLayout myCurrentToNode
  currentEdgeRadius <- getItemRadius x dataStructure
  bentEdgeRadius <- getItemRadius myItem dataStructure

  let midPoint = vertexToVector newMidPoint
```

sedgeTobedge is the core function in which the bent edge is as mentioned above, seperated into a curve of sequence of spheres which then simplifies the problem to straight edge to straight edge collision.

```
  let result = sedgeTobedge fromCurrentNodeLayout toCurrentNodeLayout currentEdgeRadius fromNodeLayout midPoint
                            toNodeLayout bentEdgeRadius myNumOfCylinders
  putStrLn(show result)
  if ( (result==True) && (x/=myItem) )
     then return (True)
     else bentEdgeToStraightEdgeCollision dataStructure xs step myItem newMidPoint settings


  bentEdgeToStraightEdgeCollision dataStructure [] step myItem newMidpoint settings = return (False)

sedgeTobedgeCollision :: IORef GxlGraphSet -> Id -> [Id] -> Vector3 GLfloat ->  Prelude.Int
-> Id -> IO (Prelude.Bool)
sedgeTobedgeCollision dataStructure myEdge (x:xs) newPosA numOfCylinders myNode = do
result <- sedgeTobedgeHandler dataStructure newPosA myEdge x numOfCylinders myNode
if ((result==True) && (myEdge/=x))
then return(True)
else sedgeTobedgeCollision dataStructure myEdge xs newPosA numOfCylinders myNode
sedgeTobedgeCollision _ _ _ _ _ _ = return (False)
```

sedgeTobedge is defined below. It works together with detection2, similarly as detection1. sedgeTobedge gets the list of points to interpolate across and detection2 does the collision detection at each step of the interpolation. This time sedgeTosedge is called. sedgeTosedge is a function which in turn, simulates the straight edge into sequence of spheres and checks them together. The whole method of collision detection used here is just by simplifying the problem into straight edge to node collision.

```
detection2 :: Vector3 GLfloat -> Vector3 GLfloat -> GLdouble -> [GLfloat] -> [GLfloat] -> [GLfloat]
-> GLdouble -> Prelude.Int -> Prelude.Bool
detection2 n1 n2 s_rad [] [] [] _ _ = False
detection2 n1 n2 s_rad (x1:[]) (y1:[]) (z1:[]) _ _ = False
detection2 n1 n2 s_rad (x1:x2:xlist) (y1:y2:ylist) (z1:z2:zlist) b_rad numOfCylinders=
               ((sedgeTosedge n1 n2 s_rad (Vector3 x1 y1 z1) (Vector3 x2 y2 z2) b_rad numOfCylinders)
                || (detection2 n1 n2 s_rad (x2:xlist) (y2:ylist) (z2:zlist) b_rad numOfCylinders))

sedgeTobedge :: Vector3 GLfloat -> Vector3 GLfloat -> GLdouble -> Vector3 GLfloat
```

```
-> Vector3 GLfloat -> Vector3 GLfloat -> GLdouble -> Prelude.Int -> Prelude.Bool
sedgeTobedge n1 n2 s_rad n3 n4 n5 b_rad numOfCylinders=
        detection2 n1 n2 s_rad xlist ylist zlist b_rad numOfCylinders
        where xlist = interp fx n3 n4 n5 (tFunction numOfCylinders)
              ylist = interp fy n3 n4 n5 (tFunction numOfCylinders)
              zlist = interp fz n3 n4 n5 (tFunction numOfCylinders)
```

While bending an edge, it may also collide with another bent edge, a similar approach is used, simulate both bent edges by a sequence of spheres and then perform collision detection on every sphere on the first edge with every sphere on the second edge. This function below takes in a list of bent edge ids and one bent edge, and determines if that bent edge is causing a collision on the graph. bentToBentToEdgeHandler is the main function for bent edge to bent edge comparison.

```
bentEdgeToBentEdgeCollision :: IORef GxlGraphSet -> Id -> [Id] -> Vector3 GLfloat ->  Prelude.Int
-> Id -> IO (Prelude.Bool)
bentEdgeToBentEdgeCollision dataStructure myEdge (x:xs) newPosA numOfCylinders myNode = do
result <- bedgeToBentToEdgeHandler dataStructure newPosA myEdge x numOfCylinders myNode
if ((result==True) && (myEdge/=x))
then return(True)
else bentEdgeToBentEdgeCollision dataStructure myEdge xs newPosA numOfCylinders myNode
bentEdgeToBentEdgeCollision _ _ _ _ _ _ = return (False)
```

The above function handles all the list of edges, the below function is what is used to compare one bent edge to another bent edge in the case of bending an edge. It calls the last deepest function which does the interpolation and simulates the bent edges with sequence of spheres.

```
bedgeToBentToEdgeHandler:: IORef GxlGraphSet -> Vector3 GLfloat -> Id ->Id ->Prelude.Int
-> Id -> IO(Prelude.Bool)
bedgeToBentToEdgeHandler dataStructure newPosA edgeId1 edgeId2 numOfCylinders myNode = do
  edgeRadius1 <- getItemRadius edgeId1 dataStructure
  edgeRadius2 <- getItemRadius edgeId2 dataStructure
  myGraphSet <- readIORef dataStructure
  let listOfGraphId = getGxlGraphs myGraphSet
  let nodeA = to myGraphSet (head (listOfGraphId)) edgeId1
```

There is two cases if a node is moved and a bent edge is connected to it, if the node that is moved has the bent edge going towards it, the block of if statement below handles the case, if it is not that the else block does it. These two cases have to be handled seperately because the arguments on the bedgeTobedge function will be of different order of arrangement depending on what is changing.

```
  if (myNode==nodeA)
   then do
    let nodeB = from myGraphSet (head (listOfGraphId)) edgeId1
    let nodeC = to myGraphSet (head (listOfGraphId)) edgeId2
    let nodeD = from myGraphSet (head (listOfGraphId)) edgeId2
    myGraphSet <- readIORef dataStructure
    midPointVertexEdge1 <- getEdgeMidPoint edgeId1 myGraphSet
    midPointVertexEdge2 <- getEdgeMidPoint edgeId2 myGraphSet
    let midPointEdge1 = vertexToVector midPointVertexEdge1
    let midPointEdge2 = vertexToVector midPointVertexEdge2
```

```
    myNodeB <- getNode nodeB dataStructure
    let nodeBLayout = extractLayout myNodeB
    myNodeC <- getNode nodeC dataStructure
    let nodeCLayout = extractLayout myNodeC
    myNodeD <- getNode nodeD dataStructure
    let nodeDLayout = extractLayout myNodeD
    let result = bedgeTobedge nodeBLayout midPointEdge1 newPosA edgeRadius1 nodeDLayout midPointEdge2
                              nodeCLayout edgeRadius2 numOfCylinders
    return(result)
   else do let nodeB = to myGraphSet (head (listOfGraphId)) edgeId1
           let nodeC = to myGraphSet (head (listOfGraphId)) edgeId2
           let nodeD = from myGraphSet (head (listOfGraphId)) edgeId2
           myGraphSet <- readIORef dataStructure
           midPointVertexEdge1 <- getEdgeMidPoint edgeId1 myGraphSet
           midPointVertexEdge2 <- getEdgeMidPoint edgeId2 myGraphSet
           let midPointEdge1 = vertexToVector midPointVertexEdge1
           let midPointEdge2 = vertexToVector midPointVertexEdge2
           myNodeB <- getNode nodeB dataStructure
           let nodeBLayout = extractLayout myNodeB
           myNodeC <- getNode nodeC dataStructure
           let nodeCLayout = extractLayout myNodeC
           myNodeD <- getNode nodeD dataStructure
           let nodeDLayout = extractLayout myNodeD
           let result = bedgeTobedge newPosA midPointEdge1 nodeBLayout edgeRadius1 nodeDLayout midPointEdge2
                                     nodeCLayout edgeRadius2 numOfCylinders
           return(result)
```

This is the function which puts it all together, when an edge is bent, these three functions are called in this main function to check if the bent edge actually caused a collision or not.

```
bendEdgeCollision:: IORef GxlGraphSet -> [Id] -> [Id] -> Id -> Vertex3 GLfloat
-> IORef SettingsDataStructure -> IO(Prelude.Bool)
bendEdgeCollision dataStructure myListOfNodes myListOfEdges myItem newLayoutAttribute settings = do
  mySettings <- readIORef settings
  result1 <- bentEdgeToNodeCollision dataStructure myListOfNodes myItem newLayoutAttribute settings
  result2 <- bentEdgeToStraightEdgeCollision dataStructure myListOfEdges 100 myItem newLayoutAttribute settings
  result3 <- bentEdgeToBentEdgeCollision dataStructure myListOfEdges step myItem settings
  return (result1||result2||result3)
```

This is the function which reduces the problem of collision between bent edges and bent edges to straight edges and bent edges. Similarly as with the other cases, the bent edge is simulated as a bunch of straight edges through an interpolated curve, and each of these straight edges are checked for collision using the sedgeTobedge function.

```
detection3 :: [GLfloat] -> [GLfloat] -> [GLfloat] -> GLdouble -> Vector3 GLfloat -> Vector3 GLfloat
-> Vector3 GLfloat -> GLdouble -> Prelude.Int -> Prelude.Bool
detection3 (a1:[]) (b1:[]) (c1:[]) _ _ _ _ _ _ = False
detection3 [] [] [] _ _ _ _ _ _ = False
detection3 (a1:a2:alist) (b1:b2:blist) (c1:c2:clist) b1_rad n1 n2 n3 b2_rad numOfCylinders =
        ((sedgeTobedge (Vector3 a1 b1 c1) (Vector3 a2 b2 c2) b1_rad n1 n2 n3 b2_rad numOfCylinders)
          || (detection3 (a2:alist) (b2:blist) (c2:clist) b1_rad n1 n2 n3 b2_rad numOfCylinders))
```

```
bedgeTobedge n1 n2 n3 b1_rad n4 n5 n6 b2_rad numOfCylinders =
        detection3 xlist ylist zlist b1_rad n4 n5 n6 b2_rad numOfCylinders
        where xlist = interp fx n1 n2 n3 (tFunction numOfCylinders)
              ylist = interp fy n1 n2 n3 (tFunction numOfCylinders)
              zlist = interp fz n1 n2 n3 (tFunction numOfCylinders)

tFunction :: Prelude.Int -> [GLfloat]
tFunction numOfCylinders = [fromIntegral i/fromIntegral numOfCylinders | i<-[0..numOfCylinders]]
```

Function bendEdgeCollision function below is the main function which determines if collision occured while bending an edge. The edge id is recorded in the argument 'myItem' and the functions explained above are merged together into this one. It checks if the bent edge collided with a node,a straight edge or another bent edge. If anyone of these checks fail (collision occurred), then it will return true for collision detected.

```
bendEdgeCollision:: IORef GxlGraphSet -> [Id] -> [Id] -> Id -> Vertex3 GLfloat
-> IORef SettingsDataStructure -> IO(Prelude.Bool)
bendEdgeCollision dataStructure myListOfNodes myListOfEdges myItem newLayoutAttribute settings = do
  mySettings <- readIORef settings
  result1 <- bentEdgeToNodeCollision dataStructure myListOfNodes myItem newLayoutAttribute settings
  result2 <- bentEdgeToStraightEdgeCollision dataStructure myListOfEdges 100 myItem newLayoutAttribute settings
  result3 <- bentEdgeToBentEdgeCollision dataStructure myListOfEdges step myItem settings
  return (result1||result2||result3)
```

The two big functions below are the functions which compares a bent edge with a straight edge for collision and a straight edge with a bent edge for collision. Two seperate functions were needed for this as sedgeTobedge takes in different arrangement of arguments depending on which edge is changing according to which node is currently being moved.

```
bedgeTosedgeHandler:: IORef GxlGraphSet -> Vector3 GLfloat -> Id ->Id ->Prelude.Int -> Id -> IO(Prelude.Bool)
bedgeTosedgeHandler dataStructure newPosA edgeId1 edgeId2 numOfCylinders myNode = do

  edgeRadius1 <- getItemRadius edgeId1 dataStructure
  edgeRadius2 <- getItemRadius edgeId2 dataStructure
  myGraphSet <- readIORef dataStructure
  let listOfGraphId = getGxlGraphs myGraphSet
  let nodeA = to myGraphSet (head (listOfGraphId)) edgeId2
```

When the node being moved is the target node of the bent edge that is connected to that node, then sedgeTobedge again, takes in a different arrangement of arguments. Anything that is changing is on the right side of the sedgeTobedge function. Therefore if the current node that is being moved is nodeA, then the position of nodeA will be in the 6th argument of the sedgeTobedge function. Otherwise, the current node that is being moved is nodeB which means that the position of nodeB will be in the 6th argument now.

```
  if (myNode==nodeA)
   then do let nodeB = from myGraphSet (head (listOfGraphId)) edgeId2
           let nodeC = to myGraphSet (head (listOfGraphId)) edgeId1
           let nodeD = from myGraphSet (head (listOfGraphId)) edgeId1
           myGraphSet <- readIORef dataStructure
           midPointVertex <- getEdgeMidPoint edgeId2 myGraphSet
```

```
        let midPoint = vertexToVector midPointVertex
        myNodeB <- getNode nodeB dataStructure
        let nodeBLayout = extractLayout myNodeB
        myNodeC <- getNode nodeC dataStructure
        let nodeCLayout = extractLayout myNodeC
        myNodeD <- getNode nodeD dataStructure
        let nodeDLayout = extractLayout myNodeD
        let result = sedgeTobedge nodeCLayout nodeDLayout edgeRadius1  nodeBLayout midPoint newPosA
                                  edgeRadius2 numOfCylinders
        return(result)
        else do let nodeB = to myGraphSet (head (listOfGraphId)) edgeId2
                let nodeC = to myGraphSet (head (listOfGraphId)) edgeId1
                let nodeD = from myGraphSet (head (listOfGraphId)) edgeId1
                myGraphSet <- readIORef dataStructure
                midPointVertex <- getEdgeMidPoint edgeId2 myGraphSet
                let midPoint = vertexToVector midPointVertex
                myNodeB <- getNode nodeB dataStructure
                let nodeBLayout = extractLayout myNodeB
                myNodeC <- getNode nodeC dataStructure
                let nodeCLayout = extractLayout myNodeC
                myNodeD <- getNode nodeD dataStructure
                let nodeDLayout = extractLayout myNodeD
                let result = sedgeTobedge nodeCLayout nodeDLayout edgeRadius1 newPosA midPoint nodeBLayout
                                          edgeRadius2 numOfCylinders
                return(result)
```

Similarly as above, the reason we have so many cases and if statements is because which node that is changing or moving is important to the sedgeTobedge function. Notice the different order of the arguments from the above. This function functions the same as above except for different arrangement of arguments.

```
sedgeTobedgeHandler:: IORef GxlGraphSet -> Vector3 GLfloat -> Id ->Id ->Prelude.Int -> Id -> IO(Prelude.Bool)
sedgeTobedgeHandler dataStructure newPosA edgeId1 edgeId2 numOfCylinders myNode = do

  edgeRadius1 <- getItemRadius edgeId1 dataStructure
  edgeRadius2 <- getItemRadius edgeId2 dataStructure
  myGraphSet <- readIORef dataStructure
  let listOfGraphId = getGxlGraphs myGraphSet
  let nodeA = to myGraphSet (head (listOfGraphId)) edgeId1
  if (myNode==nodeA)
   then do let nodeB = from myGraphSet (head (listOfGraphId)) edgeId1
           let nodeC = to myGraphSet (head (listOfGraphId)) edgeId2
           let nodeD = from myGraphSet (head (listOfGraphId)) edgeId2
           myGraphSet <- readIORef dataStructure
           midPointVertex <- getEdgeMidPoint edgeId2 myGraphSet
           let midPoint = vertexToVector midPointVertex
           myNodeB <- getNode nodeB dataStructure
           let nodeBLayout = extractLayout myNodeB
           myNodeC <- getNode nodeC dataStructure
           let nodeCLayout = extractLayout myNodeC
           myNodeD <- getNode nodeD dataStructure
           let nodeDLayout = extractLayout myNodeD
           let result = sedgeTobedge newPosA nodeBLayout edgeRadius1 nodeCLayout midPoint nodeDLayout
                                     edgeRadius2 numOfCylinders
           return(result)
```

```
   else do let nodeB = to myGraphSet (head (listOfGraphId)) edgeId1
           let nodeC = to myGraphSet (head (listOfGraphId)) edgeId2
           let nodeD = from myGraphSet (head (listOfGraphId)) edgeId2
           myGraphSet <- readIORef dataStructure
           midPointVertex <- getEdgeMidPoint edgeId2 myGraphSet
           let midPoint = vertexToVector midPointVertex
           myNodeB <- getNode nodeB dataStructure
           let nodeBLayout = extractLayout myNodeB
           myNodeC <- getNode nodeC dataStructure
           let nodeCLayout = extractLayout myNodeC
           myNodeD <- getNode nodeD dataStructure
           let nodeDLayout = extractLayout myNodeD
           let result = sedgeTobedge newPosA nodeBLayout edgeRadius1 nodeCLayout midPoint nodeDLayout
                                     edgeRadius2 numOfCylinders
           return(result)
```

These are utility functions and default values/attributes for the new nodes that are to be added.

```
xcoord :: Vector3 a -> a
xcoord (Vector3 a b c) = a

ycoord :: Vector3 a -> a
ycoord (Vector3 a b c) = b

zcoord :: Vector3 a -> a
zcoord (Vector3 a b c) = c

isMember :: Id -> [Id] -> Prelude.Bool
isMember x (y:ys) = (x==y) && isMember x ys
isMember x []     = False

vertexToVector (Vertex3 a b c ) = ( Vector3 a b c )
```

xe sci Ptg module DrawEdge provides a function to render the edges of the graph. The secret this module hides is the way this is achieved. The basic concept is that we go through the list of edges and render them one by one. There are 4 types of edges in this case. Directed both bent and straight and also undirected both bent and stright. Some design decisions to be noted are that:
1- A bent edge is represented by several straight edges, where the number of those can be adjusted by the user depending on the tradeoff between speed of rendering and quality.
2- A directed edge is represented by an edge that decreases in radius as we go from the source to the target.

```
module DrawEdge (edgeDrawLoop) where


import System.Exit ( exitWith, ExitCode(ExitSuccess) )
import Graphics.UI.GLUT
import System.Exit(exitWith, ExitCode(ExitSuccess), exitFailure)
import LabelDisplay
import GraphInterface
import Gxl_1_0_1_DTD
```

```
import GXL_DTD
import Data.IORef  ( IORef, newIORef, readIORef, modifyIORef, writeIORef)
import SettingsDataStructure

type Label = String
```

Here we define some color constants that we will be using when we draw the edge.

```
diffuseColor::Color4 GLfloat
diffuseColor = Color4 0.1 0.5 0.8 1.0

specularColor::Color4 GLfloat
specularColor = Color4 1.0 1.0 1.0 1.0

shininess::GLfloat
shininess = 50.0

emisionColor::Color4 GLfloat
emisionColor = Color4 0.0 0.0 0.0 1.0
```

A bent edge is draw as a number of straight edges. The number of straight edges used is determined by step and what tFunction returns is the positions of those straight edges along the bent edge

```
tFunction :: Prelude.Int -> [GLfloat]
tFunction step = [fromIntegral i/fromIntegral step | i<-[0..step]]
```

edgeDrawLoop is a function which given a graph set and the list of edges forming that graph set will loop through all the edges in the list and draw them. So the way the function works is by first getting an edge from the list , extract its color, label, quadric style and the two nodes it connects and possibly the control point. If the control point is not there a straight edge is drawn otherwise a bent edge is drawn. Each edge is assigned an ID on the name stack before its drawn. This process is done for every edge in the list, recursively, until we go thorugh all the list.

```
edgeDrawLoop :: IORef GxlGraphSet -> [GXL_DTD.Id] -> IORef SettingsDataStructure -> IO()
edgeDrawLoop dataStructure (x:xs) settings = do
      myGraphSet <- readIORef dataStructure
                                    myColor <- getItemColor4 x dataStructure
      myQuadricStyle <- getEdgeQuadricStyle x dataStructure
      myLabel <- getItemLabel x dataStructure
      myRadius <- getItemRadius x dataStructure
      mySlices <- getItemSlices x dataStructure
      myStacks <- getItemStacks x dataStructure
      myGraphSet <- readIORef dataStructure
      mySettings <- readIORef settings
          myNum <- getNumOfCylinders mySettings
          step <- readIORef (myNum)
      p1 <- getFromNode x myGraphSet
                                    p2 <- getEdgeMidPoint x myGraphSet
                                    p3 <- getToNode x myGraphSet
```

```
      loadName (Name (read (show x)::GLuint))
      --straight edge case
      if (p2==defaultNoMidPoint)
       then do
         isEdgeDirected<-getDirectedOrNot x myGraphSet
 if (isEdgeDirected==True)
        --straight directed Edge
  then do drawStraightDirectedEdge (xcoord p1) (ycoord p1) (zcoord p1) (xcoord p3) (ycoord p3)
          (zcoord p3) myQuadricStyle myLabel myColor myRadius
          mySlices myStacks
  --straight undirected Edge
else do drawUndirectedEdge (xcoord p1) (ycoord p1) (zcoord p1) (xcoord p3) (ycoord p3) (zcoord p3)
        myQuadricStyle myLabel myColor myRadius
        mySlices myStacks
 edgeDrawLoop dataStructure xs settings
       --bent edge
       else do
         isEdgeDirected<-getDirectedOrNot x myGraphSet
         if (isEdgeDirected==True)
                --bent directed edge
                then do drawDirectedBentEdge p1 p2 p3 (tFunction step) myQuadricStyle myLabel myColor
                        myRadius mySlices myStacks settings
                --bent undirected edge
else do drawUndirectedBentEdge p1 p2 p3 (tFunction step) myQuadricStyle myLabel myColor myRadius
        mySlices myStacks settings
      edgeDrawLoop dataStructure xs settings
edgeDrawLoop dataStructure _ _ = do
                             return ()
```

decrease is a function which will help us to compute the radius of the directed edge which decreases as we go along from the source to the target.

```
decrease :: Prelude.Int -> GLdouble -> GLdouble
decrease step = \r -> (r - r/fromIntegral step)
```

Here are three functions which return the x-coordinate, the y-coordinate and the z-coordinate of a Vertex respectively.

```
xcoord::Vertex3 a -> a
xcoord (Vertex3 a b c) = a

ycoord::Vertex3 a -> a
ycoord (Vertex3 a b c) = b

zcoord::Vertex3 a -> a
zcoord (Vertex3 a b c) = c
```

fx,fy,fz are the three components of the interpolation function, which will give us the points we will pass the edge through. Three points will be given p1,p2,p3 where they represent the center of the source node, the center of the target node and the control point.

```
fx :: (Vertex3 GLfloat) -> (Vertex3 GLfloat) -> (Vertex3 GLfloat) -> GLfloat -> GLfloat
fx p1 p2 p3 t = (1.0-t)**2*(xcoord p1) + 2.0*t*(1.0-t)*(xcoord p2) + t**2 * (xcoord p3)
```

```
fy :: (Vertex3 GLfloat) -> (Vertex3 GLfloat) -> (Vertex3 GLfloat) -> GLfloat -> GLfloat
fy p1 p2 p3 t = (1.0-t)**2*(ycoord p1) + 2.0*t*(1.0-t)*(ycoord p2) + t**2 * (ycoord p3)

fz :: (Vertex3 GLfloat) -> (Vertex3 GLfloat) -> (Vertex3 GLfloat) -> GLfloat -> GLfloat
fz p1 p2 p3 t = (1.0-t)**2*(zcoord p1) + 2.0*t*(1.0-t)*(zcoord p2) + t**2 * (zcoord p3)
```

interp is a function which maps the a set of points into their correspondent interpolation.

```
interp :: ((Vertex3 GLfloat) -> (Vertex3 GLfloat) -> (Vertex3 GLfloat) -> GLfloat -> GLfloat) -> (Vertex3 GLfloat)
-> (Vertex3 GLfloat) -> (Vertex3 GLfloat) -> [GLfloat] -> [GLfloat]
interp f p1 p2 p3 list = map (f p1 p2 p3)  list
```

checkForError is a function used in order to handle errors caused by render quadric.

```
checkForError :: IO (Maybe Error) -> IO ()
checkForError action = do
   maybeError <- action
   case maybeError of
      Nothing ->  return ()

      Just (Error _category description) -> do exitFailure
```

drawStraightDirectedEdge is a function which given the coordinates of the centers of two nodes will draw a straight directed edge between them. This is used when want to draw one edge only. drawDirectedEdge will be used when we want to draw several of them to form a bent edge.

```
drawStraightDirectedEdge :: GLfloat ->GLfloat ->GLfloat ->GLfloat ->GLfloat ->QuadricStyle -> Label
-> Color4 GLfloat -> GLdouble->GLint ->GLint -> IO()
drawStraightDirectedEdge x1 y1 z1 x2 y2 z2 myQuadricStyle myLabel myColor myRadius mySlices myStacks= do
       preservingMatrix $ do
         --move to the source node
         translate (Vector3 x1 y1 z1 :: Vector3 GLfloat)
         rotate (angle :: GLfloat) (Vector3 rx ry 0)
         --set the color
         materialAmbient   Front $= myColor
         materialDiffuse   Front $= diffuseColor
         materialSpecular  Front $= specularColor
         materialShininess Front $= shininess
         materialEmission  Front $= emisionColor
         --draw the directed edge with a decreasing radius from source to target
         checkForError $renderQuadric myQuadricStyle
                         (Cylinder myRadius (myRadius/2) ((realToFrac length)::GLdouble) mySlices myStacks)
       swapBuffers
                           where rx    = (y1-y2)
                                 ry    = (x2-x1)
                                 length= sqrt((x2-x1)**2+(y2-y1)**2 +(z2-z1)**2)
                                 angle = (180.0/pi)*acos((z2-z1)/(sqrt((x2-x1)**2+(y2-y1)**2 +(z2-z1)**2)))
```

drawDirectedEdge is a function which given the coordinates of two points will draw a straight directed edge between them. This is used when want to draw a bent edge as we will call it recursively. Each time we go through we decrease the radius to make it look like its going from one node to another.

```
drawDirectedEdge :: GLfloat ->GLfloat ->GLfloat ->GLfloat ->GLfloat ->GLfloat ->QuadricStyle -> Label
-> Color4 GLfloat -> GLdouble ->GLint ->GLint -> IORef SettingsDataStructure -> IO()
drawDirectedEdge x1 y1 z1 x2 y2 z2 myQuadricStyle myLabel myColor myRadius mySlices myStacks settings= do
       preservingMatrix $ do
         --move to the source point
         translate (Vector3 x1 y1 z1 :: Vector3 GLfloat)
         rotate (angle :: GLfloat) (Vector3 rx ry 0)
 mySettings <- readIORef settings
     myNum <- getNumOfCylinders mySettings
     step <- readIORef (myNum)
     --set the color
         materialAmbient   Front $= myColor
         materialDiffuse   Front $= diffuseColor
         materialSpecular  Front $= specularColor
         materialShininess Front $= shininess
         materialEmission  Front $= emisionColor
         --draw the directed edge with a decreasing radius from source to target
         checkForError $renderQuadric myQuadricStyle
                       (Cylinder myRadius (myRadius-myRadius/fromIntegral step) ((realToFrac length)::GLdouble) mySli
       swapBuffers

                         where rx    = (y1-y2)
                               ry    = (x2-x1)
                               length= sqrt((x2-x1)^2+(y2-y1)^2 +(z2-z1)^2)
                               angle = (180.0/pi)*acos((z2-z1)/(sqrt((x2-x1)^2+(y2-y1)^2 +(z2-z1)^2)))
```

drawUnDirectedEdge is a function which given the coordinates of any two points in space will draw a straight undirected edge between them. Here the radius is the same all the way through since it is undirected.

```
drawUndirectedEdge :: GLfloat ->GLfloat ->GLfloat ->GLfloat ->GLfloat ->GLfloat -> QuadricStyle -> Label
-> Color4 GLfloat -> GLdouble ->GLint ->GLint ->IO()
drawUndirectedEdge x1 y1 z1 x2 y2 z2 myQuadricStyle myLabel myColor myRadius mySlices myStacks = do
       preservingMatrix $ do
         --move to the source point
         translate (Vector3 x1 y1 z1 :: Vector3 GLfloat)
         rotate (angle :: GLfloat) (Vector3 rx ry 0)
         --set the color
         materialAmbient   Front $= myColor
         materialDiffuse   Front $= diffuseColor
         materialSpecular  Front $= specularColor
         materialShininess Front $= shininess
         materialEmission  Front $= emisionColor
         --draw the undirected edge with a constant radius from source to target
         checkForError $renderQuadric myQuadricStyle
                       (Cylinder myRadius myRadius ((realToFrac length)::GLdouble) mySlices myStacks)
       swapBuffers
                         where rx    = (y1-y2)
                               ry    = (x2-x1)
                               length= sqrt((x2-x1)**2+(y2-y1)**2 +(z2-z1)**2)
                               angle = (180.0/pi)*acos((z2-z1)/(sqrt((x2-x1)**2+(y2-y1)**2 +(z2-z1)**2)))
```

getknotDirected is the function which goes throught the intermediate points of a bent directed edge and calls the drawing function to render smaller straight edges between those points. This is done recursivily until we go through all the intermediate points we have. As mentionned before the radius decreases as we go along and the number of cylinders used is controlled by the user.//

```
getknotDirected  :: [GLfloat] -> [GLfloat] -> [GLfloat] -> QuadricStyle -> Label -> Color4 GLfloat
-> GLdouble ->GLint ->GLint -> IORef SettingsDataStructure -> IO()
getknotDirected  [] [] [] _ _ _ _ _ _ _                    = return()
getknotDirected  (x:[]) (y:[]) (z:[]) _ _ _ _ _ _ _       = return()
getknotDirected  (x1:x2:x) (y1:y2:y) (z1:z2:z) myQuadricStyle myLabel myColor myRadius mySlices myStacks settings = do
         mySettings <- readIORef settings
     myNum <- getNumOfCylinders mySettings
     step <- readIORef (myNum)
         drawDirectedEdge x1 y1 z1 x2 y2 z2 myQuadricStyle myLabel myColor myRadius mySlices myStacks settings
         getknotDirected (x2:x) (y2:y) (z2:z) myQuadricStyle myLabel myColor (decrease step myRadius) mySlices myStacks
```

getknotUnDirected is the function which goes throught the intermediate points of a bent undirected edge and calls the drawing function to render smaller straight edges between those points. This is done recursivily until we go through all the intermediate points we have. As mentionned before the radius here does not change as we go along and the number of cylinders used is controlled by the user.//

```
getknotUndirected  :: [GLfloat] -> [GLfloat] -> [GLfloat] -> QuadricStyle -> Label -> Color4 GLfloat
-> GLdouble ->GLint ->GLint -> IO()
getknotUndirected  [] [] [] _ _ _ _ _ _                    = return()
getknotUndirected  (x:[]) (y:[]) (z:[]) _ _ _ _ _ _      = return()
getknotUndirected  (x1:x2:x) (y1:y2:y) (z1:z2:z) myQuadricStyle myLabel myColor myRadius mySlices myStacks = do
         drawUndirectedEdge x1 y1 z1 x2 y2 z2 myQuadricStyle myLabel myColor myRadius mySlices myStacks
         getknotUndirected (x2:x) (y2:y) (z2:z) myQuadricStyle myLabel myColor myRadius mySlices myStacks
```

drawDirectedBentEdge is the top level function which coordinates the process of rendering a directed bent edge, by calling the functions mentionned above. The Label is displayed and then control is passed on to the rest of the functions.

```
drawDirectedBentEdge :: (Vertex3 GLfloat) -> (Vertex3 GLfloat) -> (Vertex3 GLfloat) -> [GLfloat]
->QuadricStyle -> Label -> Color4 GLfloat-> GLdouble ->GLint -> GLint
-> IORef SettingsDataStructure -> IO()
drawDirectedBentEdge p1 p2 p3 t myQuadricStyle myLabel myColor myRadius mySlices myStacks settings = do
   --clear the color
   clearColor $= Color4 0 0.0 0.0 0.0
   --display the label
   fontOffset <- makeRasterFont
   let myVector = vertexToVector p2
   translate myVector
   glRasterPos2s (0) (0)
   printString fontOffset myLabel
   --go back to original position
   translate (reverseTranslate myVector)
   --get the number of cyliders to be used
   mySettings <- readIORef settings
```

```
   myNum <- getNumOfCylinders mySettings
   step <- readIORef (myNum)
   --interpolate and draw
   let  xlist = interp fx p1 p2 p3 (tFunction step)
   let  ylist = interp fy p1 p2 p3 (tFunction step)
   let  zlist = interp fz p1 p2 p3 ((tFunction step)::[GLfloat])
   getknotDirected xlist ylist zlist myQuadricStyle myLabel myColor myRadius mySlices myStacks settings
```

drawUnDirectedBentEdge is the top level function which coordinates the process of rendering an undirected bent edge, by calling the functions mentionned above. The Label is displayed and then control is passed on to the rest of the functions.

```
drawUndirectedBentEdge :: (Vertex3 GLfloat) -> (Vertex3 GLfloat) -> (Vertex3 GLfloat) -> [GLfloat]
->QuadricStyle -> Label -> Color4 GLfloat-> GLdouble ->GLint -> GLint
-> IORef SettingsDataStructure -> IO()
drawUndirectedBentEdge p1 p2 p3 t myQuadricStyle myLabel myColor myRadius mySlices myStacks settings = do
   --clear the color
   clearColor $= Color4 0 0.0 0.0 0.0
   --display the label
   fontOffset <- makeRasterFont
   let myVector = vertexToVector p2
   translate myVector
   glRasterPos2s (0) (0)
   printString fontOffset myLabel
   --go back to original position
   translate (reverseTranslate myVector)
   mySettings <- readIORef settings
   myNum <- getNumOfCylinders mySettings
   step <- readIORef (myNum)
   --interpolate and draw
   let  xlist = interp fx p1 p2 p3 (tFunction step)
   let  ylist = interp fy p1 p2 p3 (tFunction step)
   let  zlist = interp fz p1 p2 p3 (tFunction step)
   getknotUndirected xlist ylist zlist myQuadricStyle myLabel myColor myRadius mySlices myStacks
```

vertextoVector is a function which gives us the vector corresponding to the vertex we pas to it.

```
vertexToVector ::  (Vertex3 GLfloat) -> (Vector3 GLfloat)
vertexToVector (Vertex3 a b c) = Vector3 a b c
```

reverseTranslate is a function which gives us the vector opposite in direction to the one we pass to it.

```
reverseTranslate :: (Vector3 GLfloat) -> (Vector3 GLfloat)
reverseTranslate (Vector3 x y z) = (Vector3 (-x) (-y) (-z))
```

Module DrawGraph, as the name indicates, gives us functions and facilities to draw a given graph. The secret it hides is how the graph is drawn.

```
module DrawGraph (displayGraph)  where

import Data.IORef  ( IORef, newIORef, readIORef, modifyIORef, writeIORef)
import IO
```

```
import Graphics.Rendering.OpenGL.GL
import Graphics.Rendering.OpenGL.GLU
import Graphics.UI.GLUT
import System.Exit(exitWith, ExitCode(ExitSuccess), exitFailure)
import Node
import LabelDisplay
import GraphInterface
import Gxl_1_0_1_DTD
import GXL_DTD
import ViewDataStructure
import GxlGraphSetManage
import Data.FiniteMap
import Text.XML.HaXml.OneOfN
import DrawEdge
import DrawNode
import SettingsDataStructure
```

displayGraph is a function which given a view and a graphSet it displays that graph from that particular view. This is achieved in the following manner, first the color buffer and the depth buffer are cleared, the background color is set to black and the view is loaded by setting the corresponding horizontal component, vertical component and the camera distance. After this is done, the graph is displayed. The transformations done to change the view are saved so that we can go back to the original coordinate system when it is necessary to do so. Since when we rotate the view the axis are changed.

```
displayGraph ::IORef View -> IORef GxlGraphSet -> IORef [GLdouble] -> IORef SettingsDataStructure -> DisplayCallback
displayGraph view dataStructure matrixStore settings = do
        clear [ColorBuffer, DepthBuffer]
        color (Color3 1.0 1.0 1.0 :: Color3 GLfloat)
        myView <- readIORef view
        preservingMatrix $ do
          let depth = getCameraDistance myView
          --rotate the view vertically
          let v = getVertical myView
          rotate ((read (show v))::Prelude.Float) (Vector3 1 0 0)
          --rotate the view horizontally
          let h = getHorizontal myView
          rotate  ((read (show h))::Prelude.Float) (Vector3 0 1 0)
          --get the current transformation matrix
          m1@(mvMatrix::(GLmatrix GLdouble))  <- get currentMatrix
          component <- getMatrixComponents ColumnMajor m1
          --zoom the view according to old coordinate system
          newVector <- transformVector (Vector3 0.0 0.0 depth) component
          translate newVector
          --update the transformation matrix
          m1@(mvMatrix::(GLmatrix GLdouble))  <- get currentMatrix
          component <- getMatrixComponents ColumnMajor m1
          --save the transformation matrix
          modifyIORef matrixStore (\x -> component)
          --draw the gaph
          drawGraph dataStructure matrixStore settings
        swapBuffers
```

drawGraph is a function which coordinates the drawing of the graph from a given graph set. Basically, it reads the graph set and extracts the list of nodes and the list of edges and appropriately calls the drawing functions for nodes

and edges.It also displays the x, y and z axis if this option is toggled on.

```
drawGraph :: IORef GxlGraphSet -> IORef [GLdouble] -> IORef SettingsDataStructure -> IO()
drawGraph dataStructure matrixStore settings = do
   myGraphSet <- readIORef dataStructure
   --get the list of nodes and draw them
   myNodeList <- getListOfNodes myGraphSet
   nodeDrawLoop dataStructure myNodeList
   --get the list of edges and draw them
   myEdgeList <- getListOfEdges myGraphSet
   edgeDrawLoop dataStructure myEdgeList settings
   --draw and label the different axis if the display axis is toggled on
   mySettings <- readIORef settings
   myAxisOnIORef <- getAxisOn mySettings
   myAxisOn <- readIORef myAxisOnIORef
   if (myAxisOn == True)
    then do fontOffset <- makeRasterFont
        translate (Vector3 (5) 0.2 0.0 :: Vector3 GLfloat)
        glRasterPos2s 0 0
        printString fontOffset "X-AXIS"
        translate (Vector3 (-5) (-0.2) 0.0 :: Vector3 GLfloat)
        renderPrimitive Lines $ do
            vertex3f(Vertex3 (-10) 0 0)
            vertex3f(Vertex3 10 0 0)
        fontOffset <- makeRasterFont
        translate (Vector3 0.2 (5) 0.0 :: Vector3 GLfloat)
        glRasterPos2s 0 0
        printString fontOffset "Y-AXIS"
        translate (Vector3 (-0.2) (-5) 0.0 :: Vector3 GLfloat)
        renderPrimitive Lines $ do
             vertex3f(Vertex3 0 (-10) 0)
             vertex3f(Vertex3 0 10 0)
        fontOffset <- makeRasterFont
        translate (Vector3 0.0 0.2  (5) :: Vector3 GLfloat)
        glRasterPos2s 0 0
        printString fontOffset "Z-AXIS"
        translate (Vector3 0.0 (-0.2) (-5) :: Vector3 GLfloat)
        renderPrimitive Lines $ do
            vertex3f(Vertex3 0 0 (-10))
            vertex3f(Vertex3 0 0 10)
        return()
    else do return()

--vertex3f is an auxilliaury function to gives us the type IO from Vertex3
vertex3f = vertex :: Vertex3 GLfloat -> IO ()
```

transformVector and transformVertex are functions which given a Vector or a Vertex respectively and a list representing the matrix that the sapce has been multiplied by, will give us the new transformed Vector/Vertex according to the new set of axis in the current space. This is important so that when we rotate the space we conserve the horizontal/vertical/depth movement irregardless of the direction of the axis.

```
transformVector :: Vector3 GLfloat -> [GLdouble] -> IO (Vector3 GLfloat)
transformVector (Vector3 a b c) xs = do
    let newa = ((read(show(xs !! 0))::GLfloat) * a) + ((read(show(xs !! 1))::GLfloat) * b) +
               ( (read(show(xs !! 2))::GLfloat) * c)
    let newb = ((read(show(xs !! 4))::GLfloat) * a) + ((read(show(xs !! 5))::GLfloat) * b) +
               ( (read(show(xs !! 6))::GLfloat) * c)
    let newc = ((read(show(xs !! 8))::GLfloat) * a) + ((read(show(xs !! 9))::GLfloat) * b) +
               ( (read(show(xs !! 10))::GLfloat) * c)
    return (Vector3 newa newb newc)

transformVertex :: Vertex3 GLdouble -> [GLdouble] -> IO (Vertex3 GLdouble)
transformVertex (Vertex3 a b c) xs = do
    let newa = ((read(show(xs !! 0))::GLdouble) * a) + ((read(show(xs !! 1))::GLdouble) * b) +
               ( (read(show(xs !! 2))::GLdouble) * c)
    let newb = ((read(show(xs !! 4))::GLdouble) * a) + ((read(show(xs !! 5))::GLdouble) * b) +
               ( (read(show(xs !! 6))::GLdouble) * c)
    let newc = ((read(show(xs !! 8))::GLdouble) * a) + ((read(show(xs !! 9))::GLdouble) * b) +
               ( (read(show(xs !! 10))::GLdouble) * c)
    return (Vertex3 newa newb newc)
```

Module DrawNode provides a function to render the nodes of the graph. The secret this module hides is the way this is achieved. The basic concept is that we go through the list of nodes and render them one by one.//

```
module DrawNode (nodeDrawLoop) where

import System.Exit ( exitWith, ExitCode(ExitSuccess) )
import Graphics.UI.GLUT
import System.Exit(exitWith, ExitCode(ExitSuccess), exitFailure)
import LabelDisplay
import GraphInterface
import Gxl_1_0_1_DTD
import GXL_DTD
import Node
import Data.IORef  ( IORef, newIORef, readIORef, modifyIORef, writeIORef)
```

checkForError is a function used in order to handle errors caused by render quadric.

```
checkForError :: IO (Maybe Error) -> IO ()
checkForError action = do
   maybeError <- action
   case maybeError of
      Nothing ->  return ()
      Just (Error _category description) -> do exitFailure
```

Here we define some color constants that we will be using when we draw the node.

```
diffuseColor::Color4 GLfloat
diffuseColor = Color4 0.1 0.5 0.8 1.0

specularColor::Color4 GLfloat
```

```
specularColor = Color4 1.0 1.0 1.0 1.0

shininess::GLfloat
shininess = 50.0

emisionColor::Color4 GLfloat
emisionColor = Color4 0.0 0.0 0.0 1.0
```

drawNode is a function which given a Node data structure it displays the corresponding node on the screen. This is done by first resetting the color to white. Then the label associated with the node is displayed. Finally the object is rendered with the appropriate attributes.

```
drawNode :: Node.Node -> IO()
drawNode node = do
     --get the necessary information
     let myLabel = extractLabel node
     let myQuadricStyle = extractQuadricStyle node
     let myQuadricPrimitive = extractQuadricPrimitive node
     let myColor = extractColor node
     --reset the color to white
     clearColor $= Color4 0 0.0 0.0 0.0
     --display the label
     fontOffset <- makeRasterFont
     translate (Vector3 (0.8) 0.2 0.0 :: Vector3 GLfloat)
     glRasterPos2s 0 0
     printString fontOffset myLabel
     translate (Vector3 (-0.8) (-0.2) 0.0 :: Vector3 GLfloat)
     --setup the colors and render node
     materialAmbient   Front $= myColor
     materialDiffuse   Front $= diffuseColor
     materialSpecular  Front $= specularColor
     materialShininess Front $= shininess
     materialEmission  Front $= emisionColor
     checkForError $
        renderQuadric myQuadricStyle myQuadricPrimitive
```

nodeDrawLoop is a function which given a graph set and the list of nodes forming that graph set will loop through all the nodes in the list and draw them at the appropriate location given by the layout. Each transformation done to reach the correct position must be undone so that the next transformation starts from the beginning. So the way the function works is by first getting a node from the list, extract its layout information, apply the correct transformation, assign it an ID on the name stack, draw it and then undo the transformation. This process is done for every node in the list, recursively, until we go thorugh all the list.

```
nodeDrawLoop :: IORef GxlGraphSet -> [GXL_DTD.Id] -> IO()
nodeDrawLoop dataStructure (x:xs) = do
  myNode <- getNode x dataStructure
  let myVector = extractLayout myNode
  translate (myVector)
  loadName (Name (read (show x)::GLuint))
  drawNode myNode
  translate (reverseTranslate (myVector) )
```

```
  nodeDrawLoop dataStructure xs

nodeDrawLoop myGraphSet _ = do return ()
```

reverseTranslate is a function which gives us the vector opposite in direction to the one we pass to it.

```
reverseTranslate :: (Vector3 GLfloat) -> (Vector3 GLfloat)
reverseTranslate (Vector3 x y z) = (Vector3 (-x) (-y) (-z))
```

Module EdgeManipulation is responsible for the manipulation of the edges in the program. Any change to the edges in the graph corresponds to changes in the graph data structure. The information in the graph data structure is updated according to how the nodes are manipulated. The only possible changes that can be done to edges that requires changes to the data structure are addition and bending of edges. Changes such as removal of edges and attribute changes(color,size,etc.) are generalized in the ItemManipulation module for both nodes and edges. The functions that are of concern here deals with addition and bending of an edge. The functions which manipulate bending of an edge is represented by how the user bends the edge. Dragging the mouse after clicking on an edge corresponds to 'bendEdgeButtonDown' while bending the edge in the Z-plane using the wheel corresponds to 'bendEdgeWheelUp' and 'bendEdgeWheelDown'.

The service of this module is that it provides a set of functions to add edges in the graph data structure and bend the edges. The secret of this module is the way the edges are added and the methods that are used to bend an edge.

```
module EdgeManipulation (addEdge,bendEdgeWheelUp,bendEdgeWheelDown,bendEdgeButtonDown)  where

import Text.XML.HaXml.Xml2Haskell
import Gxl_1_0_1_DTD
import GXL_DTD
import INIT
import Data.IORef
import Graphics.Rendering.OpenGL.GL
import Graphics.Rendering.OpenGL.GLU
import Graphics.UI.GLUT
import ViewDataStructure
import UndoDataStructure
import GraphInterface
import Text.XML.HaXml.OneOfN
import Node
import Utils
import GxlGraphSetManage
import PickObject
import SettingsDataStructure
import Collision
import Additional
```

Function addEdge is the function which is called by the keyboard mouse callback in the main program for adding an edge on a particular point on the screen. It takes in as parameters: a) the Graph data structure to be modified b) the coordinates where the user clicked the mouse on c) the Undo data structure to save a copy of the data structure before the node is added d) the current transformation matrix to determine where to place the node according to the graph's axis e) the View data structure to determine the current distance of the camera from the objects f) the Settings data structure to determine if collision is toggled on or off

Adding an edge is done by selecting the source node and then selecting the target node. If the source node and target node is valid, then an edge will added from the source node to the target node.

```
addEdge :: IORef GxlGraphSet -> GLsizei -> GLsizei -> IORef View -> IORef GXL_DTD.Id -> IORef GXL_DTD.Id
-> Prelude.String -> IORef UndoDataStructure ->IORef [GLdouble] -> IORef SettingsDataStructure -> IO()
addEdge dataStructure x y view currentItem1 currentItem2 directedOrNot undoDataStructure matrixStore settings = do
```

This function starts off by checking if the source node has been selected yet. If it is, the node which was selected will be recorded. If the source node has been selected already, then the function proceeds by using the mouse coordinates to record the target node. If both nodes are properly recorded, then the function can proceed.

```
   sourceNode <- readIORef currentItem1
   if (sourceNode==0)
    then do selectedNode <- selectObject view x y dataStructure matrixStore settings
            let newSelectedNode = (read ( show selectedNode))::GXL_DTD.Id
            modifyIORef currentItem1 (\x->newSelectedNode)
    else do selectedNode <- selectObject view x y dataStructure matrixStore settings
            let newSelectedNode = (read ( show selectedNode))::GXL_DTD.Id
            sourceNode <- readIORef currentItem1
        if ((newSelectedNode==0)||(sourceNode==newSelectedNode))
         then do return()
         else do modifyIORef currentItem2 (\d->newSelectedNode)
                 myGraphSet <- readIORef dataStructure
                 let listOfGraphID = getGxlGraphs myGraphSet
                 let graphGXLid = unMaybe (getGXLId myGraphSet (head listOfGraphID))
                 let edgeMode =getGraphEdgeMode myGraphSet graphGXLid
```

If the Gxl file that we are dealing with has its edgemode as undirected, then the user is not allowed to add a directed edge and vice versa. Those two cases are handled here by resetting the recorded source and target nodes to zero again.

```
     if (((edgeMode==Graph_edgemode_undirected)&&(directedOrNot=="Item_isdirected_true"))||
         ((edgeMode==Graph_edgemode_directed)&&(directedOrNot=="Item_isdirected_false")))
       then do modifyIORef currentItem1 (\x-> 0)
               modifyIORef currentItem2 (\x-> 0)
               return()
```

Here we call the function newEdge which actually does the adding of the edge into the graph data structure.

```
            else do newEdge dataStructure currentItem1 currentItem2 directedOrNot settings undoDataStructure
                    return()
   return()
```

newEdge does the actual construction of a new edge with default attributes and adds it into the graph data structure.

```
newEdge :: IORef GxlGraphSet -> IORef (GXL_DTD.Id) -> IORef (GXL_DTD.Id) -> Prelude.String ->
IORef SettingsDataStructure -> IORef UndoDataStructure -> IO()
newEdge dataStructure currentItem1 currentItem2 directedOrNot settings undoDataStructure = do
  sourceNode <- readIORef currentItem1
  targetNode <- readIORef currentItem2
  mydataStructure <- readIORef dataStructure
  let listOfGraphID = getGxlGraphs mydataStructure
  let graphGXLid = unMaybe (getGXLId mydataStructure (head listOfGraphID))
  myListOfEdges <- getListOfEdges mydataStructure
  myListOfNodes <- getListOfNodes mydataStructure
  mySettings <- readIORef settings
  collisionOnIORef <- getCollisionOn mySettings
```

Collision checking is done before the edge is added. The adding edge collision checking function checks if there would be a collision when a particular edge is added before it is added. If it does not cause a collision, the function proceeds as normal to add the edge.

```
  collisionOn<-readIORef (collisionOnIORef)
  collisionDetected <- collisionDetectionNewEdge collisionOn dataStructure myListOfNodes myListOfEdges sourceNode
                       targetNode settings
  if (collisionDetected==False)
   then do
```

This section of the function constructs and adds the information about the edge into the graph data structure through the addItem function. A tentacle also has to be added in the graph data structure in the case of edges.

```
    let numberOfEdges =length(myListOfEdges)
    let newdataStructure = addItem (myEdgeItemInfo numberOfEdges directedOrNot) graphGXLid mydataStructure
    modifyIORef dataStructure (\x -> newdataStructure)
    mydataStructure2 <- readIORef dataStructure
    let sourceNodeGxlId = unMaybe (getGXLId mydataStructure2 sourceNode)
    let targetNodeGxlId = unMaybe (getGXLId mydataStructure2 targetNode)
    tentOut <- myTentacleInfoOut dataStructure numberOfEdges targetNodeGxlId
    let newGraphSet1 = addTent tentOut mydataStructure2
    modifyIORef dataStructure (\x -> newGraphSet1)
    mydataStructure3 <- readIORef dataStructure
    tentIn <- myTentacleInfoIn dataStructure numberOfEdges sourceNodeGxlId
    let finaldataStructure = addTent tentIn mydataStructure3
    --trick to make undo work restore so that if undone go back
    modifyIORef dataStructure (\x ->mydataStructure)
    updateGraphDataStructure finaldataStructure dataStructure undoDataStructure
    modifyIORef currentItem1 (\x-> 0)
    modifyIORef currentItem2 (\x-> 0)
    else do modifyIORef currentItem1 (\x-> 0)
            modifyIORef currentItem2 (\x-> 0)
```

collisionDetectionNewEdge is the function which returns true when collision is detected for adding a specified edge in the data structure, or false if collision is not detected.

```
collisionDetectionNewEdge::Prelude.Bool-> IORef GxlGraphSet -> [GXL_DTD.Id] -> [GXL_DTD.Id]
-> GXL_DTD.Id -> GXL_DTD.Id -> IORef SettingsDataStructure-> IO(Prelude.Bool)
collisionDetectionNewEdge collisionOn dataStructure myListOfNodes myListOfEdges sourceNode targetNode settings =
  if (collisionOn==True) then do collisionDetected <- newEdgeCollision dataStructure myListOfNodes
                                                      myListOfEdges sourceNode targetNode 10 settings
                              return(collisionDetected)
                         else do return(False)
```

myTentacleInfoIn returns a complete tentacle that is associated with the source node that is constructed for the edge.

```
myTentacleInfoIn dataStructure numberOfEdges nodeFrom = do
 newTentacleIn <- myTentacleAttrIn dataStructure numberOfEdges nodeFrom
 let completeTentacleIn = TentacleInfo [] newTentacleIn
 return (completeTentacleIn)
```

myTentacleInfoOut returns a complete tentacle that is associated with the target node that is constructed for the edge.

```
myTentacleInfoOut dataStructure numberOfEdges nodeTo = do
 newTentacleOut <- myTentacleAttrOut dataStructure numberOfEdges nodeTo
 let completeTentacleOut = TentacleInfo [] newTentacleOut
 return (completeTentacleOut)
```

myTentacleAttrOut returns a tentacle attribute specifically for specifying where the target node of the edge, used in the construction of a complete tentacle. The Gxl Id for the new edge would be "Edge x" where x is the number of edges in the graph.

```
myTentacleAttrOut dataStructure numberOfEdges nodeTo = do
       mydataStructure <- readIORef dataStructure
       let edgeItemId = getInnerId mydataStructure ("Edge"++" "++(show(numberOfEdges)))
       let myTentacleOut = TentacleAttr edgeItemId nodeTo Nothing (Just Out) Nothing Nothing
       return (myTentacleOut)
```

myTentacleAttrIn returns a tentacle attribute specifically for specifying where the source node of the edge, used in the construction of a complete tentacle. The Gxl Id for the new edge would be "Edge x" where x is the number of edges in the graph.

```
myTentacleAttrIn dataStructure numberOfEdges nodeFrom =  do
       mydataStructure <- readIORef dataStructure
       let edgeItemId = getInnerId mydataStructure ("Edge"++" "++(show(numberOfEdges)))
       let myTentacleIn  = TentacleAttr edgeItemId nodeFrom Nothing (Just In) Nothing Nothing
       return (myTentacleIn)
```

myEdgeItemAttr returns a default ItemAttr for the new edge item for the construction of a new edge.

```
myEdgeItemAttr numberOfEdges directedOrNot = ItemAttr FEdge (Just ("Edge"++" "++(show(numberOfEdges))))
                                             (Just ((read directedOrNot)::Item_isdirected))
myEdgeItemInfo numberOfEdges directedOrNot = ItemInfo Nothing [] [] [] (myEdgeItemAttr
                                             numberOfEdges directedOrNot)
```

bendEdgeWheelUp is the function which handles bending of edges in the z axis of the screen(towards and away from user). The control point of the edge is shifted appropriately to simulate the edge bending in and out of the screen.

```
bendEdgeWheelUp ::IORef GxlGraphSet -> GXL_DTD.Id -> IORef SettingsDataStructure -> IORef [GLdouble]
-> IORef UndoDataStructure -> IO()
bendEdgeWheelUp dataStructure myItem settings matrixStore undoDataStructure = do
   let moveDiff = 0.1
if (myItem/=0)
 then do myGraphSet <- readIORef dataStructure
         updateGraphDataStructure myGraphSet dataStructure undoDataStructure
         myEdgeMidPoint <- bendEdgeMidPoint myItem dataStructure
         let xcoordinate = xcoordVertex myEdgeMidPoint
         let ycoordinate = ycoordVertex myEdgeMidPoint
         let zcoordinate = zcoordVertex myEdgeMidPoint
```

The translation vector which would translate the control point of the bended edge an appropriate amount is determined by multiplying the transformation matrix and the vector for z axis translation. This would then appropriately move the control point relative to the screen rather than the axis in the window.

```
         transformationMatrix <- readIORef matrixStore
         (Vector3 a b c) <- transformVector (Vector3 0 0 (-moveDiff)) transformationMatrix
         let newxcoordinate =  xcoordinate + a
         let newycoordinate =  ycoordinate + b
         let newzcoordinate = zcoordinate + c
         let newEdgeLayout = Vertex3 newxcoordinate newycoordinate (newzcoordinate::GLfloat)
         let newLayoutAttribute = processLayoutVertex newEdgeLayout
         myListOfEdges <- getListOfEdges myGraphSet
         myListOfNodes <- getListOfNodes myGraphSet
         mySettings <- readIORef settings
```

Collisions for bending edges are detected here. If collision detection is passed, then the edge will be added to the graph data structure finally. The undo data structure is also updated to the graph set previously before the edge is added.

```
         collisionOnIORef <- getCollisionOn mySettings
         collisionOn<-readIORef (collisionOnIORef)
         collisionDetected <- collisionDetectionBendEdge collisionOn dataStructure myListOfNodes
                              myListOfEdges myItem newEdgeLayout settings
         if (collisionDetected==False)
          then do mydataStructure <- readIORef dataStructure
          changeAttr dataStructure "midPoint" myItem newLayoutAttribute
          myseconddatastructure <-readIORef dataStructure
          modifyIORef dataStructure (\x -> mydataStructure)
          updateGraphDataStructure myseconddatastructure dataStructure undoDataStructure
  else do return ()
 else return()
```

This is similar with bendEdgeWheelUp, just a change in the direction of the z axis in the translation vector because this would be called when the user wants to bend an edge out of the screen.

```
bendEdgeWheelDown ::IORef GxlGraphSet -> GXL_DTD.Id -> IORef SettingsDataStructure -> IORef [GLdouble]
-> IORef UndoDataStructure -> IO()
bendEdgeWheelDown dataStructure myItem settings matrixStore undoDataStructure = do
let moveDiff = 0.1
if (myItem/=0)
 then do myGraphSet <- readIORef dataStructure
         updateGraphDataStructure myGraphSet dataStructure undoDataStructure
         myEdgeMidPoint <- bendEdgeMidPoint myItem dataStructure
         let xcoordinate = xcoordVertex myEdgeMidPoint
         let ycoordinate = ycoordVertex myEdgeMidPoint
         let zcoordinate = zcoordVertex myEdgeMidPoint
         transformationMatrix <- readIORef matrixStore
         (Vector3 a b c) <- transformVector (Vector3 0 0 moveDiff) transformationMatrix
         let newxcoordinate =  xcoordinate + a
         let newycoordinate =  ycoordinate + b
         let newzcoordinate = zcoordinate + c
         let newEdgeLayout = Vertex3 newxcoordinate newycoordinate (newzcoordinate::GLfloat)
         let newLayoutAttribute = processLayoutVertex newEdgeLayout
         myListOfEdges <- getListOfEdges myGraphSet
         myListOfNodes <- getListOfNodes myGraphSet
         mySettings <- readIORef settings
         collisionOnIORef <- getCollisionOn mySettings
         collisionOn<-readIORef (collisionOnIORef)
         collisionDetected <- collisionDetectionBendEdge collisionOn dataStructure myListOfNodes
                              myListOfEdges myItem newEdgeLayout settings
         if (collisionDetected==False)
          then do mydataStructure <- readIORef dataStructure
          changeAttr dataStructure "midPoint" myItem newLayoutAttribute
          myseconddatastructure <-readIORef dataStructure
          modifyIORef dataStructure (\x -> mydataStructure)
          updateGraphDataStructure myseconddatastructure dataStructure undoDataStructure
  else do return ()
 else return()
```

collisionDetectionBendEdge is a speciallized collision detection mechanism made specially for bending edges. It returns true if collision is detected.

```
collisionDetectionBendEdge::Prelude.Bool-> IORef GxlGraphSet -> [GXL_DTD.Id] -> [GXL_DTD.Id] ->
GXL_DTD.Id -> Vertex3 GLfloat -> IORef SettingsDataStructure-> IO(Prelude.Bool)
collisionDetectionBendEdge collisionOn dataStructure myListOfNodes myListOfEdges myItem newLayoutAttribute
settings =
  if (collisionOn==True)
   then do collisionDetected <- bendEdgeCollision dataStructure myListOfNodes myListOfEdges myItem
                                                  newLayoutAttribute settings
        return(collisionDetected)
   else do return(False)
```

bendEdgeButtonDown is responsible for edge bending while the left mouse button is held down. This together with motion call back simulates bending of edges in the x-y plane while the left mouse button is being held down.

```
bendEdgeButtonDown :: IORef View -> IORef GLfloat -> IORef GLfloat -> IORef GLfloat -> IORef GLfloat
-> IORef GxlGraphSet -> IORef GXL_DTD.Id -> IORef UndoDataStructure -> IORef SettingsDataStructure
-> IORef [GLdouble] -> GLsizei -> GLsizei -> IO()
bendEdgeButtonDown view oldx oldy newx newy currentGraphSet currentItem1 undoDataStructure settings matrixStore x y = d
  myItem <- readIORef currentItem1
  if (myItem/=0)
   then do oy <- readIORef oldy
           ox <- readIORef oldx
           modifyIORef newy (\d ->(fromIntegral y))
           modifyIORef newx (\d ->(fromIntegral x))
```

calculateBendEdge is called here to do the actual bending of the edge and the calculations on how much to bend it in accordance to the mouse movement.

```
           ny <- readIORef newy
           nx <- readIORef newx
           calculateBendEdge oldx oldy newx newy view currentGraphSet currentItem1
                             settings matrixStore undoDataStructure
           modifyIORef oldx (\d ->nx)
           modifyIORef oldy (\d ->ny)
           return()
    else return()
```

calculateBendEdge does the calculation and actual bending of the edges according to how the mouse is moved.

```
calculateBendEdge :: IORef GLfloat -> IORef GLfloat -> IORef GLfloat -> IORef GLfloat -> IORef View
-> IORef GxlGraphSet -> IORef GXL_DTD.Id -> IORef SettingsDataStructure
->IORef [GLdouble] -> IORef UndoDataStructure -> IO()
calculateBendEdge oldx oldy newx newy view currentGraphSet currentItem1 settings matrixStore undoDataStructure = do
  let moveDiff = 0.05
  ny <- readIORef newy
  oy <- readIORef oldy
  nx <- readIORef newx
  ox <- readIORef oldx
  myEdge <- readIORef currentItem1
```

The difference between the old mouse coordinates and new mouse coordinates is calculated and 4 cases are developed. Each case determines if the edge is to be bent up or down or left or right. Only the translation matrix is changed in each case accordingly.

```
  let diffy =  ny-oy
  let diffx =  nx-ox
  if (diffy <=(-1))
```

```
then do myGraphSet <- readIORef currentGraphSet
        myEdgeMidPoint <- bendEdgeMidPoint myEdge currentGraphSet
        let xcoordinate = xcoordVertex myEdgeMidPoint
        let ycoordinate = ycoordVertex myEdgeMidPoint
        let zcoordinate = zcoordVertex myEdgeMidPoint
```

The translation vector which would translate the control point of the bended edge an appropriate amount is determined by multiplying the transformation matrix and the translation vector. This would then appropriately move the control point relative to the screen rather than the axis in the window. Collision is

```
        transformationMatrix <- readIORef matrixStore
        (Vector3 a b c) <- transformVector (Vector3 0 moveDiff 0) transformationMatrix
        let newxcoordinate =  xcoordinate + a
        let newycoordinate =  ycoordinate + b
        let newzcoordinate = zcoordinate + c
        let newEdgeLayout = Vertex3 newxcoordinate newycoordinate (newzcoordinate::GLfloat)
        let newLayoutAttribute = processLayoutVertex newEdgeLayout
        myListOfEdges <- getListOfEdges myGraphSet
        myListOfNodes <- getListOfNodes myGraphSet
        mySettings <- readIORef settings
```

Collision detection is done here. The change is only applied when the collision detection function returns false which indicates there will be no collision when the edge is bent.

```
        collisionOnIORef <- getCollisionOn mySettings
        collisionOn<-readIORef (collisionOnIORef)
        collisionDetected <- collisionDetectionBendEdge collisionOn currentGraphSet myListOfNodes
                             myListOfEdges myEdge newEdgeLayout settings
        if (collisionDetected==False)
         then do mydataStructure <- readIORef currentGraphSet
                 changeAttr currentGraphSet "midPoint" myEdge newLayoutAttribute
                 myseconddatastructure <-readIORef currentGraphSet
                 modifyIORef currentGraphSet (\x -> mydataStructure)
                 updateGraphDataStructure myseconddatastructure currentGraphSet undoDataStructure
                 postRedisplay Nothing
         else do postRedisplay Nothing
    else if (diffy >=1)
     then do myGraphSet <- readIORef currentGraphSet
             myEdgeMidPoint <-  bendEdgeMidPoint myEdge currentGraphSet
             let xcoordinate = xcoordVertex myEdgeMidPoint
             let ycoordinate = ycoordVertex myEdgeMidPoint
             let zcoordinate = zcoordVertex myEdgeMidPoint
             transformationMatrix <- readIORef matrixStore
             (Vector3 a b c) <- transformVector (Vector3 0 (-moveDiff) 0) transformationMatrix
             let newxcoordinate =  xcoordinate + a
             let newycoordinate =  ycoordinate + b
             let newzcoordinate = zcoordinate + c
             let newEdgeLayout = Vertex3 newxcoordinate newycoordinate (newzcoordinate::GLfloat)
             let newLayoutAttribute = processLayoutVertex newEdgeLayout
             myListOfEdges <- getListOfEdges myGraphSet
             myListOfNodes <- getListOfNodes myGraphSet
             mySettings <- readIORef settings
             collisionOnIORef <- getCollisionOn mySettings
             collisionOn<-readIORef (collisionOnIORef)
             collisionDetected <-  collisionDetectionBendEdge collisionOn currentGraphSet myListOfNodes
                                   myListOfEdges myEdge newEdgeLayout settings
```

```
         if (collisionDetected==False)
          then do mydataStructure <- readIORef currentGraphSet
                  changeAttr currentGraphSet "midPoint" myEdge newLayoutAttribute
                  myseconddatastructure <-readIORef currentGraphSet
                  modifyIORef currentGraphSet (\x -> mydataStructure)
                  updateGraphDataStructure myseconddatastructure currentGraphSet undoDataStructure
                  postRedisplay Nothing
          else do postRedisplay Nothing
else if (diffx <=(-1))
 then do myGraphSet <- readIORef currentGraphSet
         myEdgeMidPoint <-  bendEdgeMidPoint myEdge currentGraphSet
         let xcoordinate = xcoordVertex myEdgeMidPoint
         let ycoordinate = ycoordVertex myEdgeMidPoint
         let zcoordinate = zcoordVertex myEdgeMidPoint
         transformationMatrix <- readIORef matrixStore
         (Vector3 a b c) <- transformVector (Vector3 (-moveDiff) 0 0) transformationMatrix
         let newxcoordinate =  xcoordinate + a
         let newycoordinate =  ycoordinate + b
         let newzcoordinate = zcoordinate + c
         let newEdgeLayout = Vertex3 newxcoordinate newycoordinate (newzcoordinate::GLfloat)
         let newLayoutAttribute = processLayoutVertex newEdgeLayout
         myListOfEdges <- getListOfEdges myGraphSet
         myListOfNodes <- getListOfNodes myGraphSet
         mySettings <- readIORef settings
         collisionOnIORef <- getCollisionOn mySettings
         collisionOn<-readIORef (collisionOnIORef)
         collisionDetected <-  collisionDetectionBendEdge collisionOn currentGraphSet myListOfNodes
                               myListOfEdges myEdge newEdgeLayout settings
         if (collisionDetected==False)
          then do mydataStructure <- readIORef currentGraphSet
                  changeAttr currentGraphSet "midPoint" myEdge newLayoutAttribute
                  myseconddatastructure <-readIORef currentGraphSet
                  modifyIORef currentGraphSet (\x -> mydataStructure)
                  updateGraphDataStructure myseconddatastructure currentGraphSet undoDataStructure
                  postRedisplay Nothing
          else do postRedisplay Nothing
else if (diffx >= 1)
 then do myGraphSet <- readIORef currentGraphSet
         myEdgeMidPoint <-  bendEdgeMidPoint myEdge currentGraphSet
         let xcoordinate = xcoordVertex myEdgeMidPoint
         let ycoordinate = ycoordVertex myEdgeMidPoint
         let zcoordinate = zcoordVertex myEdgeMidPoint
         transformationMatrix <- readIORef matrixStore
         (Vector3 a b c) <- transformVector (Vector3 (moveDiff) 0 0) transformationMatrix
         let newxcoordinate =  xcoordinate + a
         let newycoordinate =  ycoordinate + b
         let newzcoordinate = zcoordinate + c
         let newEdgeLayout = Vertex3 newxcoordinate newycoordinate (newzcoordinate::GLfloat)
         let newLayoutAttribute = processLayoutVertex newEdgeLayout
         myListOfEdges <- getListOfEdges myGraphSet
         myListOfNodes <- getListOfNodes myGraphSet
         mySettings <- readIORef settings
         collisionOnIORef <- getCollisionOn mySettings
         collisionOn<-readIORef (collisionOnIORef)
```

```
            collisionDetected <-  collisionDetectionBendEdge collisionOn currentGraphSet myListOfNodes
                                  myListOfEdges myEdge newEdgeLayout settings
            if (collisionDetected==False)
             then do mydataStructure <- readIORef currentGraphSet
                     changeAttr currentGraphSet "midPoint" myEdge newLayoutAttribute
                     myseconddatastructure <-readIORef currentGraphSet
                     modifyIORef currentGraphSet (\x -> mydataStructure)
                     updateGraphDataStructure myseconddatastructure currentGraphSet undoDataStructure
                     postRedisplay Nothing
              else do postRedisplay Nothing
      else return()
```

unMaybe ignores the Maybe type and just returns what it contains.

```
unMaybe :: Maybe a -> a
unMaybe (Just a) = a
```

These are utility functions to get certain components from the Vertex3 type

```
xcoordVertex :: Vertex3 a -> a
xcoordVertex (Vertex3 a b c) = a

ycoordVertex :: Vertex3 a -> a
ycoordVertex (Vertex3 a b c) = b

zcoordVertex :: Vertex3 a -> a
zcoordVertex (Vertex3 a b c) = c
```

processLayout converts the Vector3 type into the AttrValue type so that Vector3 types can be inserted into the graph data structure.

```
processLayoutVertex :: Vertex3 GLfloat -> AttrValue
processLayoutVertex (Vertex3 first second third) = (TenOf10 (Tup [Tup_Float (Gxl_1_0_1_DTD.Float (show first)),
Tup_Float (Gxl_1_0_1_DTD.Float (show second)),Tup_Float (Gxl_1_0_1_DTD.Float (show third))]))
```

transformVector and transformVertex are functions which given a Vector or a Vertex respectively and a list representing the matrix that the sapce has been multiplied by, will give us the new transformed Vector/Vertex according to the new set of axis in the current space. This is important so that when we rotate the space we conserve the horizontal/vertical/depth movement irregardless of the direction of the axis.

```
transformVector :: Vector3 GLfloat -> [GLdouble] -> IO (Vector3 GLfloat)
transformVector (Vector3 a b c) xs = do
    let newa = ((read(show(xs !! 0))::GLfloat) * a) + ((read(show(xs !! 1))::GLfloat) * b) +
               ( (read(show(xs !! 2))::GLfloat) * c)
    let newb = ((read(show(xs !! 4))::GLfloat) * a) + ((read(show(xs !! 5))::GLfloat) * b) +
               ( (read(show(xs !! 6))::GLfloat) * c)
    let newc = ((read(show(xs !! 8))::GLfloat) * a) + ((read(show(xs !! 9))::GLfloat) * b) +
               ( (read(show(xs !! 10))::GLfloat) * c)
    return (Vector3 newa newb newc)

transformVertex :: Vertex3 GLdouble -> [GLdouble] -> IO (Vertex3 GLdouble)
transformVertex (Vertex3 a b c) xs = do
    let newa = ((read(show(xs !! 0))::GLdouble) * a) + ((read(show(xs !! 1))::GLdouble) * b) +
```

```
            ( (read(show(xs !! 2))::GLdouble) * c)
    let newb = ((read(show(xs !! 4))::GLdouble) * a) + ((read(show(xs !! 5))::GLdouble) * b) +
            ( (read(show(xs !! 6))::GLdouble) * c)
    let newc = ((read(show(xs !! 8))::GLdouble) * a) + ((read(show(xs !! 9))::GLdouble) * b) +
            ( (read(show(xs !! 10))::GLdouble) * c)
    return (Vertex3 newa newb newc)
```

Module GraphFileManager, as the name indicates, gives us functions and facilities to open, save and close Graph Files. The secret it hides is how the graph files are manipulated to get this result. Few things to note here: first the GXL (graph exchange language) is the file format that will be used to hold graph information. Second, is that when a graph is loaded we made a decision to generate a layout for it if such information is missing or is partial. In addition when a graph is loaded the current graph is overwritten thus we can only have one graph active at a time. Finally when a graph is closed we automatically load the emprty graph so that the user can manipulate it straight away.

```
module GraphFileManager (saveGraph,openGraph,closeGraph) where

import Text.XML.HaXml.Xml2Haskell
import Gxl_1_0_1_DTD
import GXL_DTD
import INIT
import Data.IORef
import Graphics.Rendering.OpenGL.GL
import Graphics.Rendering.OpenGL.GLU
import Graphics.UI.GLUT
import Graphics.UI.WX hiding (WxcTypes.Id,KeyUp,KeyDown,color,motion,WXCore.WxcTypes.Size,
Classes.position,Attributes.get)
import Graphics.UI.WXCore.Frame
import ViewDataStructure
import GxlGraphSetXml
import GxlGraphSetManage
import UndoDataStructure
import Layout
```

Here we specify the filter that will appear when we load a file. In this case when we are manipulating graphs we are only interested in .gxl extension, which represents GXL graphs.

```
graphFiles::  [(String, [String])]
graphFiles = [("GXL files",["*.gxl"])]
```

This section concerns loading a gxl graph, this is achieved by first prompting the user for a gxl file via a file dialog provided by wxHaskell. The file is then parsed and read via functions provided by another module and the graph set corresponding to the loaded graph is returned.
OpenGraph is a function which will prompt the user for a graph to load, which is done by the facilities provided by wxHaskell. Once the user choose a graph, the graph is read and returned as an IORef. A layout for that graph is generated if no such information is present or is partial.

```
openGraph :: IORef GxlGraphSet -> IORef View -> IORef UndoDataStructure -> IO()
openGraph dataStructure view undoDataStructure = do
   --prompt the user with a file dialog
   tempGraph <-onOpenGraph
   --if no file is selected then don't do anything
```

```
   if (tempGraph == Nothing)
    then do
     return()
    else do
     --reset the view
     myView <- (initView)
        modifyIORef view (\x ->myView)
        --load the graph
        tempGraph1 <- readIORef (unMaybe(tempGraph))
        modifyIORef dataStructure (\x -> tempGraph1)
        --reset the undo data structure
        undoDataStructureIORef <- newUndoDataStructure
        myUndoDataStructure <- readIORef undoDataStructureIORef
        modifyIORef undoDataStructure (\x-> myUndoDataStructure)
        --generate the layout for the graph
        generateLayout dataStructure
```

onOpenGraph is the function that opens a file dialog for the user and prompts him for the graph file he whishes to open.

```
onOpenGraph ::IO (Maybe (IORef GxlGraphSet))
onOpenGraph
      = do f <- frameCreateDefault ("File Dialog")
           mbfname <- fileOpenDialog f False True "Open Graph" graphFiles "" ""
           if (mbfname==Nothing)
            then do return(Nothing)
            else do let myFile = unMaybe (mbfname)
                    gxlfile <- (fReadXml myFile)::IO Gxl
                    let newGraphSet = initGxlGraphSet (gxlfile)
                    myGraphSet <- newIORef newGraphSet
                    return (Just myGraphSet)
```

This section concerns saving a gxl graph, this is achieved by first prompting the user for a gxl file via a file dialog provided by wxHaskell. The current graph is then saved into then file.
SaveGraph is a function which will prompt the user for a graph to load, which is done by the facilities provided by wxHaskell. Once the user chooses a file, the current graph is saved in that file.

```
saveGraph :: IORef GxlGraphSet -> IO()
saveGraph dataStructure
      = do f <- frameCreateDefault ("File Dialog")
           myDataStructure <- readIORef dataStructure
           mbfname <- fileSaveDialog f True True "Save Graph" "" ""
           if (mbfname==Nothing)
            then do return()
            else do let myFile = unMaybe (mbfname)
                    wrtGxlGraphSetToXmlV1 myDataStructure myFile
                    return ()
```

This section concerns closing a gxl graph, this is achieved by simply loading the empty grah to replace the current existing one.

```
closeGraph:: IORef GxlGraphSet -> IORef View -> IORef UndoDataStructure -> IO()
closeGraph dataStructure view undoDataStructure =  do
  --reset the view
  myView <- (initView)
  --replace the current graph with the empty one
  let newGraphSet = addEmptyGraph newEmptyGraphSet "Graph"
  modifyIORef dataStructure (\x-> newGraphSet)
  myGraphSet <- readIORef dataStructure
  --reset the undo data structure
  undoDataStructureIORef <- newUndoDataStructure
  myUndoDataStructure <- readIORef undoDataStructureIORef
  modifyIORef undoDataStructure (\x-> myUndoDataStructure)
  modifyIORef view (\x-> myView)
  modifyIORef dataStructure (\x -> myGraphSet)
  return()
```

unMaybe is an auxilliary function used to get from Maybe type to the regular type.

```
unMaybe :: Maybe a -> a
unMaybe (Just a) = a
```

GraphInterface module enables the rest of the program to obtain all the attributes required to display an item be it a node or an edge. For a node, an element of type Node is retuned which contains all the attributes of a Node (Label, QuadricStyle, QuadricPrimitive, Color, Layout). As for an edge, the following attributes are returned (Label,QuadricStyle, Color, Layout of nodes that the edge is incident on...). In addition, this module provides functions so that the list of nodes and the list of edges can be obtained. Finally we also include functions to transform vectors and vertices from one space to another. The secrets that it hides are how those attributes are extracted from the GraphSet and their representation, and the way the list of items is compiled. In addition the default return values assigned to attributes not specified in the GraphSet are also hidden in this module.

```
module GraphInterface (getItemStacks,getItemSlices,getItemRadius,bendEdgeMidPoint, defaultNoMidPoint,getNode,
getEdgeQuadricStyle,getItemLabel,getListOfNodes,getListOfEdges,getItemColor4,getEdgeMidPoint,
getToNode,getFromNode,getDirectedOrNot)   where

import Text.XML.HaXml.Xml2Haskell
import Gxl_1_0_1_DTD
import GXL_DTD
import INIT
import Utils
import Interface
import Data.Set
import Data.FiniteMap
import Additional
import Data.IORef
import Graphics.Rendering.OpenGL.GL
import Graphics.Rendering.OpenGL.GLU
import Graphics.Rendering.OpenGL.GLU.Quadrics
import Graphics.UI.GLUT
import Graphics.UI.WX hiding (WxcTypes.Id,KeyUp,KeyDown,color,motion,WXCore.WxcTypes.Size,
Classes.position,Attributes.get)
import Graphics.UI.WXCore.Frame
import Node
```

```
import GxlGraphSetManage
import GxlGraphSetXml
import Text.XML.HaXml.OneOfN
import SettingsDataStructure
```

Here we define default attributes that nodes/edges will take in case these attributes are not found in the GXL file. These attributes are defined a constant so that they may easily be changed if the need may arise.
The default quadric normal is flat.

```
defaultNormal::Prelude.String
defaultNormal = "Flat"
```

The default quadric texture is no texture coordinates.

```
defaultTexture::Prelude.String
defaultTexture = "NoTextureCoordinates"
```

The default quadric orientation is outside.

```
defaultOrientation::Prelude.String
defaultOrientation = "Outside"
```

The default quadric draw style is fill style.

```
defaultDrawStyle::Prelude.String
defaultDrawStyle = "FillStyle"
```

If no midpoint is found we set it to a default value so that we can tell later that in this case this is a straight edge.

```
defaultNoMidPoint::Vertex3 GLfloat
defaultNoMidPoint = Vertex3 (-100) (-100) ((-100)::GLfloat)
```

The default shape is a sphere.

```
defaultShapeName::Prelude.String
defaultShapeName = "Sphere"
```

The default label is the empty string.

```
defaultLabel::Prelude.String
defaultLabel = ""
```

The default radius is equal to 0.3.

```
defaultRadius::GLdouble
defaultRadius = 0.3
```

The default number of slices is equal to 20.

```
defaultSlices::GLint
defaultSlices = 20
```

The default number of stacks is equal to 20.

```
defaultStacks::GLint
defaultStacks = 20
```

The default color is that with RGC 0.5 0.3 0.2.

```
defaultColor::Color4 Prelude.Float
defaultColor = Color4 0.5 0.3 0.2 1.0
```

getNode is a function which given a node's ID and the GraphSet it belongs to will return to us a variable of type Node which englobes the following attributes of the node: the label, the quadric style, the quadric primitice, the color and finally the layout.

```
getNode:: Id -> IORef GxlGraphSet -> IO Node.Node
getNode nodeId currentGraphSet = do
   --let myLabel = getItemLabel nodeId currentGraphSet
   myLabel <- getItemLabel nodeId currentGraphSet
   tempColor <- getItemColor4 nodeId currentGraphSet
   let myColor = tempColor
   myQuadricNormal <- getItemQuadricNormal nodeId currentGraphSet
   myTexture <- getItemQuadricTexture nodeId currentGraphSet
        myQuadricOrientation <- getItemQuadricOrientation nodeId currentGraphSet
        myQuadricDrawStyle <- getItemQuadricDrawStyle nodeId currentGraphSet
        let myQuadricStyle = QuadricStyle myQuadricNormal myTexture myQuadricOrientation myQuadricDrawStyle
        myQuadricPrimitive <- compareShapeNode nodeId currentGraphSet
        myCurrentGraphSet <- readIORef currentGraphSet
        myLayout <- getNodeLayout nodeId myCurrentGraphSet
        return ( Node.Node myLabel myQuadricStyle myQuadricPrimitive myColor myLayout)
```

getEdgeQuadricStyle is a function which given an edge's ID and the GraphSet it belongs to will return to us a the edge's quadric style. I.e information about the normal, the texture, the orientation and the draw style.

```
getEdgeQuadricStyle :: Id -> IORef GxlGraphSet -> IO QuadricStyle
getEdgeQuadricStyle edgeId dataStructure = do
        mydataStructure <- readIORef dataStructure
        myQuadricNormal <- getItemQuadricNormal edgeId dataStructure
        myTexture <- getItemQuadricTexture edgeId dataStructure
        myQuadricOrientation <- getItemQuadricOrientation edgeId dataStructure
        myQuadricDrawStyle <- getItemQuadricDrawStyle edgeId dataStructure
        let myQuadricStyle = QuadricStyle myQuadricNormal myTexture myQuadricOrientation myQuadricDrawStyle
        return (myQuadricStyle)
```

The following functions comparOrientation, compareTexture, compareStyle, compareNormal and compareShapeNode are playing the role of read instances for the QuadricOrientation, QuadricTexture, QuadricNormal, QuadricPrimitive respectively. These functions take in a string and return the variable of the appropriate type. This had to be done since OpenGL does not derive read instances for those types.

```
compareOrientation :: Prelude.String -> IO QuadricOrientation
compareOrientation input = do
  result <- newIORef Inside
  if ("Outside"==input)
   then do
    modifyIORef result (\x -> Outside )
   else do
    dummy
  tempResult <- readIORef result
  return tempResult
```

```
compareTexture :: Prelude.String -> IO QuadricTexture
compareTexture input = do
  result <- newIORef GenerateTextureCoordinates
  if ("NoTextureCoordinates"==input)
   then do
    modifyIORef result (\x -> NoTextureCoordinates )
   else do
    dummy
  tempResult <- readIORef result
  return tempResult

compareStyle :: Prelude.String -> IO QuadricDrawStyle
compareStyle input = do
result <- newIORef PointStyle
if ("LineStyle"==input)
  then do
    modifyIORef result (\x -> LineStyle)
  else if ("FillStyle"==input)
   then do
    modifyIORef result (\x -> FillStyle)
  else if ("SilhouetteStyle"==input)
    then do
    modifyIORef result (\x -> SilhouetteStyle)
  else dummy
tempResult <- readIORef result
return tempResult

compareNormal :: Prelude.String -> IO QuadricNormal
compareNormal input = do
result <- newIORef Flat
if ("Smooth"==input)
  then do
    modifyIORef result (\x -> Smooth)
  else do
    dummy
tempResult <- readIORef result
return (Just tempResult)


compareShapeNode :: Id -> IORef GxlGraphSet -> IO QuadricPrimitive
compareShapeNode nodeId dataStructure = do
    myShapeName <- getNodeShapeName nodeId dataStructure
    myShapeRadius <- getItemRadius nodeId dataStructure
    myShapeSlices <- getItemSlices nodeId dataStructure
    myShapeStacks <- getItemStacks nodeId dataStructure
    let myPrimitive = Sphere myShapeRadius myShapeSlices myShapeStacks
    return myPrimitive

dummy :: IO ()
dummy = return ()
```

getListOfNodes is a function which given a GraphSet returns a list of the nodes that form it. This list is used to go over the nodes to draw them when this is needed and used in many other places as well.

```
getListOfNodes :: GxlGraphSet -> IO ([Id])
getListOfNodes currentGraphSet = do
let listOfGraphId = getGxlGraphs currentGraphSet
if (listOfGraphId/=[]) then do let setOfNodes = nodes currentGraphSet (head (listOfGraphId))
                               let listOfNodes = setToList setOfNode
                               return (listOfNodes)
                       else do return ([])
```

The functions that extract certain attributes all share the same concept. First we obtain the finite map of the graphs that for the graph set and then transform this finite map into a list and take the head of that list since we are not considering sub-graphs. Then we construct the finite map consisting of all the attributes associated with that particular graph and proceed to querying it for specific attributes. In case the attribute is not there, then a default attribute defined in the top section of the code will be added to the item and then returned. This way devellopers can easily change the default attributes easily by replacing the values of the constants rather then modifying it everywhere in the code.
getItemLabel is a function which given the ID of an item and the graph it belongs to it returns the label attribute associated with it. If no label is found the default string defined above is returned.

```
getItemLabel :: Id -> IORef GxlGraphSet -> IO Prelude.String
getItemLabel itemId dataStructure =  do
  mydataStructure <- readIORef dataStructure
  let listOfGraphID = getGxlGraphs mydataStructure
  -- Create Map of Graph to Attributes
  let mapOfGraphAttrs = graphAttrs mydataStructure (head(listOfGraphID))
  -- Create Finite Map of Graph to Attributes from the map
  let graphFiniteMap = itemAttrs mydataStructure mapOfGraphAttrs itemId
  --lookup the attribute
  let myLabel = lookupFM graphFiniteMap (itemId,"Label")
  --if the attribute is missing
  if (myLabel==Nothing)
   then do
    --get the current item info
    let (ItemInfo a b c d e) = queryItemInfo mydataStructure itemId
    --construct the attribute
    let (z,y) = addAttrGetId (myInfoLabel) mydataStructure
    --update the graph set
    modifyIORef dataStructure (\x -> y)
    mydataStructure <- readIORef dataStructure
    --add the current attribute to the list of attribute
    let newList = z:b
    let newItemInfo = ItemInfo a newList c d e
    let newGraphSet = updateItemInfo mydataStructure itemId newItemInfo
    --update the graph set
    modifyIORef dataStructure (\x -> newGraphSet)
    --return the added attribute
    return (defaultLabel)
    --if the attribute is there
   else do
    --fetch the value of the label
    let label = getAttrValStr(unMaybe (myLabel) )
    --return the value fetched
    return (label)
```

```
myInfoLabel = AttrInfo Nothing [] (FiveOf10 (GxlString defaultLabel)) labelAttr

labelAttr = AttrAttr Nothing "Label"  Nothing
```

getNodeLayout is a function which given the ID of a node and the graph it belongs to it returns the layout attribute associated with it.

```
getNodeLayout :: Id -> GxlGraphSet -> IO (Vector3 GLfloat)
getNodeLayout nodeId currentGraphSet =  do
   let listOfGraphID = getGxlGraphs currentGraphSet
   -- Create Map of Graph to Attributes
  let mapOfGraphAttrs = graphAttrs currentGraphSet (head(listOfGraphID))
   -- Create Finite Map of Graph to Attributes from the map
   let graphFiniteMap = itemAttrs currentGraphSet mapOfGraphAttrs nodeId
   let myLayout = lookupFM graphFiniteMap (nodeId,"Layout")
   let layout = getAttrValVector3 (unMaybe (myLayout))
   return layout
layoutAttr = AttrAttr Nothing "Layout"  Nothing

processLayout (Vector3 first second third) = (TenOf10 (Tup [Tup_Float (Gxl_1_0_1_DTD.Float (show first)),
Tup_Float (Gxl_1_0_1_DTD.Float (show second)),Tup_Float (Gxl_1_0_1_DTD.Float (show third))]))
```

getItemQuadricNormal is a function which given the ID of an item and the graph it belongs to it returns the quadric normal attribute associated with it. If no normal is found the default normal defined above is inserted then returned.

```
getItemQuadricNormal :: Id -> IORef GxlGraphSet -> IO QuadricNormal
getItemQuadricNormal itemId dataStructure =  do
  mydataStructure <- readIORef dataStructure
  let listOfGraphID = getGxlGraphs mydataStructure
  -- Create Map of Graph to Attributes
  let mapOfGraphAttrs = graphAttrs mydataStructure (head(listOfGraphID))
  -- Create Finite Map of Graph to Attributes from the map
  let graphFiniteMap = itemAttrs mydataStructure mapOfGraphAttrs itemId
  let myQuadricNormal = lookupFM graphFiniteMap (itemId,"QuadricNormal")
  if (myQuadricNormal==Nothing)
   then do let (ItemInfo a b c d e) = queryItemInfo mydataStructure itemId
           let (z,y) = addAttrGetId (myInfoQuadricNormal) mydataStructure
           modifyIORef dataStructure (\x -> y)
           mydataStructure <- readIORef dataStructure
           let newList = z:b
           let newItemInfo = ItemInfo a newList c d e
           let newGraphSet = updateItemInfo mydataStructure itemId newItemInfo
           modifyIORef dataStructure (\x -> newGraphSet)
           result <- compareNormal defaultNormal
           return (result)
   else do let normal = getAttrValStr(unMaybe (myQuadricNormal) )
           result <- compareNormal normal
           return (result)

myInfoQuadricNormal = AttrInfo Nothing [] (FiveOf10 (GxlString defaultNormal)) quadricNormalAttr

quadricNormalAttr = AttrAttr Nothing "QuadricNormal"  Nothing
```

getItemQuadricTexture is a function which given the ID of an item and the graph it belongs to it returns the quadric texture attribute associated with it. If no texture is found the default texture defined above is inserted then returned.

```
getItemQuadricTexture :: Id -> IORef GxlGraphSet -> IO QuadricTexture
getItemQuadricTexture itemId dataStructure =  do
  mydataStructure <- readIORef dataStructure
  let listOfGraphID = getGxlGraphs mydataStructure
  -- Create Map of Graph to Attributes
  let mapOfGraphAttrs = graphAttrs mydataStructure (head(listOfGraphID))
  -- Create Finite Map of Graph to Attributes from the map
  let graphFiniteMap = itemAttrs mydataStructure mapOfGraphAttrs itemId
  let myQuadricTexture = lookupFM graphFiniteMap (itemId,"QuadricTexture")
  if (myQuadricTexture==Nothing)
   then do let (ItemInfo a b c d e) = queryItemInfo mydataStructure itemId
           let (z,y) = addAttrGetId (myInfoQuadricTexture) mydataStructure
           modifyIORef dataStructure (\x -> y)
           mydataStructure <- readIORef dataStructure
           let newList = z:b
           let newItemInfo = ItemInfo a newList c d e
           let newGraphSet = updateItemInfo mydataStructure itemId newItemInfo
           modifyIORef dataStructure (\x -> newGraphSet)
           result <- compareTexture defaultTexture
           return (result)
   else do let texture = getAttrValStr(unMaybe (myQuadricTexture) )
           result <- compareTexture texture
           return (result)

myInfoQuadricTexture = AttrInfo Nothing [] (FiveOf10 (GxlString defaultTexture)) quadricTextureAttr

quadricTextureAttr = AttrAttr Nothing "QuadricTexture"  Nothing
```

getItemQuadricOrientation is a function which given the ID of an item and the graph it belongs to it returns the quadric orientation attribute associated with it. If no orientation is found the default orientation defined above is inserted then returned.

```
getItemQuadricOrientation :: Id -> IORef GxlGraphSet -> IO QuadricOrientation
getItemQuadricOrientation itemId dataStructure =  do
  mydataStructure <- readIORef dataStructure
  --let graphFiniteMap = getGraphFiniteMap currentGraphSet
  let listOfGraphID = getGxlGraphs mydataStructure
  -- Create Map of Graph to Attributes
  let mapOfGraphAttrs = graphAttrs mydataStructure (head(listOfGraphID))
  -- Create Finite Map of Graph to Attributes from the map
  let graphFiniteMap = itemAttrs mydataStructure mapOfGraphAttrs itemId
  let myQuadricOrientation = lookupFM graphFiniteMap (itemId,"QuadricOrientation")
  if (myQuadricOrientation==Nothing)
   then do let (ItemInfo a b c d e) = queryItemInfo mydataStructure itemId
           let (z,y) = addAttrGetId (myInfoQuadricOrientation) mydataStructure
           modifyIORef dataStructure (\x -> y)
           mydataStructure <- readIORef dataStructure
           let newList = z:b
           let newItemInfo = ItemInfo a newList c d e
           let newGraphSet = updateItemInfo mydataStructure itemId newItemInfo
```

```
           modifyIORef dataStructure (\x -> newGraphSet)
           result <- compareOrientation defaultOrientation
           return (result)
   else do let orientation = getAttrValStr(unMaybe (myQuadricOrientation) )
           result <- compareOrientation orientation
           return (result)

myInfoQuadricOrientation = AttrInfo Nothing [] (FiveOf10 (GxlString defaultOrientation)) quadricOrientationAttr

quadricOrientationAttr = AttrAttr Nothing "QuadricOrientation"  Nothing
```

getItemQuadricDrawStyle is a function which given the ID of an item and the graph it belongs to it returns the quadric draw style attribute associated with it. If no draw style is found the default drawing style defined above is inserted then returned.

```
getItemQuadricDrawStyle :: Id -> IORef GxlGraphSet -> IO QuadricDrawStyle
getItemQuadricDrawStyle itemId dataStructure =  do
  mydataStructure <- readIORef dataStructure
  --let graphFiniteMap = getGraphFiniteMap currentGraphSet
  let listOfGraphID = getGxlGraphs mydataStructure
  -- Create Map of Graph to Attributes
  let mapOfGraphAttrs = graphAttrs mydataStructure (head(listOfGraphID))
  -- Create Finite Map of Graph to Attributes from the map
  let graphFiniteMap = itemAttrs mydataStructure mapOfGraphAttrs itemId
  let myQuadricDrawStyle = lookupFM graphFiniteMap (itemId,"QuadricDrawStyle")
  if (myQuadricDrawStyle==Nothing)
   then do let (ItemInfo a b c d e) = queryItemInfo mydataStructure itemId
           let (z,y) = addAttrGetId (myInfoQuadricDrawStyle) mydataStructure
           modifyIORef dataStructure (\x -> y)
           mydataStructure <- readIORef dataStructure
           let newList = z:b
           let newItemInfo = ItemInfo a newList c d e
           let newGraphSet = updateItemInfo mydataStructure itemId newItemInfo
           modifyIORef dataStructure (\x -> newGraphSet)
           result <- compareStyle defaultDrawStyle
           return (result)
   else do let drawStyle = getAttrValStr(unMaybe (myQuadricDrawStyle) )
           result <- compareStyle drawStyle
           return (result)


myInfoQuadricDrawStyle = AttrInfo Nothing [] (FiveOf10 (GxlString defaultDrawStyle)) quadricDrawStyleAttr

quadricDrawStyleAttr = AttrAttr Nothing "QuadricDrawStyle"  Nothing
```

getNodeShapeName is a function which given the ID of a node and the graph it belongs to it returns the shape name attribute associated with it. If no shape is found the default shape defined above is is inserted then returned.

```
getNodeShapeName :: Id -> IORef GxlGraphSet -> IO Prelude.String
getNodeShapeName nodeId dataStructure =  do
  mydataStructure <- readIORef dataStructure
  let listOfGraphID = getGxlGraphs mydataStructure
```

```
  -- Create Map of Graph to Attributes
  let mapOfGraphAttrs = graphAttrs mydataStructure (head(listOfGraphID))
  -- Create Finite Map of Graph to Attributes from the map
  let graphFiniteMap = itemAttrs mydataStructure mapOfGraphAttrs nodeId
  let myShapeName = lookupFM graphFiniteMap (nodeId,"ShapeName")
  if (myShapeName == Nothing)
   then do let (ItemInfo a b c d e) = queryItemInfo mydataStructure nodeId
           let (z,y) = addAttrGetId (myInfoShapeName) mydataStructure
           modifyIORef dataStructure (\x -> y)
           mydataStructure <- readIORef dataStructure
           let newList = z:b
           let newItemInfo = ItemInfo a newList c d e
           let newGraphSet = updateItemInfo mydataStructure nodeId newItemInfo
           modifyIORef dataStructure (\x -> newGraphSet)
           return defaultShapeName
   else do let shapeName = (getAttrValStr (unMaybe (myShapeName) ))
           return shapeName

myInfoShapeName = AttrInfo Nothing [] (FiveOf10 (GxlString defaultShapeName)) shapeNameAttr

shapeNameAttr = AttrAttr Nothing "ShapeName"  Nothing
```

getItemRadius is a function which given the ID of an item and the graph it belongs to it returns the radius attribute associated with it. If no radius is found the default radius defined above is inserted then returned.

```
getItemRadius :: Id -> IORef GxlGraphSet -> IO GLdouble
getItemRadius itemId dataStructure =  do
  mydataStructure <- readIORef dataStructure
  let listOfGraphID = getGxlGraphs mydataStructure
  -- Create Map of Graph to Attributes
  let mapOfGraphAttrs = graphAttrs mydataStructure (head(listOfGraphID))
  -- Create Finite Map of Graph to Attributes from the map
  let graphFiniteMap = itemAttrs mydataStructure mapOfGraphAttrs itemId
  let myRadius = lookupFM graphFiniteMap (itemId,"Radius")
  if (myRadius==Nothing)
   then do let (ItemInfo a b c d e) = queryItemInfo mydataStructure itemId
           let (z,y) = addAttrGetId (myInfoRadius) mydataStructure
           modifyIORef dataStructure (\x -> y)
           mydataStructure <- readIORef dataStructure
           let newList = z:b
           let newItemInfo = ItemInfo a newList c d e
           let newGraphSet = updateItemInfo mydataStructure itemId newItemInfo
           modifyIORef dataStructure (\x -> newGraphSet)
           return (defaultRadius::GLdouble)
   else do let radius = getAttrValGLfloat (unMaybe (myRadius) )
           return (radius)

myInfoRadius = AttrInfo Nothing [] (FourOf10 (Gxl_1_0_1_DTD.Float (show defaultRadius))) radiusAttr

radiusAttr = AttrAttr Nothing "Radius"  Nothing
```

getItemSlices is a function which given the ID of an item and the graph it belongs to it returns the slices attribute associated with it. If no number of slices is found the default number of slices defined above is inserted then returned.

```
getItemSlices :: Id -> IORef GxlGraphSet -> IO GLint
getItemSlices itemId dataStructure =  do
  mydataStructure <- readIORef dataStructure
  let listOfGraphID = getGxlGraphs mydataStructure
  -- Create Map of Graph to Attributes
  let mapOfGraphAttrs = graphAttrs mydataStructure (head(listOfGraphID))
  -- Create Finite Map of Graph to Attributes from the map
  let graphFiniteMap = itemAttrs mydataStructure mapOfGraphAttrs itemId
  let mySlices = lookupFM graphFiniteMap (itemId,"Slices")
  if (mySlices==Nothing)
   then do let (ItemInfo a b c d e) = queryItemInfo mydataStructure itemId
           let (z,y) = addAttrGetId (myInfoSlices) mydataStructure
           modifyIORef dataStructure (\x -> y)
           mydataStructure <- readIORef dataStructure
           let newList = z:b
           let newItemInfo = ItemInfo a newList c d e
           let newGraphSet = updateItemInfo mydataStructure itemId newItemInfo
           modifyIORef dataStructure (\x -> newGraphSet)
           return (defaultSlices)
   else do return (getAttrValGLint (unMaybe (mySlices) ))

myInfoSlices = AttrInfo Nothing [] (ThreeOf10 (Gxl_1_0_1_DTD.Int (show defaultSlices))) slicesAttr

slicesAttr = AttrAttr Nothing "Slices"  Nothing
```

getItemStacks is a function which given the ID of an item and the graph it belongs to it returns the stacks attribute associated with it. If no number of stacks is found the default number of stacks defined above is inserted then returned.

```
getItemStacks :: Id -> IORef GxlGraphSet -> IO GLint
getItemStacks itemId dataStructure =  do
  mydataStructure <- readIORef dataStructure
  let listOfGraphID = getGxlGraphs mydataStructure
  -- Create Map of Graph to Attributes
  let mapOfGraphAttrs = graphAttrs mydataStructure (head(listOfGraphID))
  -- Create Finite Map of Graph to Attributes from the map
  let graphFiniteMap = itemAttrs mydataStructure mapOfGraphAttrs itemId
  let myStacks = lookupFM graphFiniteMap (itemId,"Stacks")
  if (myStacks==Nothing)
   then do let (ItemInfo a b c d e) = queryItemInfo mydataStructure itemId
           let (z,y) = addAttrGetId (myInfoStacks) mydataStructure
           modifyIORef dataStructure (\x -> y)
           mydataStructure <- readIORef dataStructure
           let newList = z:b
           let newItemInfo = ItemInfo a newList c d e
           let newGraphSet = updateItemInfo mydataStructure itemId newItemInfo
           modifyIORef dataStructure (\x -> newGraphSet)
           return (defaultSlices)
   else do return (getAttrValGLint (unMaybe (myStacks) ))

myInfoStacks = AttrInfo Nothing [] (ThreeOf10 (Gxl_1_0_1_DTD.Int (show defaultSlices))) stacksAttr
```

```
stacksAttr = AttrAttr Nothing "Stacks"  Nothing
```

getItemColor4 is a function which given the ID of an item and the graph it belongs to it returns the color attribute associated with it. If no color is found the default color defined above is inserted then returned.

```
getItemColor4 :: Id -> IORef GxlGraphSet -> IO (Color4 GLfloat)
getItemColor4 nodeId dataStructure =  do
  mydataStructure <- readIORef dataStructure
  --let graphFiniteMap = getGraphFiniteMap currentGraphSet
  let listOfGraphID = getGxlGraphs mydataStructure
  -- Create Map of Graph to Attributes
  let mapOfGraphAttrs = graphAttrs mydataStructure (head(listOfGraphID))
  -- Create Finite Map of Graph to Attributes from the map
  let graphFiniteMap = itemAttrs mydataStructure mapOfGraphAttrs nodeId
  let myColor4 = lookupFM graphFiniteMap (nodeId,"Color4")
  if (myColor4 == Nothing)
   then do let (ItemInfo a b c d e) = queryItemInfo mydataStructure nodeId
           myColorAttrInfo <- myInfoColor
           let (z,y) = addAttrGetId (myColorAttrInfo) mydataStructure
           modifyIORef dataStructure (\x -> y)
           mydataStructure <- readIORef dataStructure
           let newList = z:b
           let newItemInfo = ItemInfo a newList c d e
           let newGraphSet = updateItemInfo mydataStructure nodeId newItemInfo
           modifyIORef dataStructure (\x -> newGraphSet)
           return (defaultColor)
   else return (getAttrValColor4 (unMaybe (myColor4) ))

colorAttr = AttrAttr Nothing "Color4"  Nothing

myInfoColor  = do let Color4 a b c d = defaultColor
                  return (AttrInfo Nothing [] (TenOf10 (Tup [Tup_Float (Gxl_1_0_1_DTD.Float (show a)),
                  Tup_Float (Gxl_1_0_1_DTD.Float (show b)),Tup_Float (Gxl_1_0_1_DTD.Float (show c)),
                  Tup_Float (Gxl_1_0_1_DTD.Float (show d))])) colorAttr)
```

getDirectedOrNot is a function which given the ID of an edge and the graph it belongs to it returns whether the edge is directed or not.

```
getDirectedOrNot :: Id -> GxlGraphSet -> IO (Prelude.Bool)
getDirectedOrNot edgeId currentGraphSet = do
  let listOfGraphID = getGxlGraphs currentGraphSet
  let directedBool = directed currentGraphSet edgeId
  return directedBool
```

getListOfEdges is a function which given a GraphSet returns a list of the edges that form it. This list is used to go over the edges to draw them when this is needed and in many other places as well.

```
getListOfEdges :: GxlGraphSet -> IO ([Id])
getListOfEdges currentGraphSet = do
  let listOfGraphId = getGxlGraphs currentGraphSet
```

```
  if (listOfGraphId/=[]) then do let setOfEdges = edges currentGraphSet (head (listOfGraphId))
                                 let listOfEdges = setToList setOfEdges
                                 return (listOfEdges)
                         else do return ([])
```

getFromNode is a function which given the ID of an edge and the graph it belongs to it returns the layout of the node that the edge is leaving from.

```
getFromNode :: Id -> GxlGraphSet -> IO (Vertex3 GLfloat)
getFromNode edgeId currentGraphSet = do
  let listOfGraphID = getGxlGraphs currentGraphSet
  let fromNode = from currentGraphSet (head(listOfGraphID)) edgeId
  myLayout <- getNodeLayout (fromNode::Id) currentGraphSet
  let fromNodeVertex = vectorToVertex myLayout
  return fromNodeVertex
```

getFromNode is a function which given the ID of an edge and the graph it belongs to it returns the layout of the node that the edge is incident upon.

```
getToNode :: Id -> GxlGraphSet -> IO (Vertex3 GLfloat)
getToNode edgeId currentGraphSet = do
  let listOfGraphID = getGxlGraphs currentGraphSet
  let toNode = to currentGraphSet (head(listOfGraphID)) edgeId
  myLayout <- getNodeLayout (toNode::Id) currentGraphSet
  let toNodeVertex = vectorToVertex myLayout
  return toNodeVertex
```

vectortoVertex is a function that changes a variable of type Vector 3 into a Vertex 3

```
vectorToVertex ::  (Vector3 GLfloat) -> (Vertex3 GLfloat)
vectorToVertex (Vector3 a b c) = Vertex3 a b c
```

getEdgeMidPoint is a function which given the ID of an edge and the graph it belongs to it returns the midPoint attribute associated with it. If no such point is found the default mid point defined above is returned.

```
getEdgeMidPoint :: Id -> GxlGraphSet -> IO (Vertex3 GLfloat)
getEdgeMidPoint edgeId currentGraphSet =  do
  --let graphFiniteMap = getGraphFiniteMap currentGraphSet
  let listOfGraphID = getGxlGraphs currentGraphSet
  -- Create Map of Graph to Attributes
  let mapOfGraphAttrs = graphAttrs currentGraphSet (head(listOfGraphID))
  -- Create Finite Map of Graph to Attributes from the map
  let graphFiniteMap = itemAttrs currentGraphSet mapOfGraphAttrs edgeId
  let myMidPoint = lookupFM graphFiniteMap (edgeId,"midPoint")
  if (myMidPoint==Nothing)
   then do return (defaultNoMidPoint)
   else do let midPointVector = getAttrValVector3 (unMaybe (myMidPoint))
           let midPointVertex = vectorToVertex midPointVector
           return midPointVertex
```

bendEdgeMidPoint is a function which given the ID of an edge and the graph it belongs to it returns the midPoint attribute associated with it. This function is called when we would like to bend the edge. If no such point is found then we insert a midPoint which is the midpoint of the segment joining the two nodes which the edge connects. This will allow us to bend edges that are initially straight.

```
bendEdgeMidPoint :: Id -> IORef GxlGraphSet -> IO (Vertex3 GLfloat)
bendEdgeMidPoint edgeId dataStructure = do
  currentGraphSet <- readIORef dataStructure
  --let graphFiniteMap = getGraphFiniteMap currentGraphSet
  let listOfGraphID = getGxlGraphs currentGraphSet
  -- Create Map of Graph to Attributes
  let mapOfGraphAttrs = graphAttrs currentGraphSet (head(listOfGraphID))
  -- Create Finite Map of Graph to Attributes from the map
  let graphFiniteMap = itemAttrs currentGraphSet mapOfGraphAttrs edgeId
  let myMidPoint = lookupFM graphFiniteMap (edgeId,"midPoint")
  if (myMidPoint==Nothing)
   then do let startNode = from currentGraphSet (head(listOfGraphID)) edgeId
           let endNode = to currentGraphSet (head(listOfGraphID)) edgeId
           startLayout <- getNodeLayout startNode currentGraphSet
           endLayout <- getNodeLayout endNode currentGraphSet
           let midPointLayout = midPointVector startLayout endLayout
           let (ItemInfo a b c d e) = queryItemInfo currentGraphSet edgeId
           let (z,y) = addAttrGetId (myInfov midPointLayout) currentGraphSet
           modifyIORef dataStructure (\x -> y)
           mydataStructure <- readIORef dataStructure
           let newList = z:b
           let newItemInfo = ItemInfo a newList c d e
           let newGraphSet = updateItemInfo mydataStructure edgeId newItemInfo
           modifyIORef dataStructure (\x -> newGraphSet)
           let midPointVertex = vectorToVertex midPointLayout
           return midPointVertex
   else do let midPointVector = getAttrValVector3 (unMaybe (myMidPoint))
           let midPointVertex = vectorToVertex midPointVector
           return midPointVertex

midPointVector (Vector3 a b c) (Vector3 x y z) = Vector3 ((a+x)/2) ((b+y)/2) ((c+z)/2)

myAttr1 = AttrAttr Nothing "midPoint"  Nothing
myInfov (Vector3 x y z) = AttrInfo Nothing [] (TenOf10 (Tup [Tup_Float (Gxl_1_0_1_DTD.Float (show x)),
Tup_Float (Gxl_1_0_1_DTD.Float (show y)),Tup_Float (Gxl_1_0_1_DTD.Float (show z))])) myAttr1
```

The following functions extract the components of a Vector.

```
xcoord :: Vector3 a -> a
xcoord (Vector3 a b c) = a

ycoord :: Vector3 a -> a
ycoord (Vector3 a b c) = b

zcoord :: Vector3 a -> a
zcoord (Vector3 a b c) = c
```

unMaybe is a function which is used to transform variables from type Maybe a to a.

```
unMaybe :: Maybe a -> a
unMaybe (Just a) = a
```

GraphManipulation is a module which gives us functionality to scale a graph and rotate it. The main idea used is we split the graph into nodes and edges and then scale and rotate each item individually. The secret it hides is how the graph is rotated and scaled and the mathematics and algorithms behind it.

```
module GraphManipulation (scaleGraph,graphRotationButtonDown)  where

import Gxl_1_0_1_DTD
import GXL_DTD
import INIT
import Data.IORef
import Graphics.Rendering.OpenGL.GL
import Graphics.Rendering.OpenGL.GLU
import Graphics.UI.GLUT
import ViewDataStructure
import GraphInterface
import Node
import Utils
import GxlGraphSetManage
import Text.XML.HaXml.OneOfN
import SettingsDataStructure
import Additional
```

scaleGraph is the function which scales a given graph. the basic idea is that we get the list of nodes and edges and scale each seperately.

```
scaleGraph::IORef GxlGraphSet -> GLfloat->IORef SettingsDataStructure -> IO()
scaleGraph dataStructure factor settings = do
   myGraphSet <- readIORef dataStructure
   myNodeList <- getListOfNodes myGraphSet
   nodeScaleLoop dataStructure factor myNodeList settings
   myEdgeList <- getListOfEdges myGraphSet
   edgeScaleLoop dataStructure factor myEdgeList settings
   return()
```

nodeScaleLoop is the function which loops through the list of nodes and multiplies the layout of each node by the factor we wish to scale the graph by.

```
nodeScaleLoop :: IORef GxlGraphSet -> GLfloat -> [GXL_DTD.Id] -> IORef SettingsDataStructure -> IO()
nodeScaleLoop dataStructure factor (x:xs) settings = do
   mydataStructure <- readIORef dataStructure
   myNode <- getNode x dataStructure
   --get current layout
   let nodeLayout = extractLayout myNode
   let xcoordinate = xcoordVector nodeLayout
```

```
   let ycoordinate = ycoordVector nodeLayout
   let zcoordinate = zcoordVector nodeLayout
   --multiply by factor
   let newxcoordinate =  xcoordinate * factor
   let newycoordinate =  ycoordinate * factor
   let newzcoordinate = zcoordinate  * factor
   let newNodeLayout = Vector3 newxcoordinate newycoordinate (newzcoordinate::GLfloat)
   --change the layout
   let newLayoutAttribute = processLayout newNodeLayout
   changeAttr dataStructure "Layout" x newLayoutAttribute
   nodeScaleLoop dataStructure factor xs settings
nodeScaleLoop dataStructure _ _ _ = do return ()
```

edgeScaleLoop is the function which loops through the list of edges and multiplies the control's point layout of each edge by the factor we wish to scale the graph by. If the edge is straight then no work needs to be done as if the node gets scaled then since the edges attach the nodes they will get scaled.

```
edgeScaleLoop :: IORef GxlGraphSet -> GLfloat -> [GXL_DTD.Id] -> IORef SettingsDataStructure -> IO()
edgeScaleLoop dataStructure factor (x:xs) settings = do
      mydataStructure <- readIORef dataStructure
      myEdgeMidPoint <- getEdgeMidPoint x mydataStructure
      if (myEdgeMidPoint /= defaultNoMidPoint)
        --bent edge
        then do
              --get current layout
              let xcoordinate = xcoordVertex myEdgeMidPoint
              let ycoordinate = ycoordVertex myEdgeMidPoint
              let zcoordinate = zcoordVertex myEdgeMidPoint
              --multiply by factor
              let newxcoordinate =  xcoordinate * factor
              let newycoordinate =  ycoordinate * factor
              let newzcoordinate = zcoordinate * factor
              let newEdgeLayout = Vertex3 newxcoordinate newycoordinate (newzcoordinate::GLfloat)
              let newLayoutAttribute = processLayoutVertex newEdgeLayout
              --change the layout
              changeAttr dataStructure "midPoint" x newLayoutAttribute
              edgeScaleLoop dataStructure factor xs settings
        else edgeScaleLoop dataStructure factor xs settings
edgeScaleLoop dataStructure _ _ _ = do return ()
```

Here are a few auxillary functions used to extract the x, y and z components from vectors and vertices.

```
xcoordVector::Vector3 a -> a
xcoordVector (Vector3 a b c) = a

xcoordVertex::Vertex3 a -> a
xcoordVertex (Vertex3 a b c) = a

ycoordVector::Vector3 a -> a
ycoordVector (Vector3 a b c) = b

ycoordVertex::Vertex3 a -> a
ycoordVertex (Vertex3 a b c) = b
```

```
zcoordVector::Vector3 a -> a
zcoordVector (Vector3 a b c) = c

zcoordVertex::Vertex3 a -> a
zcoordVertex (Vertex3 a b c) = c
```

processLayoutVertex and processLayoutVector are functions that give us the attribute value corresponding to the vertex/vector passed so that we can insert them into the attributes finite map in the goal of updateing the layout.

```
processLayoutVertex :: Vertex3 GLfloat -> AttrValue
processLayoutVertex (Vertex3 first second third) = (TenOf10 (Tup [Tup_Float (Gxl_1_0_1_DTD.Float (show first)),
Tup_Float (Gxl_1_0_1_DTD.Float (show second)),Tup_Float (Gxl_1_0_1_DTD.Float (show third))]))

processLayout :: Vector3 GLfloat -> AttrValue
processLayout (Vector3 first second third) = (TenOf10 (Tup [Tup_Float (Gxl_1_0_1_DTD.Float (show first)),
Tup_Float (Gxl_1_0_1_DTD.Float (show second)),Tup_Float (Gxl_1_0_1_DTD.Float (show third))]))
```

graphRotationButtonDown is the motion callback for rotation. As long as the mouse button is down and we are moving the mouse. The graph will be rotated in the direction specified by the mouse movement. Of course the movement will be divided into small units so that the movement is progressive with the movement. The actual calculation that determines the angle based on the mouse movement is donw in calculateGraphRotation. Once the angle is computed then we call the rotateGraph function to rotate the Graph by the resulting computed angles. We will use the View Data Structure here to put the horizontal and vertical angles in it.

```
graphRotationButtonDown :: IORef View -> IORef Prelude.Float -> IORef Prelude.Float -> IORef Prelude.Float
-> IORef Prelude.Float -> IORef GxlGraphSet -> IORef [GLdouble] -> GLsizei -> GLsizei -> IO()
graphRotationButtonDown graphView oldx oldy newx newy dataStructure matrixStore x y = do
                    --get the old position
                    oy <- readIORef oldy
                    ox <- readIORef oldx
                    --get the new position
                    modifyIORef newy (\d ->(fromIntegral y))
                    modifyIORef newx (\d ->(fromIntegral x))
                    ny <- readIORef newy
                    nx <- readIORef newx
                    --get the difference in the horizontal and vertical components
                    let diffy = ny -  oy
                    let diffx = nx - ox
                    --calculate the angles
                    calculateGraphRotation oldx oldy newx newy graphView
                    --update the old coordinates to the new ones
                    modifyIORef oldx (\d ->nx)
                    modifyIORef oldy (\d ->ny)
                    myGraph <- readIORef graphView
                    --rotate the graph
                    rotateGraph dataStructure  (read (show (getHorizontal myGraph))::GLfloat)
                             (read (show (getVertical myGraph))::GLfloat)
                    return()
```

calculateGraphRotation is a function as mentionned above that given a certain mouse movement will calculate the corresponding angle. Mouse sensitivity is controlled here and the division of the movement is also.

```
calculateGraphRotation :: IORef Prelude.Float->IORef Prelude.Float->IORef Prelude.Float
->IORef Prelude.Float->IORef View->IO ()
calculateGraphRotation oldx oldy newx newy graph = do
    --division of movement
    let moveDiff = 0.05
    --get old and new position
    ny <- readIORef newy
    oy <- readIORef oldy
    nx <- readIORef newx
    ox <- readIORef oldx
    --get the difference
    let diffy =  ny-oy
    let diffx =  nx-ox
    --get the vertical  angle
    if (diffy <=(-1))
      then do
           myGraph <- readIORef graph
            let newVertical = (-moveDiff)
            newGraph <- changeVertical myGraph newVertical
            modifyIORef graph (\x -> newGraph)
            postRedisplay Nothing
      else if (diffy >= 1)
        then do
            myGraph <- readIORef graph
            let newVertical = (moveDiff)
            newGraph <- changeVertical myGraph newVertical
            modifyIORef graph (\x -> newGraph)
            postRedisplay Nothing
      else return()
    --get the horizontal angle
    if (diffx <=(-1))
      then do
           myGraph <- readIORef graph
            let newHorizontal = (-moveDiff)
            newGraph <- changeHorizontal myGraph newHorizontal
            modifyIORef graph (\x -> newGraph)
            postRedisplay Nothing
      else if (diffx >= 1)
        then do
            myGraph <- readIORef graph
            let newHorizontal = (moveDiff)
            newGraph <- changeHorizontal myGraph newHorizontal
            modifyIORef graph (\x -> newGraph)
            postRedisplay Nothing
      else
        return()
```

rotateGraph is the function which rotates a given graph by an angle alpha horizontally and by angle beta vertically. the basic idea is that we get the list of nodes and edges and we rotate each seperately.

```
rotateGraph :: IORef GxlGraphSet -> GLfloat -> GLfloat ->IO()
rotateGraph dataStructure alpha beta = do
   myGraphSet <- readIORef dataStructure
   myNodeList <- getListOfNodes myGraphSet
   nodeRotateLoop dataStructure alpha beta myNodeList
   myEdgeList <- getListOfEdges myGraphSet
   edgeRotateLoop dataStructure alpha beta myEdgeList
   return()
```

nodeRotateLoop is the function which loops through the list of nodes and rotates the layout of each node by angle alpha horizontally and by angle beta vertically.

```
nodeRotateLoop :: IORef GxlGraphSet -> GLfloat -> GLfloat -> [GXL_DTD.Id] -> IO()
nodeRotateLoop dataStructure alpha beta (x:xs) = do
   mydataStructure <- readIORef dataStructure
   --get current layout
   myNode <- getNode x dataStructure
   let nodeLayout = extractLayout myNode
   --rotate horizontally
   newNodeLayout <- rotateVectorX nodeLayout alpha
   --rotate the result vertically
   newNodeLayout1 <- rotateVectorY newNodeLayout beta
   --update the layout
   let newLayoutAttribute = processLayout newNodeLayout1
   changeAttr dataStructure "Layout" x newLayoutAttribute
   nodeRotateLoop dataStructure alpha beta xs
nodeRotateLoop dataStructure _ _ _ = do return ()
```

edgeScaleLoop is the function which loops through the list of edges and rotates the control's point layout of each edge by angle alpha horizontally and by angle beta vertically. If the edge is straight then no work needs to be done as if the node gets rotated then since the edges attach the nodes they will get rotated.

```
edgeRotateLoop :: IORef GxlGraphSet -> GLfloat -> GLfloat -> [GXL_DTD.Id] -> IO()
edgeRotateLoop dataStructure alpha beta (x:xs) = do
      mydataStructure <- readIORef dataStructure
      myEdgeMidPoint <- getEdgeMidPoint x mydataStructure
      if (myEdgeMidPoint /= defaultNoMidPoint)
        then do
              --edge is bent
              --rotate horizontally
              newEdgeLayout <- rotateVertexX myEdgeMidPoint alpha
              --rotate the result vertically
              newEdgeLayout1 <- rotateVertexY newEdgeLayout beta
              --update the layout
              let newLayoutAttribute = processLayoutVertex newEdgeLayout1
              changeAttr dataStructure "midPoint" x newLayoutAttribute
              edgeRotateLoop dataStructure alpha beta xs
        else edgeRotateLoop dataStructure alpha beta xs
edgeRotateLoop dataStructure _ _ _ = do return ()
```

The following functions offer us interface to get a new vector/vertex resulting from the rotation a given vector by a given angle around a given axis. I.e rotateVectorX vector angle will for example rotate the vector vector by an angle angle around the X-Axis.

```
rotateVectorX:: Vector3 GLfloat -> GLfloat -> IO(Vector3 GLfloat)
rotateVectorX vector angle = do
let Vector3 x y z = vector
let newX = x
let newY = y*cos(angle)-z*sin(angle)
let newZ = y*sin(angle)+z*cos(angle)
let newVector = Vector3 newX newY newZ
return newVector

rotateVectorY:: Vector3 GLfloat -> GLfloat -> IO(Vector3 GLfloat)
rotateVectorY vector angle = do
let Vector3 x y z = vector
let newX = x*cos(angle)+z*sin(angle)
let newY = y
let newZ = ((-1)*x*sin(angle))+(z*cos(angle))
let newVector = Vector3 newX newY newZ
return newVector

rotateVectorZ:: Vector3 GLfloat -> GLfloat -> IO(Vector3 GLfloat)
rotateVectorZ vector angle = do
let Vector3 x y z = vector
let newX = (x*cos(angle))-(y*sin(angle))
let newY = (x*sin(angle))+(y*cos(angle))
let newZ = z
let newVector = Vector3 newX newY newZ
return newVector

rotateVertexX:: Vertex3 GLfloat -> GLfloat -> IO(Vertex3 GLfloat)
rotateVertexX vertex angle = do
let Vertex3 x y z = vertex
let newX = x
let newY = y*cos(angle)-z*sin(angle)
let newZ = y*sin(angle)+z*cos(angle)
let newvertex = Vertex3 newX newY newZ
return newvertex

rotateVertexY:: Vertex3 GLfloat -> GLfloat -> IO(Vertex3 GLfloat)
rotateVertexY vertex angle = do
let Vertex3 x y z = vertex
let newX = x*cos(angle)+z*sin(angle)
let newY = y
let newZ = ((-1)*x*sin(angle))+(z*cos(angle))
let newvertex = Vertex3 newX newY newZ
return newvertex

rotateVertexZ:: Vertex3 GLfloat -> GLfloat -> IO(Vertex3 GLfloat)
rotateVertexZ vertex angle = do
let Vertex3 x y z = vertex
let newX = (x*cos(angle))-(y*sin(angle))
```

```
let newY = (x*sin(angle))+(y*cos(angle))
let newZ = z
let newvertex = Vertex3 newX newY newZ
return newvertex
```

ItemManipulation is the module which offers us functions to remove Items (edges or nodes) as well as functions to change their attributes (color, radius , number of stacks, number of slices and label). These functions operate on Items not discriminating between nodes and edges. The secret it hides is the way these items are manipulated and how the user is prompted for input and the way the input is processed.

```
module ItemManipulation (removeItem,colorChange,radiusChange,stacksChange,slicesChange,labelChange)  where

import Gxl_1_0_1_DTD
import GXL_DTD
import INIT
import Data.IORef
import Graphics.Rendering.OpenGL.GL hiding (VertexSpec.Color)
import Graphics.Rendering.OpenGL.GLU
import Graphics.UI.GLUT hiding (Graphics.Rendering.OpenGL.GL.VertexSpec.Color)
import UndoDataStructure
import ViewDataStructure
import GraphInterface
import Node
import Utils
import Interface
import GxlGraphSetManage
import Text.XML.HaXml.OneOfN
import PickObject
import Graphics.UI.WX hiding (KeyUp,KeyDown,motion,WXCore.WxcTypes.Size,Classes.position,Attributes.get)
import Graphics.UI.WXCore.WxcTypes
import Graphics.UI.WXCore hiding (WxcClasses.View)
import GHC.Float
import Data.Char
import SettingsDataStructure
import Additional
```

Here we define a few constants that we will use as default return values in case the dialog boxes are cancelled so that we still return a value.

```
minimumValueFloat::Prelude.Float
minimumValueFloat = 0.3

minimumValueInt::Prelude.Int
minimumValueInt = 2
```

removeItem is a function which removes an item that the user selects. We do this as follows: first we call the picking function which returns to us an ID of the obeject selected. If no object is picked corresponding to ID = 0 then we have nothing to do and we return. Otherwise if an edge is selected, then we proceed to delete the edge and we use the update function so that we can do. If a node is slected, we delete all the edges from and to that node first and then remove the node. The same procedure as for edge is done so that we can undo.

```
removeItem :: GLsizei -> GLsizei -> IORef View -> IORef GxlGraphSet -> IORef UndoDataStructure -> IORef [GLdouble]
-> IORef SettingsDataStructure -> IO ()
removeItem x y view currentGraphSet undoDataStructure matrixStore settings= do
myGraphSet <- readIORef currentGraphSet
myEdgeList <- getListOfEdges myGraphSet
myId <- selectObject view x y currentGraphSet matrixStore settings
if (myId/=0)
 then do
        updateGraphDataStructure myGraphSet currentGraphSet undoDataStructure
        let myInnerId = (read (show (myId)))::GXL_DTD.Id
        if (isNode myGraphSet myInnerId ==True)
         then do
           getEdgesConnected currentGraphSet myInnerId undoDataStructure myEdgeList
           let newGraphSet = delItem myGraphSet myInnerId
           modifyIORef currentGraphSet (\x->newGraphSet)
         else do let newGraphSet = delItem myGraphSet myInnerId
                 modifyIORef currentGraphSet (\x->newGraphSet)
 else return()
return()
```

getEdgesConnected is a function which given the Id of a node and the list of edges will remove all the edges that are connected to that node so that we can remove the node at a later stage.

```
getEdgesConnected :: IORef GxlGraphSet -> GXL_DTD.Id -> IORef UndoDataStructure -> [ItemId] -> IO()
getEdgesConnected currentGraphSet id undoDataStructure (edge:edges) = do
myGraphSet <- readIORef currentGraphSet
let listOfGraphId = getGxlGraphs myGraphSet
if ( (to myGraphSet (head (listOfGraphId)) edge==id) || (from myGraphSet (head (listOfGraphId)) edge==id) ) then do
let newGraphSet = delItem myGraphSet id
updateGraphDataStructure newGraphSet currentGraphSet undoDataStructure
getEdgesConnected currentGraphSet id undoDataStructure edges
    else getEdgesConnected currentGraphSet id undoDataStructure edges
getEdgesConnected currentGraphSet id _ []            = return ()
```

colorChange is a function which changes the color of the item the user selects. First we call the picking function so that the user may select the item he whiches the color of to be changed. If the Id is 0. I.e no item was selected then we have nothing to do. If the user selects an item (edge or node) then we pass the call to openColorDialog which will in turn prompt the user for a color. Once we have the color we update the attribute.

```
colorChange:: GLsizei -> GLsizei ->  IORef GxlGraphSet -> IORef View -> IORef UndoDataStructure ->IORef [GLdouble]
-> IORef SettingsDataStructure -> IO ()
colorChange x y currentGraphSet view undoDataStructure matrixStore settings= do
   myGraphSet <- readIORef currentGraphSet
   myId <- selectObject view x y currentGraphSet matrixStore settings
   if (myId/=0)
    then do updateGraphDataStructure myGraphSet currentGraphSet undoDataStructure
            let myInnerId = (read (show (myId)))::GXL_DTD.Id
            myColor <- openColorDialog
            if (myColor==Nothing)
             then do return ()
```

```
            else do    myAttrVal <- processColor (unMaybe(myColor))
             changeAttr currentGraphSet "Color4" myInnerId myAttrVal
             return ()
     else return()
```

processColor is a function which converts the color representation used in wxHaskell where the RGB index goes from 0..255 to the one used in OpenGL 0..1 and return an AttrValue that we can use to change the attribute.

```
processColor:: Color -> IO(AttrValue)
processColor myColor = do
    let a = read(show(colorRed myColor))::Prelude.Float
    let b = read(show(colorBlue myColor))::Prelude.Float
    let c = read(show(colorGreen myColor))::Prelude.Float
    let red = show (a/255)
    let blue = show (b/255)
    let green = show (c/255)
    let newColor = TenOf10 (Tup [Tup_Float (Gxl_1_0_1_DTD.Float red),  Tup_Float (Gxl_1_0_1_DTD.Float green),
                   Tup_Float (Gxl_1_0_1_DTD.Float blue),  Tup_Float (Gxl_1_0_1_DTD.Float "1") ])
    return (newColor)
```

openColor dialog uses wxHaskell facility to display a color dialog where the user may pick the color he whiches. We prompt the user and get the color and return it.

```
openColorDialog::IO(Maybe (Color))
openColorDialog = do
   f <- frameCreateDefault ("Color Dialog")
   y<-colorDialog f red
   if (y==Nothing)
    then do return(Nothing)
    else do return (Just (unMaybe(y)))
```

openFloatDialog is a function which prompts the user with a wxHaskell text dialog and asks for a Float. If nothing is returned we return the current value. Also we have a restriction that the number entered must be bigger then minimumValueFolat otherwise that minimum is returned. We use reads to parse the text into a number. If garbage is entered then we return the current value. The current value is shown by default when the dialog is first rendered.

```
openFloatDialog::Prelude.String -> Prelude.Float -> IO(Prelude.Float)
openFloatDialog myString currentValue = do
  f <- frameCreateDefault (myString++" Dialog")
  y<-textDialog f ("Please Enter "++myString) myString (show(currentValue))
  if (null y)
    then do return(currentValue)
    else do let list=(reads y)::[(Prelude.Float, String)]
         if (list ==[] || (snd(head(list))/=""))
     then do return(currentValue)
     else do let x=(read (y))::Prelude.Float
             return (max minimumValueFloat x)
```

openIntDialog is a function which prompts the user with a wxHaskell text dialog and asks for an Int. If nothing is returned we return the current value. Also we have a restriction that the number entered must be bigger then

minimumValueInt otherwise that minimum is returned. We use reads to parse the text into a number. If garbage is entered then we return the current value. The current value is shown by default when the dialog is first rendered.

```
openIntDialog::Prelude.String -> Prelude.Int -> IO(Prelude.Int)
openIntDialog myString currentValue = do
  f <- frameCreateDefault (myString++" Dialog")
  y<-textDialog f ("Please Enter "++myString) myString (show(currentValue))
  if (null y)
    then do return(currentValue)
    else do let list=(reads y)::[(Prelude.Float, String)]
         if (list ==[] || (snd(head(list))/=""))
     then do return(currentValue)
     else do let x=(read (y))::Prelude.Float
             let z = float2Int x
             return (max minimumValueInt z)
```

The following functions radiusChange, slicesChange, stacksChange and labelChange all work in a similar fashion. An item is selected, if its not a node nor an edge then we have nothing to do. Otherwise we prompt the user for new values using WxHaskell facilities and update the attrbute value accordingly.
radiusChange is a function which changes the radius of an item in a similar fashion as the functions described above.

```
radiusChange::GLsizei -> GLsizei -> IORef GxlGraphSet ->IORef View -> IORef UndoDataStructure ->IORef [GLdouble]
-> IORef SettingsDataStructure -> IO ()
radiusChange x y currentGraphSet view undoDataStructure matrixStore settings = do
      myGraphSet <- readIORef currentGraphSet
      myId <- selectObject view x y currentGraphSet matrixStore settings
      if (myId/=0)
       then do updateGraphDataStructure myGraphSet currentGraphSet undoDataStructure
               let myInnerId = (read (show (myId)))::GXL_DTD.Id
               currentRadius <- getItemRadius myInnerId currentGraphSet
               myRadius <- openFloatDialog "Radius" (read(show (currentRadius))::Prelude.Float)
               myAttrVal <- processFloat myRadius
               changeAttr currentGraphSet "Radius" myInnerId myAttrVal
               return ()
       else return()
```

slicesChange is a function which changes the number of slices of an item in a similar fashion as the functions described above.

```
slicesChange::GLsizei -> GLsizei -> IORef GxlGraphSet ->IORef View -> IORef UndoDataStructure -> IORef [GLdouble]
-> IORef SettingsDataStructure -> IO ()
slicesChange x y currentGraphSet view undoDataStructure matrixStore settings = do
      myGraphSet <- readIORef currentGraphSet
      myId <- selectObject view x y currentGraphSet matrixStore settings
      if (myId/=0)
       then do updateGraphDataStructure myGraphSet currentGraphSet undoDataStructure
               let myInnerId = (read (show (myId)))::GXL_DTD.Id
               currentSlices <- getItemSlices myInnerId currentGraphSet
               mySlices <- openIntDialog "Slices" (read(show (currentSlices))::Prelude.Int)
               myAttrVal <- processInt mySlices
```

```
            changeAttr currentGraphSet "Slices" myInnerId myAttrVal
            return ()
      else return()
```

stacksChange is a function which changes the number of stacks of an item in a similar fashion as the functions described above.

```
stacksChange::GLsizei -> GLsizei -> IORef GxlGraphSet ->IORef View -> IORef UndoDataStructure -> IORef [GLdouble]
-> IORef SettingsDataStructure -> IO ()
stacksChange x y currentGraphSet view undoDataStructure matrixStore settings = do
      myGraphSet <- readIORef currentGraphSet
      myId <- selectObject view x y currentGraphSet matrixStore settings
      if (myId/=0)
       then do updateGraphDataStructure myGraphSet currentGraphSet undoDataStructure
               let myInnerId = (read (show (myId)))::GXL_DTD.Id
               currentStacks <- getItemStacks myInnerId currentGraphSet
               myStacks <- openIntDialog "Stacks" (read(show (currentStacks))::Prelude.Int)
               myAttrVal <- processInt myStacks
               changeAttr currentGraphSet "Stacks" myInnerId myAttrVal
               return ()
       else return()
```

labelChange is a function which changes the label of an item in a similar fashion as the functions described above.

```
labelChange::GLsizei -> GLsizei -> IORef GxlGraphSet ->IORef View -> IORef UndoDataStructure -> IORef [GLdouble]
-> IORef SettingsDataStructure -> IO ()
labelChange x y currentGraphSet view undoDataStructure matrixStore settings = do
      myGraphSet <- readIORef currentGraphSet
      myId <- selectObject view x y currentGraphSet matrixStore settings
      if (myId/=0)
       then do updateGraphDataStructure myGraphSet currentGraphSet undoDataStructure
               let myInnerId = (read (show (myId)))::GXL_DTD.Id
               currentLabel <- getItemLabel myInnerId currentGraphSet
               myLabel <- openTextDialog currentLabel
               myAttrVal <- processString myLabel
               changeAttr currentGraphSet "Label" myInnerId myAttrVal
               return ()
       else return()
```

processFloat is a function which takes in a float and converts it to a float attribute value so it may be inserted into the attribute finite map.

```
processFloat::Prelude.Float -> IO(AttrValue)
processFloat number = do
  let newNumber = FourOf10 (Gxl_1_0_1_DTD.Float (show(number)))
  return(newNumber)
```

processInt is a function which takes in an integer and converts it to an int attribute value so it may be inserted into the attribute finite map.

```
processInt::Prelude.Int -> IO(AttrValue)
processInt number = do
  let newNumber = ThreeOf10 (Gxl_1_0_1_DTD.Int (show(number)))
  return(newNumber)
```

processString is a function which takes in a string and converts it to a string attribute value so it may be inserted into the attribute finite map.

```
processString::Prelude.String -> IO(AttrValue)
processString myString = do
  let newString = FiveOf10 (Gxl_1_0_1_DTD.GxlString (show(myString)))
  return(newString)
```

openTextDialog is a function which uses wxHaskell facilities to prompt the user for a string, it takes the string and converts the character to capital letters as this is what we have in the label display list. The current label is shown as default when the dialog is first rendered.

```
openTextDialog::Prelude.String -> IO(Prelude.String)
openTextDialog currentValue = do
  f <- frameCreateDefault ("Label Dialog")
  y<-textDialog f ("Please Enter Label") "Label" (currentValue)
  return (map toUpper y)
```

unMaybe is a function which is used to transform variables from type Maybe a to a.

```
unMaybe :: Maybe a -> a
unMaybe (Just a) = a
```

LabelDisplay is the module which gives us facilities to display the labels (text) on the screen. The secret it hides is how strings are outputed on the screen. The code that forms this module is very closely based on font.hs which is one of the Redbook examples that installs with OpengGL. Therefore we took the freedom to reuse this code without having to write our own subroutines to display text. This copyright of this code is owned by Copyright (c) 1993-1997, Silicon Graphics, Inc..

```
module LabelDisplay (glRasterPos2s,makeRasterFont,printString)  where

import Data.Char
import Data.IORef  ( IORef, newIORef, readIORef, modifyIORef, writeIORef)
import Data.FiniteMap
import IO
import Graphics.Rendering.OpenGL.GL
import Graphics.Rendering.OpenGL.GLU
import Graphics.UI.GLUT.Callbacks.Window ( MouseButton )
import Graphics.UI.GLUT.Window
```

```
import Graphics.UI.GLUT hiding (MenuItem)
import Graphics.UI.WX hiding (KeyUp,KeyDown,color,motion,WXCore.WxcTypes.Size,Classes.position,Attributes.get)
import Graphics.UI.WXCore.Frame
import System.Exit(exitWith, ExitCode(ExitSuccess), exitFailure)
import Control.Monad ( liftM, zipWithM_ )
import Data.Char     ( ord )
import Data.List     ( genericLength )
import Foreign hiding (rotate)
foreign import "glBitmap" unsafe glBitmap :: GLsizei -> GLsizei
                                          -> GLfloat -> GLfloat
                                          -> GLfloat -> GLfloat
                                          -> Ptr GLubyte -> IO ()
foreign import "glRasterPos2s" unsafe glRasterPos2s :: GLshort  -> GLshort  -> IO ()

spaceBytes :: [GLubyte]
spaceBytes = [
   0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00 ]

lettersBytes :: [[GLubyte]]
lettersBytes = [
   [0x00, 0x00, 0xc3, 0xc3, 0xc3, 0xc3, 0xff, 0xc3, 0xc3, 0xc3, 0x66, 0x3c, 0x18],
   [0x00, 0x00, 0xfe, 0xc7, 0xc3, 0xc3, 0xc7, 0xfe, 0xc7, 0xc3, 0xc3, 0xc7, 0xfe],
   [0x00, 0x00, 0x7e, 0xe7, 0xc0, 0xc0, 0xc0, 0xc0, 0xc0, 0xc0, 0xc0, 0xe7, 0x7e],
   [0x00, 0x00, 0xfc, 0xce, 0xc7, 0xc3, 0xc3, 0xc3, 0xc3, 0xc3, 0xc7, 0xce, 0xfc],
   [0x00, 0x00, 0xff, 0xc0, 0xc0, 0xc0, 0xc0, 0xfc, 0xc0, 0xc0, 0xc0, 0xc0, 0xff],
   [0x00, 0x00, 0xc0, 0xc0, 0xc0, 0xc0, 0xc0, 0xc0, 0xfc, 0xc0, 0xc0, 0xc0, 0xff],
   [0x00, 0x00, 0x7e, 0xe7, 0xc3, 0xc3, 0xcf, 0xc0, 0xc0, 0xc0, 0xc0, 0xe7, 0x7e],
   [0x00, 0x00, 0xc3, 0xc3, 0xc3, 0xc3, 0xc3, 0xff, 0xc3, 0xc3, 0xc3, 0xc3, 0xc3],
   [0x00, 0x00, 0x7e, 0x18, 0x18, 0x18, 0x18, 0x18, 0x18, 0x18, 0x18, 0x18, 0x7e],
   [0x00, 0x00, 0x7c, 0xee, 0xc6, 0x06, 0x06, 0x06, 0x06, 0x06, 0x06, 0x06, 0x06],
   [0x00, 0x00, 0xc3, 0xc6, 0xcc, 0xd8, 0xf0, 0xe0, 0xf0, 0xd8, 0xcc, 0xc6, 0xc3],
   [0x00, 0x00, 0xff, 0xc0, 0xc0, 0xc0, 0xc0, 0xc0, 0xc0, 0xc0, 0xc0, 0xc0, 0xc0],
   [0x00, 0x00, 0xc3, 0xc3, 0xc3, 0xc3, 0xc3, 0xc3, 0xdb, 0xff, 0xff, 0xe7, 0xc3],
   [0x00, 0x00, 0xc7, 0xc7, 0xcf, 0xcf, 0xdf, 0xdb, 0xfb, 0xf3, 0xf3, 0xe3, 0xe3],
   [0x00, 0x00, 0x7e, 0xe7, 0xc3, 0xc3, 0xc3, 0xc3, 0xc3, 0xc3, 0xc3, 0xe7, 0x7e],
   [0x00, 0x00, 0xc0, 0xc0, 0xc0, 0xc0, 0xc0, 0xfe, 0xc7, 0xc3, 0xc3, 0xc7, 0xfe],
   [0x00, 0x00, 0x3f, 0x6e, 0xdf, 0xdb, 0xc3, 0xc3, 0xc3, 0xc3, 0xc3, 0x66, 0x3c],
   [0x00, 0x00, 0xc3, 0xc6, 0xcc, 0xd8, 0xf0, 0xfe, 0xc7, 0xc3, 0xc3, 0xc7, 0xfe],
   [0x00, 0x00, 0x7e, 0xe7, 0x03, 0x03, 0x07, 0x7e, 0xe0, 0xc0, 0xc0, 0xe7, 0x7e],
   [0x00, 0x00, 0x18, 0x18, 0x18, 0x18, 0x18, 0x18, 0x18, 0x18, 0x18, 0x18, 0xff],
   [0x00, 0x00, 0x7e, 0xe7, 0xc3, 0xc3, 0xc3, 0xc3, 0xc3, 0xc3, 0xc3, 0xc3, 0xc3],
   [0x00, 0x00, 0x18, 0x3c, 0x3c, 0x66, 0x66, 0xc3, 0xc3, 0xc3, 0xc3, 0xc3, 0xc3],
   [0x00, 0x00, 0xc3, 0xe7, 0xff, 0xff, 0xdb, 0xdb, 0xc3, 0xc3, 0xc3, 0xc3, 0xc3],
   [0x00, 0x00, 0xc3, 0x66, 0x66, 0x3c, 0x3c, 0x18, 0x3c, 0x3c, 0x66, 0x66, 0xc3],
   [0x00, 0x00, 0x18, 0x18, 0x18, 0x18, 0x18, 0x18, 0x3c, 0x3c, 0x66, 0x66, 0xc3],
   [0x00, 0x00, 0xff, 0xc0, 0xc0, 0x60, 0x30, 0x7e, 0x0c, 0x06, 0x03, 0x03, 0xff]]

makeRasterFont :: IO DisplayList
makeRasterFont = do
   rowAlignment Unpack $= 1

   fontDisplayLists@(fontOffset:_) <- genLists 128
   let listsStartingWith ch = drop (ord ch) fontDisplayLists
       makeLetter dl letter =
```

```
          defineList dl Compile $
             withArray letter $
                glBitmap 8 13 0 2 10 0

   zipWithM_ makeLetter (listsStartingWith 'A') lettersBytes
   makeLetter (head (listsStartingWith ' ')) spaceBytes
   return fontOffset

printString :: DisplayList -> String -> IO ()
printString fontOffset s =
   preservingAttrib [ ListAttributes ] $ do
      listBase $= fontOffset
      withArray (stringToGLubytes s) $
         callLists (genericLength s) UnsignedByte

stringToGLubytes :: String -> [GLubyte]
stringToGLubytes = map (fromIntegral . ord)
```

Module Layout gives us the function which generates the default layout in case this information is missing from the graph or partial, that is some items have layout and some don't. In this case the default layout is only applied to the items with missing layout. For items which already have layout information such information is kept intact. Note also that we only specify layout for nodes as edges unless bent do not carry any layout information. The layout generation function here we use is a very simple one which works in the following manner: It first places the first item at (j 0 0) and then the next at (0 j 0) and the next one at (0 0 j) then finally j is incremented by 1 and the rest of the locations are generated in a similar fashion. We arbitrarily start with j=3. This module has been designed in order to allow more advanced layout generation algorithms to be easily incorporated. This modules hides the function used to generate the layout.

```
module Layout (generateLayout) where

import Text.XML.HaXml.Xml2Haskell
import Gxl_1_0_1_DTD
import GXL_DTD
import INIT
import Data.IORef
import Graphics.Rendering.OpenGL.GL
import Graphics.Rendering.OpenGL.GLU
import Graphics.UI.GLUT
import GraphInterface
import Text.XML.HaXml.OneOfN
import Data.FiniteMap
import GxlGraphSetXml
import Utils
import GxlGraphSetManage
```

generateLayout is the function which gets the list of nodes of the graph and forwards the call to generate a layout to layoutGeneration.

```
generateLayout:: IORef GxlGraphSet -> IO ()
generateLayout dataStructure = do
```

```
myGraphSet <- readIORef dataStructure
myNodeList <- getListOfNodes myGraphSet
layoutGeneration dataStructure 0 3 myNodeList
return()
```

layoutGeneration is a function that recursively goes through the list of the nodes and checks each node if it has layout information. If such information is present then the functions just moves on to the next node. If no such information is found then the node is given a layout as per the scheme described above.

```
layoutGeneration:: IORef GxlGraphSet -> Prelude.Int -> Prelude.Int -> [GXL_DTD.Id] -> IO()
layoutGeneration dataStructure i j (x:xs) = do
   mydataStructure <- readIORef dataStructure
   myNode <- getNode x dataStructure
   if (i==0 `mod` 3)
    then do
      let newNodeLayout = Vector3 j 0 0
      let listOfGraphID = getGxlGraphs mydataStructure
      let mapOfGraphAttrs = graphAttrs mydataStructure (head(listOfGraphID))
         let graphFiniteMap = itemAttrs mydataStructure mapOfGraphAttrs x
      let myLayout = lookupFM graphFiniteMap (x,"Layout")
      --if the layout is missing
      if (myLayout == Nothing)
        then do
         --generate layout for that item by modifying its attribute list
         let (ItemInfo a b c d e) = queryItemInfo mydataStructure x
         let (z,y) = addAttrGetId (myInfox j) mydataStructure
         modifyIORef dataStructure (\x -> y)
         mydataStructure <- readIORef dataStructure
         let newList = z:b
         let newItemInfo = ItemInfo a newList c d e
         let newGraphSet = updateItemInfo mydataStructure x newItemInfo
         --update the graph set
         modifyIORef dataStructure (\x -> newGraphSet)
         layoutGeneration dataStructure (i+1) j xs
         else do
     --if layout info is there do nothing and go to next item
     layoutGeneration dataStructure (i) j xs
    else if (i==1 `mod` 3)
      then do
       let newNodeLayout = Vector3 0 j 0
       let listOfGraphID = getGxlGraphs mydataStructure
         let mapOfGraphAttrs = graphAttrs mydataStructure (head(listOfGraphID))
          let graphFiniteMap = itemAttrs mydataStructure mapOfGraphAttrs x
       let myLayout = lookupFM graphFiniteMap (x,"Layout")
       if (myLayout == Nothing)
        then do
         let (ItemInfo a b c d e) = queryItemInfo mydataStructure x
         let (z,y) = addAttrGetId (myInfoy j) mydataStructure
         modifyIORef dataStructure (\x -> y)
         mydataStructure <- readIORef dataStructure
         let newList = z:b
         let newItemInfo = ItemInfo a newList c d e
```

```
        let newGraphSet = updateItemInfo mydataStructure x newItemInfo
        modifyIORef dataStructure (\x -> newGraphSet)
 layoutGeneration dataStructure (i+1) j xs
 else do
  layoutGeneration dataStructure (i) j xs
else do
 let newNodeLayout = Vector3 0 0 j
 let listOfGraphID = getGxlGraphs mydataStructure
 let mapOfGraphAttrs = graphAttrs mydataStructure (head(listOfGraphID))
 let graphFiniteMap = itemAttrs mydataStructure mapOfGraphAttrs x
 let myLayout = lookupFM graphFiniteMap (x,"Layout")
 if (myLayout == Nothing)
          then do
           let (ItemInfo a b c d e) = queryItemInfo mydataStructure x
           let (z,y) = addAttrGetId (myInfoy j) mydataStructure
           modifyIORef dataStructure (\x -> y)
           mydataStructure <- readIORef dataStructure
           let newList = z:b
           let newItemInfo = ItemInfo a newList c d e
           let newGraphSet = updateItemInfo mydataStructure x newItemInfo
           modifyIORef dataStructure (\x -> newGraphSet)
           layoutGeneration dataStructure 0 (j+1) xs
          else do
           layoutGeneration dataStructure 0 (j) xs
layoutGeneration _ _ _ _ = return()
```

layoutAttr is a function which is used to create the layout attribut.

```
layoutAttr::AttrAttr
layoutAttr = AttrAttr Nothing "Layout"  Nothing
```

myInfox,y and z are functions used to produce the Attribute Info of the layout based on the coordinate. Here we are only passing one variable since are coordinates are always two zero and one non zero (j) variable.

```
myInfox::Prelude.Int -> AttrInfo
myInfox j = AttrInfo Nothing [] (TenOf10 (Tup [Tup_Float (Gxl_1_0_1_DTD.Float (show j)),
Tup_Float (Gxl_1_0_1_DTD.Float "0"),Tup_Float (Gxl_1_0_1_DTD.Float "0")]))
layoutAttr
myInfoy::Prelude.Int -> AttrInfo
myInfoy j = AttrInfo Nothing [] (TenOf10 (Tup [Tup_Float (Gxl_1_0_1_DTD.Float "0"),
Tup_Float (Gxl_1_0_1_DTD.Float (show j)),Tup_Float (Gxl_1_0_1_DTD.Float "0")]))
layoutAttr
myInfoz::Prelude.Int -> AttrInfo
myInfoz j = AttrInfo Nothing [] (TenOf10 (Tup [Tup_Float (Gxl_1_0_1_DTD.Float "0"),
Tup_Float (Gxl_1_0_1_DTD.Float "0"),Tup_Float (Gxl_1_0_1_DTD.Float (show j))]))
layoutAttr
```

processLayout is a function which given a vector in 3D will return the attribute value in the form of OneOfN variable which is used by XML in the GXL format.

```
processLayout::Vector3 GLfloat -> AttrValue
processLayout (Vector3 first second third) = (TenOf10 (Tup [Tup_Float (Gxl_1_0_1_DTD.Float (show first)),
Tup_Float (Gxl_1_0_1_DTD.Float (show second)),Tup_Float (Gxl_1_0_1_DTD.Float (show third))]))
```

Main controls the operation of the application. The application is driven by the variable currentMode which indicates the state we are currently in. Based ont he value of that parameter, the program is able to decide what to do next with the user's input.

The following is done here:

1- Keyboard and Mouse callbacks are set so that moving the mouse or clicking the keyboard/mouse buttons triger some actions depending on the mode the currect program is in.

2- The reshape callback is set here, which is the function called every time the window is reshaped.

3- Lighting is set up and turned on, this is used so that we get a true 3D feel.

4- The display callback is set, which is the function called everytime the graph needs to be rendered.

5- The menu is setup and attached to the mouse to enable the user to toggle between the different modes/options of the program.

6- The original window is initialised.

7- The variables used throughout the program are initialised.

```
import Data.IORef  ( IORef, newIORef, readIORef, modifyIORef, writeIORef)
import Graphics.Rendering.OpenGL.GL
import Graphics.Rendering.OpenGL.GLU
import Graphics.UI.GLUT.Callbacks.Window ( MouseButton )
import Graphics.UI.GLUT.Window
import Graphics.UI.GLUT hiding (MenuItem)
import Graphics.UI.WX hiding (KeyUp,KeyDown,color,motion,WXCore.WxcTypes.Size,Classes.position,Attributes.get,
Graphics.UI.WXCore.Types.when,Graphics.UI.WXCore.Events.Key,Graphics.UI.WXCore.Events.Modifiers)
import Graphics.UI.WXCore.Frame
import System.Exit(exitWith, ExitCode(ExitSuccess), exitFailure)
import Control.Monad
import ViewFileManager
import PickObject
import DrawGraph
import GraphInterface
import Gxl_1_0_1_DTD hiding (Int)
import GXL_DTD
import ViewDataStructure
import GxlGraphSetManage
import UndoDataStructure
import GraphFileManager
import NodeManipulation
import EdgeManipulation
import GraphManipulation
import ItemManipulation
import ViewManipulation
import SettingsDataStructure
import GxlGraphSetManage
```

```
import SettingsFileManager
```

keyboardMouse is the function which processes keyboard and mouse clicks, and depending on the mode the program is in will call the appropriate function to do the actual work.

```
keyboardMouse::IORef SettingsDataStructure -> IORef String -> IORef View -> IORef GLfloat -> IORef GLfloat
-> IORef GxlGraphSet -> IORef GXL_DTD.Id -> IORef GXL_DTD.Id -> IORef UndoDataStructure -> IORef [GLdouble]
-> KeyboardMouseCallback
--mouse left button is pressed
keyboardMouse settings mode view oldx oldy  dataStructure currentItem1 currentItem2 undoDataStructure matrixStore
(MouseButton LeftButton) Down _ (Position x y) = do

   currentMode <- readIORef mode
   when (currentMode == "rotateView")  $ do updateLatestPosition oldx oldy x y
   when (currentMode == "rotateGraph") $ do newGraphSet <- readIORef dataStructure;
        updateGraphDataStructure newGraphSet dataStructure undoDataStructure;
        updateLatestPosition oldx oldy x y
   when (currentMode == "zoomGraph")   $ do newGraphSet <- readIORef dataStructure;
        updateGraphDataStructure newGraphSet dataStructure undoDataStructure;
        return()
   when (currentMode == "zoomView")    $ do return()
   when (currentMode == "removeItem")  $ do removeItem x y view dataStructure undoDataStructure
                                            matrixStore settings;
        postRedisplay Nothing
   when (currentMode == "changeColor") $ do colorChange x y dataStructure view undoDataStructure
                                            matrixStore settings;
    postRedisplay Nothing
   when (currentMode == "changeLabel") $ do labelChange x y dataStructure view undoDataStructure
                                            matrixStore settings;
    postRedisplay Nothing
   when (currentMode == "changeRadius") $ do radiusChange x y dataStructure view undoDataStructure
                                            matrixStore settings;
     postRedisplay Nothing
   when (currentMode == "changeSlices") $ do slicesChange x y dataStructure view undoDataStructure
                                            matrixStore settings;
     postRedisplay Nothing
   when (currentMode == "changeStacks") $ do stacksChange x y dataStructure view undoDataStructure
                                            matrixStore settings;
     postRedisplay Nothing
   when (currentMode == "moveNode")    $ do selectedNode <- selectObject view x y dataStructure matrixStore settings;
        let newNode = (read ( show selectedNode))::GXL_DTD.Id;
    modifyIORef currentItem1 (\x->newNode);
    postRedisplay Nothing
   when (currentMode == "bendEdge")    $ do selectedEdge <- selectObject view x y dataStructure matrixStore settings;
        let newEdge = (read ( show selectedEdge))::GXL_DTD.Id;
    modifyIORef currentItem1 (\x->newEdge);
    postRedisplay Nothing
   when (currentMode == "addDirectedEdge") $ do addEdge dataStructure x y view currentItem1 currentItem2
                                               "Item_isdirected_true" undoDataStructure matrixStore settings;
            postRedisplay Nothing
   when (currentMode == "addUndirectedEdge") $ do addEdge dataStructure x y view currentItem1 currentItem2
                                               "Item_isdirected_false" undoDataStructure matrixStore settings;
```

```
      postRedisplay Nothing
   when (currentMode == "addNode")     $ do newGraphSet <- readIORef dataStructure;
          addNode dataStructure x y settings matrixStore view undoDataStructure;
    postRedisplay Nothing

--Mouse wheel is scrolled up
keyboardMouse settings mode view _ _ dataStructure currentItem1 _ undoDataStructure matrixStore (MouseButton WheelUp)
Down _ _= do
 let scaleFactor = 1.1
 currentMode <- readIORef mode
 myItem <- readIORef currentItem1
 when (currentMode == "moveNode") $ do  moveNodeWheelUp dataStructure myItem settings matrixStore undoDataStructure;
             postRedisplay Nothing

 when ((currentMode == "zoomView") || (currentMode == "")) $ do  zoomViewWheelUp view;
                                                                  postRedisplay Nothing
 when (currentMode == "bendEdge") $ do   bendEdgeWheelUp dataStructure myItem settings matrixStore undoDataStructure;
               postRedisplay Nothing
 when (currentMode == "scaleGraph")$ do  myGraphSet <- readIORef dataStructure;
   updateGraphDataStructure myGraphSet dataStructure undoDataStructure;
   scaleGraph dataStructure scaleFactor settings;
 postRedisplay Nothing
--Mouse wheel is scrolled down
keyboardMouse settings mode view _ _ dataStructure currentItem1 _ undoDataStructure matrixStore
(MouseButton WheelDown) Down _ _= do
 let scaleFactor = 0.9
 currentMode <- readIORef mode
 myItem <- readIORef currentItem1
 when (currentMode == "moveNode") $ do  moveNodeWheelDown dataStructure myItem settings
                                        matrixStore undoDataStructure;
          postRedisplay Nothing
 when ((currentMode == "zoomView") || (currentMode == "")) $ do  zoomViewWheelDown view;
                                                                  postRedisplay Nothing
 when (currentMode == "bendEdge") $ do   bendEdgeWheelDown dataStructure myItem settings
                                         matrixStore undoDataStructure;
   postRedisplay Nothing
 when (currentMode == "scaleGraph")$ do  myGraphSet <- readIORef dataStructure;
   updateGraphDataStructure myGraphSet dataStructure undoDataStructure;
   scaleGraph dataStructure scaleFactor settings;
 postRedisplay Nothing
--Uparrow key of keyboard is presses
keyboardMouse _ _ view _ _ _ _ _ _ _ (SpecialKey KeyUp) Down _ _= do zoomViewWheelUp view;
                                                                     postRedisplay Nothing

--Lowarrow key of keyboard is presses
keyboardMouse _ _ view _ _ _ _  _ _ _ (SpecialKey KeyDown) Down _ _= do zoomViewWheelDown view;
                                                                        postRedisplay Nothing
--Keyboard Shortcuts
keyboardMouse _ mode view _ _ dataStructure _ _ undoDataStructure _ (Char character) Down modifier  _ = do
           let Modifiers shiftKey controlKey altKey = modifier;
                   if (controlKey==Down)
    then do
        --control-L is open graph
     if (character==’\f’)
```

```
   then do openGraph dataStructure view undoDataStructure
           postRedisplay Nothing
   --control-Y is redo
   else if (character==’\EM’)
     then do redo dataStructure undoDataStructure
             postRedisplay Nothing
     --control-Z is undo
     else if (character==’\SUB’)
      then do undo dataStructure undoDataStructure
              postRedisplay Nothing
      --control-S is save graph
      else if (character==’\DC3’)
       then do saveGraph dataStructure
               postRedisplay Nothing
       --control-C is close graph
       else if (character==’\ETX’)
        then do closeGraph dataStructure view undoDataStructure
        postRedisplay Nothing
else do return()
            else do return()
--Do nothing when anything other then the above is pressed
keyboardMouse _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ = return ()
```

reshape is the function that is associated with the reshape call back. Every time the window is reshaped this function is called. Here we set the viewing point and the perspective from which we are looking from and where are we looking to and the upward direction.

```
reshape :: ReshapeCallback
reshape size@(Size w h) = do
   let initialCameraDistance = 14.0::GLdouble
   --setup the rectangular region of the window where the image is drawn, here the whole window
   viewport $= (Position 0 0, size)
   matrixMode $= Projection
   loadIdentity
   --setup the projection matrix such that further objects apear in perspective to nearer ones
   --the field of view is set to 45 degrees and the aspect is the width dvided by the height
   --the near plane is how far the nearest object can be its 1 and 500 is the furthest it can be
   --at and sitt be visible.
   perspective 45.0 (fromIntegral w / fromIntegral h) 1 500.0
   matrixMode $= Modelview 0
   loadIdentity
   {-look at the graph by placing the camera at 0 0 initialCameraDistance
   facing the origin and the upward direction is 0 1 0 -}
   lookAt (Vertex3 0.0 0.0 initialCameraDistance) (Vertex3 0.0 0.0 0.0) (Vector3 0 1 0)
```

initWindow initialises the current window by first setting its properties for color and buffering, and then sets the size to 600*600 pixels. Finally rhe color buffer and the depth buffer are cleared.

```
initWindow :: IO ()
initWindow  = do
          initialDisplayMode $= [ DoubleBuffered, RGBMode, WithDepthBuffer ]
```

```
          initialWindowSize $= Size (600) (600)
          clear [ColorBuffer,DepthBuffer]
```

motion is the function which process mouse motion input as the name indicates, and depending on the mode the program is in will call the appropriate function to do the actual work.

```
motion ::IORef String -> IORef View -> IORef View -> IORef GLfloat -> IORef GLfloat -> IORef GLfloat
-> IORef GLfloat -> IORef GxlGraphSet -> IORef GXL_DTD.Id -> IORef UndoDataStructure -> IORef SettingsDataStructure
-> IORef [GLdouble] -> MotionCallback
motion selectMode view graph oldx oldy newx newy currentGraphSet currentItem1 undoDataStructure settings
matrixStore (Position x y) = do
       myGraphSet <- readIORef currentGraphSet
       currentMode <- readIORef selectMode
       if (currentMode=="rotateView")
  then do
            rotateViewButtonDown view oldx oldy newx newy x y
          else  if (currentMode=="moveNode")
      then do
moveNodeButtonDown view oldx oldy newx newy currentGraphSet currentItem1 undoDataStructure settings matrixStore x y
           else  if (currentMode=="bendEdge")
          then do
bendEdgeButtonDown view oldx oldy newx newy currentGraphSet currentItem1 undoDataStructure settings matrixStore x y
       else if (currentMode=="rotateGraph")
      then do
            graphRotationButtonDown view oldx oldy newx newy currentGraphSet matrixStore x y
                        else postRedisplay Nothing
```

setupLighting sets up the lighting at specified position and with specified attributes and the light is turned on and enable. Use of lighting is essential to give us a true 3 dimensional feel.

```
setupLighting:: IO ()
setupLighting = do
        normalize $= Enabled
        depthFunc $= Just Less
        shadeModel $= Smooth
        position (Light 0) $= Vertex4 0 3 (2) 0
        ambient (Light 0) $= Color4 0.4 0.4 0.4 1
        diffuse (Light 0) $= Color4 1 1 1 1
        specular (Light 0) $= Color4 1 1 1 1
        light (Light 0) $= Enabled
        lighting  $= Enabled
```

userInterface creates and new window and sets up the user interface. First we initialise all the variables and then we add the menu and attach it to the mouse button so that the user can select different options. Note that GLUT menus are used here since they have to be rendered withing a GLUT window therefore not enabling us to use wxHaskell windows. Also the motion, keyboardmouse and display callbacks are set.

```
userInterface :: IORef Int -> IORef GxlGraphSet -> IORef UndoDataStructure -> IO ()
userInterface view_count dataStructure undoDataStructure = do
initWindow
x <- createWindow "3-D Graph Editor"
myView <- (initView)
```

```
myGraph <- (initView)
graph <- newIORef myGraph
view <- newIORef myView
oldy <- newIORef 0.0
oldx <- newIORef 0.0
newy <- newIORef 0.0
newx <- newIORef 0.0
matrixStore <- newIORef []
currentItem1 <- newIORef (0::GXL_DTD.Id)
currentItem2 <- newIORef (0::GXL_DTD.Id)
selectMode <- newIORef ""
settings <- newSettingsDataStructure
setupLighting
modifyIORef view_count (\x -> (x+1))
attachMenu RightButton (Menu [
 SubMenu "View" (Menu [
   MenuEntry "New" (do modifyIORef selectMode (\x ->"")
                       userInterface view_count dataStructure undoDataStructure),
   MenuEntry "Load" (openView view),
   MenuEntry "Save" (saveView view),
          MenuEntry "Close"  (closeView x view_count)]),
 MenuEntry "------------------" (return()),
 SubMenu "Graph" (Menu [
   MenuEntry "Load" (openGraph dataStructure view undoDataStructure),
   MenuEntry "Save" (saveGraph dataStructure),
          MenuEntry "Close" (closeGraph dataStructure view undoDataStructure)]),
         MenuEntry "------------------" (return()),
 SubMenu "Add" (Menu [
    MenuEntry "Node" (do modifyIORef selectMode (\x ->"addNode")),
    MenuEntry "Undirected Edge" (do modifyIORef currentItem1 (\x -> 0);
         modifyIORef selectMode (\x ->"addUndirectedEdge")),
    MenuEntry "Directed Edge" (do   modifyIORef currentItem1 (\x -> 0);
         modifyIORef selectMode (\x ->"addDirectedEdge"))]),
 SubMenu "Remove" (Menu [
   MenuEntry "Remove Item" (do modifyIORef selectMode (\x ->"removeItem")) ]),
 MenuEntry "--------------------" (return()),
 SubMenu "Move  " (Menu [
   MenuEntry "Node"  (do modifyIORef selectMode (\x ->"moveNode"))]),
 SubMenu "Zoom" (Menu [
    MenuEntry "Graph" (do modifyIORef selectMode (\x ->"scaleGraph")),
    MenuEntry "View" (do modifyIORef selectMode (\x ->"zoomView"))]),
         SubMenu "Rotate" (Menu [
    MenuEntry "Graph" (do modifyIORef selectMode (\x ->"rotateGraph")),
    MenuEntry "View" (do  modifyIORef selectMode (\x ->"rotateView"))]),

 SubMenu "Bend" (Menu [
    MenuEntry "Edge" (do modifyIORef selectMode (\x ->"bendEdge"))]),
 MenuEntry "------------------" (return()),
 SubMenu "Change" (Menu [
   MenuEntry "Color" (do modifyIORef selectMode (\x ->"changeColor")),
   MenuEntry "Label" (do modifyIORef selectMode (\x ->"changeLabel")),
   MenuEntry "Radius" (do modifyIORef selectMode (\x ->"changeRadius")),
   MenuEntry "Slices" (do modifyIORef selectMode (\x ->"changeSlices")),
   MenuEntry "Stacks" (do modifyIORef selectMode (\x ->"changeStacks"))]),
```

```
 MenuEntry "------------------" (return()),
 SubMenu "Settings" (Menu [
   MenuEntry "Load" (openSettings settings),
   MenuEntry "Save" (saveSettings settings),
   MenuEntry "Cylinder Number" (changeCylinderNumber settings),
   MenuEntry "Collision Detection" (changeCollisionDetection settings),
   MenuEntry "Axis Rendering" (changeAxisDisplay settings)]),
 MenuEntry "------------------" (return()),
 MenuEntry "Undo"  (undo dataStructure undoDataStructure),
 MenuEntry "Redo"  (redo dataStructure undoDataStructure),
 MenuEntry "Exit"  (exitWith ExitSuccess)])
displayCallback $= (displayGraph view dataStructure matrixStore settings)
reshapeCallback $= (Just reshape)
keyboardMouseCallback $= (Just (keyboardMouse settings selectMode view oldx oldy dataStructure currentItem1
                          currentItem2 undoDataStructure matrixStore))
motionCallback $= (Just (motion selectMode view graph oldx oldy newx newy dataStructure currentItem1
                         undoDataStructure settings matrixStore))
mainLoop
```

main is the function which originally starts the whole process first we initialise the number of open views to 0, then we load the empty graph and we initialise the undo data structure, then the application is started.

```
main :: IO ()
main = do
     view_count <- newIORef 0
     let newGraphSet = addEmptyGraph newEmptyGraphSet "Graph"
     dataStructure <- newIORef newGraphSet
     undoDataStructure <- newUndoDataStructure
     getArgsAndInitialize
     start (userInterface view_count dataStructure undoDataStructure)
```

updateLatestPosition updates the IORefs which represent the old coordinate of x and old coordinate of y to the new coordinates which the user clicked on. This is used in conjunction with rotation while holding the left mouse button down. The position where the user clicked is the position where the rotations will be calculated from. This is not only used for views however, for graph rotation, there is a view data structure which stores the amount it is rotated by also, so the old x coordinate and old y coordinates for that function is updated here too.

```
updateLatestPosition::IORef GLfloat -> IORef GLfloat -> GLsizei -> GLsizei ->IO()
updateLatestPosition oldx oldy x y = do
 modifyIORef oldy (\d -> (fromIntegral y))
 modifyIORef oldx (\d -> (fromIntegral x))
 return()
```

Module Node provides us with the data structure Node which consists of the following attributes: Label, QuadricStyle, QuadricPrimitive, Color and Layout. It also provides a set of functions to extract information about each particular field. The secret it hides is how the Node data structure is represented and how the attributes are individually extracted.

```
module Node (extractLabel, extractColor, extractQuadricStyle, extractQuadricPrimitive , extractLayout,
Node(..)) where

import Graphics.Rendering.OpenGL.GL
```

```
import Graphics.Rendering.OpenGL.GLU
import Graphics.UI.GLUT
```

We define a type synonym Label for String.

```
type Label     = String
```

We define the Node data structure as being formed by the following primitive types: Label QuadricStyle QuadricPrimitive (Color4 GLfloat) (Vector3 GLfloat) and the constructor Node.

```
data Node      = Node Label QuadricStyle QuadricPrimitive (Color4 GLfloat) (Vector3 GLfloat)
```

The following functions are self explanatory and are there to extract individual attributes from the Node data structure.

```
extractLabel :: Node -> Label
extractLabel (Node a b c d e) = a

extractColor :: Node -> Color4 GLfloat
extractColor (Node a b c d e) = d

extractQuadricStyle :: Node -> QuadricStyle
extractQuadricStyle (Node a b c d e) = b

extractQuadricPrimitive :: Node -> QuadricPrimitive
extractQuadricPrimitive (Node a b c d e)  = c

extractLayout :: Node -> (Vector3 GLfloat)
extractLayout (Node a b c d e) = e
```

Module NodeManipulation is responsible for the manipulation of the nodes in the program. Any change to the nodes in the graph corresponds to changes in the graph data structure. The information in the graph data structure is updated according to how the nodes are manipulated. The only possible changes that can be done to a graph that associates strictly to nodes are addition and movement of nodes. Changes such as removal of nodes and attribute changes(color,size,etc.) are generalized in the ItemManipulation module for both nodes and edges. The functions that are of concern here are addition and movement of nodes, the functions which manipulate movement of nodes are represented by how the user moves the node. Dragging the mouse after clicking on a node corresponds to 'moveNodeButtonDown' while moving the node in the Z-plane using the wheel corresponds to 'moveNodeWheelUp' and 'moveNodeWheelDown'.

The service of this module is that it provides a set of functions to add and move nodes in the graph data structure. The secret of this module is the way the nodes are added and the methods that are used to move a node.

```
module NodeManipulation (addNode,moveNodeButtonDown,moveNodeWheelUp,moveNodeWheelDown)  where

import Text.XML.HaXml.Xml2Haskell
import Gxl_1_0_1_DTD
import GXL_DTD
import INIT
import Data.IORef
import Graphics.Rendering.OpenGL.GL
```

```
import Graphics.Rendering.OpenGL.GLU
import Graphics.UI.GLUT
import ViewDataStructure
import UndoDataStructure
import GraphInterface
import Text.XML.HaXml.OneOfN
import Node
import Utils
import GxlGraphSetManage
import SettingsDataStructure
import Collision
import Additional
```

Function addNode is the main function which is called by the keyboard mouse callback in the main program for adding a node on a particular point on the screen. It takes in as parameters: a) the Graph data structure to be modified
b) the coordinates where the user clicked the mouse on
c) the Settings data structure to determine if collision is toggled on or off
d) the current transformation matrix to determine where to place the node according to the graph's axis
e) the View data structure to determine the current distance of the camera from the objects
f) the Undo data structure to save a copy of the data structure before the node is added

```
addNode :: IORef GxlGraphSet -> GLsizei -> GLsizei -> IORef SettingsDataStructure -> IORef [GLdouble]
-> IORef View -> IORef UndoDataStructure -> IO()
addNode dataStructure x y settings matrixStore view undoDataStructure = do
```

Here we read the data that is needed before addition of a new node can be done

```
  let initialCameraDistance = 14.0::GLdouble
  mydataStructure <- readIORef dataStructure
  let listOfGraphID = getGxlGraphs mydataStructure
  myList <- getListOfNodes mydataStructure
  let numberOfNodes =length (myList)
  vp@((Position lowerx lowery), (Size width height)) <- get viewport
```

mvMatrix stores the current ModelView matrix which is the current transformation matrix.

```
  component <- readIORef matrixStore
  (mvMatrix::(GLmatrix GLdouble)) <- newMatrix ColumnMajor component
```

The pixel coordinates of the mouse where it was clicked is transformed into the coordinates of the object space by 'unProject'. The new vertex which it returns specifies the coordinates in the object space.

```
  matrixMode $= Projection
  m2@(projMatrix::(GLmatrix GLdouble)) <- get currentMatrix
  projectionMatrix <- getMatrixComponents ColumnMajor m2
  matrixMode $= Modelview 0
  m1@(mvMatrix2::(GLmatrix GLdouble)) <- get currentMatrix
  newcomponent <- getMatrixComponents ColumnMajor m1
  let realX = fromIntegral x
  let realY = fromIntegral (height - y - 1)
  Just (Vertex3 wx2 wy2 wz2) <- unProject (Vertex3 realX realY 0) mvMatrix2 projMatrix vp
```

Assign the new node with the default attributes, which is stored in myInfoLayoutNode and myItemInfo. It is inserted into the data structure by calling addItem together with the constructed node.

```
let (z,newStructure) = addAttrGetId myInfoLayoutNode mydataStructure
modifyIORef dataStructure (\x -> newStructure)
mydataStructure2 <- readIORef dataStructure
let listOfGraphID = getGxlGraphs mydataStructure2
let graphGXLid = unMaybe (getGXLId mydataStructure2 (head listOfGraphID))
let newdataStructure = addItem (myItemInfo numberOfNodes z) graphGXLid mydataStructure2
modifyIORef dataStructure (\x -> newdataStructure)
```

Here, the new node is moved to the position that it is supposed to be. Since the axis on the screen can be rotated and the movement of the node across the screen is kept the 'intuitive' way (moving the node according to the mouse rather than according to the axis in the window), directly changing the position of the node in the graph data structure using the coordinates from the mouse is not correct. Rather, we used calculateMovementNodeStatic which moves a node to a specified point which is multiplied by the camera's distance from the object space. This then correctly displays the node according to where the node was moved by the mouse. Collision detection is also done here before adding the node, if collision is not detected, then the node is added, otherwise the node is not added.

```
readedDataStructure <- readIORef dataStructure
let myInnerId = getInnerId readedDataStructure ("Node " ++ show (numberOfNodes))
myView <- readIORef view
let currentCameraDistance =  read (show (getCameraDistance myView))::GLdouble
let cameraDistance = read (show (initialCameraDistance - currentCameraDistance))::GLdouble
let defaultRadius = 0.5
mySettings <- readIORef settings
collisionOnIORef <- getCollisionOn mySettings
collisionOn<-readIORef (collisionOnIORef)
modifyIORef dataStructure (\x->mydataStructure)
myListOfEdges <- getListOfEdges mydataStructure
myListOfNodes <- getListOfNodes mydataStructure
collisionDetected <- collisionDetectionNewNode collisionOn dataStructure myListOfNodes
myListOfEdges (Vector3 (read(show ((wx2*cameraDistance)))::GLfloat)
               (read(show ((wy2*cameraDistance)))::GLfloat) (0) ) defaultRadius settings
if (collisionDetected==False)
 then do updateGraphDataStructure newdataStructure dataStructure undoDataStructure
         calculateNodeMovementStatic 0 0 (read(show ((wx2*cameraDistance)))::GLfloat)
                                (read(show ((wy2*cameraDistance)))::GLfloat)
                                dataStructure myInnerId settings matrixStore
         return()
else do return()
```

collisionDetectionNewNode returns true if a collision is added in the addition of the new node, otherwise it returns false.

```
collisionDetectionNewNode::Prelude.Bool-> IORef GxlGraphSet -> [GXL_DTD.Id] -> [GXL_DTD.Id] -> Vector3 GLfloat
-> GLdouble ->IORef SettingsDataStructure -> IO(Prelude.Bool)
collisionDetectionNewNode collisionOn dataStructure myListOfNodes myListOfEdges newNodeLayout defaultRadius
settings =  if (collisionOn==True)
          then do collisionDetected <- addNodeCollision dataStructure myListOfNodes myListOfEdges newNodeLayout
                                       defaultRadius settings
                  return(collisionDetected)
          else do return(False)
```

moveNodeWheelUp is called when the user uses the mouse wheel to move the node along the z axis. In this case the node is moved into the screen, therefore away from the user. The position of the node that was selected is extracted (layout) and a new layout for the node is constructed by applying the transformation matrix and the translation in the z axis to the old layout of the node. If collision is detected, then the change to the layout is not applied, if it passes collision detection, the layout is updated with the new layout. The undo data structure is updated because of this change in the graph data structure. Similarly for moveNodeWheelDown the same process is used, except instead of moving into the screen we move out of the screen now.

```
moveNodeWheelUp :: IORef GxlGraphSet -> GXL_DTD.Id -> IORef SettingsDataStructure -> IORef [GLdouble]
-> IORef UndoDataStructure -> IO()
moveNodeWheelUp dataStructure myItem settings matrixStore undoDataStructure = do
  let moveDiff = 0.1
  if (myItem/=0)
    then do myGraphSet <- readIORef dataStructure
            node <- getNode myItem dataStructure
            let nodeLayout = extractLayout node
            let xcoordinate = xcoord nodeLayout
            let ycoordinate = ycoord nodeLayout
            let zcoordinate = zcoord nodeLayout
            transformationMatrix <- readIORef matrixStore
            (Vector3 a b c) <- transformVector (Vector3 0 0 (-moveDiff)) transformationMatrix
            let newxcoordinate =  xcoordinate + a
            let newycoordinate =  ycoordinate + b
            let newzcoordinate = zcoordinate + c
            let newNodeLayout = Vector3 newxcoordinate newycoordinate (newzcoordinate::GLfloat)
            let newLayoutAttribute = processLayout newNodeLayout
            myListOfEdges <- getListOfEdges myGraphSet
            myListOfNodes <- getListOfNodes myGraphSet
            mySettings <- readIORef settings
            collisionOnIORef <- getCollisionOn mySettings
            collisionOn<-readIORef (collisionOnIORef)
            collisionDetected <- collisionDetectionMoveNode collisionOn dataStructure
                                 myListOfNodes myListOfEdges myItem newNodeLayout settings
            if (collisionDetected==False)
              then do mydataStructure <- readIORef dataStructure
                      changeAttr dataStructure "Layout" myItem newLayoutAttribute
                      myseconddatastructure <-readIORef dataStructure
                      modifyIORef dataStructure (\x -> mydataStructure)
                      updateGraphDataStructure myseconddatastructure dataStructure undoDataStructure
              else do return ()
     else return()

moveNodeWheelDown :: IORef GxlGraphSet -> GXL_DTD.Id -> IORef SettingsDataStructure ->IORef [GLdouble]
-> IORef UndoDataStructure -> IO()
moveNodeWheelDown dataStructure myItem settings matrixStore undoDataStructure = do
  let moveDiff = 0.1
  if (myItem/=0)
    then do myGraphSet <- readIORef dataStructure
            node <- getNode myItem dataStructure
            let nodeLayout = extractLayout node
            let xcoordinate = xcoord nodeLayout
            let ycoordinate = ycoord nodeLayout
            let zcoordinate = zcoord nodeLayout
            transformationMatrix <- readIORef matrixStore
```

```
          (Vector3 a b c) <- transformVector (Vector3 0 0 (moveDiff)) transformationMatrix
          let newxcoordinate =  xcoordinate + a
          let newycoordinate =  ycoordinate + b
          let newzcoordinate = zcoordinate + c
          let newNodeLayout = Vector3 newxcoordinate newycoordinate (newzcoordinate::GLfloat)
          let newLayoutAttribute = processLayout newNodeLayout
          myListOfEdges <- getListOfEdges myGraphSet
          myListOfNodes <- getListOfNodes myGraphSet
          mySettings <- readIORef settings
          collisionOnIORef <- getCollisionOn mySettings
          collisionOn<-readIORef (collisionOnIORef)
          collisionDetected <- collisionDetectionMoveNode collisionOn dataStructure
                               myListOfNodes myListOfEdges myItem newNodeLayout settings
          if (collisionDetected==False)
            then do mydataStructure <- readIORef dataStructure
                    changeAttr dataStructure "Layout" myItem newLayoutAttribute
                    myseconddatastructure <-readIORef dataStructure
                    modifyIORef dataStructure (\x -> mydataStructure)
                    updateGraphDataStructure myseconddatastructure dataStructure undoDataStructure
            else do return ()
    else return()
```

moveNodeButtonDown is called when the user clicks on a node and moves it by dragging the mouse. Basically the difference between the new mouse position and initial mouse position where the user clicked on is the amount which the node will move by. The function calculateNodeMovementDynamic applies the layout changes of the node according to the new coordinates of the mouse. These two functions together with the mouse motion callback forms the movement of node while being 'dragged' on the screen.

```
moveNodeButtonDown :: IORef View -> IORef GLfloat -> IORef GLfloat -> IORef GLfloat -> IORef GLfloat
-> IORef GxlGraphSet -> IORef GXL_DTD.Id -> IORef UndoDataStructure -> IORef SettingsDataStructure
-> IORef [GLdouble] -> GLsizei -> GLsizei -> IO()
moveNodeButtonDown view oldx oldy newx newy dataStructure currentItem1 undoDataStructure
settings matrixStore x y = do
  myItem <- readIORef currentItem1
  if (myItem/=0)
  then do oy <- readIORef oldy
          ox <- readIORef oldx
          modifyIORef newy (\d ->(fromIntegral y))
          modifyIORef newx (\d ->(fromIntegral x))
          ny <- readIORef newy
          nx <- readIORef newx
          let diffy = ny -  oy
          let diffx = nx - ox
          calculateNodeMovementDynamic oldx oldy newx newy view dataStructure currentItem1 settings
                                       matrixStore undoDataStructure
          modifyIORef oldx (\d ->nx)
          modifyIORef oldy (\d ->ny)
          return()
  else return()
```

– Calculate actual screen coordinates instead of mouse coordinates to make it follow the mouse The calculateNode-MovementDynamic function takes the new mouse coordinates and the previous mouse coordinates when the mouse was moved with the left mouse button being held, and uses it to calculate the new layout of the currently selected node. Majority of the code is repeated for all 4 cases, difference in y coordinates less than 1/more than 1 and difference

in x coordinates less than 1/more than 1. Collision detection is checked in each of the cases, only if no collision is detected, then the changes to that node will be applied to the graph data structure.

```
calculateNodeMovementDynamic :: IORef GLfloat -> IORef GLfloat -> IORef GLfloat -> IORef GLfloat -> IORef View
-> IORef GxlGraphSet -> IORef GXL_DTD.Id -> IORef SettingsDataStructure
-> IORef [GLdouble] -> IORef UndoDataStructure -> IO()
calculateNodeMovementDynamic oldx oldy newx newy view currentGraphSet currentItem1 settings
matrixStore undoDataStructure = do
  let moveDiff = 0.025
  ny <- readIORef newy
  oy <- readIORef oldy
  nx <- readIORef newx
  ox <- readIORef oldx
  myNode <- readIORef currentItem1
  let diffy =  ny-oy
  let diffx =  nx-ox
  if (diffy <=(-1))
    then do myGraphSet <- readIORef currentGraphSet
            node <- getNode myNode currentGraphSet
            let nodeLayout = extractLayout node
            let xcoordinate = xcoord nodeLayout
            let ycoordinate = ycoord nodeLayout
            let zcoordinate = zcoord nodeLayout
            transformationMatrix <- readIORef matrixStore
```

Multiplying the translation vector with the transformation matrix, so that the node moves intuitively.

```
            (Vector3 a b c) <- transformVector (Vector3 0 moveDiff 0) transformationMatrix
            let newxcoordinate =  xcoordinate + a
            let newycoordinate =  ycoordinate + b
            let newzcoordinate = zcoordinate + c
            let newNodeLayout = Vector3 newxcoordinate newycoordinate (newzcoordinate::GLfloat)
            let newLayoutAttribute = processLayout newNodeLayout
            myListOfEdges <- getListOfEdges myGraphSet
            myListOfNodes <- getListOfNodes myGraphSet
            mySettings <- readIORef settings
            collisionOnIORef <- getCollisionOn mySettings
            collisionOn<-readIORef (collisionOnIORef)
            collisionDetected <- collisionDetectionMoveNode collisionOn currentGraphSet
                         myListOfNodes myListOfEdges myNode
                         newNodeLayout settings
            if (collisionDetected==False)
             then do mydataStructure <- readIORef currentGraphSet
                     changeAttr currentGraphSet "Layout" myNode newLayoutAttribute
                     myseconddatastructure <-readIORef currentGraphSet
                     modifyIORef currentGraphSet (\x -> mydataStructure)
                     updateGraphDataStructure myseconddatastructure currentGraphSet undoDataStructure
                     postRedisplay Nothing
              else do postRedisplay Nothing
      else if (diffy >= 1)
       then do myGraphSet <- readIORef currentGraphSet
               node <- getNode myNode currentGraphSet
               let nodeLayout = extractLayout node
               let xcoordinate = xcoord nodeLayout
               let ycoordinate = ycoord nodeLayout
```

```
          let zcoordinate = zcoord nodeLayout
          transformationMatrix <- readIORef matrixStore
          (Vector3 a b c) <- transformVector (Vector3 0 (-moveDiff) 0) transformationMatrix
          let newxcoordinate =  xcoordinate + a
          let newycoordinate =  ycoordinate + b
          let newzcoordinate = zcoordinate + c
          let newNodeLayout = Vector3 newxcoordinate newycoordinate (newzcoordinate::GLfloat)
          let newLayoutAttribute = processLayout newNodeLayout
          myListOfEdges <- getListOfEdges myGraphSet
          myListOfNodes <- getListOfNodes myGraphSet
          mySettings <- readIORef settings
          collisionOnIORef <- getCollisionOn mySettings
          collisionOn<-readIORef (collisionOnIORef)
          collisionDetected <- collisionDetectionMoveNode collisionOn currentGraphSet
                    myListOfNodes myListOfEdges myNode
                    newNodeLayout settings
          if (collisionDetected==False)
           then do mydataStructure <- readIORef currentGraphSet
                   changeAttr currentGraphSet "Layout" myNode newLayoutAttribute
                   myseconddatastructure <-readIORef currentGraphSet
                   modifyIORef currentGraphSet (\x -> mydataStructure)
                   updateGraphDataStructure myseconddatastructure currentGraphSet undoDataStructure
                   postRedisplay Nothing
          else do postRedisplay Nothing
  else return()
if (diffx <=(-1))
  then do myGraphSet <- readIORef currentGraphSet
          node <- getNode myNode currentGraphSet
          let nodeLayout = extractLayout node
          let xcoordinate = xcoord nodeLayout
          let ycoordinate = ycoord nodeLayout
          let zcoordinate = zcoord nodeLayout
          transformationMatrix <- readIORef matrixStore
          (Vector3 a b c) <- transformVector (Vector3 (-moveDiff) 0 0) transformationMatrix
          let newxcoordinate =  xcoordinate + a
          let newycoordinate =  ycoordinate + b
          let newzcoordinate = zcoordinate + c
          let newNodeLayout = Vector3 newxcoordinate newycoordinate (newzcoordinate::GLfloat)
          let newLayoutAttribute = processLayout newNodeLayout
          myListOfEdges <- getListOfEdges myGraphSet
          myListOfNodes <- getListOfNodes myGraphSet
          mySettings <- readIORef settings
          collisionOnIORef <- getCollisionOn mySettings
          collisionOn<-readIORef (collisionOnIORef)
          collisionDetected <- collisionDetectionMoveNode collisionOn currentGraphSet
                    myListOfNodes myListOfEdges myNode
                    newNodeLayout settings
          if (collisionDetected==False)
           then do mydataStructure <- readIORef currentGraphSet
                   changeAttr currentGraphSet "Layout" myNode newLayoutAttribute
                   myseconddatastructure <-readIORef currentGraphSet
                   modifyIORef currentGraphSet (\x -> mydataStructure)
                   updateGraphDataStructure myseconddatastructure currentGraphSet undoDataStructure
                   postRedisplay Nothing
```

```
          else do postRedisplay Nothing

     else if (diffx >= 1)
      then do myGraphSet <- readIORef currentGraphSet
              node <- getNode myNode currentGraphSet
              let nodeLayout = extractLayout node
              let xcoordinate = xcoord nodeLayout
              let ycoordinate = ycoord nodeLayout
              let zcoordinate = zcoord nodeLayout
              transformationMatrix <- readIORef matrixStore
              (Vector3 a b c) <- transformVector (Vector3 (moveDiff) 0 0) transformationMatrix
              let newxcoordinate =  xcoordinate + a
              let newycoordinate =  ycoordinate + b
              let newzcoordinate = zcoordinate + c
              let newNodeLayout = Vector3 newxcoordinate newycoordinate (newzcoordinate::GLfloat)
              let newLayoutAttribute = processLayout newNodeLayout
              myListOfEdges <- getListOfEdges myGraphSet
              myListOfNodes <- getListOfNodes myGraphSet
              mySettings <- readIORef settings
              collisionOnIORef <- getCollisionOn mySettings
              collisionOn<-readIORef (collisionOnIORef)
              collisionDetected <- collisionDetectionMoveNode collisionOn currentGraphSet
                         myListOfNodes myListOfEdges myNode
                         newNodeLayout settings
              if (collisionDetected==False)
               then do mydataStructure <- readIORef currentGraphSet
                       changeAttr currentGraphSet "Layout" myNode newLayoutAttribute
                       myseconddatastructure <-readIORef currentGraphSet
                       modifyIORef currentGraphSet (\x -> mydataStructure)
                       updateGraphDataStructure myseconddatastructure currentGraphSet undoDataStructure
                       postRedisplay Nothing
              else do postRedisplay Nothing
```

collisionDetectionMoveNode returns true when collision is detected when a particular node is to be moved to a specified point in the graph.

```
collisionDetectionMoveNode::Prelude.Bool-> IORef GxlGraphSet -> [GXL_DTD.Id] -> [GXL_DTD.Id] -> GXL_DTD.Id ->
Vector3 GLfloat -> IORef SettingsDataStructure-> IO(Prelude.Bool)

collisionDetectionMoveNode collisionOn dataStructure myListOfNodes myListOfEdges myNode
newNodeLayout settings =  if (collisionOn==True)
          then do collisionDetected <- moveNodeCollision dataStructure myListOfNodes myListOfEdges myNode
                                       newNodeLayout settings
          return(collisionDetected)
          else do return(False)
```

calculateNodeMovementStatic is used by node addition for moving the node to where it is to be added. The old x and old y coordinates are going to be (0,0) in this case, because addition of nodes adds the node at the origin, then moves it to the desired position from there. This function is only to be used by addNode. Again, the code is seperated into four cases, whether the node is to be moved up/down the y-axis or the x-axis. The translation vector is again multiplied by the transformation matrix so that the node moves in the correct way on the screen(following the mouse), rather than according to the graph's axis on the screen.

```
calculateNodeMovementStatic :: GLfloat -> GLfloat -> GLfloat -> GLfloat -> IORef GxlGraphSet -> GXL_DTD.Id
-> IORef SettingsDataStructure ->IORef [GLdouble] -> IO()
calculateNodeMovementStatic ox oy nx ny currentGraphSet myNode settings matrixStore = do
```

```
let moveDiff = 0.025
let diffy =  ny-oy
let diffx =  nx-ox
if (diffy <=(0))
    then do myGraphSet <- readIORef currentGraphSet
            node <- getNode myNode currentGraphSet
            let nodeLayout = extractLayout node
            let xcoordinate = xcoord nodeLayout
            let ycoordinate = ycoord nodeLayout
            let zcoordinate = zcoord nodeLayout
            transformationMatrix <- readIORef matrixStore
            (Vector3 a b c) <- transformVector (Vector3 0 diffy 0) transformationMatrix
            let newxcoordinate =  xcoordinate + a
            let newycoordinate =  ycoordinate + b
            let newzcoordinate = zcoordinate + c
            let newNodeLayout = Vector3 newxcoordinate newycoordinate (newzcoordinate::GLfloat)
            let newLayoutAttribute = processLayout newNodeLayout
            changeAttr currentGraphSet "Layout" myNode newLayoutAttribute
            postRedisplay Nothing
    else if (diffy >= 0)
    then do myGraphSet <- readIORef currentGraphSet
            node <- getNode myNode currentGraphSet
            let nodeLayout = extractLayout node
            let xcoordinate = xcoord nodeLayout
            let ycoordinate = ycoord nodeLayout
            let zcoordinate = zcoord nodeLayout
            transformationMatrix <- readIORef matrixStore
            (Vector3 a b c) <- transformVector (Vector3 0 diffy 0) transformationMatrix
            let newxcoordinate =  xcoordinate + a
            let newycoordinate =  ycoordinate + b
            let newzcoordinate = zcoordinate + c
            let newNodeLayout = Vector3 newxcoordinate newycoordinate (newzcoordinate::GLfloat)
            let newLayoutAttribute = processLayout newNodeLayout
            changeAttr currentGraphSet "Layout" myNode newLayoutAttribute
            postRedisplay Nothing
    else return()
  if (diffx <=(0))
    then do myGraphSet <- readIORef currentGraphSet
            node <- getNode myNode currentGraphSet
            let nodeLayout = extractLayout node
            let xcoordinate = xcoord nodeLayout
            let ycoordinate = ycoord nodeLayout
            let zcoordinate = zcoord nodeLayout
            transformationMatrix <- readIORef matrixStore
            (Vector3 a b c) <- transformVector (Vector3 diffx 0 0) transformationMatrix
            let newxcoordinate =  xcoordinate + a
            let newycoordinate =  ycoordinate + b
            let newzcoordinate = zcoordinate + c
            let newNodeLayout = Vector3 newxcoordinate newycoordinate (newzcoordinate::GLfloat)
            let newLayoutAttribute = processLayout newNodeLayout
            changeAttr currentGraphSet "Layout" myNode newLayoutAttribute
            postRedisplay Nothing
    else if (diffx >=0)
     then do myGraphSet <- readIORef currentGraphSet
```

```
            node <- getNode myNode currentGraphSet
            let nodeLayout = extractLayout node
            let xcoordinate = xcoord nodeLayout
            let ycoordinate = ycoord nodeLayout
            let zcoordinate = zcoord nodeLayout
            transformationMatrix <- readIORef matrixStore
            (Vector3 a b c) <- transformVector (Vector3 diffx 0 0) transformationMatrix
            let newxcoordinate =  xcoordinate + a
            let newycoordinate =  ycoordinate + b
            let newzcoordinate = zcoordinate + c
            let newNodeLayout = Vector3 newxcoordinate newycoordinate (newzcoordinate::GLfloat)
            let newLayoutAttribute = processLayout newNodeLayout
            changeAttr currentGraphSet "Layout" myNode newLayoutAttribute
            postRedisplay Nothing
      else
        return()
```

These are utility functions and default values/attributes for the new nodes that are to be added.

```
xcoord :: Vector3 a -> a
xcoord (Vector3 a b c) = a

ycoord :: Vector3 a -> a
ycoord (Vector3 a b c) = b

zcoord :: Vector3 a -> a
zcoord (Vector3 a b c) = c
```

processLayout converts the Vector3 type into the AttrValue type so that Vector3 types can be inserted into the graph data structure.

```
processLayout :: Vector3 GLfloat -> AttrValue
processLayout (Vector3 first second third) = (TenOf10 (Tup [Tup_Float (Gxl_1_0_1_DTD.Float (show first)),
Tup_Float (Gxl_1_0_1_DTD.Float (show second)),Tup_Float (Gxl_1_0_1_DTD.Float (show third))]))
```

myItemAttr returns a default ItemAttr for a newly constructed node. ItemAttr contains the Gxl Id of the graph and FNode states that the current item is a node. Our node's Gxl Id's are generated by naming them "Node 1","Node 2" ... "Node x" where x is the number of nodes in the graph. If the new node is the 5th node in the graph, the node's Gxl Id would be "Node 5".

```
myItemAttr :: Prelude.Int -> ItemAttr
myItemAttr numberOfNodes = ItemAttr FNode (Just ("Node"++" "++(show(numberOfNodes)))) Nothing
```

myItemInfo returns a default ItemInfo for a newly constructed node.

```
myItemInfo :: Prelude.Int -> GXL_DTD.Id -> ItemInfo
myItemInfo numberOfNodes z = ItemInfo Nothing [z] [] [] (myItemAttr numberOfNodes)
```

myInfoLayoutNode returns a default AttrInfo for the construction of a new node. In this case, the new node's layout or position in the graph would be set to (0,0,0) which is the origin.

```
myInfoLayoutNode :: AttrInfo
myInfoLayoutNode = AttrInfo Nothing [] (TenOf10 (Tup [Tup_Float (Gxl_1_0_1_DTD.Float (show 0)),
Tup_Float (Gxl_1_0_1_DTD.Float (show 0)),Tup_Float (Gxl_1_0_1_DTD.Float (show 0))]))
layoutAttr
```

layoutAttr represents the "Layout" field of a node in the graph data structure.

```
layoutAttr :: AttrAttr
layoutAttr = AttrAttr Nothing "Layout"  Nothing
```

unMaybe ignores the Maybe type and just returns what it contains.

```
unMaybe :: Maybe a -> a
unMaybe (Just a) = a
```

transformVector and transformVertex are functions which given a Vector or a Vertex respectively and a list representing the matrix that the sapce has been multiplied by, will give us the new transformed Vector/Vertex according to the new set of axis in the current space. This is important so that when we rotate the space we conserve the horizontal/vertical/depth movement irregardless of the direction of the axis.

```
transformVector :: Vector3 GLfloat -> [GLdouble] -> IO (Vector3 GLfloat)
transformVector (Vector3 a b c) xs = do
    let newa = ((read(show(xs !! 0))::GLfloat) * a) + ((read(show(xs !! 1))::GLfloat) * b) +
               ( (read(show(xs !! 2))::GLfloat) * c)
    let newb = ((read(show(xs !! 4))::GLfloat) * a) + ((read(show(xs !! 5))::GLfloat) * b) +
               ( (read(show(xs !! 6))::GLfloat) * c)
    let newc = ((read(show(xs !! 8))::GLfloat) * a) + ((read(show(xs !! 9))::GLfloat) * b) +
               ( (read(show(xs !! 10))::GLfloat) * c)
    return (Vector3 newa newb newc)

transformVertex :: Vertex3 GLdouble -> [GLdouble] -> IO (Vertex3 GLdouble)
transformVertex (Vertex3 a b c) xs = do
    let newa = ((read(show(xs !! 0))::GLdouble) * a) + ((read(show(xs !! 1))::GLdouble) * b) +
               ( (read(show(xs !! 2))::GLdouble) * c)
    let newb = ((read(show(xs !! 4))::GLdouble) * a) + ((read(show(xs !! 5))::GLdouble) * b) +
               ( (read(show(xs !! 6))::GLdouble) * c)
    let newc = ((read(show(xs !! 8))::GLdouble) * a) + ((read(show(xs !! 9))::GLdouble) * b) +
               ( (read(show(xs !! 10))::GLdouble) * c)
    return (Vertex3 newa newb newc)
```

module PickObject provides a function to select an object that the user clicks on using his mouse. This example is closely based on that in the RedBook called PickDepth.hs that comes with GLUT. The secret this module hides is the way this is achieved. The basic concept is that we create a region which the user clicked nearby. In this region a hit buffer is set up, then we render the graph. Any object that is rendered in that region is recorded in the hit record. After that is acomplished we then process the hit record in a seperate function and get the object that is nearest on the screen to the user and return that object's ID.//

```
module PickObject (selectObject)  where

import Data.IORef  ( IORef, newIORef, readIORef, modifyIORef, writeIORef)
import Graphics.Rendering.OpenGL.GL
import Graphics.Rendering.OpenGL.GLU
import Graphics.UI.GLUT.Callbacks.Window ( MouseButton )
import Graphics.UI.GLUT.Window
import Graphics.UI.GLUT hiding (MenuItem)
import DrawGraph
import ViewDataStructure
import GxlGraphSetManage
import Gxl_1_0_1_DTD
import GXL_DTD
import Utils
import SettingsDataStructure
```

Here we set the buffer size connstant to 512, this can be easily changed here without affecting the rest of the code.//

```
bufSize :: GLsizei
bufSize = 512
```

selectObject is the function which does the majority of the work. It returns the hit object. This is accomplished in the following fashion: we create the picking region, render the graph and then call the process hit function to process the records of the hit objects.

```
selectObject :: IORef View -> GLsizei -> GLsizei -> IORef GxlGraphSet -> IORef [GLdouble]
-> IORef SettingsDataStructure -> IO(GLuint)
selectObject view x y dataStructure matrixStore settings= do
   vp@(_, (Size width height)) <- get viewport
   (_, maybeHitRecords) <- getHitRecords bufSize $
    withName (Name 0) $ do
     matrixMode $= Projection
     preservingMatrix $ do
       loadIdentity
       -- create 1x1 pixel picking region near cursor location
       pickMatrix (fromIntegral x, fromIntegral height - fromIntegral y) (0.1,0.1) vp
       perspective 45.0 (fromIntegral width / fromIntegral height) 1 200.0
       matrixMode $= Modelview 0
       loadIdentity
       lookAt (Vertex3 0.0 0.0 14.0) (Vertex3 0.0 0.0 0.0) (Vector3 0 1 0)
       displayGraph view dataStructure matrixStore settings
       matrixMode $= Projection
     matrixMode $= Modelview 0
     flush
   hit <- processHits maybeHitRecords
   postRedisplay Nothing
   return(hit)
```

processHits is the function which takes in the record of hits and then returns the nearest object on the screen. The objects are processed one by one, and each time we check the distance and save it together with its corresponding object if it is the smallest one we have so far. Finally the nearest object is returned. If no object is hit we return 0 as the Id.

```
processHits :: Maybe[HitRecord] -> IO GLuint
processHits (Just hitRecords) = do
   min <- newIORef 2.0
   num <- newIORef 0
   flip mapM_ hitRecords $ \(HitRecord z1 z2 names) -> do
      m <- readIORef min
      --z1 is the minimum depth of that hit
      if (m>z1) then do
             (modifyIORef min (\x ->(z1)))
                              sequence_ [ modifyIORef num (\x -> n) | Name n <- names ]
 else (modifyIORef min (\x ->m))
   n <- readIORef num
   return n
processHits Nothing = return (0)
```

Module SettingsFileManager, as the name indicates, gives us functions and facilities to open and save Settings Files. The secret it hides is how the settings files are manipulated to get this result. A decision was made here to use our

own format for a setting file, which will consist of three lines the first having the number of cylinders used to render a bent edge, the second whether collision is on or off and whether axis rendering is on or off to match the created Settings Data Structure.

```
module SettingsFileManager (openSettings,saveSettings)  where

import Data.Char
import Data.IORef  ( IORef, newIORef, readIORef, modifyIORef, writeIORef)
import Data.FiniteMap
import IO
import Graphics.Rendering.OpenGL.GL
import Graphics.Rendering.OpenGL.GLU
import Graphics.UI.GLUT.Callbacks.Window ( MouseButton )
import Graphics.UI.GLUT.Window
import Graphics.UI.GLUT hiding (MenuItem)
import Graphics.UI.WX hiding (KeyUp,KeyDown,color,motion,WXCore.WxcTypes.Size,Classes.position,Attributes.get)
import Graphics.UI.WXCore.Frame
import System.Exit(exitWith, ExitCode(ExitSuccess), exitFailure)
import Control.Monad ( liftM, zipWithM_ )
import Data.Char     ( ord )
import Data.List     ( genericLength )
import SettingsDataStructure
```

settingsFiles is used to filter the settings files, here we allow the settings file to be of any type.

```
settingsFiles::  [(String, [String])]
settingsFiles = [("Settings files",["*"])]
```

loadSettingsFile is used to load a settings file. We prompt the user for a file and once that is returned we read it in and return the corresponding settings. If an error is encountered we just return.

```
loadSettingsFile :: FilePath  -> IORef SettingsDataStructure -> IO ()
loadSettingsFile path settings =  catch(do
  handle <- openFile path ReadWriteMode
  first <- hGetLine handle
  second <- hGetLine handle
  third <- hGetLine handle
  updateNumOfCylinders ((read first)::Prelude.Int) settings
  updateCollisionOn ((read second)::Prelude.Bool) settings
  updateAxisOn  ((read third)::Prelude.Bool) settings
  hClose handle)
  (\err -> return() )
```

openSettings is a function which uses wxHaskell facilities by opening a file dialog for the user and prompting him for the settings file he whishes to open.

```
openSettings ::IORef SettingsDataStructure -> IO ()
openSettings settings
      = do f <- frameCreateDefault ("File Dialog")
           mbfname <- fileOpenDialog f False True "Open Settings" settingsFiles "" ""
           case mbfname of
             Nothing    -> return ()
             Just fname -> loadSettingsFile fname settings
```

saveSettingsFile is used to save a settings file. We prompt the user for a file and once that is returned we save the settings in it. If an error is encountered we just return.

```
saveSettingsFile :: FilePath  -> IORef SettingsDataStructure -> IO ()
saveSettingsFile path settings =  catch (do
  handle <- openFile path ReadWriteMode
  mySettings <- readIORef settings
  myNumOfCylindersIORef <- getNumOfCylinders mySettings
  myNumOfCylinders <- readIORef myNumOfCylindersIORef
  myCollisionOnIORef <- getCollisionOn mySettings
  myCollisionOn <- readIORef myCollisionOnIORef
  myAxisOnIORef <- getCollisionOn mySettings
  myAxisOn <- readIORef myAxisOnIORef
  hPutStrLn handle (show myNumOfCylinders)
  hPutStrLn handle (show myCollisionOn)
  hPutStrLn handle (show myAxisOn)
  hClose handle)
  (\err -> return() )
```

saveSettings is a function which uses wxHaskell facilities by opening a file dialog for the user and prompting him for a file that he wishes to save the settings into.

```
saveSettings ::IORef SettingsDataStructure -> IO ()
saveSettings settings
      = do f <- frameCreateDefault ("File Dialog")
           mbfname <- fileSaveDialog f False True "Save Settings" "" ""
           case mbfname of
             Nothing    -> return ()
             Just fname -> saveSettingsFile fname settings
```

Module SettingsDataStructure provides us with the data structure SettingsDataStructure which consists of the following: an IORef of type integer and two IORef of type boolean. The integer IORef refers to the number of cylinders that is used to draw bended edges. The first boolean IORef refers to whether collision detection is turned on or off and finally the last boolean IORef refers to whether or not axis is to be rendered. This module presents an input text dialog box for modifying the number of cylinders and a dialog box which toggles collision detection / axis rendering to on or off.

The service of this module is that it provides a set of functions to determine the values of the IORefs in the data structure and to modify each of them. The way the settings are modified is by presenting a dialog box stating what the current setting is and what it would be changed to. Since we using wxHaskell in our implementation of dialog boxes and user interface items, there will be wxHaskell functions in the implementation. Once the values are changed, it will modify the IORefs appropriately. Initially collision detection is set to false (off), axis rendering is set to false (off) and the initial number of cylinders is set to 30. We have set that the minimum value of cylinders to be 2 as we have one control point for the interpolation of the bended edge. Any less than 2 will not be valid. If the user enters a number less than 2, the minimum value will be used instead. The secret of this module is that it hides how the SettingsDataStructure is represented and how the fields are individually extracted and changed.

```
module SettingsDataStructure (SettingsDataStructure,initSettingsDataStructure,newSettingsDataStructure,
getNumOfCylinders,getCollisionOn,getAxisOn,changeCylinderNumber,changeCollisionDetection,changeAxisDisplay,
updateNumOfCylinders,updateCollisionOn,updateAxisOn)  where
```

```
import Data.IORef  ( IORef, newIORef, readIORef, modifyIORef, writeIORef)
import Graphics.UI.WX hiding (KeyUp,KeyDown,motion,WXCore.WxcTypes.Size,Classes.position,Attributes.get)
import Graphics.UI.WXCore.WxcTypes
import Graphics.UI.WXCore hiding (WxcClasses.View)
import GHC.Float
import IO
```

The settings data structure is defined here as consisting of an IORef to an integer and two IORefs to a boolean value.

```
data SettingsDataStructure = SettingsDataStructure (IORef Prelude.Int ) (IORef Prelude.Bool) (IORef Prelude.Bool)
```

The constants which define the initial number of cylinders, initial value for collision detection, initial value for collision detection, and the minimum value of cylinders are written as below.

```
intialNumOfCylinders::Prelude.Int
intialNumOfCylinders=30

initialCollisionOn::Prelude.Bool
initialCollisionOn=False

initialAxisOn::Prelude.Bool
initialAxisOn=False

minimumValueInt::Prelude.Int
minimumValueInt = 2
```

initSettingsDataStructure is used to initialize the IORefs in the SettingsDataStructure it takes as its parameter. This is used when reinitializing the SettingsDataStructure to the default values is needed.

```
initSettingsDataStructure:: SettingsDataStructure -> IO()
initSettingsDataStructure (SettingsDataStructure numOfCylinders collisionOn axisOn) = do
  modifyIORef numOfCylinders (\x -> intialNumOfCylinders)
  modifyIORef collisionOn (\x -> initialCollisionOn)
  modifyIORef axisOn (\x -> initialAxisOn)
  return()
```

newSettingsDataStructure returns an IORef to a new settings data structure where its values are initialized to its default values. This function is needed to be called at least once to create a newSettingsDataStructure.

```
newSettingsDataStructure::IO(IORef SettingsDataStructure)
newSettingsDataStructure = do
  numOfCylinders <- newIORef intialNumOfCylinders
  collisionOn <- newIORef initialCollisionOn
  axisOn <- newIORef initialAxisOn
  settingsDataStructure <- newIORef (SettingsDataStructure numOfCylinders collisionOn axisOn)
  return (settingsDataStructure)
```

getNumOfCylinders returns the number of cylinders currently set in the particular SettingsDataStructure which it takes in as a paremeter. Similarly getCollisionOn determines if collision is turned on or off in the particular SettingsDataStructure which it takes in as a parameter and getAxisOn determines if axis displaying is turbed on or off.

```
getNumOfCylinders:: SettingsDataStructure -> IO (IORef Prelude.Int)
getNumOfCylinders (SettingsDataStructure numOfCylinders collisionOn axisOn) = return (numOfCylinders)

getCollisionOn:: SettingsDataStructure -> IO (IORef Prelude.Bool)
getCollisionOn (SettingsDataStructure numOfCylinders collisionOn axisOn) = return (collisionOn)

getAxisOn:: SettingsDataStructure -> IO (IORef Prelude.Bool)
getAxisOn (SettingsDataStructure numOfCylinders collisionOn axisOn) = return (axisOn)
```

updateNumOfCylinders is used to modify the number of cylinders in a SettingsDataStructure. The function takes in the new value desired and modifies the IORef to the SettingsDataStructure to the new value. Similarly with updateCollisionOn, the function takes in a new boolean value and modifies the IORef of the SettingsDataStructure. Finally in a similar fashion updateAxisOn takes in a new boolean value and modifies the IORef of the SettingsDataStructure. All three of these functions are called after retrieving the new desired value from the user via the dialog boxes.

```
updateNumOfCylinders:: Prelude.Int -> IORef SettingsDataStructure -> IO ()
updateNumOfCylinders newNumber settingsDataStructure  = do
    mySettingsDataStructure <- readIORef settingsDataStructure
    myNumOfCylinders <- newIORef newNumber
    myCollisionOn <- getCollisionOn mySettingsDataStructure
    myAxisOn <- getAxisOn mySettingsDataStructure
    modifyIORef settingsDataStructure (\x -> (SettingsDataStructure myNumOfCylinders myCollisionOn myAxisOn))
    return()

updateCollisionOn:: Prelude.Bool -> IORef SettingsDataStructure -> IO ()
updateCollisionOn newBoolean settingsDataStructure  = do
    mySettingsDataStructure <- readIORef settingsDataStructure
    myCollisionOn <- newIORef newBoolean
    myNumOfCylinders <- getNumOfCylinders mySettingsDataStructure
    myAxisOn <- getAxisOn mySettingsDataStructure
    modifyIORef settingsDataStructure (\x -> (SettingsDataStructure myNumOfCylinders myCollisionOn myAxisOn))
    return()

updateAxisOn:: Prelude.Bool -> IORef SettingsDataStructure -> IO ()
updateAxisOn newBoolean settingsDataStructure  = do
    mySettingsDataStructure <- readIORef settingsDataStructure
    myAxisOn <- newIORef newBoolean
    myCollisionOn <- getCollisionOn mySettingsDataStructure
    myNumOfCylinders <- getNumOfCylinders mySettingsDataStructure
    modifyIORef settingsDataStructure (\x -> (SettingsDataStructure myNumOfCylinders myCollisionOn myAxisOn))
    return()
```

changeCylinderNumber opens a dialog box which asks the user for an integer, which is then used with the functions above to update the SettingsDataStructure to the new values. The dialog boxes are implemented using wxHaskell therefore wxHaskell functions are used. But for changeCollisionDetection and changeAxisDisplay it opens a different dialog box which instead of asking for the desired value for the collision detection setting, it asks if the user wants to toggle the setting by presenting a simple confirmation dialog. This is more convenient for the user, as entering "Off" or "On" in a text input box would be rather tedious.

```
changeCylinderNumber:: IORef SettingsDataStructure -> IO ()
changeCylinderNumber settings = do
  newNumber <- openIntDialog settings
  updateNumOfCylinders newNumber settings
```

```
  return()

changeCollisionDetection:: IORef SettingsDataStructure -> IO ()
changeCollisionDetection settings = do
  newBool <- openBoolConfirmationDialogCollision settings
  updateCollisionOn newBool settings
  return()

changeAxisDisplay:: IORef SettingsDataStructure -> IO ()
changeAxisDisplay settings = do
  newBool <- openBoolConfirmationDialogAxis settings
  updateAxisOn newBool settings
  return()
```

openIntDialog is responsible for creating the text dialog box in which the user will enter the new desired value for the number of cylinders. If the value entered is not an integer (i.e. decimal numbers), then the integer part of that value is returned. If the value is smaller than the minimum value set, it will return the minimum value instead of the invalid value. openBoolConfirmationDialogCollision/openBoolConfirmationDialogAxis opens a confirmation dialog asking the user if he wants the value for collision/axis rendering detection to be toggled. There is no error detection there as there is no other choice to change boolean values. Basically these three functions just retrive the desired values from the user via dialog boxes and returns it to the calling function which will update the settingsDataStructure.

```
openIntDialog::IORef SettingsDataStructure -> IO(Prelude.Int)
openIntDialog settings = do
  mySettings <- readIORef settings
  myNum <- getNumOfCylinders mySettings
  defaultValueInt <- readIORef (myNum)
  f <- frameCreateDefault ("Number of Cylinders Dialog")
  y<-textDialog f ("Please Enter Number of Cylinders") "Number Of Cylinders" (show(defaultValueInt))
  if (null y)
    then do return(defaultValueInt)
    else do let list=(reads y)::[(Prelude.Float, String)]
         if (list==[])
     then do return(minimumValueInt)
     else do let x=(read (y))::Prelude.Float
                 let z = float2Int x
                 return (max minimumValueInt z)


openBoolConfirmationDialogCollision::IORef SettingsDataStructure -> IO(Prelude.Bool)
openBoolConfirmationDialogCollision settings = do
  mySettings <- readIORef settings
  myDetection <- getCollisionOn mySettings
  booleanValue <- readIORef (myDetection)
  let complementValue = complement (booleanValue)
  f <- frameCreateDefault ("Collision Detection Dialog")
  y <- confirmDialog f "Confirm" ("Would you like to turn collision detection "++complementValue) True
  if (y==True)
    then if (complementValue=="On")
          then return(True)
  else return(False)
    else if (complementValue=="On")
          then return(False)
```

```
  else return(True)

openBoolConfirmationDialogAxis::IORef SettingsDataStructure -> IO(Prelude.Bool)
openBoolConfirmationDialogAxis settings = do
  mySettings <- readIORef settings
  myDetection <- getAxisOn mySettings
  booleanValue <- readIORef (myDetection)
  let complementValue = complement (booleanValue)
  f <- frameCreateDefault ("Axis Rendering Dialog")
  y <- confirmDialog f "Confirm" ("Would you like to turn axis rendering "++complementValue) True
  if (y==True)
    then if (complementValue=="On")
          then return(True)
  else return(False)
    else if (complementValue=="On")
          then return(False)
  else return(True)
```

complement returns "Off" if its parameter is true and "On" if its parameter is false.

```
complement::Prelude.Bool -> Prelude.String
complement True = "Off"
complement False = "On"
```

Module UndoDataStructure provides us with the data structure UndoDataStructure which consists of the following: two IORefs each referring to a list of GxlGraphSets. This data structure supports both undo and redo, where one list of GxlGraphSets are for undo's, hence the undoList and the other IORef is for redo's, hence the redoList. The way this undo and redo is implemented is that, when anything in the graph is changed, that particular instance of the graph data structure is added to the undoList. When the user requests for an undo, the latest graph data structure stored in the undoList is retrived and then it is transferred to the redoList. When the user requests for a redo, the latest graph data structure stored in the redoList is retrived and then it is transferred to the undoList. This process ensures that undo's and redo's are processed correctly. The length of the lists are limited to maxList, which is 10. So only 10 levels undos or redos are possible at one time.

The service of this module is that it provides a set of functions to extract the latest graph data structure from the undoList or the redoList, to save graph data structures into the undoList, to undo or redo which follows the procedure described above and it also provides a function to initialize an UndoDataStructure where it sets both the IORefs to refer to the empty list. view to a default value who's fields are set by constants defined below. The secret of the module is that it hides how the undo data structure is represented and how the fields are individually extracted.

```
module UndoDataStructure (UndoDataStructure,initUndoDataStructure,newUndoDataStructure,
updateGraphDataStructure,undo,redo)  where
import Data.IORef  ( IORef, newIORef, readIORef, modifyIORef, writeIORef)
import IO
import Gxl_1_0_1_DTD hiding (Int)
import GXL_DTD

data UndoDataStructure = UndoDataStructure (IORef [GxlGraphSet]) (IORef [GxlGraphSet])
```

maxList defines the maximum length of the undo list and redo list

```
maxList::Prelude.Int
maxList = 10
```

initUndoDataStructure initializes the undo and redo lists of an UndoDataStructure to the empty list.

```
initUndoDataStructure:: UndoDataStructure -> IO()
initUndoDataStructure (UndoDataStructure undoList redoList) = do
  modifyIORef undoList (\x -> [])
  modifyIORef redoList (\x -> [])
  return()
```

newUndoDataStructure returns a new UndoDataStructure. This data structure would have the undo and redo lists being empty. This function is required to be called once for there to be an undoDataStructure to work with.

```
newUndoDataStructure::IO(IORef UndoDataStructure)
newUndoDataStructure = do
  undoList <- newIORef []
  redoList <- newIORef []
  undoDataStructure <- newIORef (UndoDataStructure undoList redoList)
  return (undoDataStructure)
```

getUndoList and getRedoList are local functions which retrieves the undo list for the purpose of the other functions in the module.

```
getUndoList:: UndoDataStructure -> IO (IORef [GxlGraphSet])
getUndoList (UndoDataStructure undoList redoList) = return (undoList)

getRedoList:: UndoDataStructure -> IO (IORef [GxlGraphSet])
getRedoList (UndoDataStructure undoList redoList) = return (redoList)
```

updateGraphDataStructure updates the UndoDataStructure with a new graph data structure. Whenever a changed that can be undoed is done, this function is called to save the previous state of the graph data structure before the change into the undo data structure. When the length of the undo list is full, it drops the earliest item in the list to make space for the newer one.

```
updateGraphDataStructure:: GxlGraphSet -> IORef GxlGraphSet -> IORef UndoDataStructure -> IO ()
updateGraphDataStructure graphSet dataStructure undoDataStructure = do
    myUndoDataStructure <- readIORef undoDataStructure
    myUndoList <- getUndoList myUndoDataStructure
    myRedoList <- getRedoList myUndoDataStructure
    myDataStructure <- readIORef dataStructure
    undoList <- readIORef myUndoList
    let lengthOfUndoList = length(undoList)
    if (lengthOfUndoList>=maxList)
          then do
             let shortenedUndoList = take (lengthOfUndoList-1) undoList
             let newUndoList = myDataStructure:shortenedUndoList
             modifyIORef myUndoList (\x -> newUndoList)
             modifyIORef undoDataStructure (\x -> (UndoDataStructure myUndoList myRedoList))
             modifyIORef dataStructure (\x -> graphSet)
             return()
           else do
             let newUndoList = myDataStructure:undoList
```

```
            modifyIORef myUndoList (\x -> newUndoList)
            modifyIORef undoDataStructure (\x -> (UndoDataStructure myUndoList myRedoList))
            modifyIORef dataStructure (\x -> graphSet)
            return()
    return()
```

undo and redo is as its name says, it undoes and redoes. Undo takes in the IORef to the current graph data structure and overwrites it with the latest copy of the graph data structure in the undo list, therefore 'undoing' all changes that was done. The graph data structure in the undo list is then dropped from the list and added to the redo list instead. Similarly redo takes in the IORef to the current graph data structure and overwrites it with the latest copy of the graph data structure in the redo list, therefore 'redoing' all the changes that was undoed. The graph data structure in the redo list is then dropped from the list and added to the undo list instead.

```
undo::IORef GxlGraphSet -> IORef UndoDataStructure -> IO()
undo dataStructure undoDataStructure = do
myUndoDataStructure <- readIORef undoDataStructure
myUndoList <- getUndoList myUndoDataStructure
myRedoList <- getRedoList myUndoDataStructure
myDataStructure <- readIORef dataStructure
undoList <- readIORef myUndoList
redoList <- readIORef myRedoList
if ((length undoList)>=1)
  then do
     let newGraphSet = undoList !! 0
     let newUndoList = drop 1 undoList
     let newRedoList = myDataStructure:redoList
     modifyIORef myUndoList (\x -> newUndoList)
     modifyIORef myRedoList (\x -> newRedoList)
     modifyIORef undoDataStructure (\x -> (UndoDataStructure myUndoList myRedoList))
     modifyIORef dataStructure (\x -> newGraphSet)
  else return()
return()

redo::IORef GxlGraphSet -> IORef UndoDataStructure -> IO()
redo dataStructure undoDataStructure = do
myUndoDataStructure <- readIORef undoDataStructure
myUndoList <- getUndoList myUndoDataStructure
myRedoList <- getRedoList myUndoDataStructure
myDataStructure <- readIORef dataStructure
undoList <- readIORef myUndoList
redoList <- readIORef myRedoList
if ((length redoList)>=1)
  then do
     let newGraphSet = redoList !! 0
     let newRedoList = drop 1 redoList
     let newUndoList = myDataStructure:undoList
     modifyIORef myUndoList (\x -> newUndoList)
     modifyIORef myRedoList (\x -> newRedoList)
     modifyIORef undoDataStructure (\x -> (UndoDataStructure myUndoList myRedoList))
     modifyIORef dataStructure (\x -> newGraphSet)
  else return()
return()
```

Module ViewDataStructure provides us with the data structure View which consists of the following: a horizontal component of type GLfloat, a vertical component of type GLfloat and finally the camera distance of type GLfloat. The horizontal and vertical components of the data structure will basically store the amount the user has rotated along the x-axis or y-axis. This module is responsible for keeping track of graph rotation, view rotation and zooming. The service of this module is that it provides are a set of functions to extract information and to save values of GLfloat to any particular field, and it also provides a function to initialize a view to a default value who's fields are set by constants defined below. The secret of the module is that it hides how the View data structure is represented and how the fields are individually extracted.

```
module ViewDataStructure (View,getHorizontal,getVertical,getCameraDistance,
changeHorizontal,changeVertical,changeCameraDistance,initView) where

import Data.IORef  ( IORef, newIORef, readIORef, modifyIORef, writeIORef)
import Graphics.Rendering.OpenGL.GL
```

Below, the View data type is defined as described above where its constructor is View.

```
data View = View GLfloat GLfloat GLfloat
```

The default view fields are defined using constants to support modifiability.

```
defaultHorizontal::GLfloat
defaultHorizontal = 0

defaultVertical::GLfloat
defaultVertical = 0

defaultCameraDistance::GLfloat
defaultCameraDistance = (0.0::GLfloat)
```

The following functions are used to extract individual fields from the View data structure.

```
getHorizontal :: View -> GLfloat
getHorizontal (View a b c) = a

getVertical :: View -> GLfloat
getVertical (View a b c) = b

getCameraDistance :: View -> GLfloat
getCameraDistance (View a b c) = c
```

The following functions are used to change individual fields in the View data structure. It takes in as input the View data structure and the new value and returns the modified View data structure.

```
changeHorizontal :: View -> GLfloat -> IO View
changeHorizontal (View a b c) d = return (View d b c)

changeVertical :: View -> GLfloat -> IO View
changeVertical (View a b c) d = return (View a d c)

changeCameraDistance :: View -> GLfloat -> IO View
changeCameraDistance (View a b c) d = return (View a b d)
```

initView returns the View data structure with the default values using the constants defined above.

```
initView :: IO (View)
initView = do
      return (View defaultHorizontal defaultVertical defaultCameraDistance)
```

Module ViewFileManager, as the name indicates, gives us functions and facilities to open, save and close View Files. The secret it hides is how the view files are manipulated to get this result. A decision was made here to use our own format for a view file, which will consist of three lines the first having the horizontal angle, the second the vertical and the third the camera distance to match the created View Data Structure.

```
module ViewFileManager (openView,saveView,closeView)  where

import Data.Char
import Data.IORef  ( IORef, newIORef, readIORef, modifyIORef, writeIORef)
import Data.FiniteMap
import IO
import Graphics.Rendering.OpenGL.GL
import Graphics.Rendering.OpenGL.GLU
import Graphics.UI.GLUT.Callbacks.Window ( MouseButton )
import Graphics.UI.GLUT.Window
import Graphics.UI.GLUT hiding (MenuItem)
import Graphics.UI.WX hiding (KeyUp,KeyDown,color,motion,WXCore.WxcTypes.Size,Classes.position,Attributes.get)
import Graphics.UI.WXCore.Frame
import System.Exit(exitWith, ExitCode(ExitSuccess), exitFailure)
import Control.Monad ( liftM, zipWithM_ )
import Data.Char     ( ord )
import Data.List     ( genericLength )
import ViewDataStructure
```

viewFiles is used to filter the view files, here we allow the view file to be of any type.

```
viewFiles::  [(String, [String])]
viewFiles = [("View files",["*"])]
```

loadViewFile is used to load a view file. We prompt the user for a file and once that is returned we read it in and return the corresponding view. If an error is encountered we just return.

```
loadViewFile :: FilePath  -> IORef View -> IO ()
loadViewFile path view =  catch(do
  myView <- initView
  handle <- openFile path ReadWriteMode
  first <- hGetLine handle
  second <- hGetLine handle
  third <- hGetLine handle
  myView1 <- changeHorizontal myView ((read first)::GLfloat)
  myView2 <-  changeVertical myView1 ((read second)::GLfloat)
  myView3 <-  changeCameraDistance myView2 ((read third)::GLfloat)
  modifyIORef view (\x -> myView3)
  hClose handle)
  (\err -> return() )
```

openView is a function which uses wxHaskell facilities by opening a file dialog for the user and prompting him for the view file he whishes to open.

```
openView ::IORef View -> IO ()
openView view = do
  f <- frameCreateDefault ("File Dialog")
  mbfname <- fileOpenDialog f False True "Open View" viewFiles "" ""
  case mbfname of
             Nothing    -> return ()
             Just fname -> loadViewFile fname view
```

saveViewFile is used to save a view file. We prompt the user for a file and once that is returned we save the view in it. If an error is encountered we just return.

```
saveViewFile :: FilePath  -> IORef View -> IO ()
saveViewFile path view =  catch (do
  handle <- openFile path ReadWriteMode
  myView <- readIORef view
  hPutStrLn handle (show (getHorizontal myView))
  hPutStrLn handle (show (getVertical myView))
  hPutStrLn handle (show (getCameraDistance myView))
  hClose handle)
  (\err -> return() )
```

saveView is a function which uses wxHaskell facilities by opening a file dialog for the user and prompting him for a file that he wishes to save the view into.

```
saveView ::IORef View -> IO ()
saveView view = do
  f <- frameCreateDefault ("File Dialog")
  mbfname <- fileSaveDialog f False True "Save View" "" ""
  case mbfname of
             Nothing    -> return ()
             Just fname -> saveViewFile fname view
```

closeView is a function which closes the window associated with the current view and decrements the number of windows current open $view_count$. If this is the last window that was open then the whole application is closed.

```
closeView:: Graphics.UI.GLUT.Window.Window -> IORef Int -> IO ()
closeView x view_count=do
   modifyIORef view_count (\x -> x-1)
   p <- readIORef view_count
   if p==0 then (exitWith ExitSuccess)
           else (destroyWindow x)
```

Module ViewManipulation is responsible for the manipulation of the views in the program. The data structure View from the module ViewDataStructure is changed, modified and updated using the functions from this module. There is two things that can modify the view, that is when the user zooms in the view or rotates the view. The view data structure stores values that state how much did the view get rotated or zoomed. It is this module together with the motion callback which updates these values according to how much the user moves the mouse. This module's functions are seperated according to how the user changes the values. For instance, holding the left mouse button while moving

the mouse would be using the rotateViewButtonDown function, while zooming using the wheel would be calling the zoomViewWheelUp and zoomViewWheelDown. All that is needed to rotate a particular graph view is by modifying the values stored in its View data structure. The graph drawing module takes these values and draws appropriately.

The service of this module is that it provides a set of functions to update the View data structure and the IORefs which store the amount of rotation according to what how the user rotates or zooms. The secret of thie module is the way the view data structure is updated and how the IORefs containing the amount of rotation is calculated to the new amount.

```
module ViewManipulation (rotateViewButtonDown,zoomViewWheelUp,zoomViewWheelDown)  where

import Gxl_1_0_1_DTD
import GXL_DTD
import INIT
import Data.IORef
import Graphics.Rendering.OpenGL.GL
import Graphics.Rendering.OpenGL.GLU
import Graphics.UI.GLUT
import ViewDataStructure
import GraphInterface
import Node
import Utils
import GxlGraphSetManage
import Text.XML.HaXml.OneOfN
```

rotateViewButtonDown is responsible for modifying the new mouse coordinates and old mouse coordinates according to the current mouse coordinates. The real functionality of rotation is in the function calculateViewRotation.

```
rotateViewButtonDown :: IORef View -> IORef GLfloat -> IORef GLfloat -> IORef GLfloat -> IORef GLfloat
-> GLsizei -> GLsizei -> IO()
rotateViewButtonDown view oldx oldy newx newy x y = do
  oy <- readIORef oldy
  ox <- readIORef oldx
  modifyIORef newy (\d ->(fromIntegral y))
  modifyIORef newx (\d ->(fromIntegral x))
  ny <- readIORef newy
  nx <- readIORef newx
  calculateViewRotation oldx oldy newx newy view
  modifyIORef oldx (\d ->nx)
  modifyIORef oldy (\d ->ny)
  return()
```

calculateViewRotation takes in as parameters the IORefs which represents the old mouse coordinates, the new mouse coordinates and the current mouse coordinates. This function calculates the difference between the old mouse coordinates and new coordinates. From the difference, we can infer which way the mouse is moved, therefore modify the values in the view data structure accordingly. After modifying the view data structure, postRedisplay is called to redraw the graph using the new rotation.

```
calculateViewRotation :: IORef Prelude.Float->IORef Prelude.Float->IORef Prelude.Float
->IORef Prelude.Float->IORef View->IO ()
calculateViewRotation oldx oldy newx newy view = do
    ny <- readIORef newy
    oy <- readIORef oldy
    nx <- readIORef newx
```

```
    ox <- readIORef oldx
    let diffy =  ny-oy
    let diffx =  nx-ox
    if (diffy <=(-1))
      then do
            myView <- readIORef view
            let newVertical = ((getVertical myView)+1)
            newView <- changeVertical myView newVertical
            modifyIORef view (\x -> newView)
            postRedisplay Nothing
      else if (diffy >= 1)
        then do
            myView <- readIORef view
            let newVertical = ((getVertical myView)-1)
            newView <- changeVertical myView newVertical
            modifyIORef view (\x -> newView)
            postRedisplay Nothing
      else return()
    if (diffx <=(-1))
      then do
            myView <- readIORef view
            let newHorizontal = ((getHorizontal myView)+1)
            newView <- changeHorizontal myView newHorizontal
            modifyIORef view (\x -> newView)
            postRedisplay Nothing
      else if (diffx >= 1)
        then do
            myView <- readIORef view
            let newHorizontal = ((getHorizontal myView)-1)
            newView <- changeHorizontal myView newHorizontal
            modifyIORef view (\x -> newView)
            postRedisplay Nothing
      else
        return()
```

zoomViewWheelUp modifies the component in the view data structure which corresponds to the distance of the camera from the objects. The wheel up of the mouse is for zooming in and wheel down is for zooming out.

```
zoomViewWheelUp::IORef View -> IO()
zoomViewWheelUp view = do
  let moveDiff = 0.5
  myView <- readIORef view
  let newCameraDistance = ((getCameraDistance myView)+moveDiff)
  newView <- changeCameraDistance myView newCameraDistance;
  modifyIORef view (\x -> newView)
  return()

zoomViewWheelDown::IORef View -> IO()
zoomViewWheelDown view = do
  let moveDiff = 0.5
  myView <- readIORef view
  let newCameraDistance = ((getCameraDistance myView)-moveDiff)
  newView <- changeCameraDistance myView newCameraDistance;
  modifyIORef view (\x -> newView)
  return()
```

4 VERIFICATION

4.1 High Level Test Plan

The team tested the application using several approaches to ensure the most confidence in the final product's functionality.

It was be very difficult to perform automated testing on 3-dimensional graphs due to its visual nature, so most of the testing was be done manually.

White box testing was conducted on each module by testing its interface functions. The focus of this round of tests was to ensure that the functions tested perform at least their basic functions with some degree of reliability. The test cases and their results are discussed in detail in table (1). Documenting this testing phase was very important as anytime a particular function was modified to fix a bug discovered in the black box testing phase, we had a set of pre-compiled tests which would tell us, rather quickly, whether the bug fix introduced further bugs or not . The test cases were generated in a rather systematic way by considering the possible flows that could occur within the function and making sure that in each of those cases the desired result is delivered. Special attention was given to functions which retrieve input from the user as to make sure that whatever the user enters, the system handles gracefully.

In addition, black box testing was conducted on the completed system. The focus, in this testing phase, was to ensure that each of the components of the system perform together as expected, after we have ensured that in isolation they perform as expected (white box testing). In addition, we wanted to ensure that to the best of our understanding, the end users will be satisfied with the end result, as the product meets the requirements as outlined in the requirements section (section 1). The test cases and their results are discussed in detail in table (2). The test cases here were generated more or less randomly by considering as many different combinations of probable user actions as we can to increase the confidence in the application. In this phase, we tried to be as objective as possible when producing the test cases so that we dont let our knowledge of the code blindfold us when trying to unveil bugs.

4.2 White Box Testing

As mentioned in the high level test plans, white box testing was conducted on each module through testing its interface functions. The focus of this round of tests was to ensure that the functions tested perform at least their basic functions with some degree of reliability. Table (1) summarizes the results of this phase. The first column contains the description of the test case, the second column contains the input data used, the third column indicates the expected result, the fourth indicates the actual result in case the test case failed (otherwise it is left blank) and finally the last column indicates the status of the test case as a Pass/Fail value. Documenting this testing phase was very important as anytime a particular function was modified to fix a bug discovered in the black box testing phase, we had a set of pre-compiled tests which would tell us, rather quickly, whether the bug fix introduced actually fixes a bug and introduces another. The test cases were generated in a rather systematic way by considering the possible flows that could occur within the function and making sure that in each of those cases the desired result is delivered. Special attention was given to functions which retrieve input from the user as to make sure that whatever the user enters is processed properly.

The bugs encountered during this phase were:

-Trying to add an edge between two nodes that already have an edge connecting them
-Trying to add an edge between a node and an edge or between two edges
-Trying to load a non existing graph file or a graph file that does not have correct syntax
-Trying to load a view file with invalid syntax

These bugs were reported using the issue tracking system and can be tracked via issues CZJ23-27 in figure (2).

Due to lack of time and since the bugs affect scenarios that rarely occur, we decided to document them and leave their resolution to future work. These bugs' scope are localized so they can easily be fixed without disturbing the rest of the system.

4.3 Black Box Testing

As mentioned is the high level test plans (section 1.3), black box testing was conducted on the completed system. The focus, in this testing phase, was to ensure that each of the components of the system perform together as expected, after we have ensured that in isolation they perform as expected (white box testing). In addition, we wanted to ensure that to the best of our understanding, the end users will be satisfied with the end result, as the product meets the requirements as outlined in the requirements section (section 1). Table (2) summarizes the results of this phase. Again, the same format was used to document the test cases here. The test cases here were generated more or less randomly by considering as many different combinations of user actions as we can to increase the confidence in the application, the test cases were considered with collision on and off and with several views open simultaneously. In this phase, we tried to be as objective as possible when producing the test cases so that we dont let our knowledge of the code blindfold us when trying to unveil bugs.

The bugs encountered during this phase were:

-Collision detection between bent edge and bent edge is not very accurate
-When switching from collision off to collision on and the graph contains a collision already, the collision can't be removed

These bugs were reported using the issue tracking system and can be tracked via issues CZJ31-32 in figure (2).

Due to lack of time, we decided to document them and leave their resolution to future work. These bugs' scope are localized so they can easily be fixed without disturbing the rest of the system.

4.4 Issue Tracking

As mentioned in the implementation section 1.3, the issue tracking system, Scarab, was extensively used to keep track of any issues encountered or modifications made to the requirements, design and implementation and to report/document any bugs during the testing phase. Figure (2) summarizes the issues that were documented. For more details please refer to the online system.

Figure 2: Issue Tracking

Issue type	Issue ID	Summary	Description
Feature	CZJ1	Color Selection	This function should prompt the user with a color dialog through wxHaskell, read it and return a Color4 GLUT color vector.
Feature	CZJ2	Label Entering	This function should prompt the user for a label through a wxHaskell dialog, read it and return a string containing the label entered.
Task	CZJ3	Node Data Structure	A node will be represented as a finite map. The key will consist of an integer which represents the Object ID to be pushed into the name stack. The element will consist of a data structure containing: a) a Label of type string b) a Color4 RGB vector specifying the color of the node c) the Shape of type enumerate string and the necessary parameters (i.e. radius...) d) the texture of the node enumerated type : Flat, Smooth, None
Task	CZJ4	Edge Data Structure	An Edge will be represented as a finite map. The key will consist of an integer which represents the Object ID to be pushed into the name stack. The element will consist of a data structure containing: a) a Label of type string b) a Color4 RGB vector specifying the color of the edge c) a set of vertices around which the edge is to be rendered d) the texture of the edge enumerated type : Flat, Smooth, None e) a pair of integers representing the nodes that this edge connects.
Task	CZJ5	Add Node Function	Need to implement a function add node which take the element data structure as prescribed in the node data structure and draws the node with those attributes.
Task	CZJ6	Add Edge function	Need to implement a function add edge which take the element data structure as prescribed in the edge data structure and draws the edge with those attributes.
Task	CZJ7	Layout File Structure	The layout filed will be structured in lines of the following form: ObjectID X(GLFloat) Y(GLFloat) Z(GLFloat)
Task	CZJ8	Layout Data Structure	The Layout will be stored in a finitemap where the key will be the ObjectID and the element will be the coordinates (x,y,z).
Task	CZJ9	Modifications towards new HOpenGL API on GHC 6.2	From now onwards versions of the software have to be written to conform with the new API of ghc 6.2.
Task	CZJ10	Reading GXL files in Haskell	We need to read, understand and be able to work with the interface at www.cas.mcmaster.ca/~wuj that reads GXL files into Haskell. Need to obtain a copy of the source code and be able to compile it.
Task	CZJ11	Writting to GXL files from Haskell	Obtain code from the Graduate student to enable us to write into GXL file so we can save such files when the user wishes to do so.
Feature	CZJ12	Adding a Node	After choosing the right menu. The user will be able to click the mouse at a certain position and a node with some default attributes should be dropped there.
Feature	CZJ13	Keyboard Shortcuts	Menu features should be accessible through keyboard shortcuts.
Feature	CZJ14	Moving a Node	The user can select and node and with the appropriate menu can choose to move it. The node is to be moved by the user input be it mouse or keyboard
Task	CZJ15	Encapsulation of View	The view data structure should be encapsulated to allow modification of format or data structure.
Task	CZJ16	Directed Graphs required	Graphs can be directed or undirected.
Task	CZJ17	Scale Graph redefinition	Scaling a graph just means stretching or squeezing it, only layout attributes will thus be changed and the actual node attributes will not.
Task	CZJ18	Undo and Redo Functionality	Undo and Redo functionality can be easily added (and should be) as IORefs will be used to represent the GraphSet.
Task	CZJ19	Bending an edge	The user should be able to bend an edge after selcting it. The mouse button will be used to bend in the x and y direction and the mouse wheel in the z direction.
Task	CZJ20	Collision Detection and Handling	Collisions between items should be detected and handled. However collision comes in only after the user releases any current movement. So that only in the final state is the graph to be collision free. During movement we don't need to worry about collision.
Task	CZJ21	Error Handling	Errors should be shown to the user in the form of popup windows but in such a way that that the enter key is autofocused on the new window. So that by pressing enter the window goes away with no movement of the mouse required.
Task	CZJ22	Layout Generation	If the layout information is not found in the loaded GXL file we are to use an algorithm to generate the layout.
Defect	CZJ23	View File with invalid syntax	Restart the application, load graph graph1.gxl and load the view file view3 using the menu. The program crashes.
Defect	CZJ24	Graph File with invalid syntax	Restart the application, load graph graph2.gxl from the menu. The application crashes.
Defect	CZJ25	Loading a non existing graph file	The current graph is kept and no graph is loaded as we don't have read access to the file. Th application crashes.
Defect	CZJ26	Adding an already existing edge again	Restart the application, load graph graph5.gxl select add directed edge from the menu, and select NodeA and NodeB from the graph. The edge is added on top of the already existing edge. This is the same for directed and undirected edge.
Defect	CZJ27	Adding an edge between a node and an edge	Restart the application, load graph graph5.gxl select add directed edge from the menu, and select NodeC then EdgeA then NodeD from the graph. We get: Error: Non-exhaustive patterns in function unMaybe. This is the same for directed and undirected edge.
Task	CZJ28	Changes to the High Level Design	At the time where the high level design was written, we didn't have had enough time to think about it, nor enough knowledge about the problem and this was clearly mentionned in the EPP. Therefore we went back and re-edited this section to reflect the high level design adopted after we had more time to think about it. The major difference is in the module division. We prefered to put all the operations which manipulate the graph into one module rather then splitting rotating and scaling. Same thing for the view. In addition Settings module were introduced to enable the user to toggle certain features on and off depending on the visualization they want. The error handling module has been removed as we have decided to not do anything when an invalid action was performed. In addition we created 3 additional modules one for layout (to generate layout), one for collision (to detect collision) and one for undo (to undo changes done to graph).
Task	CZJ29	Changes to the Requirements	The requirements section of the EPP, mostly stayed as it is in the final report. The changes that were done include rephrasing some of the requirements (linguistic changes) as per the coordinator's request, in addition we added a new requirement to allow undo/redo.
Task	CZJ30	Capacity Requirement	The capacity not functional requirement has been waived off and will be the object of future work, mainly optimising the GXL Graph Set datatstructure.
Defect	CZJ31	Collision Detection	Bent Edge to Bent Edge collision is not functionning well. This problem appears when we are bending an edge and the edge collides with another bent edge or when we are moving a node that has a bent edge and that edge collides with another bent edge.
Defect	CZJ32	Collision Detection with prior collision	When a graph is loaded and originaly has a collision or a graph has a collision when the mode is toggled on then the user can't resolve the collision, unless he switches to detection off and resolves the collision.

4.5 Evaluation of Work

During development, we followed an iterative approach when it came to implementing functionality. So what we did was first implemented all the functionalities at a more or less basic level, then as time permitted iterated through them again and enhanced them.

The source code was very well documented to allow future developers to easily access, understand and modify the existing source code to enhance certain functionalities, where we felt more efficient algorithms or methods could be used. In other words, the framework has been laid out for future work.

Of course there are numerous areas in which this tool can be improved, including but not limited to the following:

- Implementing a more efficient layout generation / collision detection method such as using the particle and spring model or using BSP trees.
- Optimizing the GXL Graph Set data structure, to allow faster access to read and write to the data structure hence making the tool faster.

Future work may also include allowing hyper-edges in the graph (i.e having hyper-graphs), and possibly allowing nested graphs .

The only requirement we failed to meet was regarding capacity (Issue CZJ30 in figure (2)) . We tried to do profiling on the application to see where the slow down is occurring, however some of the packages being used, namely WxHaskelll and HaXml do not support profiling by default. We strongly suspect that the slow down is caused by the numerous interactions with the graph data structure (read and update), as this data structure was not implemented with performance in mind.

Finally to accurately evaluate the work several factors have to be taken into account:

- This was our first experience developing an application in a functional programming language in general and Haskell in particular.
- HOpenGL is a fairly recent standard and lacks documentation and tutorials, this made the task of learning it harder as we had to interpret OpenGL programs written in C.
- Mid-way through implementation GHC released a new version of its Haskell compiler in which the API of OpenGL was completely changed, this forced us to stop implementation and update all the existing files to conform to the new API.
- The installation of the software/packages/drivers needed to develop this tool is a very meticulous process that took a lot of our time.

With that being said, we think that we exceeded our own expectations and have accomplished a considerable piece of work.

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A USER MANUAL

A.1 OVERVIEW

About the Graph Editor

The 3-Dimensional Graph Editor In Haskell features the ability to view/edit/create 3-Dimensional graphs. This application was developed in Haskell using HOpenGL as the underlying graphics package at McMaster University during the 2003/2004 academic year.

This application uses the emerging standard Graph eXchange Language (GXL) format as input/output graph format.

The key features of this software are:

- Create and save GXL Graphs
- Load and modify existing GXL graphs obtained from other applications
- Visualize the graph from different views simultaneously with the ability to load/save individual views
- Customize visualization options

System Requirements

The Graph Editor has been installed and tested on the following machines with reasonable performance:

CPU: Intel Pentium 4 Processor or AMD Athlon 1.4 Ghz

Operating System: Linux Redhat 8-9

Software Requirements:

a) A Haskell Compiler (Preferably GHC 6.2 with OpenGL enabled)
b) WxHaskell package
c) HaXml package

Memory: 512 MB RAM

Video: A 3D accelerator video card with support for OpenGL and at least 64 MB of video memory is required.

The application can be easily ported to other operating systems such as Unix and Windows as it only uses the standard OpenGL interface.

Installation Guide

The first step is to install GHC 6.2 from source, which is a Haskell compiler. This compiler can be downloaded from http://www.haskell.org/ghc/download.html . When configuring be sure to configure as follos: configure –enable-hopengl, so that the hopengl library gets installed with the compiler. After that is done, WxHaskell 0.2 needs to be installed, again from source. This can be obtained from http://wxhaskell.sourceforge.net/download.html. When installing, you might be required to download some additional library files in some cases. If so, you can easily find the files on the internet and install them. Finally HaXml 1.09 needs to be installed, again from source. This can be obtained from http://www.cs.york.ac.uk/fp/HaXml.

Once everything mentioned above is configured and running, you need to checkout the source files from the CVS Repository. The CVS repository is located on the Ritchie server at McMaster University. SSH into the server ritchie.cas.mcmaster.ca then point your cvs root environment variable to /u1/cs4zp6/cs4zp6gj/cvs_repository after that checkout the folder 3dGraphEditor.

Finally, run the makefile which will generate the executable, which you can then use.

N.B: The installation of the compiler and the necessary packages can be quite tedious and time consuming

A.2 GRAPHS

In this section, it would be useful to define the following terms which will be used:

a) Items - An item refers either to an edge or a node in the graph.
b) Stacks and slices - Stacks and slices defines how detailed the items are drawn. The higher the number of stacks and slices, the smoother the object.

Loading a Graph

To load a saved graph: press the right mouse button to invoke the popup menu then go to Graph then select Load or alternatively using the keyboard shortcut Control-L. A file dialog will appear, enter the file name you wish to load to or select it from the list. If the file exists, you have read permision and the file is a valid view file (i.e Has the right information and syntax) the graph file will be loaded and the corresponding graph will be displayed, otherwise the current graph is kept. The graph file should have extension *.gxl . Of course, the loaded graph will appear on all currently opened views and not only to the view where you invoked the menu from. Undoing or Redoing this operation is not supported.

Saving a Graph

To save the current graph: press the right mouse button to invoke the popup menu then go to Graph then select Save or alternatively using the keyboard shortcut Control-S. A file dialog will appear, enter the file name you wish to save to or select it from the list. If the file already exists then you will be asked if you whish to overwrite it, of course you need in any case to have write permision for that file/disk. If you succesfully chosen a file which is either new or you confirmed to overwrite an existing file and you have write permision then the graph is saved, otherwise the current graph is not saved. The graph file should have extension *.gxl . Saving the graph from any of the views open will have the same effect as they all display the same graph but from different views. Undoing or Redoing this operation is not supported.

Rotating a Graph

To rotate the current graph: press the right mouse button to invoke the popup menu then go to Rotate then select Graph. After that hold down the mouse left button and move the mouse according to the desired effect. Moving the mouse horizontaly will rotate the graph aroung the horizontal axis and moving the mouse verticaly will rotate the graph around the vertical axis, of course moving the mouse diagonally will rotate around both the horizontal and vertical axis. Undoing or Redoing this operation is supported.

Scaling a Graph

To scale the graph: press the right mouse button to invoke the popup menu then go to Zoom then select Graph. After that use the wheel to scale the graph. Of course when collision is turned on the graph will only be scaled if the graph after its scaled is collision free. Undoing or Redoing this operation is supported.

Adding Nodes to a Graph

To add a node: press the right mouse button to invoke the popup menu then go to Add then select Node. After that you must select the location on the screen where the node is to be added: if collision detection is off then the node is added, otherwise if collision detection is on and the location clicked on causes a collision then the node is not added. Undoing or Redoing this operation is not supported.

Adding Edges to a Graph

a) Adding a Directed Edge:

To add a directed edge: press the right mouse button to invoke the popup menu then go to Add then select Directed Edge. After that you must select the from and then the to nodes that this edge will connect. Clicking on an edge meanwhile or nothing at all will not have any effect and you still have to pick the 2 nodes. Once that has been done and the two nodes are neither the same nor already connected by an edge, the edge mode is not undirected and the resulting edge does not cause a collision in case collision detection is on, a directed edge is added between the two nodes. Otherwise no edge is added. Undoing or Redoing this operation is supported.

b) Adding an Undirected Edge:

To add an undirected edge: press the right mouse button to invoke the popup menu then go to Add then select Undirected Edge. After that you must select the two nodes that this edge will connect. Clicking on an edge meanwhile or nothing at all will not have any effect and you still have to pick the 2 nodes. Once that has been done, the two nodes are neither the same nor already connected by an edge, the edge mode is not undirected and the resulting edge does not cause a collision in case collision detection is on, an undirected edge is added between the two nodes. Otherwise no edge is added. Undoing or Redoing this operation is supported.

Moving Nodes in a Graph

To move a node: press the right mouse button to invoke the popup menu then go to Move then select Node. After that you must select the node that you want to move, once that is done while holding the left mouse button down move your mouse to move the selected node in the horizontal-vertical plane and/or use the wheel to move it in depth. Of course when collision is turned on then a node may not collide with another object while on its way to its destination. Undoing or Redoing this operation is supported.

Bending Edges in a Graph

To bend an edge: press the right mouse button to invoke the popup menu then go to Bend then select Edge. After that you must select the edge that you want to bend, once that is done while holding the left mouse button down move your mouse to bend the selected edge in the horizontal-vertical plane and/or use the wheel to bend it in depth. Of course when collision is turned on then a bent edge may not collide with another object while being bent. Undoing or Redoing this operation is supported.

Changing the Label of an Item

To change an Item's Label: press the right mouse button to invoke the popup menu then go to Change then select Label. After that you must select the item that you want its label changed, once that is done a dialog box will prompt you for a new label, by default the label shown is the current one. Any Label is accepted but digits will not show on the display. Undoing or Redoing this operation is supported.

Changing the Radius of an Item

To change an Item's Radius: press the right mouse button to invoke the popup menu then go to Change then select Radius. After that you must select the item that you want its radius changed, once that is done a dialog box will prompt you for a new radius, by default the radius shown is the current one. The radius is then updated with the following restrictions apply:

a) If a number does not have the right format (having characters..) the current radius is kept
b) If the radius entered is below the minimum value of 0.3 then the value of the radius is changed to 0.3

Undoing or Redoing this operation is supported.

Changing the Color of an Item

To change an item's color: press the right mouse button to invoke the popup menu then go to Change then select Color. After that you must select the item that you want its color changed, once that is done a color dialog will prompt you for a color pick a pre-defined color or make your own custom color by adjusting the RGB vector and then adding the customer color. Finally press OK to accept this color. Undoing or Redoing this operation is supported.

Changing the Number of Stacks of an Item

To change an Item's Number of stacks: press the right mouse button to invoke the popup menu then go to Change then select Stacks. After that you must select the item that you want its number of stacks changed, once that is done a dialog box will prompt you for the new number of stacks, by default the number of stacks shown is the current one. The number of stacks is then updated with the following restrictions apply:

a) If a number does not have the right format (having characters..) the current number of stacks is kept
b) If the number of stacks entered is below the minimum value of 2 then the value of the number of stacks is changed to 2

Undoing or Redoing this operation is supported.

Changing the Number of Slices of an Item

To change an Item's Number of Slices: press the right mouse button to invoke the popup menu then go to Change then select Slices. After that you must select the item that you want its number of slices changed, once that is done a dialog box will prompt you for the new number of slices, by default the number of slices shown is the current one. The number of slices is then updated with the following restrictions apply:

a) If a number does not have the right format (having characters..) the current number of slices is kept
b) If the number of slices entered is below the minimum value of 2 then the value of the number of slices is changed to 2

Undoing or Redoing this operation is supported.

Removing an Item from the Graph

To remove an item of the graph: press the right mouse button to invoke the popup menu then go to Remove then select Item. After that you must select the item that you want to remove, once that is done the item is deleted. If a node is selected all edges incident on it will also be deleted in the process. If an edge is selected, only that edge is deleted. Undoing or Redoing this operation is supported.

Undoing/Redoing an Action

To undo a change to the graph: press the right mouse button to invoke the popup menu then select Undo or alternatively press Control-Z. For the actions which support undo as outlined in the description of each individual function, the action is undone. You can undo up to 10 consecutive actions.

To redo a change to the graph: press the right mouse button to invoke the popup menu then select Redo or alternatively press Control-Y. For the actions which support redo as outlined in the description of each individual function, the action is undone. You can redo up to 10 consecutive actions.

Closing a Graph

To close the current graph: press the right mouse button to invoke the popup menu then go to Graph then select Close or alternatively using the keyboard shortcut Control-C. The current graph is closed and the empty graph is loaded. Closing the graph from any of the views open will close it in the other views. Undoing or Redoing this operation is not supported.

A.3 VIEWS

In this section, it would be useful to define the following terms which will be used:

a) View - Any window that displays the graph is really displaying it from some particular view which can be thought of as the position and the orientation of the viewer in the 3-dimensional space. Of course this means, that for a given graph, we have an infinite number of views. Any changes done to the view itself does not affect the graph.

Opening a New View

To open a new view of the current graph: press the right mouse button to invoke the popup menu then go to View then select New. The new view opened will have the default view parameters. Any changes done to the graph will be applied to all the currently open views, however changes made to the view or to the settings will be localised to that view only. Undoing or Redoing this operation is not supported.

Loading a View

To load a saved view and apply that view to the current graph: press the right mouse button to invoke the popup menu then go to View then select Load. A file dialog will appear, enter the file name you wish to load to or select it from the list. If the file exists, you have read permision and the file is a valid view file (i.e Has the right information and syntax), the view file will be loaded and the corresponding view will be applied to the current graph, otherwise the current view is kept. The view file can have any extension *.* . Of course, the view is applied to the window where you invoked the menu from, in case you have several views open at the same time. Undoing or Redoing this operation is not supported.

Saving a View

To save the current view of the current graph: press the right mouse button to invoke the popup menu then go to View then select Save. A file dialog will appear, enter the file name you wish to save to or select it from the list. If the file already exists then you will be asked if you whish to overwrite it, of course you need in any case to have write permision for that file/disk. If you succesfully chosen a file which is either new or you confirmed to overwrite an existing file and you have write permision then the view file is saved, otherwise the current view is not saved. The view file can have any extension *.* . Of course, the view saved is that of the window where you invoked the menu from, in case you have several views open at the same time. Undoing or Redoing this operation is not supported.

Rotating a View

To rotate the current view of the current graph: press the right mouse button to invoke the popup menu then go to Rotate then select Rotate. After that hold down the mouse left button and move the mouse according to the desired effect. Moving the mouse horizontaly will rotate the view aroung the horizontal axis and moving the mouse verticaly will rotate the view around the vertical axis, of course moving the mouse diagonally will rotate around both the horizontal and vertical axis. Undoing or Redoing this operation is not supported.

Zooming in/out of a View

To zoom into/out of the view: press the right mouse button to invoke the popup menu then go to Zoom then select View. After that use the wheel to zoom the view or alternatively use the upward and downward keys. Undoing or Redoing this operation is not supported.

Closing a View

To close an existing view of the current graph: press the right mouse button to invoke the popup menu then go to View then select Close. If the view you are trying to close is the only view currently open the application will exit, otherwise only that view will be closed and the rest of the views will remain there. Undoing or Redoing this operation is not supported.

A.4 SETTINGS

In this section, it would be useful to define the following terms which will be used:

a) Number of Cylinders - A bent edge consists of a continous arrangement of cylinders. The number of cylinders used is what is being refered to. The more cylinders used, the smoother the bent edge looks, but the slower the rendering is.

Loading Settings

To load a saved settings file and apply those settings to the current graph: press the right mouse button to invoke the popup menu then go to Settings then select Load. A file dialog will appear, enter the file name you wish to load to or select it from the list. If the file exists, you have read permision and the file is a valid settings file (i.e Has the right information and syntax), the settings file will be loaded and the corresponding settings will be applied to the current graph, otherwise the current settings are kept. The settings file can have any extension *.* . Of course, the settings are applied to the window where you invoked the menu from, in case you have several views open at the same time. Undoing or Redoing this operation is not supported.

Saving the Settings

To save the current settings of the current graph: press the right mouse button to invoke the popup menu then go to Settings then select Save. A file dialog will appear, enter the file name you wish to save to or select it from the list. If the file already exists then you will be asked if you whish to overwrite it, of course you need in any case to have write permision for that file/disk. If you succesfully chosen a file which is either new or you confirmed to overwrite an existing file and you have write permision then the settings file is saved, otherwise the current settings are not saved. The settings file can have any extension *.* . Of course, the settings saved are those of the window where you invoked the menu from, in case you have several views open at the same time. Undoing or Redoing this operation is not supported.

Toggling Collision Detection

To toggle collision detection: press the right mouse button to invoke the popup menu then go to Settings then select Collision Detection. A confirmation box will appear, clicking on yes will toggle collision detection while clicking no will keep this setting the same. By default collision detection is off. Undoing or Redoing this operation is not supported.

Toggling Axis Rendering

To toggle axis rendering: press the right mouse button to invoke the popup menu then go to Settings then select Axis rendering. A confirmation box will appear, clicking on yes will toggle axis rendering while clicking no will keep this setting the same. By default axis rendering is off. Undoing or Redoing this operation is not supported.

Changing the Number of Cylinders

Changing the number of Cylinders: press the right mouse button to invoke the popup menu then go to Settings then select Cylinder Number. After that a dialog box will prompt you for the new number of cylinders used in rendering bent edges, by default the number of cylinders shown is the current one. The number of cylinders is then updated with the following restrictions apply: a) If a number does not have the right format (having characters..) the current number of cylinders is kept b) If the number of cylinders entered is below the minimum value of 2 then the value of the number of cylinders is changed to 2 Undoing or Redoing this operation is not supported.

B WHITEBOX TESTING RESULTS

Steps	Data	Expected Results	Actual Results	Status
Toggle Axis: a) Start the application. b) Toggle Axis Rendering On from the settings menu. c) Toggle Axis Rendering Off from the settings menu.		a) Axis are not rendered. b) Axis are rendered and displayed. c) Axis are not rendered.		a) Pass b) Pass c) Pass
Toggle Collision Detection: a) Start the application, load graph graph1.gxl and move node to collide with another node in the graph. b) Toggle Collision Detection On from the settings menu and reproduce the same movement in a). c) Toggle Collision Detection Off from the settings menu and reproduce the same movement in a).	graph1.gxl	a) Movement is allowed and the two nodes overlap. b) Movement is not allowed, the node that is being moved should stop moving towards the other node once they are about to collide.. c) Movement is allowed and the two nodes overlap.		a) Pass b) Pass c) Pass
Open New View: a) Start the application, load graph graph1.gxl and open a new view from the menu. b) In the new view open a new view there using the menu.	graph1.gxl	a) The same graph that appeared in the original window should appear in the new opened window. b) The same graph that appeared in the original window should appear in the new opened window.		a) Pass b) Pass c) Pass

Load View File: a) Start the application, load graph graph1.gxl and load the view file view1 using the menu. b) Restart the application, load graph graph1.gxl and load the view file view2 using the menu. c) Restart the application, load graph graph1.gxl and load the view file view3 using the menu. d) Restart the application, load graph graph1.gxl and load the view file view4 using the menu. e) Restart the application, load graph graph1.gxl and load the view file view5 using the menu. f) Restart the application, load graph graph1.gxl and load a view file that does not exist using the menu.	graph1.gxl view1 view2 view3 view4 view5	a) The graph should be displayed in according to the view parameters in the file. b) The graph's current view is kept as the view file being loaded is empty. c) The graph's current view is kept as the view file being loaded does not have the appropriate syntax. d) The graph should be displayed in according to the view parameters in the file. e) The graph's current view is kept as we don't have read permission for the view file being loaded. f) The graph's current view is kept.	c) Parse Error	a) Pass b) Pass c) Fail d) Pass e) Pass f) Pass

Save View: a) Start the application, load graph graph1.gxl and save the current view in a new file. b) Restart the application, load graph graph1.gxl and save the current view in an already existing file to which you have write permission and you accept overwriting. c) Restart the application, load graph graph1.gxl and save the current view in an already existing file to which you do not have write permission.	graph1.gxl	a) The file we save the view into contains the default view. b) The view is saved, and the file we save the view into contains the default view. c) The view is not saved to the file, the application should behave as if nothing has happened, the view that was there previously should be kept.		a) Pass b) Pass c) Pass
Close View: a) Start the application, load graph graph1.gxl and open 2 new views using the menu, we will label the original window by viewA the other two viewB and viewC respectively. Then Close viewA.. b) Close ViewC. c) Close ViewB.	graph1.gxl	a) viewA is closed and viewB and viewC are intact. b) viewC is closed and viewB is intact. c) The application is closed.		a) Pass b) Pass c) Pass

Load Graph: a) Start the application, load graph graph1.gxl using the menu. b) Restart the application, load graph graph2.gxl from the menu. c) Restart the application, load graph graph3.gxl from the menu. d) Restart the application, load a graph that does not exist from the menu.	graph1.gxl graph2.gxl graph3.gxl	a) Graph1 is loaded and displayed. b) The current graph is kept and no graph is loaded as the graph file is invalid. c) The current graph is kept and no graph is loaded as we don't have read access to the file. d) The current graph is kept.	b) Parse Error on input file d) openFile: does not exist (No such file or directory)	a) Pass b) Fail c) Pass d) Fail
Save Graph: a) Start the application, save the graph (empty graph) into a new file using the menu. b) Restart the application, save the graph (empty graph) into an already existing file to which you have write permission using the menu and you accept overwriting. c) Restart the application, save the graph (empty graph) into an already existing file to which you do not have write permission using the menu.		a) The file we save the graph into contains the empty graph. b) The file we save the graph into contains the empty graph. c) The graph is not saved, the application should behave as if nothing has happened, the graph that was there previously should be kept.		a) Pass b) Pass c) Pass

Load Settings File: a) Start the application, load graph graph1.gxl and load the settings file settings1 using the menu. b) Restart the application, load graph graph1.gxl and load the settings file settings2 using the menu. c) Restart the application, load graph graph1.gxl and load the settings file settings3 using the menu. d) Restart the application, load graph graph1.gxl and load the settings file settings4 using the menu. e) Restart the application, load graph graph1.gxl and load the settings file settings5 using the menu. f) Restart the application, load graph graph1.gxl and load a settings file that does not exist using the menu.	graph1.gxl settings1 settings2 settings3 settings4 settings5	a) The graph should be displayed in according to the settings parameters in the file. b) The graph's current settings are kept as the settings file being loaded is empty. c) The graph's current settings are kept as the settings file being loaded does not have the appropriate syntax. d) The graph's settings should be according to the settings parameters in the file. e) The graph's current settings are kept as we don't have read permission for the settings file being loaded. f) The graph's current settings are kept.		a) Pass b) Pass c) Pass d) Pass e) Pass f) Pass

Save Settings File: a) Start the application, load graph graph1.gxl and save the current settings in a new file using the menu. b) Restart the application, load graph graph1.gxl and save the current settings in an already existing file, using the menu, to which you have write permission and you accept overwriting. c) Restart the application, load graph graph1.gxl and save the current settings in an already existing file, using the menu, to which you do not have write permission.	graph1.gxl	a) The file we save the settings into contains the default settings. b) The settings are saved, and the file we save the settings into contains the default settings. c) The settings are not saved, the application should behave as if nothing has happened, the settings that were there previously should be kept.		a) Pass b) Pass c) Pass

View Rotation: a) Start the application, load graph graph1.gxl select the view rotation from the menu, press the left button and move the mouse horizontally to the right. b) With the mouse left button down, start moving horizontally to the left. c) With the mouse left button still down, start moving the mouse vertically in the upward direction. d) With the mouse left button still down, start moving the mouse vertically in the downward direction.	graph1.gxl	a) The view is rotated around the horizontal axis in an anti-clockwise motion with reasonable speed relative to the mouse motion. b) The view rotates in the clockwise direction around the horizontal axis to reverse the motion done in a) with reasonable speed relative to the mouse motion. c) The view is rotated around the vertical axis in an anti-clockwise motion with reasonable speed relative to the mouse motion. d) The view rotates in the clockwise direction around the vertical axis to reverse the motion done in a) with reasonable speed relative to the mouse motion.		a) Pass b) Pass c) Pass d) Pass

Graph Rotation: a) Start the application, load graph graph1.gxl select the graph rotation from the menu, press the left button and move the mouse horizontally to the right. b) With the mouse left button down, start moving horizontally to the left. c) With the mouse left button still down, start moving the mouse vertically in the upward direction. d) With the mouse left button still down, start moving the mouse vertically in the downward direction.	graph1.gxl	a) The graph is rotated around the horizontal axis in an anti-clockwise motion with reasonable speed relative to the mouse motion. b) The graph rotates in the clockwise direction around the horizontal axis to reverse the motion done in a) with reasonable speed relative to the mouse motion. c) The graph is rotated around the vertical axis in an anti-clockwise motion with reasonable speed relative to the mouse motion. d) The graph rotates in the clockwise direction around the vertical axis to reverse the motion done in a) with reasonable speed relative to the mouse motion.		a) Pass b) Pass c) Pass d) Pass

Add Directed Edge: a) Start the application, load graph graph4.gxl select add directed edge from the menu, and select NodeA and NodeB from the graph. b) Restart the application, load graph graph5.gxl select add directed edge from the menu, and select NodeA and NodeB from the graph. c) Restart the application, load graph graph6.gxl select add directed edge from the menu, and select NodeA and NodeB from the graph. d) Restart the application, load graph graph5.gxl select add directed edge from the menu, and select NodeC then EdgeA then NodeD from the graph. e) Restart the application, load graph graph4.gxl select add directed edge from the menu, and select NodeA then select empty then NodeB from the graph. f) Restart the application, load graph graph4.gxl select add directed edge from the menu, and select empty then select NodeA then select empty then NodeB from the graph. g) Restart the application, load graph graph4.gxl select add directed edge from the menu, and select NodeA twice from the graph . h) Restart the application, load graph graph4.gxl, switch collision detection on, select add directed edge from the menu, and select NodeC and NodeD from the graph.	graph4.gxl graph5.gxl graph6.gxl	a) A directed edge is added going from NodeA to NodeB. b) A directed edge already exists from NodeA to NodeB, no edge is added. c) A directed edge is not added since edge mode is undirected. d) A directed edge is added going from NodeA to NodeB. e) A directed edge is added going from NodeA to NodeB. f) A directed edge is added going from NodeA to NodeB. g) A directed edge is not added. h) A directed edge is not added since a collision is detected.	b) Two Edges added on top of each other d) Error: Non-exhaustive patterns in function unMaybe	a) Pass b) Fail c) Pass d) Fail e) Pass f) Pass g) Pass h) Pass

Add Undirected Edge: a) Start the application, load graph graph4.gxl select add undirected edge from the menu, and select NodeA and NodeB from the graph. b) Restart the application, load graph graph5.gxl select add undirected edge from the menu, and select NodeA and NodeB from the graph. c) Restart the application, load graph graph7.gxl select add undirected edge from the menu, and select NodeA and NodeB from the graph. d) Restart the application, load graph graph5.gxl select add undirected edge from the menu, and select NodeA then EdgeA then NodeB from the graph. e) Restart the application, load graph graph4.gxl select add undirected edge from the menu, and select NodeA then select empty then NodeB from the graph. f) Restart the application, load graph graph4.gxl select add undirected edge from the menu, and select empty then select NodeA then select empty then NodeB from the graph. g) Restart the application, load graph graph4.gxl select add undirected edge from the menu, and select NodeA twice from the graph . h) Restart the application, load graph graph4.gxl, switch collision detection on, select add undirected edge from the menu, and select NodeC and NodeD from the graph.	graph4.gxl graph5.gxl graph7.gxl	a) An undirected edge is added going from NodeA to NodeB. b) An undirected edge already exists from NodeA to NodeB, no edge is added. c) An undirected edge is not added since edge mode is directed. d) An undirected edge is added going from NodeA to NodeB. e) An undirected edge is added going from NodeA to NodeB. f) An undirected edge is added going from NodeA to NodeB. g) An undirected edge is not added. h) An undirected edge is not added since a collision is detected.	b) Two Edges added on top of each other d) Error: Non-exhaustive patterns in function un-Maybe	a) Pass b) Fail c) Pass d) Fail e) Pass f) Pass g) Pass h) Pass

Change Color: a) Start the application, load graph graph1.gxl, Select change color from menu, select NodeA and change its color through ready made colors. b) Select change color from menu, select NodeA and change its colors through custom made colors. c) Select change color from menu, select EdgeA and change its color through ready made colors. d) Repeat above and change its colors through custom made colors. e) Select change color from menu, select NodeA and press cancel at the color dialog box. f) Select change color from menu, select EdgeA and press cancel at the color dialog box.	graph1.gxl	a) Color of NodeA is changed appropriately to what is selected. b) Color of NodeA is changed appropriately to what is selected as a custom color. c) Color of EdgeA is changed appropriately to what is selected. d) Color of EdgeA is changed appropriately to what is selected as a custom color. e) Color of NodeA is left unchanged. f) Color of EdgeA is left unchanged.		a) Pass b) Pass c) Pass d) Pass e) Pass f) Pass

Change Label: a) Start the application, load graph graph1.gxl, Select change label from menu, select NodeA and input a non-empty string. b) Select change label from menu, select NodeA and input an empty string. c) Select change label from menu, select EdgeA and input a non-empty string. d) Select change label from menu, select EdgeA and input an empty string. e) Select change label from menu, select NodeA and press cancel at the text input box. f) Select change label from menu, select EdgeA and press cancel at the text input box.	graph1.gxl	a) Label of NodeA is changed appropriately to what was entered as input in the text box. b) Label of NodeA is changed to the empty string, therefore showing no label. c) Label of EdgeA is changed appropriately to what was entered as input in the text box. d) Label of EdgeA is changed to the empty string, therefore showing no label. e) Label of NodeA is set to default label. (Empty string) f) Label of EdgeA is set to default label. (Empty string)		a) Pass b) Pass c) Pass d) Pass e) Pass f) Pass

Change Radius: a) Start the application, load graph graph1.gxl, select change radius from menu, select NodeA and input an integer > 0. b) Select change radius from the menu, select NodeA and input an integer < 0. c) Select change radius from the menu, select NodeA and input an integer $= 0$. d) Select change radius from the menu, select NodeA and input a number with decimal. e) Select change radius from the menu, select EdgeA and input an integer > 0. f) Select change radius from the menu, select EdgeA and input an integer < 0. g) Select change radius from the menu, select EdgeA and input an integer $= 0$. h) Select change radius from the menu, select EdgeA and input a number with decimal. i) Select change radius from the menu, select NodeA and press cancel at the text input box. j) Select change radius from the menu, select EdgeA and press cancel at the text input box. k) Select change radius from the menu, select NodeA and input an invalid value (Not a number)	graph1.gxl	a) Radius of the node is changed appropriately. b) Radius of the node is changed to its default value. c) Radius of the node is changed to its default value. d) Radius of the node is changed appropriately. e) Radius of the node is changes appropriately. f) Radius of the edge is changed to its default value. g) Radius of the edge is changed to its default value. h) Radius of the edge is changed appropriately. i) Radius of the node remains unchanged. j) Radius of the edge remains unchanged. k) Radius of the edge remains unchanged.		a) Pass b) Pass c) Pass d) Pass e) Pass f) Pass g) Pass h) Pass i) Pass j) Pass k) Pass

Change Slices: a) Start the application, load graph graph1.gxl select change slices from menu, select NodeA and input an integer > 0. b) Select change slices from the menu, select NodeA and input an integer < 0. c) Select change slices from the menu, select NodeA and input an integer $= 0$. d) Select change slices from the menu, select NodeA and input a number with decimal. e) Select change slices from the menu, select EdgeA and input an integer > 0. f) Select change slices from the menu, select EdgeA and input an integer < 0. g) Select change slices from the menu, select EdgeA and input an integer $= 0$. h) Select change slices from the menu, select EdgeA and input a number with decimal. i) Select change slices from the menu, select NodeA and press cancel at the text input box. j) Select change slices from the menu, select EdgeA and press cancel at the text input box. k) Select change slices from the menu, select NodeA and input an invalid value (Not a number).	graph1.gxl	a) Slices of the node and its appearance is changed appropriately. b) Slices of the node is changed to its default value. c) Slices of the node is changed to its default value. d) Slices of the node is changed to the integer part of the decimal number. e) Slices of the node is changed appropriately. f) Slices of the edge is changed to its default value. g) Slices of the edge is changed to its default value. h) Slices of the edge is changed to the integer part of the decimal number. i) Slices of the node remains unchanged. j) Slices of the edge remains unchanged. k) Slices of the edge remains unchanged.		a) Pass b) Pass c) Pass d) Pass e) Pass f) Pass g) Pass h) Pass i) Pass j) Pass k) Pass

Change Stacks: a) Start the application, load graph graph1.gxl select change stacks from menu, select NodeA and input an integer > 0. b) Select change stacks from the menu, select NodeA and input an integer < 0. c) Select change stacks from the menu, select NodeA and input an integer $= 0$. d) Select change stacks from the menu, select NodeA and input a number with decimal. e) Select change stacks from the menu, select EdgeA and input an integer > 0. f) Select change stacks from the menu, select EdgeA and input an integer < 0. g) Select change stacks from the menu, select EdgeA and input an integer $= 0$. h) Select change stacks from the menu, select EdgeA and input a number with decimal. i) Select change stacks from the menu, select NodeA and press cancel at the text input box. j) Select change stacks from the menu, select EdgeA and press cancel at the text input box. k) Select change stacks from the menu, select NodeA and input an invalid value (Not a number).	graph1.gxl	a) Stacks of the node and its appearance is changed appropriately. b) Stacks of the node is changed to its default value. c) Stacks of the node is changed to its default value. d) Stacks of the node is changed to the integer part of the decimal number. e) Stacks of the node is changed appropriately. f) Stacks of the edge is changed to its default value. g) Stacks of the edge is changed to its default value. h) Stacks of the edge is changed to the integer part of the decimal number. i) Stacks of the node remains unchanged. j) Stacks of the edge remains unchanged. k) Stacks of the node remains unchanged.		a) Pass b) Pass c) Pass d) Pass e) Pass f) Pass g) Pass h) Pass i) Pass j) Pass k) Pass

Move Node Collision Off: a) Start the application, load graph graph1.gxl select move node from the menu, press the left button and move the mouse horizontally to the right b) With the mouse left button down, start moving horizontally to the left c) With the mouse left button still down, start moving the mouse vertically in the upward direction d) With the mouse left button still down, start moving the mouse vertically in the downward direction e) Select move node from the menu, select NodeA and move the node using the mouse wheel. f) Select move node from the menu, select an EdgeA. g) Select move node from the menu, select an empty space on the graph with no objects.	graph1.gxl	a) The node moves appropriately to the right according to the mouse movement. b) The node moves appropriately to the left according to the mouse movement. c) The node moves appropriately upwards according to the mouse movement. d) The node moves appropriately downwards according to the mouse movement. e) The node moves appropriately in and out of the screen according to the mouse wheel. f) Nothing will happen. g) Nothing will happen.		a) Pass b) Pass c) Pass d) Pass e) Pass f) Pass g) Pass

Move Node Collision On: a) Start the application, turn collision detection on, select move node from the menu, select NodeA and move the node by moving the mouse to the right with the node colliding into a node. b) With the mouse left button down, start moving horizontally to the left with the node colliding into a node. c) With the mouse left button still down, start moving the mouse vertically in the upward direction with the node colliding into a node. d) With the mouse left button still down, start moving the mouse vertically in the downward direction with the node colliding into a node. e) Select move node from the menu, select NodeA and move the node by using the mouse wheel until it collides into a node. f) Select move node from the menu, select EdgeA. g) Select move node from the menu, select empty space on the graph.	graph1.gxl	a) On collision with the other node, NodeA will stop its movement right before it goes 'through' the other node. b) On collision with the other node, NodeA will stop its movement right before it goes 'through' the other node. c) On collision with the other node, NodeA will stop its movement right before it goes 'through' the other node. d) On collision with the other node, NodeA will stop its movement right before it goes 'through' the other node. e) On collision with the other node, NodeA will stop its movement right before it goes 'through' the other node. f) Nothing will happen. g) Nothing will happen.		a) Pass b) Pass c) Pass d) Pass e) Pass f) Pass g) Pass

Zoom Graph: a) Start the application, load graph graph1.gxl select zoom graph from the menu, zoom the graph in by rolling the mouse wheel upwards. b) Zoom the graph out by rolling mouse wheel downwards. c) Restart the application, toggle collision detection on, select zoom graph from the menu, zoom the graph in by rolling the mouse wheel upwards, without the items colliding into each other. d) Select zoom graph from the menu, zoom the graph in by rolling the mouse wheel upwards until the items collide into each other. e) With collision detection on, select zoom graph from the menu, zoom the graph out by rolling the mouse wheel downwards.	graph1.gxl	a) The graph will be zoomed appropriately, in this case, it will be larger. b) The graph will be zoomed appropriately, in this case, it will be smaller. c) The graph will be zoomed appropriately, in this case it will be larger. d) The graph will be zoomed appropriately but stops when objects are about to collide with each other. e) The graph will be zoomed appropriately, in this case, it will be smaller.		a) Pass b) Pass c) Pass d) Pass e) Pass
Zoom View: a) Start the application, load graph graph1.gxl select zoom view from the menu, zoom the view by rolling the mouse wheel upwards. b) Zoom the view out by rolling mouse wheel downwards.	graph1.gxl	a) The view will be zoomed appropriately, in this case, the camera will move into the object space. b) The view will be zoomed appropriately, in this case, the camera will move away from the object space.		a) Pass b) Pass

Add Node: a) Start the application, load graph graph1.gxl select add node from the menu, add a node on an empty space in the screen. b) Select add node from the menu, add a node at a position where a node exists. c) Select add node from the menu, add a node at a position where an edge exists. d) Restart the application, turn collision detection on, load graph graph1.gxl select add node from the menu, add a node on an empty space in the screen. e) Select add node from the menu, add a node at a position where a node exists. f) Select add node from the menu, add a node at a position where an edge exists. g) Select add node from the menu, add a node on an empty space.	graph1.gxl	a) A new node will be added at the position the mouse clicked. b) A new node will be added overlapping the node at that position. c) A new node will be added overlapping the edge at that position. d) A new node will be added at the position the mouse clicked. e) A new node will not be added and the graph remains unchanged. f) A new node will not be added and the graph remains unchanged. g) A new node will be added at the position the mouse clicked.		a) Pass b) Pass c) Pass d) Pass e) Pass f) Pass g) Pass

Bend Edge Collision Off: a) Start the application, load graph graph1.gxl select bend edge from the menu, select a directed straight edge and hold the left mouse button while moving the mouse vertically upwards. b) Select bend edge from the menu, select a directed straight edge and hold the left mouse button while moving the mouse vertically downwards. c) Select bend edge from the menu, select a directed straight edge and hold the left mouse button while moving the mouse to the right. d) Select bend edge from the menu, select a directed straight edge and hold the left mouse button while moving the mouse to the left. e) Select bend edge from the menu, select a directed straight edge and hold the left mouse button while rolling the mouse wheel downwards. f) Select bend edge from the menu, select a directed straight edge and hold the left mouse button while rolling the mouse wheel upwards. g) Select bend edge from the menu, select a node. h) Select bend edge from the menu, select an empty space in the screen.	graph1.gxl	a) The edge will bend upwards appropriately. b) The edge will bend downwards appropriately. c) The edge will bend to the right appropriately. d) The edge will bend to the left appropriately. e) The edge will bend towards the user appropriately. f) The edge will bend away from the user appropriately. g) Nothing will happen. h) Nothing will happen.		a) Pass b) Pass c) Pass d) Pass e) Pass f) Pass g) Pass h) Pass

Bend Edge Collision On: a) Restart the application, turn collision detection on, select bend edge from the menu, select a directed straight edge and hold the left mouse button while moving the mouse vertically upwards onto a node. b) Select bend edge from the menu, select a directed straight edge and hold the left mouse button while moving the mouse vertically downwards onto a node. c) Select bend edge from the menu, select a directed straight edge and hold the left mouse button while moving the mouse to the right onto a node. d) Select bend edge from the menu, select a directed straight edge and hold the left mouse button while moving the mouse to the left onto a node . e) Select bend edge from the menu, select a directed straight edge and hold the left mouse button while rolling the mouse wheel downwards onto a node. f) Select bend edge from the menu, select a directed straight edge and hold the left mouse button while rolling the mouse wheel upwards onto a node. g) Select bend edge from the menu, select a node. h) Select bend edge from the menu, select an empty space in the screen.	graph1.gxl	a) The edge will bend away from the user appropriately. b) The edge will bend upwards and stop bending once it is almost colliding with another object. c) The edge will bend downwards and stop bending once it is almost colliding with another object. d) The edge will bend to the left and stop bending once it is almost colliding with another object. e) The edge will bend to the right and stop bending once it is almost colliding with another object. f) The edge will bend towards the user and stop bending once it is almost colliding with another object. g) The edge will bend away from the user and stop bending once it is almost colliding with another object. h) Nothing will happen. i) Nothing will happen.		a) Pass b) Pass c) Pass d) Pass e) Pass f) Pass g) Pass h) Pass i) Pass

Change Cylinder Number: a) Start the application, load graph graph1.gxl select the cylinder number from the settings menu. Enter an integer > 0. b) Select the cylinder number from the settings menu. Enter an integer < 0. c) Select the cylinder number from the settings menu. Enter 0 as the cylinder number. d) Select the cylinder number from the settings menu. Enter a decimal number.	graph1.gxl	a) The number of cylinders is changed to what was entered. b) The number of cylinders remains unchanged. c) The number of cylinders remains unchanged. d) The number of cylinders is changed to the integer part of the decimal number that was entered.		a) Pass b) Pass c) Pass d) Pass
Undo And Redo: a) Start the application, load graph graph1.gxl, add a node into the graph and select undo from the menu. b) Select redo from the menu. c) Add 12 nodes into the graph and select undo from the menu 12 times. d) Select redo 12 times. e) Restart the application, load graph graph1.gxl add 10 nodes into the graph, and select undo from the menu 10 times. f) Select redo 10 times.	graph1.gxl	a) The node that was added will be removed. b) The node that was removed will be added. c) The first two nodes that were added will remain while the rest will be removed. d) The 10 removed nodes will be readded. e) All the nodes that were added are removed. f) All the nodes are readded.		a) Pass b) Pass c) Pass d) Pass e) Pass f) Pass

Remove Item: a) Start the application, load graph graph1.gxl, select remove item from the menu and select a node that has no edges connected to it. b) Select remove item from the menu and select a node with an edge connected to it. c) Select remove item from the menu and select an edge in the graph. d) Select remove item from the menu and click on an empty space in the graph.	graph1.gxl	a) The node selected is removed. b) The node selected with all its edges are removed altogether. c) The edge selected will be removed. d) Nothing happens.		a) Pass b) Pass c) Pass d) Pass

Table 1: White Box Testing Results

C BLACKBOX TESTING RESULTS

Steps	Data	Expected Results	Actual Results	Status
Test Case 1: a) Start the application. Load graph graph1.gxl. Select add node from the menu. Add a node on an empty space in the screen. Save graph into result.gxl. Load result.gxl . b) Restart the application. Select add node from the menu. Add a node on an empty space in the screen. Select remove item from the menu and remove the added node. Save graph into result.gxl. Load result.gxl to check saved file. c) Restart the application. Select add node from the menu. Add a node on an empty space in the screen. Select move node from the menu and move the node to an empty space on the screen. Save graph into result.gxl. Load result.gxl to check. d) Restart the application. Select add node from the menu. Add a node on an empty space in the screen. Select move node from the menu and move that node. After the node is moved, select remove item and remove the node that was moved. Save the graph into result.gxl. Load result.gxl to check. e) Restart the application. Select add node from the menu. Add a node on an empty space of the screen. Select move node from the menu and move the node to an empty space on the screen. Remove that node. Add a new node. Move the new node. Save the graph into result.gxl. Load result.gxl to check.	graph1.gxl, result.gxl	a) The graph is loaded properly and the node is seen added to the screen at the correct position. When the graph is saved. When result.gxl is loaded, it displays the correct graph that was saved before. b) The graph is loaded properly and the removed node is removed from both the file and the screen. result.gxl displays the correct graph with the node removed. c) The node moves properly and when result.gxl is loaded, the latest position of the node is displayed. d) The node moves properly and when result.gxl is loaded, the removed node should not appear. e) The node moves properly and when result.gxl is loaded, the latest position of the added node is displayed.		a) Pass b) Pass c) Pass d) Pass e) Pass

Test Case 2: a) Start application and turn on collision detection in the settings menu. Repeat test case 1.	graph1.gxl, result.gxl	a) The graph is loaded properly and the node is seen added to the screen at the correct position. When the graph is saved. When result.gxl is loaded, it displays the correct graph that was saved before. b) The graph is loaded properly and the removed node is removed from both the file and the screen. result.gxl displays the correct graph with the node removed. c) The node moves properly and when it collides with another item, it will stop and not go 'through' the item. When result.gxl is loaded, the latest position of the node is displayed. d) The node moves properly and when it collides with another item, it will stop and not go 'through' the item. When result.gxl is loaded the removed node should not appear. e) The node moves properly and when it collides with another item, it will stop and not go 'through' the item. When result.gxl is loaded the latest position of the added node is displayed.		a) Pass b) Pass c) Pass d) Pass e) Pass

Test Case 3: a) Start the application. Load graph graph1.gxl. Open a new view. Select add node from the menu. Add a node on an empty space in view 1. Add a node on an empty space in view 2. Save graph into result.gxl. Load result.gxl . b) Restart the application. Load graph graph1.gxl. Open a new view. Select add node from the menu. Add a node on an empty space in view 1. Add a node on an empty space in view 2. Remove the added node from view 1. Save graph into result.gxl. Load result.gxl . c) Restart the application. Load graph graph1.gxl. Open a new view. Select add node from the menu. Add a node on an empty space in view 1. Add a node on an empty space in view 2. Select move node from the menu and move the node in view 2. Save graph into result.gxl. Load result.gxl to check. d) Restart the application. Load graph graph1.gxl. Open a new view. Select add node from the menu. Add a node on an empty space in view 1. Add a node on an empty space in view 2. Select move node from the menu and move the node in view 2. After that node is moved, remove that node from view 1. Save graph into result.gxl. Load result.gxl to check. e) Restart the application. Load graph graph1.gxl. Open a new view. Select add node from the menu. Add a node on an empty space in view 1. Add a node on an empty space in view 2. Select move node from the menu and move the node in view 2. After that node is moved, remove that node from view 1. Add a new node in view 2. Move the new node in view 1. Save the graph into result.gxl. Load result.gxl to check.	graph1.gxl, result.gxl	a) The graph is loaded properly and the node is seen added to the screen at the correct position. When the node is added in one of the views, it should appear in both of them. When the graph is saved. When result.gxl is loaded, it displays the correct graph that was saved before. b) The graph is loaded properly and the removed node is removed from both the file and the screen. result.gxl displays the correct graph with the node removed. c) The node moves properly in both views and when result.gxl is loaded, the latest position of the node is displayed. d) The node moves properly and when the node is removed, it is removed from both views automatically result.gxl is loaded, the removed node should not appear. e) The node moves properly in both views, when the node is removed, it is removed from both views, the new node that is added should appear in both the views. When the new node is moved, the node should move in both the views. When result.gxl is loaded, the latest position of the added node is displayed.		a) Pass b) Pass c) Pass d) Pass e) Pass

Test case 4: a) Start the application. Turn collision detection on in the settings menu. Load graph graph1.gxl. Open a new view. Select add node from the menu. Add a node on an empty space in view 1. Add a node on an empty space in view 2. Save graph into result.gxl. Load result.gxl . b) Restart the application. Turn collision detection on in the settings menu. Load graph graph1.gxl. Open a new view. Select add node from the menu. Add a node on an empty space in view 1. Add a node on an empty space in view 2. Remove the added node from view 1. Save graph into result.gxl. Load result.gxl . c) Restart the application. Turn collision detection on in the settings menu. Load graph graph1.gxl. Open a new view. Select add node from the menu. Add a node on an empty space in view 1. Add a node on an empty space in view 2. Select move node from the menu and move the node in view 2. Save graph into result.gxl. Load result.gxl to check. d) Restart the application. Turn collision detection on in the settings menu. Load graph graph1.gxl. Open a new view. Select add node from the menu. Add a node on an empty space in view 1. Add a node on an empty space in view 2. Select move node from the menu and move the node in view 2. Remove that node in view 1. Save graph into result.gxl. Load result.gxl to check. e) Restart the application. Turn collision detection on in the settings menu. Load graph graph1.gxl. Open a new view. Select add node from the menu. Add a node on an empty space in view 1. Add a node on an empty space in view 2. Select move node from the menu and move the node in view 2. After that node is moved, remove that node from view 1. Add a new node and move it in view 1. Save the graph into result.gxl. Load result.gxl to check.	graph1.gxl, result.gxl	a) The graph is loaded properly and the node is seen added to the screen at the correct position. When the node is added in one of the views, it should appear in both of them. When the graph is saved. When result.gxl is loaded, it displays the correct graph that was saved before. b) The graph is loaded properly and the removed node is removed from both the file and the screen. result.gxl displays the correct graph with the node removed. c) The node moves properly in both views. When the node is about to collide into another object, it will stop moving right before it does and when result.gxl is loaded, the latest position of the node is displayed. d) The node moves properly and when the node is removed, it is removed from both views automatically result.gxl is loaded, the removed node should not appear. When the node is about to collide into another object, it will stop moving right before it does. e) The node moves properly in both views, when the node is removed, it is removed from both views, the new node that is added should appear in both the views. When the new node is moved, the node should move in both the views. When result.gxl is loaded, the latest position of the added node is displayed. When the node is about to collide into another object, it will stop moving right before it does.		a) Pass b) Pass c) Pass d) Pass e) Pass

Test case 5: a) Start application and load graph1.gxl. Select add edge from the menu. Add an edge from NODEA to NODEB. Save the graph into result.gxl. Load result.gxl b) Restart the application and load graph1.gxl. Select add edge from the menu. Add an edge from NODEA to NODEB. Select bend edge from the menu and bend the added edge. Save the graph as result.gxl. Load result.gxl. c) Restart the application and load graph1.gxl. Select add edge from the menu. Add an edge from NODEA to NODEB. Select bend edge from the menu and bend the added edge. Remove that edge. Save the graph as result.gxl. Load result.gxl. d) Restart the application. Add three nodes and add one edge between NODEA and NODEB, and one edge between NODEB and NODEC. Bend the added edges. Save the graph as result.gxl. Load the graph. e) Restart the application. Add three nodes and add one edge between NODEA and NODEB, and one edge between NODEB and NODEC. Bend the added edges. Save the graph as result.gxl. Remove the edge from NODEB to NODEC. Save graph as result.gxl. Load result.gxl.	graph1.gxl, result.gxl	a) A directed edge would appear from NODEA to NODEB. When result.gxl is loaded, the edge should appear exactly the same as it was added. b) A directed edge would appear from NODEA to NODEB. When the edge is bended, the edge would bend appropriately in the correct direction. When result.gxl is loaded, the edge should appear already bended. c) A directed edge would appear from NODEA to NODEB. When the edge is bended, the edge would bend appropriately in the correct direction. When the edge is removed, it should disappear from the view. When result.gxl is loaded, the edge should not appear. d) A directed edge would appear from NODEA to NODEB and from NODEB to NODEC. When the edges are bended, the edges would bend appropriately in the correct direction. When result.gxl is loaded, the edge should appear already bended. e) A directed edge would appear from NODEA to NODEB and from NODEB to NODEC. When the edges are bended, the edges would bend appropriately in the correct direction. When the edges are removed, it should disappear from the view. When result.gxl is loaded, the edges should not appear.		a) Pass b) Pass c) Pass d) Pass e) Pass

Test case 6: a) Start application and turn on collision detection in the settings menu. Load graph1.gxl. Select add edge from the menu. Add an edge from NODEA to NODEB. Save the graph into result.gxl. Load result.gxl b) Restart the application and turn on collision detection in the settings menu. Load graph1.gxl. Select add edge from the menu. Add an edge from NODEA to NODEB. Select bend edge from the menu and bend the added edge towards other items in the graph. Save the graph as result.gxl. Load result.gxl. c) Restart the application and turn on collision detection in the settings menu. Load graph1.gxl. Select add edge from the menu. Add an edge from NODEA to NODEB. Select bend edge from the menu and bend the added edge towards other items in the graph. Remove that edge. Save the graph as result.gxl. Load result.gxl. d) Restart the application and turn on collision detection in the settings menu. Add three nodes, NODEA, NODEB, NODEC and add one edge between NODEA and NODEB, and one edge between NODEB and NODEC. Bend the added edges towards other items in the graph. Save the graph as result.gxl. Load the graph. e) Restart the application and turn on collision detection in the settings menu. Add three nodes, NODEA, NODEB, NODEC and add one edge between NODEA and NODEB, and one edge between NODEB and NODEC. Bend the added edges towards other items in the graph. Remove the edge from NODEB to NODEC. Save graph as result.gxl. Load result.gxl.	graph1.gxl, result.gxl	a) A directed edge would appear from NODEA to NODEB. When result.gxl is loaded, the edge should appear exactly the same as it was added. b) A directed edge would appear from NODEA to NODEB. When the edge is bended, the edge would bend appropriately in the correct direction. If the edge collides with another item, it should not go 'through' it but stop right before it collides. When result.gxl is loaded, the edge should appear already bended. c) A directed edge would appear from NODEA to NODEB. When the edge is bended, the edge would bend appropriately in the correct direction. If the edge collides with another item, it should not go 'through' it but stop right before it collides. When the edge is removed, it should disappear from the screen. When result.gxl is loaded, the edge should not appear. d) A directed edge would appear from NODEA to NODEB and from NODEB to NODEC. When the edges are bended, the edges would bend appropriately in the correct direction. If the edge collides with another item, it should not go 'through' it but stop right before it collides. When result.gxl is loaded, the edge should appear already bended. e) A directed edge would appear from NODEA to NODEB and from NODEB to NODEC. When the edges are bended, the edges would bend appropriately in the correct direction If the edge collides with another item, it should not go 'through' it but stop right before it collides. When the edges are removed, it should disappear from the screen. When result.gxl is loaded, the edges should not appear.		a) Pass b) Pass c) Pass d) Pass e) Pass

Test Case 7: a) Start application and load graph1.gxl. Open a new view. Select add edge from the menu. Add an edge from NODEA to NODEB in view 2. Save the graph into result.gxl. Load result.gxl b) Restart the application and load graph1.gxl. Open a new view. Select add edge from the menu. Add an edge from NODEA to NODEB in view 2. Select bend edge from the menu and bend the added edge view 1. Save the graph as result.gxl. Load result.gxl. c) Restart the application and load graph1.gxl. Open a new view. Select add edge from the menu. Add an edge from NODEA to NODEB in view 2. Select bend edge from the menu and bend the added edge in view 2. Remove that edge in view 1. Save the graph as result.gxl. Load result.gxl. d) Restart the application. Open a new view. Add three nodes and add one edge between NODEA and NODEB in view 2, and one edge between NODEB and NODEC in view 1. Bend the added edges in view 2. Save the graph as result.gxl. Load the graph. e) Restart the application. Open a new view. Add three nodes and add one edge between NODEA and NODEB in view 2, and one edge between NODEB and NODEC in view 1. Bend the added edges in view 2. Save the graph as result.gxl. Remove the edge from NODEB to NODEC in view 1. Save graph as result.gxl. Load result.gxl.	graph1.gxl, result.gxl	a) A directed edge would appear from NODEA to NODEB in both views. When result.gxl is loaded, the edge should appear exactly the same as it was added. b) A directed edge would appear from NODEA to NODEB in both views. When the edge is bended, the edge would bend appropriately in the correct direction in both views. When result.gxl is loaded, the edge should appear already bended. c) A directed edge would appear from NODEA to NODEB in both views. When the edge is bended, the edge would bend appropriately in the correct direction in both views. When the edge is removed, it should disappear from both views. When result.gxl is loaded, the edge should not appear. d) A directed edge would appear from NODEA to NODEB and from NODEB to NODEC in both views. When the edges are bended, the edges would bend appropriately in the correct direction in both views. When result.gxl is loaded, the edge should appear already bended. e) A directed edge would appear from NODEA to NODEB and from NODEB to NODEC in both views. When the edges are bended, the edges would bend appropriately in the correct direction in both views. When the edges are removed, it should disappear from both views. When result.gxl is loaded, the edges should not appear.		a) Pass b) Pass c) Pass d) Pass e) Pass

Test Case 8: a) Start application and load graph1.gxl. Turn on collision detection in the settings menu. Open a new view. Select add edge from the menu. Add an edge from NODEA to NODEB in view 2. Save the graph into result.gxl. Load result.gxl b) Restart the application and load graph1.gxl. Turn on collision detection in the settings menu. Open a new view. Select add edge from the menu. Add an edge from NODEA to NODEB in view 2. Select bend edge from the menu and bend the added edge view 1. Save the graph as result.gxl. Load result.gxl. c) Restart the application and load graph1.gxl. Turn on collision detection in the settings menu. Open a new view. Select add edge from the menu. Add an edge from NODEA to NODEB in view 2. Select bend edge from the menu and bend the added edge in view 2. Remove that edge in view 1. Save the graph as result.gxl. Load result.gxl. d) Restart the application. Turn on collision detection in the settings menu. Open a new view. Add three nodes and add one edge between NODEA and NODEB in view 2, and one edge between NODEB and NODEC in view 1. Bend the added edges in view 2. Save the graph as result.gxl. Load the graph. e) Restart the application. Open a new view. Add three nodes and add one edge between NODEA and NODEB in view 2, and one edge between NODEB and NODEC in view 1. Bend the added edges in view 2. Save the graph as result.gxl. Remove the edge from NODEB to NODEC in view 1. Save graph as result.gxl. Load result.gxl.	graph1.gxl, result.gxl	a) A directed edge would appear from NODEA to NODEB in both views. When result.gxl is loaded, the edge should appear exactly the same as it was added. b) A directed edge would appear from NODEA to NODEB in both views. When the edge is bended, the edge would bend appropriately in the correct direction in both views. If the edge collides with another item, it should not go 'through' it but stop right before it collides. When result.gxl is loaded, the edge should appear already bended. c) A directed edge would appear from NODEA to NODEB in both views. When the edge is bended, the edge would bend appropriately in the correct direction in both views. If the edge collides with another item, it should not go 'through' it but stop right before it collides. When the edge is removed, it should disappear from both views. When result.gxl is loaded, the edge should not appear. d) A directed edge would appear from NODEA to NODEB and from NODEB to NODEC in both views. When the edges are bended, the edges would bend appropriately in the correct direction in both views. If the edge collides with another item, it should not go 'through' it but stop right before it collides. When result.gxl is loaded, the edge should appear already bended. e) A directed edge would appear from NODEA to NODEB and from NODEB to NODEC in both views. When the edges are bended, the edges would bend appropriately in the correct direction in both views. If the edge collides with another item, it should not go 'through' it but stop right before it collides. When the edges are removed, it should disappear from both views. When result.gxl is loaded, the edges should not appear.		a) Pass b) Pass c) Pass d) Pass e) Pass

Test Case 9: a) Start the application. Add 4 nodes, NODEA, NODEB, NODEC and NODED. Add an edge(EDGEA) between NODEA and NODEB. Add an edge(EDGEB) betwen NODEC and NODED such that it is parallel to EDGEA. Move NODEA across the other side of EDGEA. Save graph as result.gxl. Load result.gxl. b) Remove NODEA. Save graph as result.gxl. Load result.gxl. c) Restart the application. Add 4 nodes, NODEA, NODEB, NODEC and NODED. Add an edge(EDGEA) between NODEA and NODEB. Add an edge(EDGEB) betwen NODEC and NODED such that it is parallel to EDGEA. Move NODEA across the other side of EDGEA. Remove EDGEB and remove NODEA. d) Save graph as result.gxl. Load result.gxl.	result.gxl	a) The 4 nodes and edges should display correctly when added. When the NODEA is moved across the other side of EDGEA, NODEA should pass 'through' all the items in its way safely and EDGEA would follow NODEA wherever it goes. When result.gxl is loaded, the graph should appear as it was last seen after the movement. b) When NODEA is removed, EDEGA should also be automatically removed. When result.gxl is loaded, the graph should only contain NODEB, NODEC, NODED and EDGEB. c) The 4 nodes and edges should display correctly when added. When the NODEA is moved across the other side of EDGEA, NODEA should pass 'through' all the items in its way safely and EDGEA would follow NODEA wherever it goes. When EDGEB and NODEA is removed, the graph would be only displaying NODEB,NODEC and NODED. d) When result.gxl is loaded, the graph should be displaying only NODEB, NODEC and NODED.		a) Pass b) Pass c) Pass d) Pass

Test Case 10: a) Start the application. Start application and turn on collision detection in the settings menu. Add 4 nodes, NODEA, NODEB, NODEC and NODED. Add an edge(EDGEA) between NODEA and NODEB. Add an edge(EDGEB) betwen NODEC and NODED such that it is parallel to EDGEA. Move NODEA across the other side of EDGEA. Save graph as result.gxl. Load result.gxl. b) Remove NODEA. Save graph as result.gxl. Load result.gxl. c) Restart the application. Turn on collision detection in the settings menu. Add 4 nodes, NODEA, NODEB, NODEC and NODED. Add an edge(EDGEA) between NODEA and NODEB. Add an edge(EDGEB) betwen NODEC and NODED such that it is parallel to EDGEA. Move NODEA across the other side of EDGEA. Remove EDGEB and remove NODEA. d) Save graph as result.gxl. Load result.gxl.	result.gxl	a) The 4 nodes and edges should display correctly when added. When the NODEA is moved across the other side of EDGEA, NODEA should not pass 'through' all the items in its way but EDGEA would follow NODEA wherever it goes. When result.gxl is loaded, the graph should appear as it was last seen after the movement. b) When NODEA is removed, EDEGA should also be automatically removed. When result.gxl is loaded, the graph should only contain NODEB, NODEC, NODED and EDGEB. c) The 4 nodes and edges should display correctly when added. When the NODEA is moved across the other side of EDGEA, NODEA should not pass 'through' all the items in its way but EDGEA would follow NODEA wherever it goes. When EDGEB and NODEA is removed, the graph would be only displaying NODEB,NODEC and NODED. d) When result.gxl is loaded, the graph should be displaying only NODEB, NODEC and NODED.	c) Collision detection fails on detecting the case of EDGEA colliding with EDGEB.	a) Pass b) Pass c) Fail d) Pass

Test Case 11: a) Start the application. Open a new view. Add 4 nodes, NODEA in view 1, NODEB in view 2, NODEC and NODED in view 1. Add an edge(EDGEA) between NODEA and NODEB in view 1. Add an edge(EDGEB) betwen NODEC and NODED such that it is parallel to EDGEA in view 2. Move NODEA across the other side of EDGEA. Save graph as result.gxl. Load result.gxl. b) Remove NODEA. Save graph as result.gxl. Load result.gxl. c) Restart the application. Open a new view. Add 4 nodes, NODEA in view 1, NODEB in view 2, NODEC and NODED in view 1. Add an edge(EDGEA) between NODEA and NODEB in view 1. Add an edge(EDGEB) betwen NODEC and NODED such that it is parallel to EDGEA in view 2. Move NODEA across the other side of EDGEA in view 2. Remove EDGEB and remove NODEA in view 1. d) Save graph as result.gxl. Load result.gxl.	result.gxl	a) The 4 nodes and edges should display correctly in all the views when added. When the NODEA is moved across the other side of EDGEA, NODEA should pass 'through' all the items in its way safely and EDGEA would follow NODEA wherever it goes. When result.gxl is loaded, the graph should appear as it was last seen after the movement. b) When NODEA is removed, EDEGA should also be automatically removed from all views. When result.gxl is loaded, the graph should only contain NODEB, NODEC, NODED and EDGEB. c) The 4 nodes and edges should display correctly in all the views when added. When the NODEA is moved across the other side of EDGEA, NODEA should pass 'through' all the items in its way safely and EDGEA would follow NODEA wherever it goes. When EDGEB and NODEA is removed, the graph would be only displaying NODEB,NODEC and NODED in all the views. d) When result.gxl is loaded, the graph should be displaying only NODEB, NODEC and NODED.		a) Pass b) Pass c) Pass d) Pass

Test Case 12: a) Start the application. Turn on collision detection in the settings menu. Open a new view. Add 4 nodes, NODEA in view 1, NODEB in view 2, NODEC and NODED in view 1. Add an edge(EDGEA) between NODEA and NODEB in view 1. Add an edge(EDGEB) betwen NODEC and NODED such that it is parallel to EDGEA in view 2. Move NODEA across the other side of EDGEA. Save graph as result.gxl. Load result.gxl. b) Remove NODEA. Save graph as result.gxl. Load result.gxl. c) Restart the application. Turn on collision detection in the settings menu. Open a new view. Add 4 nodes, NODEA in view 1, NODEB in view 2, NODEC and NODED in view 1. Add an edge(EDGEA) between NODEA and NODEB in view 1. Add an edge(EDGEB) betwen NODEC and NODED such that it is parallel to EDGEA in view 2. Move NODEA across the other side of EDGEA in view 2. Remove EDGEB and remove NODEA in view 1. d) Save graph as result.gxl. Load result.gxl.	result.gxl	a) The 4 nodes and edges should display correctly in all the views when added. When the NODEA is moved across the other side of EDGEA, NODEA should not pass 'through' all the items in its way but EDGEA would follow NODEA wherever it goes. When result.gxl is loaded, the graph should appear as it was last seen after the movement. b) When NODEA is removed, EDEGA should also be automatically removed from all views. When result.gxl is loaded, the graph should only contain NODEB, NODEC, NODED and EDGEB. c) The 4 nodes and edges should display correctly in all the views when added. When the NODEA is moved across the other side of EDGEA, NODEA should not pass 'through' all the items in its way but EDGEA would follow NODEA wherever it goes. When EDGEB and NODEA is removed, the graph would be only displaying NODEB,NODEC and NODED in all the views. d) When result.gxl is loaded, the graph should be displaying only NODEB, NODEC and NODED.	c) Collision detection fails on detecting the case of EDGEA colliding with EDGEB.	a) Pass b) Pass c) Fail d) Pass

Test Case 13: a) Start the application. Add 4 nodes, NODEA, NODEB, NODEC and NODED. Add an edge(EDGEA) between NODEA and NODEB. Add an edge(EDGEB) betwen NODEC and NODED such that it is parallel to EDGEA. Move NODEA across the other side of EDGEA. Bend EDGEB. Save graph as result.gxl. Load result.gxl. b) Remove NODEA. Save graph as result.gxl. Load result.gxl. c) Restart the application. Add 4 nodes, NODEA, NODEB, NODEC and NODED. Add an edge(EDGEA) between NODEA and NODEB. Add an edge(EDGEB) betwen NODEC and NODED such that it is parallel to EDGEA. Move NODEA across the other side of EDGEA. Bend EDGEB. Remove EDGEB and remove NODEA. d) Save graph as result.gxl. Load result.gxl.	result.gxl	a) The 4 nodes and edges should display correctly when added. When the NODEA is moved across the other side of EDGEA, NODEA should pass 'through' all the items in its way safely and EDGEA would follow NODEA wherever it goes. When EDGEB is bent, the edge should bend appropriately. When result.gxl is loaded, the graph should appear as it was last seen after the movement and bending. b) When NODEA is removed, EDEGA should also be automatically removed. When result.gxl is loaded, the graph should only contain NODEB, NODEC, NODED and EDGEB. c) The 4 nodes and edges should display correctly when added. When the NODEA is moved across the other side of EDGEA, NODEA should pass 'through' all the items in its way safely and EDGEA would follow NODEA wherever it goes. When EDGEB is bent, the edge should bend appropriately. When EDGEB and NODEA is removed, the graph would be only displaying NODEB,NODEC and NODED. d) When result.gxl is loaded, the graph should be displaying only NODEB, NODEC and NODED.		a) Pass b) Pass c) Pass d) Pass

Test Case 14: a) Start the application. Open a new view. Add 4 nodes, NODEA and NODEB in view 1, NODEC and NODED in view 2. Add an edge(EDGEA) between NODEA and NODEB in view 1. Add an edge(EDGEB) betwen NODEC and NODED such that it is parallel to EDGEA in view 2. Move NODEA across the other side of EDGEA in view 1. Bend EDGEB in view 2. Save graph as result.gxl. Load result.gxl. b) Remove NODEA from view 2. Save graph as result.gxl. Load result.gxl. c) Restart the application. Open a new view. Add 4 nodes, NODEA and NODEB in view 1, NODEC and NODED in view 2. Add an edge(EDGEA) between NODEA and NODEB in view 1. Add an edge(EDGEB) betwen NODEC and NODED such that it is parallel to EDGEA in view 2. Move NODEA across the other side of EDGEA in view 1. Bend EDGEB in view 2. Remove EDGEB and remove NODEA in view 1. d) Save graph as result.gxl. Load result.gxl.	result.gxl	a) The 4 nodes and edges should display correctly in all 2 views when added. When the NODEA is moved across the other side of EDGEA, NODEA should pass 'through' all the items in its way safely and EDGEA would follow NODEA wherever it goes. When EDGEB is bent, the edge should bend appropriately. All changes in one view should always show in all the views too. When result.gxl is loaded, the graph should appear as it was last seen after the movement and bending. b) When NODEA is removed, EDEGA should also be automatically removed. When result.gxl is loaded, the graph should only contain NODEB, NODEC, NODED and EDGEB. All changes in one view should always show in all the other views. c) The 4 nodes and edges should display correctly when added. When the NODEA is moved across the other side of EDGEA, NODEA should pass 'through' all the items in its way safely and EDGEA would follow NODEA wherever it goes. When EDGEB is bent, the edge should bend appropriately. When EDGEB and NODEA is removed, the graph would be only displaying NODEB,NODEC and NODED. All changes in one view should always show in all the views too. d) When result.gxl is loaded, the graph should be displaying only NODEB, NODEC and NODED.		a) Pass b) Pass c) Pass d) Pass

Test Case 15: a) Start the application. Add 4 nodes, NODEA, NODEB, NODEC and NODED. Add an edge(EDGEA) between NODEA and NODEB. Add an edge(EDGEB) betwen NODEC and NODED such that it is parallel to EDGEA. Move NODEA across the other side of EDGEA. Bend EDGEB. Save graph as result.gxl. Load result.gxl. b) Remove NODEA. Save graph as result.gxl. Load result.gxl. c) Restart the application. Add 4 nodes, NODEA, NODEB, NODEC and NODED. Add an edge(EDGEA) between NODEA and NODEB. Add an edge(EDGEB) betwen NODEC and NODED such that it is parallel to EDGEA. Move NODEA across the other side of EDGEA. Bend EDGEB. Remove EDGEB and remove NODEA. d) Save graph as result.gxl. Load result.gxl.	result.gxl	a) The 4 nodes and edges should display correctly when added. When the NODEA is moved across the other side of EDGEA, NODEA should not pass 'through' all the items in its way and EDGEA would follow NODEA wherever it goes. When EDGEB is bent, the edge should bend appropriately and not pass 'through' any items in its way. When result.gxl is loaded, the graph should appear as it was last seen after the movement and bending. b) When NODEA is removed, EDEGA should also be automatically removed. When result.gxl is loaded, the graph should only contain NODEB, NODEC, NODED and EDGEB. c) The 4 nodes and edges should display correctly when added. When the NODEA is moved across the other side of EDGEA, NODEA should not pass 'through' all the items in its way and EDGEA would follow NODEA wherever it goes. When EDGEB is bent, the edge should bend appropriately and not pass 'through' any items in its way. When EDGEB and NODEA is removed, the graph would be only displaying NODEB,NODEC and NODED. d) When result.gxl is loaded, the graph should be displaying only NODEB, NODEC and NODED.	a) Collision detection fails on detecting the case of EDGEA colliding with EDGEB. c) Collision detection fails on detecting the case of EDGEA colliding with EDGEB.	a) Fail b) Pass c) Fail d) Pass

Test Case 16: a) Start the application. Open a new view. Add 4 nodes, NODEA and NODEB in view 1, NODEC and NODED in view 2. Add an edge(EDGEA) between NODEA and NODEB in view 1. Add an edge(EDGEB) betwen NODEC and NODED such that it is parallel to EDGEA in view 2. Move NODEA across the other side of EDGEA in view 1. Bend EDGEB in view 2. Save graph as result.gxl. Load result.gxl. b) Remove NODEA in view 1. Save graph as result.gxl. Load result.gxl. c) Restart the application. Add 4 nodes, NODEA and NODEB in view 1, NODEC and NODED in view2. Add an edge(EDGEA) between NODEA and NODEB in view 1. Add an edge(EDGEB) betwen NODEC and NODED such that it is parallel to EDGEA in view 2. Move NODEA across the other side of EDGEA in view 1. Bend EDGEB in view 2. Remove EDGEB and remove NODEA in view1. d) Save graph as result.gxl. Load result.gxl.	result.gxl	a) The 4 nodes and edges should display correctly when added. When the NODEA is moved across the other side of EDGEA, NODEA should not pass 'through' all the items in its way and EDGEA would follow NODEA wherever it goes. When EDGEB is bent, the edge should bend appropriately and not pass 'through' any items in its way. All changes in one view should always show in all the views too. When result.gxl is loaded, the graph should appear as it was last seen after the movement and bending. b) When NODEA is removed, EDEGA should also be automatically removed. When result.gxl is loaded, the graph should only contain NODEB, NODEC, NODED and EDGEB. All changes in one view should always show in all the views too. c) The 4 nodes and edges should display correctly when added. When the NODEA is moved across the other side of EDGEA, NODEA should not pass 'through' all the items in its way and EDGEA would follow NODEA wherever it goes. When EDGEB is bent, the edge should bend appropriately and not pass 'through' any items in its way. When EDGEB and NODEA is removed, the graph would be only displaying NODEB,NODEC and NODED. All changes in one view should always show in all the views too. d) When result.gxl is loaded, the graph should be displaying only NODEB, NODEC and NODED.	a) Collision detection fails on detecting the case of EDGEA colliding with EDGEB. c) Collision detection fails on detecting the case of EDGEA colliding with EDGEB.	a) Fail b) Pass c) Fail d) Pass

Test Case 17: a) Start the application and load graph1.gxl. Select rotate view from the menu and rotate the view. Select rotate graph from the menu and rotate the graph. Save graph as result.gxl. Load result.gxl b) Restart the application and load graph1.gxl. Select rotate view from the menu and rotate the view. Select rotate graph from the menu and rotate the graph. Undo all the operations. Save graph as result.gxl. Load result.gxl c) Restart the application. Toggle axis on in the settings menu. Add two nodes (NODEA,NODEB). Rotate the view. Save graph as result.gxl. Load result.gxl. d) Restart the application. Toggle axis on in the settings menu. Add two nodes (NODEA,NODEB). Rotate the graph. Save graph as result.gxl. Load result.gxl. e) Restart the application. Add two nodes (NODEA,NODEB), and an edge (EDGEA) for the nodes. Rotate the graph. Rotate the view. Save graph as result.gxl. Load result.gxl. f) Bend EDGEA from above. Rotate the view. Rotate the graph.	graph1.gxl, result.gxl	a) Rotation of the view and rotation of the graph should behave appropriately. When result.gxl is loaded, the rotated graph is shown without the rotation of the view. b) All the operations only in the graph rotation should be undone. When result.gxl is loaded, the graph with no graph rotations would be displayed. c) The view should rotate appropriately together with the axis and when result.gxl is loaded, the rotation from previously should not be displayed. d) The graph should rotate appropriately but not with the axis and when result.gxl is loaded, the rotation done to the graph should be displayed. e) Rotation of the view and rotation of the graph should behave appropriately. When result.gxl is loaded, the rotated graph without the view rotation is displayed. f) Rotation of the view and rotation of the graph should behave appropriately and not affect the bending of the edges in an unnatural way.		a) Pass b) Pass c) Pass d) Pass e) Pass f) Pass

Test Case 18: a) Start the application and load graph1.gxl. Open a new view. Select rotate view from the menu and rotate the view in view 1. Select rotate graph from the menu and rotate the graph in view 2. Save graph as result.gxl. Load result.gxl b) Restart the application and load graph1.gxl. Open a new view. Select rotate view from the menu and rotate the view in view 1. Select rotate graph from the menu and rotate the graph in view 2. Undo all the operations. Save graph as result.gxl. Load result.gxl c) Restart the application. Open a new view. Toggle axis on in the settings menu. Add two nodes (NODEA,NODEB) in view 1. Rotate the view in view 2. Save graph as result.gxl. Load result.gxl. d) Restart the application. Open a new view. Toggle axis on in the settings menu. Add two nodes (NODEA,NODEB) in view 1. Rotate the graph in view 2. Save graph as result.gxl. Load result.gxl. e) Restart the application. Open a new view. Add two nodes (NODEA,NODEB) in view 1, and an edge (EDGEA) for the nodes in view 2. Rotate the graph in view 1. Rotate the view in view 2. Save graph as result.gxl. Load result.gxl. f) Bend EDGEA from above in view 1. Rotate the view in view 2. Rotate the graph.	graph1.gxl, result.gxl	a) Rotation of the view and rotation of the graph should behave appropriately. When result.gxl is loaded, the rotated graph is shown without the rotation of the view. The rotated graph is updated in both views. View rotation should only affect its own view. b) All the operations only in the graph rotation should be undone. When result.gxl is loaded, the graph with no graph rotations would be displayed. The rotated graph is updated in both views. View rotation should only affect its own view. c) The view should rotate appropriately together with the axis and when result.gxl is loaded, the rotation from previously should not be displayed. The rotated graph is updated in both views. View rotation should only affect its own view. d) The graph should rotate appropriately but not with the axis and when result.gxl is loaded, the rotation done to the graph should be displayed. The rotated graph is updated in both views. View rotation should only affect its own view. e) Rotation of the view and rotation of the graph should behave appropriately. When result.gxl is loaded, the rotated graph without the view rotation is displayed. The rotated graph is updated in both views. View rotation should only affect its own view. f) Rotation of the view and rotation of the graph should behave appropriately and not affect the bending of the edges in an unnatural way. When rotation is done on view 2, view 1's graph should not rotate, only view 2's. The rotated graph is updated in both views. View rotation should only affect its own view.		a) Pass b) Pass c) Pass d) Pass e) Pass f) Pass

Test Case 19: a) Start the application and load graph1.gxl. Select rotate view from the menu and rotate the view. Select rotate graph from the menu and rotate the graph. Move NODEA. Save graph as result.gxl. Load result.gxl b) Restart the application and load graph1.gxl. Select rotate view from the menu and rotate the view. Select rotate graph from the menu and rotate the graph. Move NODEA. Undo all the operations. Save graph as result.gxl. Load result.gxl c) Restart the application. Toggle axis on in the settings menu. Add two nodes (NODEA,NODEB). Rotate the view. Move NODEA. Save graph as result.gxl. Load result.gxl. d) Restart the application. Toggle axis on in the settings menu. Add two nodes (NODEA,NODEB). Rotate the graph. Move NODEA. Save graph as result.gxl. Load result.gxl. e) Restart the application. Add two nodes (NODEA,NODEB), and an edge (EDGEA) for the nodes. Rotate the graph. Rotate the view. Move NODEA. Save graph as result.gxl. Load result.gxl. f) Bend EDGEA from above. Rotate the view. Rotate the graph.	graph1.gxl, result.gxl	a) Rotation of the view and rotation of the graph should behave appropriately. NODEA moves properly acoording to the mouse when moved. When result.gxl is loaded, the rotated graph is shown without the rotation of the view. b) All the operations only in the graph rotation should be undone. NODEA moves properly acoording to the mouse when moved. When result.gxl is loaded, the graph with no graph rotations would be displayed. c) The view should rotate appropriately together with the axis. NODEA moves properly acoording to the mouse when moved. When result.gxl is loaded, the rotation from previously should not be displayed. d) The graph should rotate appropriately but not with the axis. NODEA moves properly acoording to the mouse when moved. When result.gxl is loaded, the rotation done to the graph should be displayed. e) Rotation of the view and rotation of the graph should behave appropriately. NODEA moves properly acoording to the mouse when moved. When result.gxl is loaded, the rotated graph without the view rotation is displayed. f) NODEA moves properly acoording to the mouse when moved. Rotation of the view and rotation of the graph should behave appropriately and not affect the bending of the edges in an unnatural way.		a) Pass b) Pass c) Pass d) Pass e) Pass f) Pass

Test Case 20: a) Start the application and load graph1.gxl. Open a new view. Select rotate view from the menu and rotate the view in view 1. Select rotate graph from the menu and rotate the graph in view 2. Move NODEA in view 1. Save graph as result.gxl. Load result.gxl b) Restart the application and load graph1.gxl. Open a new view. Select rotate view from the menu and rotate the view in view 1. Select rotate graph from the menu and rotate the graph in view 2. Move NODEA in view 1. Undo all the operations. Save graph as result.gxl. Load result.gxl c) Restart the application. Open a new view. Toggle axis on in the settings menu. Add two nodes (NODEA,NODEB) in view 1. Rotate the view in view 2. Move NODEA in view 1. Save graph as result.gxl. Load result.gxl. d) Restart the application. Open a new view. Toggle axis on in the settings menu. Add two nodes (NODEA,NODEB) in view 1. Rotate the graph in view 2. Move NODEA in view 1. Save graph as result.gxl. Load result.gxl. e) Restart the application. Open a new view. Add two nodes (NODEA,NODEB) in view 1, and an edge (EDGEA) for the nodes in view 2. Rotate the graph in view 1. Rotate the view in view 2. Move NODEA in view 1. Save graph as result.gxl. Load result.gxl. f) Bend EDGEA from above in view 1. Rotate the view in view 2. Rotate the graph in view 1.	graph1.gxl, result.gxl	a) Rotation of the view and rotation of the graph should behave appropriately. NODEA moves properly acoording to the mouse when moved. When result.gxl is loaded, the rotated graph is shown without the rotation of the view. All changes done to a graph in one view should always be shown in other views. b) All the operations only in the graph rotation should be undone. NODEA moves properly acoording to the mouse when moved. When result.gxl is loaded, the graph with no graph rotations would be displayed. All changes done to a graph in one view should always be shown in other views. c) The view should rotate appropriately together with the axis. NODEA moves properly acoording to the mouse when moved. When result.gxl is loaded, the rotation from previously should not be displayed. All changes done to a graph in one view should always be shown in other views. Changes to a view do not get updated in all other views. d) The graph should rotate appropriately but not with the axis. NODEA moves properly acoording to the mouse when moved. When result.gxl is loaded, the rotation done to the graph should be displayed. All changes done to a graph in one view should always be shown in other views. Changes to a view do not get updated in all other views. e) Rotation of the view and rotation of the graph should behave appropriately. NODEA moves properly acoording to the mouse when moved. When result.gxl is loaded, the rotated graph without the view rotation is displayed. All changes done to a graph in one view should always be shown in other views. f) NODEA moves properly acoording to the mouse when moved. Rotation of the view and rotation of the graph should behave appropriately and not affect the bending of the edges in an unnatural way. All changes done to a graph in one view should always be shown in other views.		a) Pass b) Pass c) Pass d) Pass e) Pass f) Pass

Test Case 21: a-f) From test case x of rotation and zooming, perform zoom graph on the graph right before saving it into result.gxl for each case.	graph1.gxl, result.gxl	a) Rotation and zooming of the graph should behave appropriately. When result.gxl is loaded, the zoomed graph is shown without the rotation of the view. b) All the operations only in the graph rotation should be undone. When result.gxl is loaded, the graph with no graph rotations would be displayed. c) The graph should zoom appropriately together with the axis and when result.gxl is loaded, the rotation from previously should not be displayed. d) The graph should zoom appropriately but not with the axis and when result.gxl is loaded, the scaling done to the graph should be displayed. e) Zooming of the graph should behave appropriately. When result.gxl is loaded, the scaled graph without the view rotation is displayed. f) Rotation of the view and rotation/zooming of the graph should behave appropriately and not affect the bending of the edges in an unnatural way.		a) Pass b) Pass c) Pass d) Pass e) Pass f) Pass

Test Case 22: a-f) From test case x of rotation and zooming with multiple views, perform zoom graph on the graph in view 1 right before saving it into result.gxl for each case.	graph1.gxl, result.gxl	a) Rotation and zooming of the graph should behave appropriately. When result.gxl is loaded, the zoomed graph is shown without the rotation of the view. b) All the operations only in the graph rotation should be undone. When result.gxl is loaded, the graph with no graph rotations would be displayed. All changes done to a graph in one view should always be shown in other views automatically. Changes to a view do not get updated in all other views. c) The graph should zoom appropriately together with the axis and when result.gxl is loaded, the rotation from previously should not be displayed. All changes done to a graph in one view should always be shown in other views automatically. Changes to a view do not get updated in all other views. d) The graph should zoom appropriately but not with the axis and when result.gxl is loaded, the scaling done to the graph should be displayed. All changes done to a graph in one view should always be shown in other views automatically. Changes to a view do not get updated in all other views. e) Zooming of the graph should behave appropriately. When result.gxl is loaded, the scaled graph without the view rotation is displayed. All changes done to a graph in one view should always be shown in other views automatically. Changes to a view do not get updated in all other views. f) Rotation of the view and rotation/zooming of the graph should behave appropriately and not affect the bending of the edges in an unnatural way. All changes done to a graph in one view should always be shown in other views automatically. Changes to a view do not get updated in all other views.		a) Pass b) Pass c) Pass d) Pass e) Pass f) Pass

Test Case 23: a-f) From test case x of zoom(scale) graph, perform zooming the view before saving it into result.gxl for each case.	graph1.gxl, result.gxl	a) Zooming of the view after all the other operations should behave appropriately. When result.gxl is loaded, the zoomed graph is shown without the zooming of the view. b) All the operations only in the graph rotation should be undone. When result.gxl is loaded, the graph with no graph rotations would be displayed. c) The view should zoom appropriately together with the axis and when result.gxl is loaded, the rotation from previously should not be displayed. d) The graph should zoom appropriately and when result.gxl is loaded, the scaling done to the graph should be displayed but not the zooming of the view. e) Zooming of the graph and view should behave appropriately. When result.gxl is loaded, the scaled graph without the view rotation and view zooming is displayed. f) Rotation/zooming of the view and rotation/zooming of the graph should behave appropriately and not affect the bending of the edges in an unnatural way.		a) Pass b) Pass c) Pass d) Pass e) Pass f) Pass

Test Case 24: a-f) From test case x of zoom(scale) graph, open a new view right after starting the application, perform zooming the view right before saving it into result.gxl for each case.	graph1.gxl, result.gxl	a) Zooming of the view after all the other operations should behave appropriately. When result.gxl is loaded, the zoomed graph is shown without the zooming of the view. All changes done to a graph in one view should always be shown in other views automatically. Changes to a view do not get updated in all other views. b) All the operations only in the graph rotation should be undone. When result.gxl is loaded, the graph with no graph rotations would be displayed. All changes done to a graph in one view should always be shown in other views automatically. Changes to a view do not get updated in all other views. c) The view should zoom appropriately together with the axis and when result.gxl is loaded, the rotation from previously should not be displayed. All changes done to a graph in one view should always be shown in other views automatically. Changes to a view do not get updated in all other views. d) The graph should zoom appropriately and when result.gxl is loaded, the scaling done to the graph should be displayed but not the zooming of the view. All changes done to a graph in one view should always be shown in other views automatically. Changes to a view do not get updated in all other views. e) Zooming of the graph and view should behave appropriately. When result.gxl is loaded, the scaled graph without the view rotation and view zooming is displayed. All changes done to a graph in one view should always be shown in other views automatically. Changes to a view do not get updated in all other views. f) Rotation/zooming of the view and rotation/zooming of the graph should behave appropriately and not affect the bending of the edges in an unnatural way. All changes done to a graph in one view should always be shown in other views automatically. Changes to a view do not get updated in all other views.		a) Pass b) Pass c) Pass d) Pass e) Pass f) Pass

Test Case 25: a) Start the application. Save the view file for each of the test cases in test case x (zoom scale graph zoom view) a-f) From test case x of (zoom scale graph zoom view), save the view as TestView.txt and save the graph as result.gxl in each case. Load the view after that.	graph1.gxl, result. gxl, TestView. txt	a) When TestView.txt is loaded, the correct view when it was saved is displayed. b) All the operations only in the graph rotation should be undone. When result.gxl is loaded, the graph with no graph rotations would be displayed. When TestView.txt is loaded, the correct view when it was saved is displayed. c) The graph should zoom appropriately together with the axis and when result.gxl is loaded, the rotation from previously should not be displayed. When TestView.txt is loaded, the correct view when it was saved is displayed. d) The graph should zoom appropriately but not with the axis and when result.gxl is loaded, the scaling done to the graph should be displayed. When TestView.txt is loaded, the correct view when it was saved is displayed. e) Zooming of the graph should behave appropriately. When result.gxl is loaded, the scaled graph without the view rotation is displayed. When TestView.txt is loaded, the correct view when it was saved is displayed. f) Rotation of the view and rotation/zooming of the graph should behave appropriately and not affect the bending of the edges in an unnatural way. When TestView.txt is loaded, the correct view when it was saved is displayed.		a) Pass b) Pass c) Pass d) Pass e) Pass f) Pass

Test Case 26: a) Start the application and open 3 new view. Load graph1.gxl. b) Close the graph and open graph1.gxl. c) Close the graph, close one view and open graph1.gxl d) Close all views.	graph1.gxl, result.gxl	a) When the views are opened, seperate windows should appear to display each view. When graph1.gxl is loaded, each view would display graph1. b) When the graph is closed, all the 3 views should display nothing. When graph1.gxl is loaded again, the graph is display in all views again. c) When the graph is closed, all the 3 views should display nothing. When one view is closed, we would be left with 2 windows (2 views). When graph1.gxl is loaded, the graph should be display in both the windows remaining. d) When all views are closed, the program terminates.		a) Pass b) Pass c) Pass d) Pass
Test Case 27: a) Start the application and load graphNoLayout.gxl. b) Save graph into result.gxl. Load result.gxl.	noLayout .gxl	a) When graphNoLayout is loaded, a layout will be generated for the nodes automatically therefore arranging the nodes in a visible pattern. b) When result.gxl is loaded, the graph with the generated layout will be displayed.		a) Pass b) Pass

Table 2: Black Box Testing Results

D SCHEDULE LISTING

Activity	Start Date	End Date	Team Member
Requirements Gathering and Analysis	10/27/2003	11/08/2003	O.Halabieh, W.S.Tan
High-Level Design	11/10/2003	11/19/2003	All members
Extended Project Proposal	11/20/2003	12/1/2003	O.Halabieh, W.S.Tan
Proof Of Concept Version 1	11/20/2003	12/07/2003	N.Liu, L.Zhao
Proof Of Concept Version 2	12/15/2003	01/05/2004	O.Halabieh, W.S.Tan
Detailed Design	01/05/2004	01/15/2004	O.Halabieh, W.S.Tan
Implementation: Module Main, Module DrawGraph, Module View Manipulation, Module View Data Structure	01/15/2004	01/21/2004	O.Halabieh, W.S.Tan
Implementation: Module DrawGraph	01/15/2004	01/21/2004	All members
Implementation: Module Graph Data Structure	01/21/2004	01/28/2004	O.Halabieh, W.S.Tan
Implementation: Module Graph Manipulation	02/01/2004	02/07/2004	O.Halabieh, W.S.Tan
Implementation: Module Collision	02/01/2004	03/01/2004	All members
Implementation: Module Graph File Manager, Module Layout	02/07/2003	02/14/2004	O.Halabieh, W.S.Tan
Implementation: Module Undo Data Structure, Module Settings Data Structure, Module Settings File Manager	02/15/2003	02/21/2004	O.Halabieh, W.S.Tan
White Box Testing	03/01/2004	03/07/2004	O.Halabieh, W.S.Tan
Black Box Testing	03/08/2004	03/22/2004	O.Halabieh, W.S.Tan
Final Report	03/23/2004	04/01/2004	O.Halabieh, W.S.Tan

Table 3: Project Plan