Rigi User's Manual

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Contents

1 Introduction **1**

1.1 What is Rigi? 1

1.2 About This Book 2

1.3 System Requirements 2

1.4 Acknowledgments 3

2 Demos **5**

2.1 Using the Editor 5

2.1.1 Basics 6

2.2 List Demo 7

2.3 Ray Demo 7

2.4 SQL / DS Demo 7

3 Tutorial **9**

3.1 Using the Editor 10

3.1.1 Basics 11

3.1.2 Traversing the subsystem hierarchy 13

3.1.3 Object level 14

3.1.4 Making selections 15
3.1.5 Arranging nodes 16
3.1.6 Identifying subsystems 18
3.1.7 Traversing the hierarchy 21
3.1.8 Detailed information 25
3.1.9 Graph quality 27
3.1.10 Rigi Views 29
3.1.11 Scripting 31
3.1.12 Finishing Up 36

4 Handbook **37**

4.1 Running the Editor 38
4.2 Working with Menus 39
4.2.1 Using the Node menu 40
4.2.2 Using the Arc menu 40
4.3 Configuring the Editor 41
4.3.1 Rigi configuration parameters 41
4.3.2 Creating a new configuration file 43
4.3.3 Modifying a configuration file 44
4.3.4 Overriding the configuration file 45
4.3.5 Defining the default domain model 45
4.3.6 Defining the default database directory 45
4.3.7 Defining the default text editor 46
4.3.8 Defining the default web browser 46

4.3.9 Defining the number of backing stores 47
4.3.10 Defining the default background canvas color 47
4.3.11 Defining fonts 48
4.4 Working with Domains 49
4.4.1 Domain files 50
4.4.2 Switching the current domain model 52
4.5 Running Scripts 53
4.5.1 Entering a script command 54
4.5.2 Retrieving previously entered commands 54
4.5.3 Loading and running a script file 55
4.5.4 Listing available commands 56
4.5.5 Listing global variables 57
4.6 Finishing Up 58
4.6.1 Exiting 58
4.6.2 Aborting 59
4.7 Working with Graphs 60
4.7.1 Rigi Standard Format 60
4.7.2 Saving a graph 62
4.7.3 Loading a graph 62
4.7.4 Clearing a graph 63
4.8 Window Basics 64
4.8.1 Window types 65
4.8.2 Activating a window 66

4.8.3 Raising the active window 66
4.8.4 Stacking (cascading) the windows 66
4.8.5 Refreshing a window 67
4.8.6 Updating a window 67
4.8.7 Closing the active window 68
4.8.8 Closing all windows 68
4.8.9 Bringing up the Settings dialog 69
4.9 Making Selections 70
4.9.1 Selecting a node 70
4.9.2 Selecting an arc 70
4.9.3 Selecting grouped nodes by dragging 71
4.9.4 Selecting and deselecting nodes by shift-clicking 71
4.9.5 Selecting all nodes 72
4.9.6 Complementing selected nodes 72
4.9.7 Deselecting a node 73
4.9.8 Deselecting all nodes 73
4.9.9 Selecting nodes by name 74
4.9.10 Selecting nodes by attribute 75
4.9.11 Selecting nodes by structure 76
4.9.12 Selecting nodes by type 77
4.9.13 Selecting neighboring nodes along outgoing arcs 78
4.9.14 Selecting neighboring nodes along incoming arcs 79
4.9.15 Selecting reachable nodes along outgoing arcs 80

4.9.16 Selecting reachable nodes along incoming arcs 81
4.10 Working with Nodes 82
4.10.1 Node types 82
4.10.2 Changing current node type 83
4.10.3 Renaming a node 83
4.10.4 Changing the type of a node 84
4.10.5 Editing attributes of a node 84
4.10.6 Editing annotation for a node 85
4.10.7 Editing the source text for a node 85
4.10.8 Opening a URL for a node 87
4.10.9 Changing node type colors 88
4.11 Working with Arcs 89
4.11.1 Arc types 89
4.11.2 Changing current arc type 90
4.11.3 Changing the type of an arc 90
4.11.4 Editing attributes of an arc 91
4.11.5 Editing annotation for an arc 91
4.11.6 Opening a URL for an arc 92
4.11.7 Changing arc type colors 92
4.12 Opening windows 93
4.12.1 Presenting the children of nodes 93
4.12.2 Presenting the parents of nodes 94
4.12.3 Presenting the neighbors of nodes 95

4.12.4 Presenting selected nodes in a new window 95
4.12.5 Presenting a projection 96
4.12.6 Presenting an overview 97
4.12.7 Presenting a fisheye view 97
4.13 Editing the Graph 98
4.13.1 Creating a new node 98
4.13.2 Creating a new arc 98
4.13.3 Deleting nodes 99
4.13.4 Deleting an arc 99
4.13.5 Collapsing a subsystem 100
4.13.6 Expanding a subsystem 101
4.13.7 Cutting a subgraph 102
4.13.8 Copying a subgraph 102
4.13.9 Pasting a subgraph 102
4.13.10 Showing the clipboard 103
4.13.11 Clearing the clipboard 103
4.14 Using Filters 104
4.14.1 Hiding names of nodes 104
4.14.2 Showing names of nodes 104
4.14.3 Hiding selected nodes 105
4.14.4 Showing previously hidden nodes 105
4.14.5 Showing and hiding nodes by type 106
4.14.6 Showing and hiding arcs by type 107

4.14.7 Inheriting filter settings 108
4.15 Scaling the Focus 109
4.15.1 Fitting nodes within a window 109
4.15.2 Fitting selected nodes within a window 110
4.15.3 Zooming in 110
4.15.4 Zooming out 111
4.15.5 Restoring the focus 111
4.15.6 Automatic scaling 112
4.16 Making Arrangements 113
4.16.1 Moving a node 113
4.16.2 Moving several selected nodes 113
4.16.3 Arranging nodes horizontally 114
4.16.4 Arranging nodes vertically 115
4.16.5 Arranging nodes into a grid 116
4.16.6 Arranging all nodes into a grid 116
4.16.7 Arranging reachable nodes along outgoing arcs into a tree . 117
4.16.8 Arranging reachable nodes along incoming arcs into a tree . 118
4.16.9 Arranging all nodes in a Sugiyama layout 119
4.16.10 Arranging all nodes in a spring layout 119
4.16.11 Moving nodes to a pile 121
4.16.12 Moving nodes in synch 121
4.16.13 Moving nodes with constraints 122
4.17 Viewing Reports 123

4.17.1 Reporting numbers of nodes and arcs 123
4.17.2 Reporting cyclomatic complexity 123
4.17.3 Viewing node neighborhood and dependency information . 124
4.17.4 Reporting subsystem information 125
4.17.5 Viewing information for an arc 126
4.17.6 Reporting information for a composite arc 127
4.17.7 Reporting graph quality 128
4.18 Working with Views 130
4.18.1 Saving a view 130
4.18.2 Loading a view 131
4.19 Using SHriMP Windows 132
4.19.1 Presenting a SHriMP window 133
4.19.2 Revealing the children of a node 133
4.19.3 Eliding the children of a node 134
4.19.4 Filtering children 134
4.19.5 Enlarging the size of a node 135
4.19.6 Reducing the size of a node 135
4.19.7 Seeing the node name 136
4.19.8 Adjusting the step size 136
4.19.9 Overlapping children 136
4.19.10 Layout constraints 137
4.19.11 Presenting a Children window 137
4.19.12 Viewing the annotation for a node 138

4.19.13 Editing the source text for a node 138

4.19.14 Printing a SHriMP window 138

4.20 Using the Toolbar 139

4.20.1 Toolbar Buttons 139

A **141**

A.1 Directory Structure 142

A.2 Mouse Actions 143

A.3 Keyboard Shortcuts 144

A.4 Menu Commands 145

A.4.1 File menu 145

A.4.2 Edit menu 145

A.4.3 Navigate menu 145

A.4.4 Select menu 146

A.4.5 Filter menu 146

A.4.6 Scale menu 146

A.4.7 Layout menu 146

A.4.8 Report menu 147

A.4.9 Window menu 147

A.4.10 Demo menu 147

A.4.11 Options menu 147

A.4.12 Help menu 147

A.4.13 Node menu 148

A.4.14 Arc menu 148

Chapter 1

Introduction

1.1 What is Rigi?

Rigi is a system for understanding large information spaces such as software programs, documentation, and the World Wide Web. This is done through a reverse engineering approach that models the system by extracting artifacts from the information space, organizing them into higher level abstractions, and presenting the model graphically.

The Rigi user interface is a graph editor, called `rigiedit`, which is used to browse, analyze, and modify a graph that models a given system. This graph is simplified by hierarchically clustering related artifacts into *subsystems* that, in turn, are clustered into larger subsystems.

The choice of components in a subsystem depends on its function, the intended audience, the application area, and the goals of the modeling exercise.

The `rigiedit` program has built-in operations to assist in program understanding. The editor can be used to select and group artifacts based on certain modularity principles such as data abstraction, low coupling among subsystems, and high cohesion within subsystems. Various statistical reports can help with maintenance or reengineering tasks.

Also, `rigiedit` is programmable using a scripting language called Tcl. A library of scripts is supplied for performing common reverse engineering tasks. User-defined scripts can easily be written for specific needs.

Graph models are stored and retrieved by `rigiedit`. The data is formatted in Rigi Standard Format (RSF), which is a stream of triplets used to define graph nodes, arcs, and attributes. Attributes can be used to link to information outside the model, such as source code, documentation, images, and hypertext.

1.2 About This Book

The *Rigi User's Manual* provides setup instructions, a guide to the automated demos, an introductory tutorial, and a definitive, step-by-step handbook of operations that Rigi supports.

☛ **Tip:** The table of contents and index will help you to quickly locate a task you want to do.

If you are new to the Rigi system, it is useful to follow the tutorial to learn the basic operations available and the Rigi approach to software reverse engineering.

▲ **Warning:** Ignoring warnings and other important messages can lead to corrupted data.

△ **Note:** Limitations and potentially unexpected behavior are noted in the manual.

1.3 System Requirements

The graph editor `rigiedit` runs on the following platforms:

- a Sun SPARCstation with SunOS 4.1.x or SunOS 5.4.x (Solaris),
- an IBM RISC System 6000 workstation with AIX 4.1.x,
- an IBM-compatible Personal Computer with Microsoft Windows 95, Windows NT 4.0, or Linux 2.x.

On a Unix platform, `rigiedit` requires X11R5 or greater; `rigiedit` has the Motif look and feel, but is not limited to running under the Motif window manager.

You should be somewhat familiar with the appropriate operating system. On Unix, you should be familiar with the C shell, the X Window System, and the Motif user interface. Knowledge of the Tcl scripting language is useful if you want to write custom scripts.

Installation and setup instructions are provided by the `README` file that accompanies the software distribution.

1.4 Acknowledgments

The results of the Rigi project would not be possible without the tireless efforts of several research associates and graduate students over the past decade.

Lynn Baker
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Most of all, our deepest thanks go to Hausi Müller for his encouragement and unwaivering support of the Rigi group members over the years.

Kenny Wong
June 1998.

Chapter 2

Demos

This chapter is a brief introduction to running the semi-automated demos. These demos show how Rigi is used for program understanding.

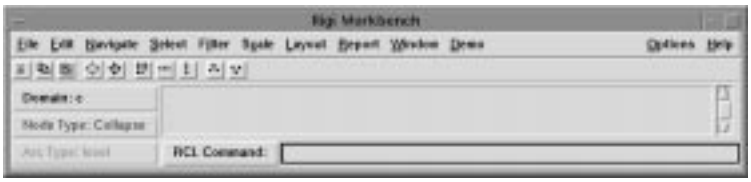
2.1 Using the Editor

The `rigiedit` program is a graph editor whose user interface is based on windows, menus, color, and the mouse pointer. You use `rigiedit` to traverse and modify the graph model represented in the input file. The nodes of the graph are displayed as squares and the arcs are displayed with lines.

To manage the complexity of the graph for large information spaces, you identify clusters of related nodes and collapse them into *subsystem* nodes. By recursively applying this subsystem composition operation, you form a subsystem (containment) hierarchy. The editor can present specific levels in this hierarchy as well as the tree-like structure of the hierarchy itself in separate windows.

2.1.1 Basics

When you run `rigiedit`, you initially see the Rigi Workbench window and an empty root window.



To run a semi-automatic demo:

1. **Choose one of the commands in the Demo menu.**
   You are reminded that changing domain models clears the graph in memory.
2. **Click OK**
   The demo loads, presenting a message window at each step.
3. **Click OK to advance to the next step.**
   Or click Cancel to stop the demo and return to `rigiedit`.

To finish your session with Rigi:

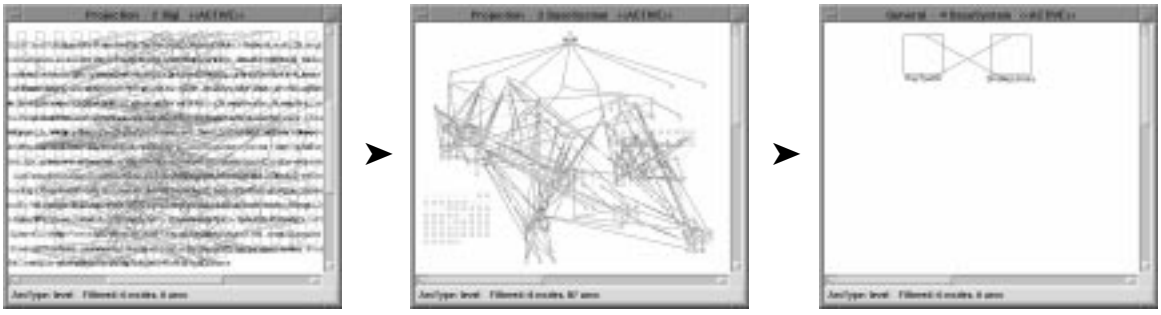
1. **Choose Exit from the File menu.**
   An alert appears reminding you that exiting does not save the graph.
2. **Click Exit to exit.**

2.2 List Demo

The List demo is about understanding a small, 200 line C program for linked list manipulation. The demo covers the basics of `rigiedit`, including how subsystems are identified and used to reduce the complexity of understanding programs.

2.3 Ray Demo

The Ray demo is about reverse engineering a 10000 line C program for geometric rendering. The demo covers the stages of reverse engineering software, including the complex initial graph of extracted artifacts to the final subsystem hierarchy.



2.4 SQL/DS Demo

The SQL/DS demo is about managing the complexity of a 1.5 million line legacy software system. This system is an IBM product written in PL/AS. The demo covers the need for scalable and programmable approaches to legacy software understanding.

Chapter 3

Tutorial

This tutorial introduces the basics of the Rigi system and illustrates the Rigi software reverse engineering methodology by analyzing a simple list manipulation program.

In this tutorial, you will learn about:

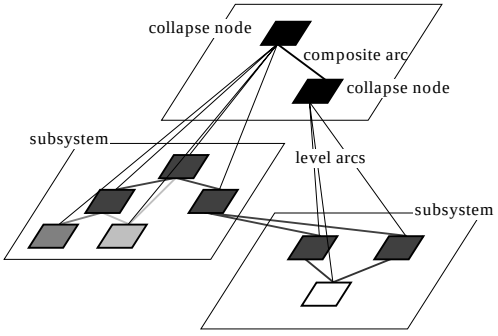
- loading graphs,
- nodes, arcs, and their types,
- traversing the subsystem hierarchy,
- overview, children, and parents windows,
- making selections,
- producing arrangements or layouts,
- identifying and collapsing new subsystems,
- viewing reports,
- measuring graph quality,
- saving and loading Rigi views, and
- running script commands.

3.1 Using the Editor

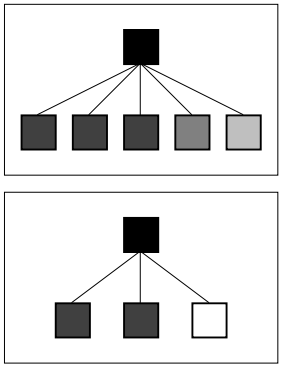
The `rigiedit` program is a graph editor whose user interface is based on windows, menus, color, and the mouse pointer. You use `rigiedit` to traverse and modify the graph model represented in the input file. The nodes of the graph are displayed as squares and the arcs are displayed with lines.

To manage the complexity of the graph for large information spaces, you identify clusters of related nodes and collapse them into nodes that represent subsystems. By recursively applying this subsystem composition operation, you form a subsystem (containment) hierarchy. The editor can present specific levels in this hierarchy as well as the tree-like structure of the hierarchy itself in separate windows.

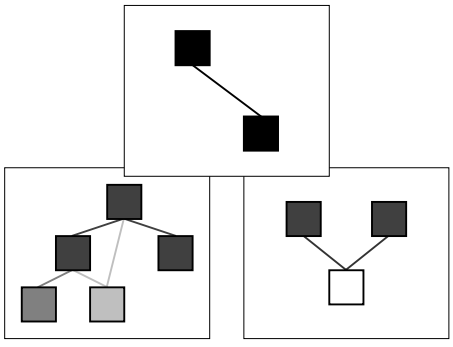
Rigi Graph Model:



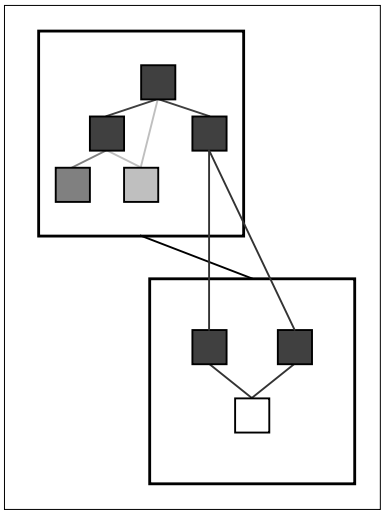
Overview Windows (Vertical Slices):



Children / Parent Windows (Horizontal Slices):



Contextual Fish-eye Perspective:



3.1.1 Basics

When you run `rigiedit`, you initially see the Rigi Workbench window and an empty root window.

The Workbench window presents:

- a menubar with menus File, Edit, Navigate, Select, Filter, Scale, Layout, Report, Window, Demo, Options, and Help;
- a toolbar with several icon buttons for common operations;
- three buttons labeled Domain, Node Type, and Arc Type that bring up three corresponding palettes;
- a button labeled RCL Command;
- a command entry field; and
- a scrollable command history list.

Most of these items is described at an appropriate point in the tutorial.

The editor opens separate windows to provide multiple, usually editable perspectives of the graph model. Each of these windows has a scrollable *canvas* area, where a particular set of nodes and arcs is presented, and a message area at the bottom where messages are displayed.
For example, a window may present an overview of the subsystem hierarchy or the children of a parent node.
The initial window titled Root is used to display the parent(s) of the subsystem hierarchy; this window is always present.

The editor has a notion of a currently *active* window, where operations are applied. A mouse click in the canvas of a window causes that window to become active and display ACTIVE in its title.

△ **Note:** On Unix platforms, the active window is unrelated to the pointer focus.

Most of the mouse interaction with `rigiedit` is through the left mouse button (such as choosing menu items or clicking buttons); the right mouse button is used only within a canvas area.

To load the tutorial example:

1. **Click the Domain button in the Workbench window.**
   A Domain palette appears.

2. **Pick the c domain from the palette.**

   You are reminded that loading a domain model clears the graph in memory.

3. **Click OK to continue.**

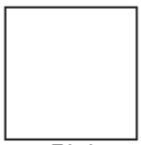
   A simplified domain model for understanding C language programs is loaded. This includes a specification of valid node and arc types, attributes, and colors.

4. **Choose Load Graph ... from the File menu.**
   A File dialog appears, presenting a view of the current directory contents.

5. **Navigate into the `list-d` directory, select the file called `rsf`, and click OK.**
   You are reminded that loading clears the current graph model in memory.
6. **Click OK to load `rsf`.**
   A Rigi Standard Format (RSF) file containing syntactic data representing the implementation of a linked list module (written in C) is loaded.
   The root window displays a single node representing the root of a subsystem hierarchy.

3.1.2 Traversing the subsystem hierarchy

The initial node in the root window, named `Rigi`, represents the *root* level node in the layered, hierarchical graph stored in the `rsf` file. At times there may be more than one node at the root level, each of which represents additional hierarchical structures.



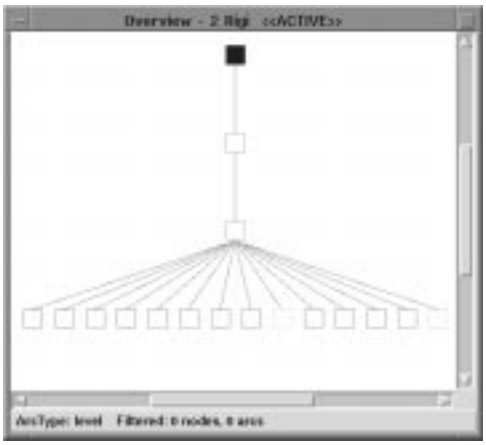
To perform an overview of the subsystem hierarchy descending from the `Rigi` node:

1. **Place the pointer over the `Rigi` node and click the left mouse button on it to select the node.**

   Selected nodes are highlighted, that is, shown in a solid color.

2. **Choose Overview from the Navigate menu.**

   A new *Overview* window appears, presenting the tree-like structure below the `Rigi` node. The `Rigi` node is at the top of the tree. An Overview window presents a vertical "slice" of the hierarchy. The arcs you see that span levels in the hierarchy are known as *level* arcs. For clarity, the arcs within a level and the node labels are filtered in an Overview window.



☛ **Tip:** Resize this window and place it in a corner of the screen while you work.

To traverse down the hierarchy by opening nodes:

1. **Double-left-click on the `Rigi` node in the original root window to open the node and descend to the *system* level.**

   A new *Children* window appears, showing the children of `Rigi` in the hierarchy; the parent node, `Rigi`, is named in the window title. There is one node, named `Base`, in this particular example. For more complex software systems, there may be multiple at this level to, for example, represent several functional components.

2. **Open the `Base` node to descend to the *directory* level.**

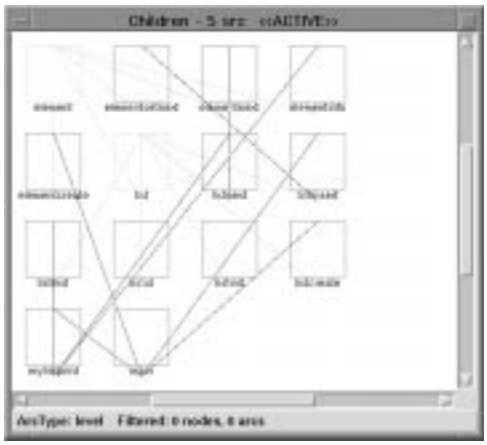
   A new Children window appears, showing the children of `Base`. Similarly, there is one node though there can be more. This node, named `src`, represents the directory which contains the source code of the list example. For a more complex system, there may be multiple directories containing its code.

3. **Open the `src` System node to descend to the *object* level.**

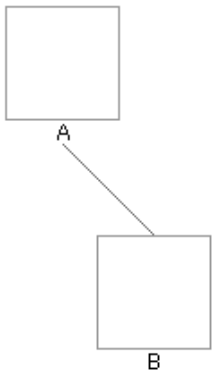
   A new Children window appears, becoming active and showing the children of `src`. This level is the lowest one in the current hierarchy; you will later identify subsystems at this level, collapse related nodes, and form an even deeper hierarchy.

3.1.3 Object level

A Children window typically presents the structure of a single node, that is, the dependencies among the children of the node. This portrays part of a level in the hierarchy, in a kind of horizontal "slice". The name of the parent node appears on the title bar.
Arcs or relationships connecting nodes in the graph are displayed as lines. Both nodes and arcs can be of various types; they are distinguished with customizable colors.



Arcs are also directed. An arc *from* source node A *to* destination node B is represented as a line from the *bottom* of node A to the *top* of node B. Node A is called a *client* of node B and node B is called a *supplier* of node A. The arc is an *outgoing* arc of node A and an *incoming* arc of node B. A node may have an arc going to itself, for a recursive relationship. You see this as a line from the bottom of a node to its top.



At the object level (of a C program), there are typically at least two kinds of nodes: *data types* and *functions*. A data type node, which represents an aggregate structure

or user-defined type, is displayed as a node of type Data. A function node, which represents a function or procedure in the source code, is displayed as a node of type Function. The list example has two Data nodes and twelve Function nodes.

Also, within the object level (of a C program), there are typically at least three types of arcs: *call*, *data*, and *composite*. A call arc represents a function call from the source function to the destination function. A data arc represents one of the following:

- *access* to the internal structure of a data type from a function
- *containment* of one data type from within another
- *reference* of one data type from within another

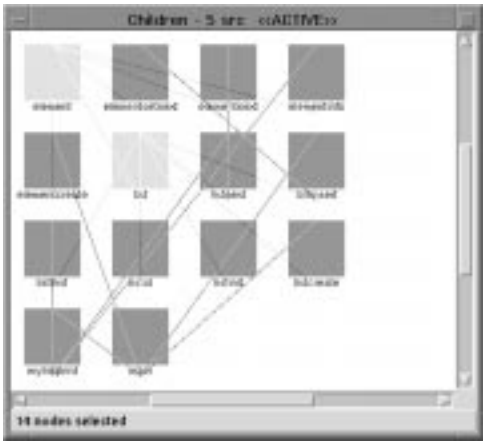
A composite arc is derived from a bundle of one or more non-composite arcs. Arc types are customizable; more non-composite arc types can be added.

3.1.4 Making selections

Most operations in `rigiedit` work on a *current selection* of nodes or arcs in a window.

☛ **Tip:** The current selection is highlighted even if it is not within the active window.

To select and deselect nodes:



- **Choose All from the Select menu.** All visible nodes in the canvas become selected and highlighted. The message area indicates the number of nodes that are selected. As you select these nodes, you may also see them highlighted in other windows, such as the overview window.

- **Left click over a clear area of the canvas.**

All nodes become deselected. You also could choose None from the Select menu.

- **Place the pointer over a clear area of the canvas, press the left mouse button, drag to form a selection rectangle, and release the mouse button.**

  All the nodes that are either completely or partly inside the selection rectangle become selected.

- **Left click on a node (or arc) that is not selected.**

  The node (or arc) becomes selected and all the other nodes and arcs become deselected.

  △ **Note:** Only one arc can be selected at a time.

- **While holding down the shift key, left click on a node.**

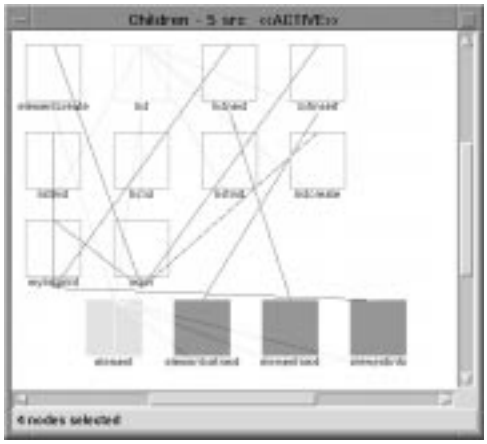
  If the node was selected, it is deselected; if the node was not selected, it is added to the current selection. Any other selected nodes and arc are not affected.

3.1.5 Arranging nodes

Arrangements of nodes are preserved by `rigiedit`. You can perform automatic graph layouts and tweak them manually for a more understandable appearance.

To arrange nodes horizontally:

1. **Select one or more nodes.**
2. **Right-click near the bottom of the canvas.**
3. **Choose Horizontal from the Layout menu.**
   The selected node(s) are arranged horizontally, starting from the point on the canvas where you clicked, and remain selected.



Similarly, you can choose Vertical or Grid from the Layout menu for other simple kinds of arrangements.

To move a group of nodes:

1. **Select one or more nodes.**
2. **Place the pointer over any node in the selected group, hold down the shift key, press the left mouse button, drag to another area, and release.**

   The selected node(s) are moved as a group to the area where the mouse button was released.

You can automatically produce a tree-like arrangement of nodes to, for example, show a call hierarchy (within part of a level in the subsystem hierarchy).

Such hierarchical arrangements should not be confused with the subsystem hierarchy presented in an Overview window; that is, these arrangements are hierarchies in appearance only and are not directly represented in the graph model.

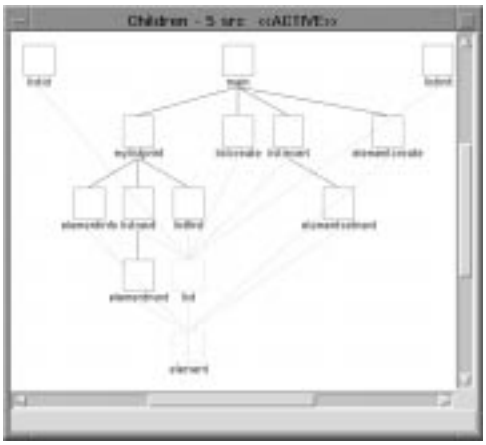
To produce a layered, tree-like arrangement:

- **Choose Sugiyama from the Layout menu.**
  The Sugiyama algorithm attempts to minimize crossings in the layout.

  ▲ **Warning:**

  If the number of nodes on a level in the tree becomes too high, the Sugiyama implementation fails.

  ☛ **Tip:** This hierarchy is in appearance only and should not be confused with the subsystem hierarchy.



By default, automatic arrangements shift and scale nodes, if necessary, to stay within the boundaries of the window.

3.1.6 Identifying subsystems

The object level, as you see it now, lacks explicit structure and is essentially *flat*. For complex software systems, with many more nodes and arcs, the resulting visual clutter can be confusing. However, there is usually some organization.

Abstraction is one way of managing complexity. It is good software engineering practice to encapsulate a data type and its access functions into a software subsystem, forming an abstract data type.

The `rigiedit` program provides many ways to help you in identifying subsystems of related artifacts. These subsystems may, for example, represent high-level software components, personnel assignments, or other application-specific information.

To identify the data types in the system by filtering the Function nodes:

1. **Choose Filter by Node Type ... from the Filter menu.**

   A Filter by Node Type dialog appears for the active window.
   Filters are used to show or hide nodes and arcs of different types. This dialog presents a choice of node type filters each of which can be toggled on to hide or off to show the associated type of node.

2. **Toggle on the Function item from the dialog.**

   Click on the box beside Function.

3. **Click Apply.**

   Nodes representing functions are now filtered (hidden), making it easy to identify and select the data type nodes. (For simple examples, this isn't necessary.)

4. **Move the Data nodes aside in the canvas.**

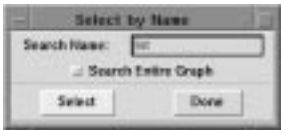
5. **Toggle off the Function item from the dialog and click Apply.**

   Nodes representing functions are shown again.

6. **Click Done to dismiss the dialog.**

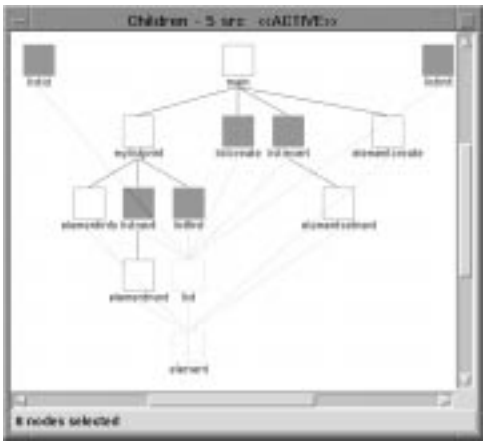
To identify the access functions of the `list` abstract data type:

1. **Choose By Name ... from the Select menu.**
   A Select by Name dialog appears. Selecting by name may be more useful for very large graphs.



2. **Type `list` and click Select.**
   The `list` Data node becomes selected.
3. **Click Done to dismiss the dialog.**
4. **Click the Arc Type button in the Workbench window.**
   An Arc Type palette appears.
   This palette causes certain selection operations to consider or match only specific arc types (data arcs, here). The any choice in the palette matches any arc type.

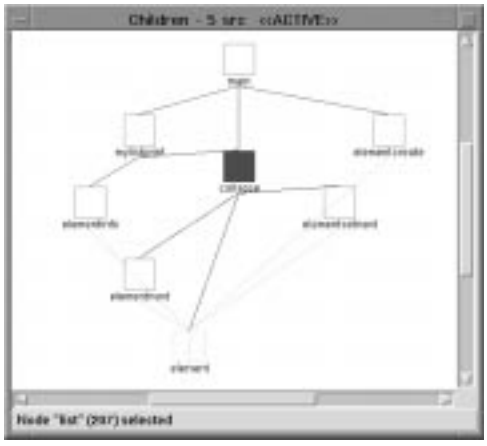
5. **Pick the data item from the Arc Type palette.**
6. **Choose Incoming Nodes from the Select menu.**
   All neighboring nodes along incoming arcs, that is, clients of `list`, are selected, identifying all functions that *access* the internal structure of the `list` data type (through a data arc).



To create a new subsystem node to represent the `list` abstract data type:

1. **While holding down the shift key, left click the `list` node.**
   The `list` Data node is added to the previously selected group of six Function nodes.
2. **Choose Collapse from the Edit menu.**

A new subsystem node is created that has all of the previously selected nodes as its children, thus simplifying the graph in the active window. The previously selected nodes are moved to a lower level in the hierarchy (and are deselected). The new node is of type Collapse and becomes selected. Composite arcs are added to relate the new node to other nodes in the window.



☛ **Tip:** To undo a collapse, choose Expand from the Edit menu for the subsystem node.

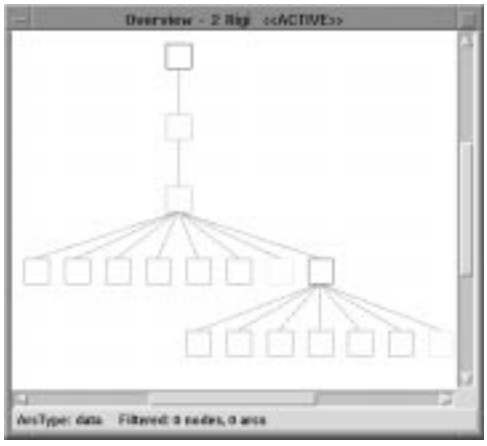
3. **Right-click on the new subsystem node.**

   A *Node menu* appears. You can bring up a Node menu on any node, even if it is not selected; the available choices apply to that node. Canvas menus in `rigiedit` are context sensitive and depend on what node or arc is under the pointer.

4. **Choose Rename from the Node menu, type `ListADT`, and press the enter key.**

   The new subsystem node is renamed to `ListADT`.

5. **Activate the Overview window.**



   ☛ **Tip:** Right-clicking on the canvas of the window to activate it does not disturb the current selection.

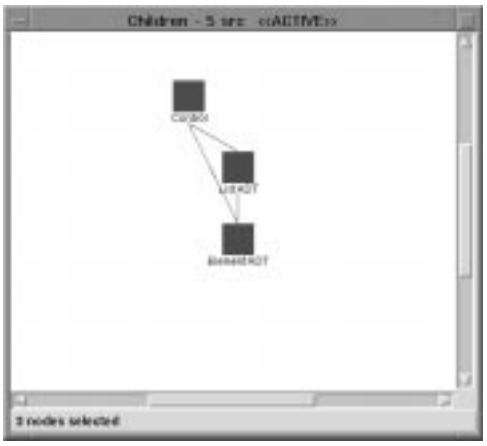
6. **Choose Update from the Window menu.**
   The hierarchy in the Overview window is updated to reflect the newly created subsystem.

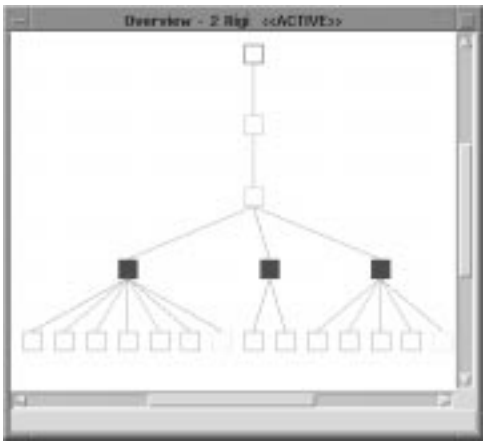
7. **Choose To Fit from the Scale menu.**

   The nodes in the active window are scaled to fit, making the newly added level in the hierarchy more visible.

On your own, return to the Children window and identify the four Function clients of the `element` Data node. Note that the `element` data type has a recursive data dependency and is a client of itself. Collapse the five selected nodes to form another subsystem node called `ElementADT`.

Collapse the remaining two nodes into another subsystem and name it `Control`. Update the Overview window and move aside the Children window so that you can find it more easily for operations in the rest of the tutorial.





3.1.7 Traversing the hierarchy

By visually inspecting the subsystem graph, you get a high-level summary of the major components of the program. The completed subsystem hierarchy is a navigational structure for exploring and documenting the subject software. The hierarchy created for the list example can be explored when trying to understand the list program.

The simplest traversal technique is to open a node and traverse down in the hierarchy.

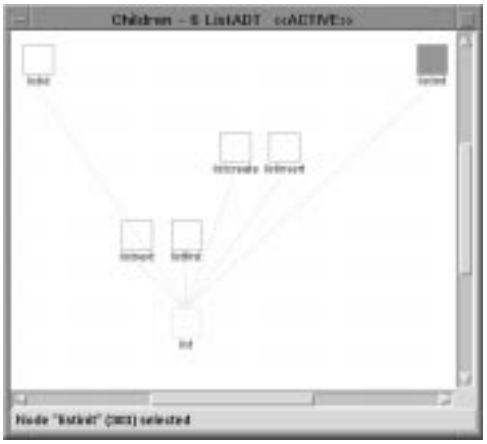
- **Double-left-click on the `ListADT` subsystem node (or choose Children from the Navigate menu).**

  A new Children window appears, showing the access functions and `list` data type within the `ListADT` subsystem.

You can also traverse up in the hierarchy to see the parent node(s):

1. **Select the `listinit` Function node in the newly opened Children window.**
2. **Choose Parents from the Navigate menu.**

   A new *Parents* window appears, showing the parent of `listinit` in the hierarchy; the original child node, `listinit`, is named in the window title.



Close the two windows just opened before proceeding:

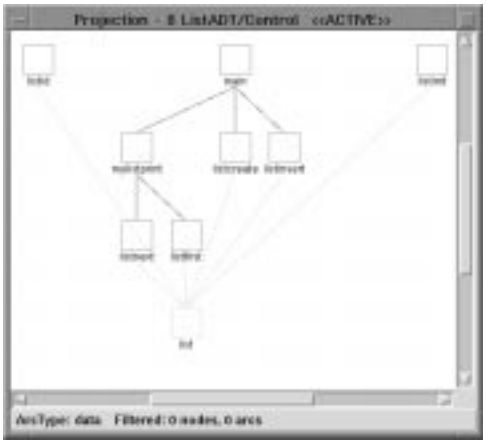
- **Activate each window and choose Close Active from the Window menu.**

  ☛ **Tip:** You can also close each window through your window manager.

You can produce a *projection* perspective:

1. **Select the `ListADT` and `Control` subsystem nodes.**
2. **Choose Settings from the Options menu.**
   The Settings dialog appears, allowing you to change some parameters that influence various operations provided by `rigiedit`.
3. **Adjust the Projection Depth slider to the value 1.**
   The parameter change is immediate.
4. **Click Done to dismiss the dialog.**
5. **Choose Projection from the Navigate menu.**

A new *Projection* window appears, containing a union of all nodes that are exactly *one* level below the selected nodes. The names of the selected nodes that were projected appear on the title of the Projection window (`ListADT/Control`).
If the slider value is -1, the projection depth is infinite and a projection would display all the nodes in the subhierarchies rooted at the selected nodes. Leaf nodes are included in the projection if the slider value is set too deep for certain branches of the hierarchy.



△ **Note:** You cannot directly modify the graph model from within a Projection window. You can, however, open a node or project a group of nodes from a Projection window.

To view the hierarchy rooted or starting at the `ListADT` subsystem node:

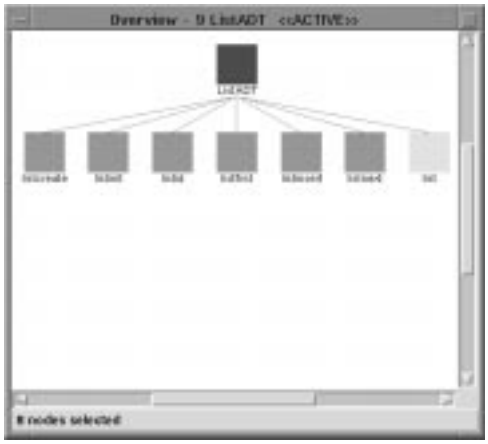
1. **Select just the `ListADT` node.**
2. **Choose Overview from the Navigate menu.**

   A new Overview window appears, presenting the subhierarchy below the `ListADT` node.

By default, the nodes in an Overview window are initially displayed without labels, but you can change that.

1. **Select all the nodes in the `ListADT` Overview window.**
2. **Choose Filter by Selection ... from the Filter menu.**
   A Filter by Selection dialog appears.

3. **Click Show Names.**
   The labels of the selected nodes in the active window are displayed.
4. **Click Done to dismiss the dialog.**



Before proceeding, close the Projection window and Overview window just opened.

3.1.8 Detailed information

Although the construction of a subsystem hierarchy makes the subject software easier to understand, it also hides many low-level details.

To view information on the immediate neighborhood around the `ListADT` subsystem node as it is presented within a window:

1. **Choose View Information from the Node menu of the `ListADT` subsystem node.**
   A textual Information window appears, presenting information about `ListADT` (in the window just activated).

   This information includes the node's:

   - internal node ID,
   - node type,
   - incoming and outgoing arcs by arc type, and
   - neighboring nodes along these arcs (with their node name and type).

   Some of this information is dimmed for nodes and arcs not visible in the active window.

2. **Click Done to dismiss the Information window.**

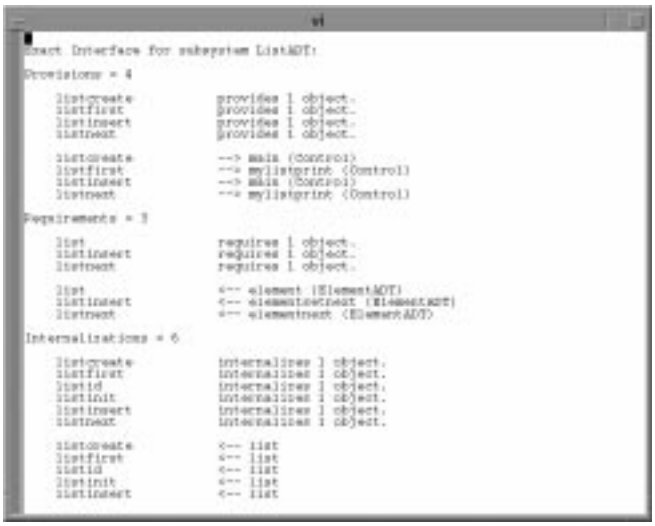
An *exact interface* report is typically used on a subsystem node to provide detailed dependency information about the nodes within in it (in relation to nodes outside it).

To produce an exact interface report for the `ListADT` subsystem:

1. **Select the `ListADT` subsystem node.**

2. **Choose Exact Interface from the Report menu.**

   The report appears in a Text editor window; this editor is a separate process outside the direct control of `rigiedit`.



The report includes three kinds of information for the selected subsystem: *provisions*, *requirements*, and *internalizations*. A provision is a dependency from a node *inside* the subsystem to a node *outside* the subsystem; the internal node *provides* at least one object. A requirement is a dependency from a node *outside* the subsystem to a node *inside* the subsystem; the internal node *requires* at least one object. An internalization is a dependency between two nodes inside the subsystem.

To produce information about any particular arc:

1. **Right-click on the arc.**

   An *Arc menu* appears. You can bring up an Arc menu on any arc, even if it is not selected; the available choices apply to that arc.

2. **Choose View Information from the Arc menu for the arc.**

To produce an exact interface report for the composite arc between the `ListADT` and `ElementADT` subsystems:

1. **Select the arc between the `ListADT` and `ElementADT` subsystem nodes.**

2. **Choose Exact Interface from the Report menu.**

   A record of the lower-level dependencies between the two subsystems appears in a Text editor window. This editor is a separate process outside the direct control of `rigiedit`.

△ **Note:** This report only works for composite arcs.

3.1.9 Graph quality

You can produce a *graph quality* report which evaluates the quality of a selected subsystem according to a set of software modularity measures. Each measure is normalized to a range from 0 to 1. Higher values are "better."

1. **Select the** `ListADT` **subsystem node.**
2. **Choose Graph Quality (C) from the Report menu.**

   A report of the graph quality appears in a Text editor window. This editor is a separate process outside the direct control of `rigiedit`.

The overall quality is based on the:

- *partition* quality,
- *control encapsulation* quality, and
- *data encapsulation* quality.

The partition quality measure *increases* as the number of interfaces between nodes in the subsystem *decrease*. This is the principle of low coupling in modular design. The interfaces are classified into high-, medium-, and low-strength interfaces. The thresholds for this classification can be adjusted using the Low Threshold and High Threshold sliders in the Settings dialog.

The control encapsulation quality measure *increases* with the number of control flow dependencies between nodes inside the subsystem, and *decreases* with the number of control flow dependencies from nodes inside the subsystem to nodes outside. This favors localized control and small interfaces.

The data encapsulation quality measure *increases* with the number of local references to data types, and *decreases* with the number of external references to data types. This favors data encapsulation and object-oriented designs.

3.1.10 Rigi Views

One way to document the graph is to create, save, and load `rigiedit` *views*. A `rigiedit` view is a snapshot of the appearance of one or more windows and their contents at a given point in time. After loading a view, you can still interact with its windows. Views provide a flexible way to focus attention on important facets of the subject software. You generally create views after the subsystem hierarchy is completed.

△ **Note:** A view and the underlying graph model on which the view is based must correspond. If the graph in memory changes, older views may not work correctly.

△ **Note:** Text editor windows and their report contents cannot be saved in a view.

To save a `rigiedit` view of all the canvas windows on the screen:

1. **Open and arrange the contents of the windows as desired.**

   Locations of nodes, filter settings, and current selections (anything you see) are part of the view.

2. **Move and resize the windows of your view as desired.**

   Position, size, and scroll settings are recorded.

3. **Choose Save Graph As ... from the File menu.**

   A File dialog appears for saving your work. You need to save the graph model on which a view depends.

4. **Type a filename for the graph and click OK to save the graph.**

   ☛ **Tip:** A suffix of `.rsf` is useful for distinguishing graph files.

5. **Choose Save View As ... from the File menu.**

   A File dialog appears for saving the view.

6. **Type a filename for the view in the File dialog and click OK.**

   ☛ **Tip:** A suffix of `.view` is useful for distinguishing view files.

If necessary, the file suffixes are added automatically.

When loading a `rigiedit` view, you must ensure that the graph in memory is the same as the graph on which the view was based.

To load a `rigiedit` view:

1. **Choose Close All from the Window menu.**

   All `rigiedit` windows become closed except the root window.

2. **Choose Load Graph ... from the File menu.**

   A File dialog appears for loading the graph on which the view is based.

3. **Select the graph to load, and click OK.**

   When loading a graph, an alert appears, reminding you that the graph in memory will be cleared.

4. **Choose Load View ... from the File menu.**

   A File dialog appears for loading the view.

5. **Pick the view to load and click OK.**

   One or more windows will be opened with the same contents and arrangement as the windows previously saved in the view.

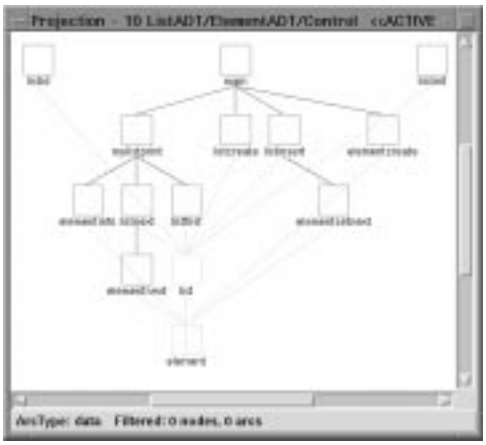
3.1.11 Scripting

You can program the editor by writing scripts using the *Rigi Command Library* (RCL) to automate tasks, customize features, and integrate capabilities. There is an RCL command corresponding to each menu command. These commands (and others) can be assembled into procedures.

Return to the Children window with the `ListADT`, `ElementADT`, and `Control` subsystem nodes.

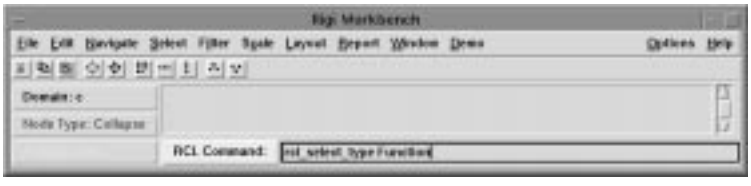
For scripting experiments, make a test window of leaf nodes by performing a projection of the subsystems with infinite depth:

1. **Select the three subsystem nodes.**
2. **Choose Settings from the Options menu.**
3. **Adjust the Projection Depth slider to the value** -1**.**
4. **Choose Projection from the Navigate menu.**
   A Projection window appears, containing the lowest level nodes in the subsystem hierarchy; the structure of the hierarchy is not modified after producing a projection.



You can produce custom layouts. To enter an RCL command:

1. **Place the pointer to the command entry field and click.**



2. **Type** `rcl_select_type Function`**.**

   Press the enter key after typing each script command.

   The `rcl_select_type` command selects nodes by their type (here, it is Function).

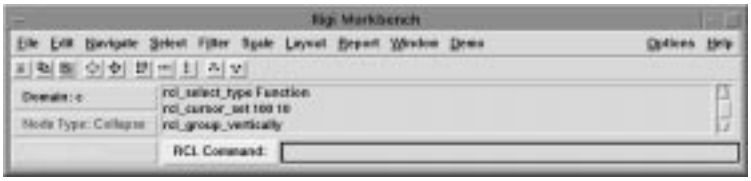
3. **Type** `rcl_cursor_set 100 10`**.**

   The `rcl_cursor_set` command moves a cursor to location $(x, y) = (100, 10)$ on the canvas. This is equivalent to clicking the mouse at that location (usually as a prelude for arrangement operations).

4. **Type** `rcl_group_vertically`**.**
   The `rcl_group_vertically` command corresponds to choosing Vertical from the Layout menu; the selected nodes are arranged in a vertical line along the left side of the canvas.

   △ **Note:** RCL is case sensitive.

As each command is entered, it is put into a scrollable command history list located below the menubar.



Clicking on a command in the list automatically places it into the command entry field. Double-clicking on a command in the list runs it right away (and appends this command to the bottom of the list).

Now, using the current commands in the command history list, retrieve and edit them as appropriate to lay out the two remaining Data nodes in a vertical line to the right of the Function nodes.

Using a separate text editor, you can write script files that can be loaded into `rigiedit`. For example, type the following script into a file called `myscript.rcl` in your home directory. The lines starting with # are comments. Try to figure out what the script does.

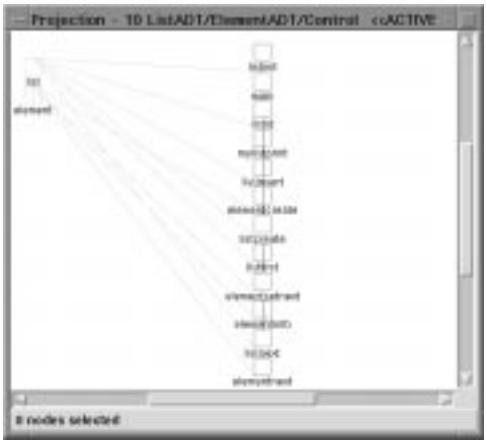
```
proc columns {} {
    # select all nodes in the active window
    rcl_select_all

    # for each node that is selected ...
    foreach nodeID [rcl_select_get_list] {
        # check off its node type as being used
        set nodeTypes([rcl_get_node_type $nodeID]) 1
    }

    # get the number of distinct node types
    set numNodeTypes [array size nodeTypes]
    if {$numNodeTypes == 0} {
        # do nothing if the window has no nodes
        return
    }

    # set horizontal cursor increment and starting point
    set xDelta [expr [rcl_win_canvas_width] / $numNodeTypes]
    set xPos [expr $xDelta / 2]

    # for each node type used ...
    foreach nodeType [array names nodeTypes] {
        # select all nodes in the active window of that type
        rcl_select_type $nodeType
        # set the cursor
        rcl_cursor_set $xPos 0
        # lay out the selected nodes vertically at the cursor
        rcl_group_vertically
        # step the cursor
        incr xPos $xDelta
    }

    # scale the nodes to fit inside the active window
    rcl_scale_to_window
    # deselect all nodes in the active window
    rcl_select_none
}
```

This script arranges the nodes in the active window into columns by their node type.

To load the `myscript.rcl` into `rigiedit` and run the layout algorithm:

1. **Type** `source ~/myscript.rcl` **in the command entry field.**

2. **Type** `columns`**.**

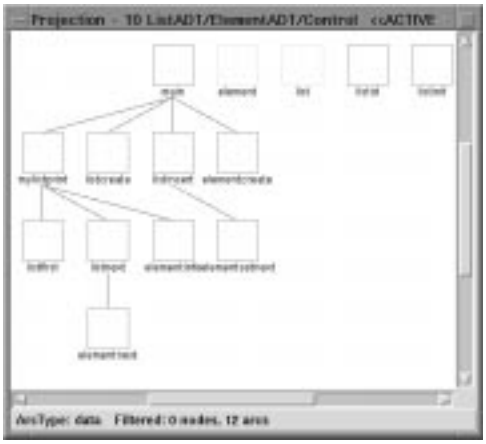


To use script commands to access external tools such as graph layout programs:

1. **Type** `rcl_filter_arctype data 0` **then** `rcl_filter_apply 0 arc` **in the command entry field.**

   These two commands hide the data arcs in the active window (the Projection window).

2. **Type** `sugiyama call 0`**.**
   The call arcs of the graph in the current window are presented in a layered, tree-like form using the Sugiyama directed graph layout algorithm. The `sugiyama` command takes an arc type as the first parameter and a window number as the second parameter (zero meaning the current window). The window number is shown in the title bar of a window, following the type.



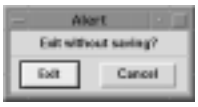
☛ **Tip:** This technique is a quick way of producing call graphs for a program.

3.1.12 Finishing Up

To finish your session with Rigi:

1. **Choose Exit from the File menu.**

   An alert appears reminding you that exiting does not save the graph.



2. **Click Exit to exit.**

Chapter 4

Handbook

4.1 Running the Editor

The `rigiedit` graph editor program takes various command-line options. On a Unix platform, you must be in an X session (preferably with a Motif-compliant window manager). Since `rigiedit` is an X client, you can run it on a remote host machine and, as usual, have the interaction directed to the display you are using.

`rigiedit [-dm` *`domain`*`] [-env` *`configfile`*`] [-fd] [-h] [-i` *`scriptfile`*`] [-poll] [-s` *`host`*`[:`*`port`*`]] [-v]`

Options for `rigiedit`:

- `-dm` *`domain`*

  Specify the default *domain* model (§4.4.1).

- `-env` *`configfile`*

  Load the configuration file, *configfile*, upon startup (§4.3.1).

- `-fd`

  Use fast arc drawing, at the expense of accuracy.

- `-h`

  Print a terse list of `rigiedit` options.

- `-i` *`scriptfile`*

  Load the RCL script file, *scriptfile*, upon startup (§4.5).

- `-poll`

  Run the RCL command `rcl_poll_proc` (if defined) once every second.

- `-s` *`host`*`[:`*`port`*`]`

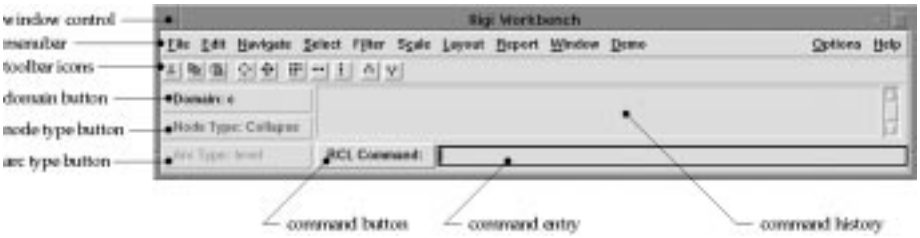
  Specify a *host* on which the mbus software message bus is running and, optionally, the associated *port* number it is using. (By default, the *port* number is 0.) Connect to this bus.

- `-v`

  Specify verbose debugging output.

4.2 Working with Menus

When you run `rigiedit`, you initially see the Rigi Workbench window and an empty root window.



The `rigiedit` menubar has pull-menus File, Edit, Navigate, Select, Filter, Scale, Layout, Report, Window, Demo, Options, and Help. To pull down these menus, place the pointer over a menu name, press with the left mouse button, drag to the desired menu item, and release.

☛ **Tip:** There are accelerator keys to pull down these menus and choose items (*see* §A.3).

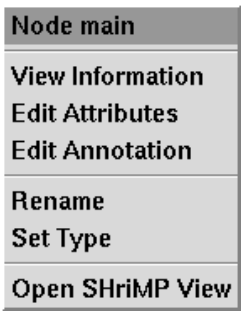
For `rigiedit` windows that display nodes and arcs in a canvas area, there are two context-sensitive popup menus depending on what object (node or arc) is under the pointer. For these popup menus in the canvas area, you use the right mouse button.

4.2.1 Using the Node menu

There is a Node menu that can be brought up for each node in a window. The title of each Node menu displays the name of the node; this title is color-coded according to the type of the node.

To use the Node menu:

1. **Place the pointer over a specific node and right-click to raise the Node menu.**
   Operations from the Node menu apply to the specified node and sometimes the subhierarchy rooted at this node.
2. **Move the pointer over a menu item and right-click to perform the node operation.**

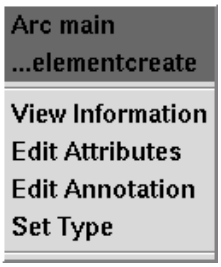


4.2.2 Using the Arc menu

There is an Arc menu that can be brought up for each arc in a window. The title of each Arc menu displays the names of the source and destination nodes of the arc; this title is color-coded according to the type of the arc.

To use the Arc menu:

1. **Place the pointer over a specific arc and right-click to raise the Arc menu.**
   Operations from the Arc menu apply to the specified arc.
2. **Move the pointer over a menu item and right-click to perform the arc operation.**



4.3 Configuring the Editor

This section describes tasks for customizing the Rigi environment through various configuration parameters.

4.3.1 Rigi configuration parameters

The `rigiedit` editor stores its preferences or configuration parameters in a file. It considers the following locations, in sequence, to find and load this configuration file:

1. the filename specified in the `-env` flag to `rigiedit`,
2. a `rigicfg.env` file in the current working directory where `rigiedit` was invoked,
3. a `rigicfg.env` file in the directory named by the environment variable `RIGIUSER`, or
4. a `rigicfg.env` file in the directory named by the environment variable `RIGI`.

Table 4.1 lists the standard Rigi configuration parameters, with a short description, and the default value (if any).

The usual parameters to change are:

`RIGIUSER`	(e.g., to ~)
`RIGIDOMAIN`	(§4.3.5)
`SRCDIR`	(§4.10.7)
`RIGIURCL`	(§4.5)
`DBDIR`	(§4.3.6)
`TEXTEDITOR`	(§4.3.7)
`WEBBROWSER`	(§4.3.8)
`NUMBACKSTORES`	(§4.3.9)
`CANVASCOLOR`	(§4.3.10)
`GRAPHFONT`	(§4.3.11)
`MESSAGEFONT`	(§4.3.11)
`TEXTFONT`	(§4.3.11)
`WORKBENCHFONT`	(§4.3.11)

Table 4.1: Rigi Configuration Parameters

Variable	Description	Default Value
RIGI	installation directory	
RIGIUSER	personal home directory†	~
	personal home directory‡	.
RIGIBIN	executables directory	$RIGI/bin
RIGILIB	support files directory	$RIGI/Rigi
RIGIINIT	domains directory	$RIGI/Rigi/domain
RIGIDOMAIN	default domain subdirectory	c
ICONDIR	icons directory	$RIGI/Rigi/icons
SRCDIR	source files directory	$RIGI/Rigi/src
RIGIRCL	standard RCL startup script	$RIGI/Rigi/rcl/rc.rcl
RIGISTY	standard user interface script	$RIGI/Rigi/rcl/sty/rigi
RIGIURCL	personal RCL startup script	
RIGIUSTY	personal user interface script	
DBDIR	database directory	$RIGI/Rigi/db
DBREFDIR	database reference directory	$RIGI/Rigi/db
TMPDIR	temporary files directory†	/tmp
	temporary files directory‡	$RIGI/Rigi/tmp
TEXTEDITOR	text editor format string†	xterm -e vi +%d
	text editor format string‡	notepad.exe
WEBBROWSER	web browser format string	netscape -remote openURL(%s)
WEBROOT	web root URL	http://
RIGITITLE	title on stdout window‡	Rigi Visual Editor - Rigiedit
ROOTLOCATION	root window position	0 185
ROOTFRAMEDIM	window frame dimensions	529 456
ROOTWINDOWDIM	window internal dimensions	500 400
MAXCANVASDIM	canvas dimensions	1284 1024
NUMBACKSTORES	number of backing stores	2
CANVASCOLOR	background canvas color	
DEMOFONT	demo messages font⋆	Helvetica, bold, 12 point
GRAPHFONT	node label font⋆	Helvetica, medium, 10 point
MESSAGEFONT	messages font⋆	Helvetica, bold, 12 point
TEXTFONT	text font⋆	Courier, medium, 10 point
WORKBENCHFONT	workbench font⋆	Helvetica, bold, 12 point
RIGIDBPORT	mbus port number	0
RIGIDBHOST	mbus host machine name	

†Unix version. ‡Windows version. ⋆Expressed using an X font specification.

4.3.2 Creating a new configuration file

To create a new configuration file:

1. **Choose Configuration from the Options menu.**

   A Configuration dialog appears, showing a list of configuration parameters.

   For each parameter, there is a short description, the corresponding environment variable which would override it, and the current value.

2. **Choose New from the File menu of the Configuration dialog.**

   A new configuration is created with default values for the parameters.

3. **Choose Save As ... from the File menu of the dialog.**

   A File dialog appears.

4. **Enter a name for the new configuration file and click OK.**

   Use the name `rigicfg.env` so that `rigiedit` can automatically attempt to find it.

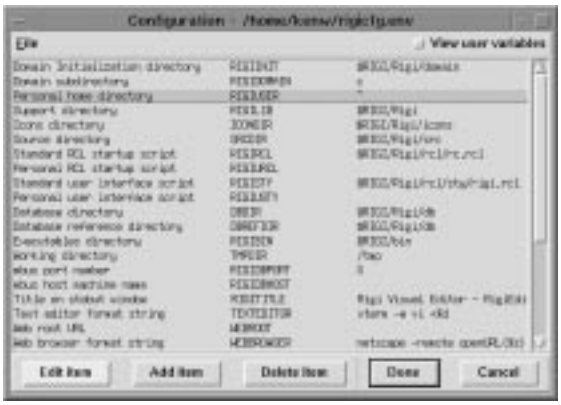
5. **Click Done to dismiss the Configuration dialog.**

4.3.3 Modifying a configuration file

To modify an existing configuration file:

1. **Choose Configuration from the Options menu.**

   A Configuration dialog appears, showing a list of configuration parameters.
   For each parameter, there is a short description, the corresponding environment variable which would override it, and the current value.
   The configuration file being modified is indicated in the title bar of the dialog.



2. **Pick a parameter from the list by left clicking on it.**
3. **Click Edit Item to edit the current value for this parameter.**
   A dialog window appears, presenting an entry field.
   ☛ **Tip:** You could also double-click on a parameter from the list to present this dialog.

4. **Make the required change and click Done.**

   Or click Cancel to cancel and return to the Configuration dialog.

   Clicking Default retrieves the default value of the selected parameter.

5. **Click Done to commit the changes and dismiss the Configuration dialog.**

   If you made any changes, an alert appears asking whether you want to save them.

6. **Click OK.**

   Or click Cancel to cancel without changes.

   If you clicked OK, you will be reminded to exit and restart `rigiedit` to see the changes.

△ **Note:** You need to restart `rigiedit` (with the appropriate configuration file) to use the changed configuration parameters.

4.3.4 Overriding the configuration file

`setenv` *`variable value`*

There is an environment variable for each configuration parameter (as shown in Table 4.1). By defining any of these environment variables, you override the corresponding definition in the active configuration file.

Some of these variables may be further overridden or augmented by command-line arguments to `rigiedit` (§4.1).

4.3.5 Defining the default domain model

The configuration parameter `RIGIDOMAIN` specifies the name of the default domain model to be set when `rigiedit` is started.

To find the appropriate domain files (§4.4.1), the name specifies a subdirectory within a directory pointed to by the configuration parameter `RIGIINIT`.

To change or override these parameters, *see* §4.3.3 or *see* §4.3.4.

☛ **Tip:** The default domain model can also be specified in the `-dm` command-line option (§4.1) to `rigiedit`.

4.3.6 Defining the default database directory

The configuration parameter `DBDIR` specifies the (default) database directory to be used when loading and saving files such as graphs, views, and annotations. This parameter is also used to help locate the demos listed in the Demo menu.

To change or override these parameters, *see* §4.3.3 or *see* §4.3.4.

☛ **Tip:** You are also asked to (re)set the database directory when clearing the graph (§4.7.4); this does not require restarting `rigiedit`.

△ **Note:** Changing the database directory may cause `rigiedit` to forget where the demo files are located.

4.3.7 Defining the default text editor

The configuration parameter `TEXTEDITOR` specifies the command to launch a text editor. A `%d` code in the value string is replaced by a line number. The text editor is launched as a separate process outside the direct control of `rigiedit`.

To change or override these parameters, *see* §4.3.3 or *see* §4.3.4.

For a non-graphical editor under Unix, you may need to launch the editor indirectly through the X client `xterm`. For example, `TEXTEDITOR` can be set to `xterm -e vi +%d` to run `vi` as your editor.

4.3.8 Defining the default web browser

The configuration parameter `WEBBROWSER` specifies the command to launch a web browser. A `%s` code in the value string is replaced by a Uniform Resource Locator (URL). The web browser is launched as a separate process outside the direct control of `rigiedit`.

To change or override these parameters, *see* §4.3.3 or *see* §4.3.4.

4.3.9 Defining the number of backing stores

A backing store is an in-memory pixmap used to accelerate the refresh of window contents. The configuration parameter `NUMBACKSTORES` specifies the maximum number of such backing stores. A typical value is `4`, subject to memory limits. The memory needed for each store depends on the canvas height and width (in pixels) specified by the configuration parameter `MAXCANVASDIM`.

To change or override these parameters, *see* §4.3.3 or *see* §4.3.4.

★ **Technical:** A backing store is allocated to a canvas window on a first-come first-served basis, provided that the redraw contents exceed a certain level of visual complexity. A store is freed for use whenever a canvas window is closed. A store may be allocated to an existing window if one was not available at the time the window was created.

△ **Note:** A backing store is never allocated to a SHriMP window.

4.3.10 Defining the default background canvas color

The configuration parameter `CANVASCOLOR` specifies the background color of canvas windows. Typical values are `Black` or `White`. If no value is given (the system default), `rigiedit` makes a choice, based on the color map, that leads to the most efficient color drawing.

To change or override these parameters, *see* §4.3.3 or *see* §4.3.4.

△ **Note:** The background color of a SHriMP window is not affected by this parameter.

4.3.11 Defining fonts

The font (typestyle) parameters are typically expressed using an X font specification with the form:

-foundry-family-weight-slant-width--pixelsize-pointsize-*-*-*-*-*-*

Here are some typical values (not all combinations are possible):

foundry	`adobe`, `misc`
family	`fixed`, `courier`, `helvetica`, `times`
weight	`medium`, `bold`
slant	`r`
width	`normal`
pixelsize	`10`, `12`, `14`, `18`, `24`
pointsize	`100`, `120`, `140`, `160`, `180`, `240`

To view the possible combinations, use the X client `xfontsel`.

4.4 Working with Domains

The `rigiedit` graph editor can be specialized for particular domains, such as C language programming, LaTeX technical writing, and Web exploration.

The handbook uses C as the domain for the sample screen images; however, `rigiedit` is not limited to C and most operations work across different domains.

A domain is described by a domain *model* that determines what node and arc types, and node and arc attributes are possible in the domain.

This model is a meta-level description of actual, token-level graph data conforming to the domain (§4.7.1).

4.4.1 Domain files

Each domain has a set of appropriate node and arc types, and node and arc attributes. These aspects are expressed in a set of five files.

These files are stored in a subdirectory, of the same name as the domain, within a directory pointed to by the configuration parameter `RIGIINIT`.

These files are described below.

- `Riginode` declares the names of node types. Each line has the form:
  nodeType

  ☛ **Tip:** One useful convention is to capitalize node type names.

- `Rigiarc` declares the names of arc types (relating two starting and ending node types). Each line has the form:
  arcType [*startNodeType endNodeType*]

  △ **Note:** The node types, if given, do not constrain the declared arc type to relate only these types of nodes. However, when an arc of the declared arc type is encountered, the given node types can be used, if needed, to infer the appropriate types of the starting and / or ending nodes.

- `Rigiattr` declares the names of node and / or arc attributes. Each line has the form:
  `attr Node` *nodeAttribute*
  `attr Arc` *arcAttribute*

  △ **Note:** All node types share the same set of possible node attributes; a node type cannot have a different set of attributes from another node type. This also applies to arc types and arc attributes. (However, nodes and arcs can have differing attribute values from each other.)

- `Rigicolor` determines node and arc colors.

  ☛ **Tip:** It is simplest to configure these colors within `rigiedit`.

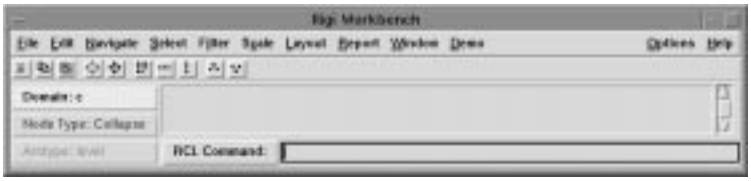
- `Rigircl` is a Tcl script to be run when switching to this domain.

Typically, a domain has a Collapse node type (§4.10.1) declared in the `Riginode` file. If omitted, this node type is automatically added.

☛ **Tip:** It is useful to include an Unknown node type that `rigiedit` can use to set the (default) types of nodes that are somehow untyped (or yet to have their types inferred). If included, this node type should appear as the first entry in the `Riginode` file.

Also, a domain typically has level and composite arc types (§4.11.1) declared in the `Rigiarc` file. If omitted, these arc types are automatically added.

4.4.2 Switching the current domain model



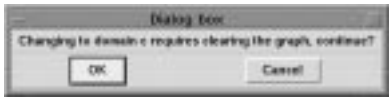
To switch the current domain model:

1. **Click the Domain button in the Workbench window.**

   A Domain palette appears.

2. **Pick the desired domain from the palette.**

   You are reminded that changing domain models clears the graph in memory.



3. **Click OK to continue.**

   Or click Cancel to cancel.

   The loaded domain model includes a specification of the valid node and arc types, attributes, and the optional script to be run (§4.4.1).

4.5 Running Scripts

You can program the editor by writing scripts using the *Rigi Command Library* (RCL) to automate tasks, customize features, and integrate capabilities. There is an RCL command corresponding to each menu command.

☞ **Tip:** For most tasks in the handbook, the corresponding RCL command(s) are listed at the end of the task description.

These commands (and others) can be assembled into procedures using the Tcl scripting language; this language is described in the book:

> John K. Ousterhout, *Tcl and the Tk Toolkit*, Addison-Wesley, April 1994, ISBN 0-201-63337-X.

★ **Technical:** The editor uses Tcl 7.4, Tk 4.0, and Tix 4.1.0.

When `rigiedit` starts, it loads the system RCL startup script specified by the configuration parameter `RIGIRCL`.

★ **Technical:** This file essentially defines RCL in terms of more primitive commands (prefixed by double underscores); you can completely redefine RCL if you want.

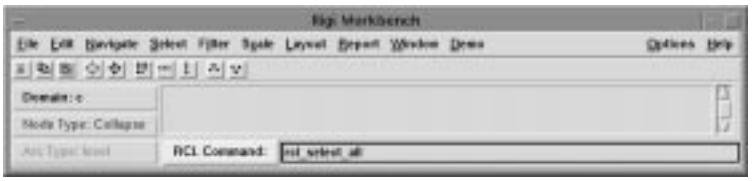
Then `rigiedit` loads your personal RCL startup script specified by the configuration parameter `RIGIURCL` (if defined). Then, if so specified, the script file specified in the `-i` command-line option (§4.1) to `rigiedit` is loaded.

A domain model may also specify a domain-specific script to be run initially whenever the model is loaded (§4.4.1). This script is named `Rigircl` and is stored in a subdirectory, of the same name as the domain, within a directory pointed to by the configuration parameter `RIGIINIT`.

4.5.1 Entering a script command

To enter a script command:

1. **Place the pointer in the command entry field and click.**
   The field obtains the keyboard focus; you can now type into it.
2. **Type the desired script command.**



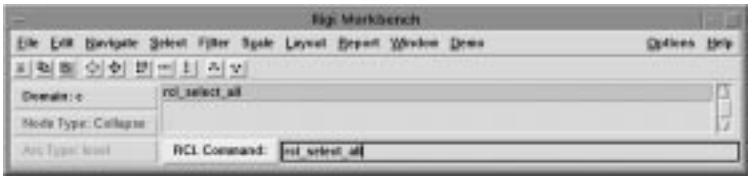
   Press the enter key after typing each command.

△ **Note:** RCL is case sensitive.

4.5.2 Retrieving previously entered commands

As each command is entered, it is put into a scrollable command history list located below the menubar.

- **Click on a command in the list to automatically place it into the command entry field.**

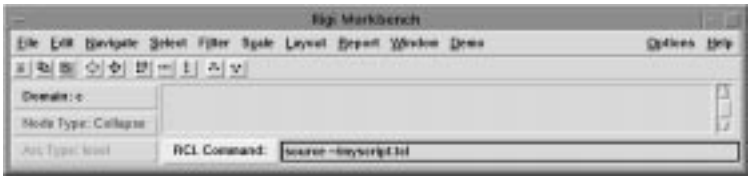


- **Double-click on a command in the list to run it immediately.**
  This command is also appended to the bottom of the list.

4.5.3 Loading and running a script file

To load a file of script commands:

1. **Place the pointer in the command entry field and click.**
2. **Enter** `source`**, space, and the filename of the script file.**



The script file is loaded and run.

☛ **Tip:** Like the C shell, a leading ∼ in the filename can be used to refer to a user home directory.

4.5.4 Listing available commands

To list the available Tcl procedures or RCL commands:

1. **Click the RCL Command: button in the Workbench window.**

   A Commands dialog appears.

2. **Pick the Procedures choice in the dialog.**
   A list of Tcl commands matching the filter string in the dialog is presented.

   ☛ **Tip:** If the command entry field is non-empty when you clicked on the RCL Command: button, the (partial) entry is used as the basis for filtering items in the list.

3. **Type in a filter string and press the enter key to update the list.**

   The filter string can contain wildcard characters: '?' will match any single character, and '*' will match a sequence of zero or more characters.

   All RCL commands have the same `rcl_` prefix. Some useful filter strings are:

`rcl_open_*`	open windows	`rcl_filter_*`	filter objects
`rcl_win_*`	control windows	`rcl_scale_*`	scale nodes
`rcl_node_*`	node operations	`rcl_group_*`	arrange nodes
`rcl_arc_*`	arc operations	`rcl_set_*`	set values
`rcl_select_*`	select objects	`rcl_get_*`	get values

4. **Select a command from the list.**

5. **If desired, click Show Script to present the argument list and body of the selected command.**

   Or double-click a command from the list.

   A textual window appears; you can have several such windows at the same time.

6. **If desired, click Enter Command to transfer the selected command to the command entry field.**

7. **Click Done to dismiss the dialog.**

4.5.5 Listing global variables

To list the current global Tcl variables:

1. **Click the RCL Command: button in the Workbench window.**

   A Commands dialog appears.

2. **Pick the Global Vars choice in the dialog.**
   A list of global Tcl variables matching the filter string in the dialog is presented.
3. **Type in a new filter string and press the enter key to update the list.**
   The filter string can contain wildcard characters: '?' will match any single character, and '*' will match a sequence of zero or more characters.
4. **Select a variable from the list.**
5. **If desired, click Show Value to present the current value of the variable.**

   Or double-click a variable from the list.

   If the variable is a scalar, then a message appears with its value. If the variable is an array, then a textual window appears, listing all the individual elements; you can have several such windows at the same time.

6. **Click Done to dismiss these windows or the dialog.**

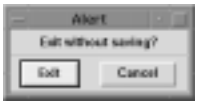
4.6 Finishing Up

4.6.1 Exiting

To exit `rigiedit`:

1. **Choose Exit from the File menu.**

   An alert appears, reminding you that exiting does not save the graph.



2. **Click Exit to exit.**

   Or click Cancel to cancel.

`rcl_quit`
`rcl_quit_no_verify`

4.6.2 Aborting

To abort `rigiedit` under Unix:

1. **Bring the shell window from which you launched `rigiedit` to the foreground.**

   If necessary, bring the `rigiedit` process to the foreground.

2. **Type Ctrl-c to stop `rigiedit`.**

   ★ **Technical:** The `rigiedit` program traps the resulting SIGINT signal.

   You will be prompted whether you really want to exit.

   ```
   Quit rigiedit? [y/n]:
   ```

3. **Type a `y` for yes or `n` for no.**

   If yes, you will be prompted whether to dump a core file (an image of `rigiedit` in memory) for debugging purposes.

   ```
   Dump a core file? [y/n]:
   ```

   ☛ **Tip:** You normally do not want to dump a core file.

4. **Type `y` or `n`.**

To abort `rigiedit` under Windows 95:

- **Press Ctrl-Alt-Del and select `rigiedit` as the task to terminate from the provided task list.**

4.7 Working with Graphs

4.7.1 Rigi Standard Format

Rigi Standard Format (RSF) is the main file format for graphs in `rigiedit`. There are two major dialects of RSF: unstructured and structured. In general, external tools, conceptual modelers, and parsers provide unstructured RSF for `rigiedit`, and `rigiedit` saves the graph as structured RSF, including spatial information such as the subsystem hierarchy.

The following describes unstructured RSF.

An RSF file or stream consists of a sequence of triples, one triple on a line. Blank lines and comment lines starting with # are allowed. The format for a triple is three optionally quoted strings; the quotes are useful if the string contains whitespace characters:

verb subject object

The RSF files contain information such as actual software artifacts (and are described below). Domain-model files specify the valid verbs for these *token-level* RSF files (§4.4).

An RSF triple can represent an arc between two nodes to the graph editor:

arcType startNodeName endNodeName

For example, using a domain model that has Function and Data type nodes interconnected by call and data access arcs, a token-level RSF stream then contains triples like:

```
call    main          printf
call    main          listcreate
data    main          FILE
data    listcreate    List
...
```

As well, an RSF triple can bind values to attributes of nodes:

nodeAttribute nodeName attributeValue

For example, you might note the defining file and line number where the definition of a function occurs:

```
file    listcreate    "list.c"
lineno  listcreate    10
...
```

Such information would allow you to write a Tcl procedure that opens a text editor at the function definition.

A particularly important triple assigns the type of a node:

`type` *nodeName nodeType*

For example, to note function names:

```
type    listcreate    Function
```

This is sometimes unnecessary. The type of a node can be inferred from the types of arcs connecting to (from) it if one of these arc types (declared in the domain model) specifies the ending (starting) node type.

For example, call arcs in the provided C domain model each relate two Function nodes. Thus, `main` and `listcreate` are inferred as Function nodes in this triple:

```
call    main          listcreate
```

△ **Note:** Binding values to attributes of arcs and naming arcs are not supported in unstructured RSF.

4.7.2 Saving a graph

To save the graph model in memory to a file:

1. **Choose Save Graph As ... from the File menu.**
   A File dialog appears.
2. **Type a filename for the graph.**

   ☛ **Tip:** A suffix of `.rsf` is useful for distinguishing graph files. If no file suffix is specified, `.rsf` is added automatically.
3. **Click OK to save the graph.**
   Or click Cancel to cancel.
   The graph is saved as structured RSF.

△ **Note:** To save visual information such as node positions, you need to save `rigiedit` views (§4.18.1).

`rcl_save`

4.7.3 Loading a graph

▲ **Warning:** When loading a graph, you *must* ensure that the correct domain model is being used.

To load a file containing a graph into memory:

1. **Change to the appropriate domain.**
   See §4.4.2.
2. **Choose Load Graph ... from the File menu.**
   A File dialog appears, presenting a view of the current directory contents.
3. **Select the file containing the graph to load.**
4. **Click OK to load the graph.**
   Or click Cancel to cancel.
   If loading a graph, an alert appears, reminding you that the graph in memory will be cleared.

`rcl_load`

4.7.4 Clearing a graph

To empty or clear the graph model in memory:

1. **Choose Initialize from the File menu.**

   An alert appears, reminding you that initializing does not save the graph before clearing it.

2. **Click Initialize.**

   A File dialog appears, prompting you to (re)set the database directory used for loading and saving graph, view, and annotation files.

3. **If necessary, specify a database directory, then click OK to clear the graph.**

   Or click Cancel to cancel.

4.8 Window Basics

The `rigiedit` editor opens separate windows to provide multiple, usually editable perspectives of the graph model. Most of these windows have a scrollable *canvas* area, where a particular set of nodes and arcs is presented, and a message area at the bottom where informational messages are displayed. For example, a canvas window may present an overview of the subsystem hierarchy or the children of a parent node.
The initial window titled Root is used to display the parent(s) of the subsystem hierarchy; this window is always present.

The editor has a notion of a currently *active* window, where operations are applied. A mouse click in a window causes that window to become active and display ACTIVE in its title.

△ **Note:**
On Unix platforms, the active window is unrelated to the pointer focus.

Most of the mouse interaction with `rigiedit` is through the left mouse button (such as choosing menu items or clicking buttons); the right mouse button is used only within a canvas area.

You can use the frame or control gadgets of a window to iconize, maximize, raise, lower, or delete windows. These operations depend on the window manager or operating system being used.

4.8.1 Window types

There are five major types of canvas windows (in decreasing order of flexibility and consistency):

- general
- projection,
- overview,
- scratch (clipboard), and
- SHriMP.

Also, there are four types of general canvas windows:

- children,
- parents,
- neighbors, and
- selection.

Do not confuse these canvas window types with the other specialized dialogs, alerts, and windows used in `rigiedit`.

The title bar of a canvas window indicates its type, its numeric ID (optional), its label, and whether it is active (optional).

△ **Note:** Text editor windows may be spawned by `rigiedit` to display report, annotation, or source data; these windows are controlled by processes that are independent of `rigiedit` and do not respond to actions chosen from the Window menu.

4.8.2 Activating a window

To make a canvas window the current active window:

- **Click the left or right mouse button on the canvas of the window.**

  ☛ **Tip:** Right-clicking does not disturb the current selection.

4.8.3 Raising the active window

To raise the active window:

- **Choose Raise Active from the Window menu.**

  The active window is raised above all other canvas windows. Also raised are all the filter dialogs, attribute dialogs, and Information windows associated with it.

4.8.4 Stacking (cascading) the windows

To neatly stack the canvas windows:

- **Choose Cascade from the Window menu.**

  The canvas windows are stacked (offset slightly), with the active window on top.

△ **Note:** SHriMP windows are not included in the cascade.

4.8.5 Refreshing a window

To refresh the displayed contents of the active window:

- **Choose Refresh from the Window menu.**

  The contents of the active window are redrawn, fixing anything that may have garbled its display.

`rcl_refresh`

4.8.6 Updating a window

To update the displayed contents of the active window because of a change to the graph model:

- **Choose Update from the Window menu.**

  The active window updates its contents to match the graph model.

△ **Note:** You may need to update windows that have been outdated because of a change to the graph model initiated in another window or by a script.

`rcl_update`

4.8.7 Closing the active window

To close the active window:

- **Choose Close Active from the Window menu.**
  The active window is closed along with the following other windows:
  - any related Filter by Node Type dialog,
  - any related Filter by Arc Type dialog,
  - any information windows opened on a node in the active window;
  - any attribute editors opened on a node or arc in the active window.

  ☛ **Tip:** You can also close a window through your window manager.

△ **Note:** The root window cannot be closed.

`rcl_close`

4.8.8 Closing all windows

To close all windows:

- **Choose Close All from the Window menu.**
  All `rigiedit` windows close except for the root window.

△ **Note:** The root window cannot be closed.

`rcl_close_all`

4.8.9 Bringing up the Settings dialog

To bring up the Settings dialog:

- **Choose Settings from the Options menu.**

  The Settings dialog appears, presenting various settings that you can adjust; these settings are described elsewhere in this handbook.

△ **Note:** Any changes to these settings are committed immediately.

4.9 Making Selections

You can select nodes, arcs, and subgraphs that are in the active window based on various criteria. Selected nodes are highlighted in the canvas by being drawn in a solid color. A selected arc is highlighted by a wider line.

Because of multiple perspectives on the same graph model, the same essential selected node(s) may appear highlighted in separate windows.

4.9.1 Selecting a node

To select a single node:

1. **Place the pointer over the node to select and click the left mouse button.**
   The node becomes selected and all other nodes and arcs become deselected.

4.9.2 Selecting an arc

To select a single arc:

1. **Place the pointer over the arc to select and click the left mouse button.**
   The arc becomes selected and all other nodes and arcs become deselected.

△ **Note:** Only one arc can be selected at a time (among all windows).

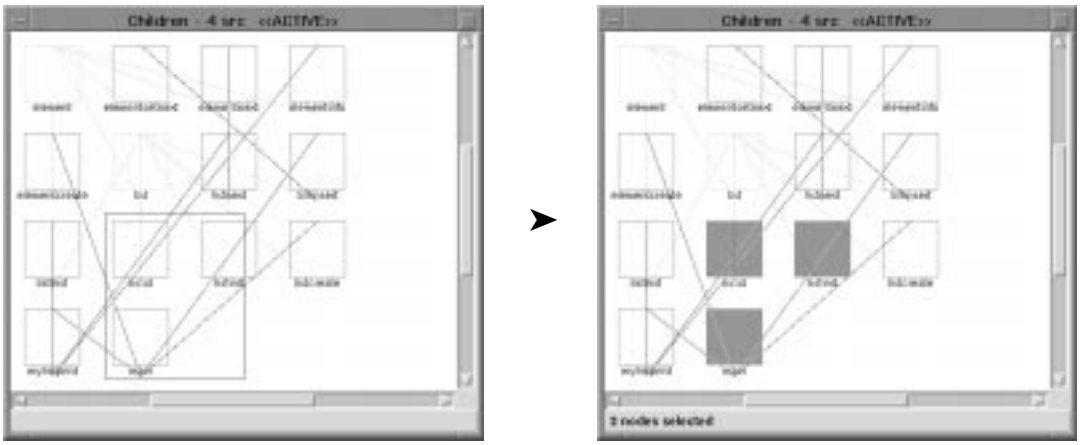
4.9.3 Selecting grouped nodes by dragging

To select a group of nodes by dragging:

1. **Place the pointer over a clear area of the canvas above and to the left of the group of nodes you want to select.**
2. **Press the left mouse button and drag down and to the right around the group.**

   A rectangle appears, enclosing the nodes you want to select.
3. **Release the mouse button.**

   Any nodes that are either completely or partly inside the selection rectangle become selected.



4.9.4 Selecting and deselecting nodes by shift-clicking

You can select nodes, perhaps in scattered locations within a window, using this technique.

1. **Select a node.**
2. **Hold down the shift key and continue to select or deselect individual nodes by clicking the left mouse button.**

   If the clicked node was selected, it is deselected; if the node was not selected, it is added to the current selection. Any other selected nodes or arc are not affected.

4.9.5 Selecting all nodes

To select all the nodes in the active window:

- **Choose All from the Select menu.** All nodes in the active window are selected.

The accelerator key for this operation is Ctrl-a.

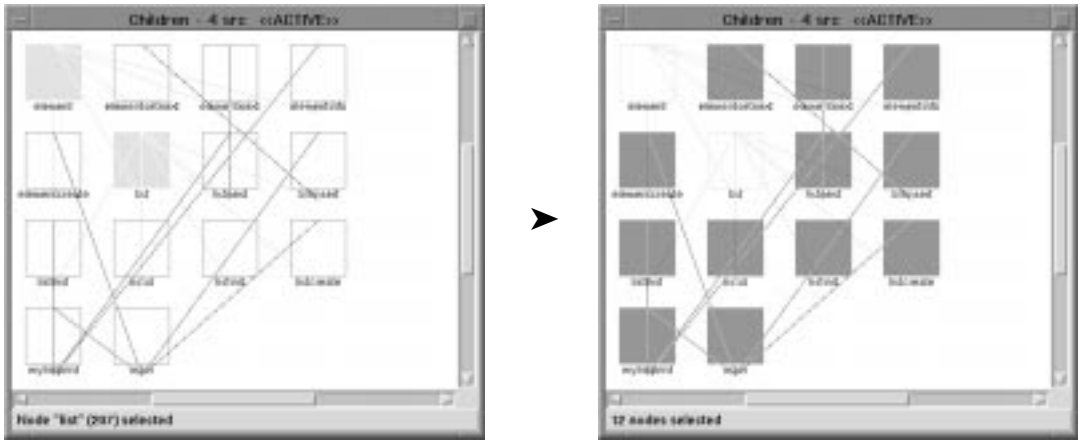
`rcl_select_all`

4.9.6 Complementing selected nodes

Sometimes it's quicker to select what you don't want and taking the complement.

- **Choose Complement from the Select menu.**

  Nodes not selected become selected and nodes already selected become deselected.



`rcl_select_invert`

4.9.7 Deselecting a node

To deselect a node:

1. **Place the pointer over the selected node to deselect.**
2. **Hold down the shift key and click the left mouse button.**
   The clicked node is deselected.

4.9.8 Deselecting all nodes

To deselect all nodes in the active window:

- **Place the pointer over a clear area of the canvas and click the left mouse button.**
  You can also choose None from the Select menu.
  All selected nodes in the active window become deselected.

`rcl_select_none`

4.9.9 Selecting nodes by name

Sometimes it's quicker to select nodes by matching on their names.

To select nodes by matching on their names:

1. **Choose By Name ... from the Select menu.**
   A Select by Name dialog appears.
2. **Enter a search string.**
   The search string can contain wildcard characters: '?' will match any single character, and '*' will match a sequence of zero or more characters.

3. **Toggle the Search Entire Graph item as required.**
   Toggle on this item if you want to search for nodes in the whole graph model, or toggle off this item to search only in the active window.
4. **Click Select to start the search.**
   Nodes with names matching the search string are selected.
   A series of searches is possible; if you hold down the shift key while clicking Select, the matching nodes are added to the current selection (rather than replacing it).

4.9.10 Selecting nodes by attribute

Nodes can be selected according to whether they have a specific value for a particular node attribute. Node attributes are domain specific.

To select nodes by matching on their attributes:

1. **Choose By Attribute ... from the Select menu.**
   A Select by Attribute dialog appears.
2. **Pick a node attribute from the Node Attribute popup menu of the dialog.**

3. **Enter the desired attribute value to match in the Value: entry field.**
   The value can contain wildcard characters: '?' will match any single character, and '*' will match a sequence of zero or more characters.
4. **Toggle the Search Entire Graph item as required.**
   Toggle on this item if you want to search for nodes in the whole graph model, or toggle off this item to search only in the active window.
5. **Click Select to start the search.**
   Nodes with an attribute value matching the specified one are selected.
   A series of searches is possible; if you hold down the shift key while clicking Select, the matching nodes are added to the current selection (rather than replacing it).

4.9.11 Selecting nodes by structure

Nodes can be selected based on their node type and the arc type, direction, and number of arcs incident to them.

To select nodes by matching on their incident arc structure in the active window:

1. **Choose By Structure ... from the Select menu.**
   A Select by Structure dialog appears.

2. **Toggle on the desired set of node types from the Node types popup menu of the dialog.**

   The any choice in the popup menu matches any node type.

3. **Toggle on the desired set of arc types from the Arc types popup menu of the dialog.**

   The any choice in the popup menu matches any arc type.

   Since composite arcs may contain (elided) non-composite arcs of the specified arc type, the search may pass through these composite arcs to select the matching nodes. The composite arc type choice matches only composite arcs.

   △ **Note:** The arc type set must be non-empty.

4. **Select an arc direction from the Direction popup menu.**

   The in choice specifies incoming, the out choice specifies outgoing, and the any choice specifies any direction.

5. **Enter an arc count in the Count: entry field.**

6. **Select the type of arithmetic comparison to the arc count from the Comparison popup menu of the dialog.**

   The five comparison operators are: lt (less than), le (less than or equal), eq (equal), ge (greater than or equal), and gt (greater than).

7. **Click Select to start the search.**

   Nodes with the specified node types are selected if the count of the incident arcs of the specified arc type and direction match according to the comparison operator.

   A series of searches is possible; if you hold down the shift key while clicking Select, the matching nodes are added to the current selection (rather than replacing it).

4.9.12 Selecting nodes by type

To select nodes by node type:

1. **Choose By Structure ... from the Select menu.**

   A Select by Structure dialog appears.

2. **Toggle on the desired set of node types from the Node types popup menu of the dialog.**

   The any choice in the popup menu matches any node type.

3. **Enter 0 (zero) as an arc count in the Count: entry field.**

4. **Select eq from the Comparison popup menu of the dialog.**

5. **Click Select to start the search.**

   Nodes with the specified node types are selected in the active window.

   A series of searches is possible; if you hold down the shift key while clicking Select, the matching nodes are added to the current selection (rather than replacing it).

4.9.13 Selecting neighboring nodes along outgoing arcs

To select neighboring nodes along outgoing arcs:

1. **Select one or more source nodes.**
2. **Pick the appropriate arc type for the outgoing arcs from the Arc Type palette.**

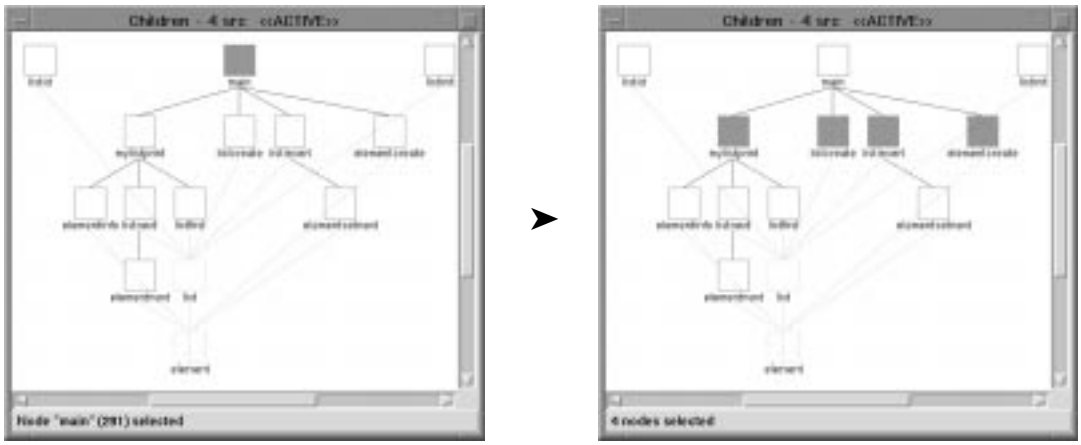
   The any choice in the palette matches any arc type.

   Since composite arcs may contain (elided) non-composite arcs of the specified arc type, the search may pass through these composite arcs to select the matching nodes. The composite arc type choice matches only composite arcs.

3. **Choose Outgoing Nodes from the Select menu.**

   Neighboring nodes that are connected to any of the source nodes by outgoing arcs of the specified type become selected.

   If you hold down the shift key while choosing the Outgoing menu item, the neighboring nodes are added to the previously selected source nodes (rather than replacing them).



4.9.14 Selecting neighboring nodes along incoming arcs

To select neighboring nodes along incoming arcs:

1. **Select one or more destination nodes.**
2. **Pick the appropriate arc type for the incoming arcs from the Arc Type palette.**

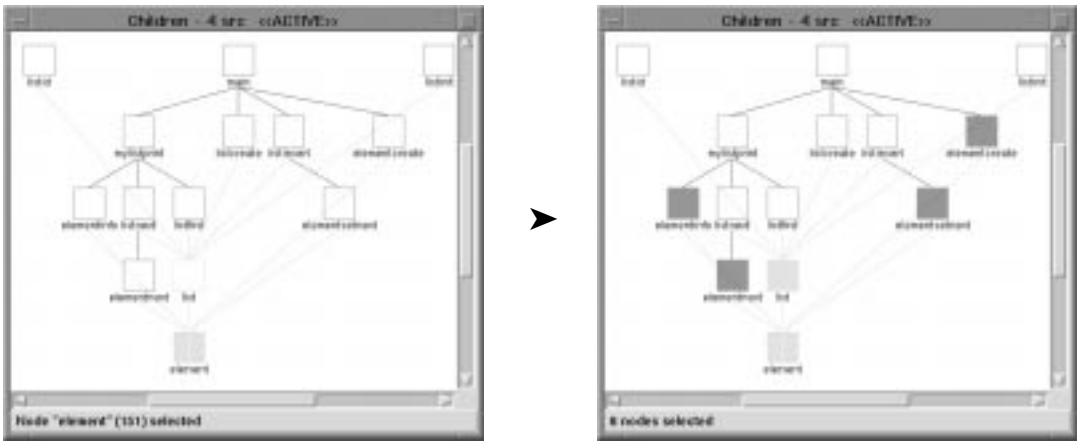
   The any choice in the palette matches any arc type.

   Since composite arcs may contain (elided) non-composite arcs of the specified arc type, the search may pass through these composite arcs to select the matching nodes. The composite arc type choice matches only composite arcs.

3. **Choose Incoming Nodes from the Select menu.**

   Neighboring nodes that are connected to any of the destination nodes by incoming arcs of the specified type become selected.

   If you hold down the shift key while choosing the Incoming menu item, the neighboring nodes are added to the previously selected destination nodes (rather than replacing them).



4.9.15 Selecting reachable nodes along outgoing arcs

You can select all the nodes on which a selected group of nodes depends.

To select reachable nodes along outgoing arcs:

1. **Select one or more starting nodes.**
2. **Pick the appropriate arc type for the outgoing arcs from the Arc Type palette.**

   The any choice in the palette matches any arc type.

   Since composite arcs may contain (elided) non-composite arcs of the specified arc type, the search may pass through these composite arcs to select the matching nodes. The composite arc type choice matches only composite arcs.
3. **Choose Forward Tree from the Select menu.**

   Nodes that are reachable along outgoing arcs of the specified type from the starting nodes become selected.

   The reachable nodes are added to the previously selected starting nodes (rather than replacing them).

`rcl_select_forward_tree`

4.9.16 Selecting reachable nodes along incoming arcs

You can select all the nodes which depend on a selected group of nodes.

To select reachable nodes along incoming arcs:

1. **Select one or more starting nodes.**
2. **Pick the appropriate arc type for the incoming arcs from the Arc Type palette.**

   The any choice in the palette matches any arc type.

   Since composite arcs may contain (elided) non-composite arcs of the specified arc type, the search may pass through these composite arcs to select the matching nodes. The composite arc type choice matches only composite arcs.
3. **Choose Reverse Tree from the Select menu.**

   Nodes that are reachable along incoming arcs of the specified type to the starting nodes become selected.

   The reachable nodes are added to the previously selected starting nodes (rather than replacing them).

`rcl_select_reverse_tree`

4.10 Working with Nodes

When working with nodes, you need to select them before applying an operation.

4.10.1 Node types

In a `rigiedit` operation, you may be required to specify a particular node type (through the Node Type palette). Most node types are domain-specific; following is a description of the domain-independent node types that arise when producing a subsystem containment hierarchy.

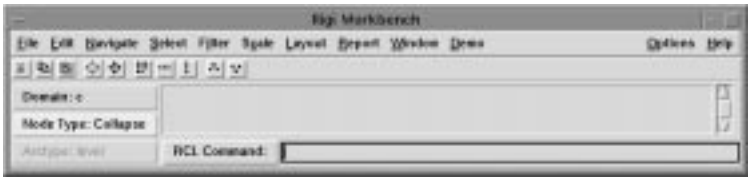
- Collapse

  Nodes of this type are subsystems that contain other nodes and are formed by collapsing these other nodes.

The Collapse node type is automatically added if not present in the loaded domain model.

★ **Technical:** Multiple types of subsystem nodes are supported through RCL commands. Essentially, any node type can become the current subsystem node type. By default, the current subsystem node type is the one named Collapse.

4.10.2 Changing current node type



To change the global current node type (used as a parameter in many `rigiedit` operations):

1. **Click the Node Type button in the Workbench window.**

   A Node Type palette appears.

2. **Pick the desired node type from the palette.**
   Or move the pointer outside this palette to cancel.

   This palette causes certain operations to consider only specific node types.

4.10.3 Renaming a node

To rename a node:

1. **Choose Rename from the Node menu for the node.**
   A dialog appears for entering the new name.

2. **Type in the new node name and press the enter key (or click Rename).**
   Or click Cancel to cancel.

`rcl_node_rename`

4.10.4 Changing the type of a node

To change the node type of a particular node:

1. **Choose Set Type from the Node menu for the node.**
   A palette appears, presenting a choice of node types.
2. **Pick a new node type by clicking on the appropriate choice.**
   Or move the pointer away to cancel.

4.10.5 Editing attributes of a node

To edit the attributes of a node:

1. **Choose Edit Attributes from the Node menu of the node.**
   An Attributes dialog appears, listing the available node attributes and their values.

2. **Pick a node attribute from the list and click Edit.**
   A dialog appears for changing the value of the attribute.
3. **Type in the desired value and press the enter key (or click Change).**
   The new value appears in the Attributes dialog.
4. **Click Done to commit the changes and dismiss the dialog.**
   Or click Cancel to cancel.

4.10.6 Editing annotation for a node

Each node can have an annotation file linked to it. This file is specified by the annotate attribute for the node. The value of this attribute can be modified (§4.10.5). The annotation files are stored in the directory named in the configuration parameter DBDIR.

To edit the annotation for a node:

- **Choose Edit Annotation from the Node menu of the node.**

  A Text editor window appears, after loading the annotation file for the node. If the annotate attribute is empty, a new filename is created and entered as the attribute value before loading. The editor is a separate process outside the direct control of rigiedit.

▲ **Warning:** The DBDIR parameter must be set to an existing, writeable directory (§4.3.6); otherwise, the annotations will not be saved properly.

☞ **Tip:** If a node in a SHriMP window is a leaf in the subsystem hierarchy, you can double-left-click on it to view its annotation.

4.10.7 Editing the source text for a node

Each node can have a text file linked to it (such as source code or documentation). This file is specified by the file attribute for the node. A line position within the file is specified by the lineno attribute. The values of these attributes can be modified (§4.10.5). The source files are stored in the directory named in the configuration parameter SRCDIR.

If the file attribute is not empty, then to edit the associated text for a node:

- **Choose Edit Source from the Node menu for the node.**

  A Text editor window appears, after loading the text file linked to the node. If the lineno attribute is not empty, then it is used to point the text editor to that line in the file. The editor is a separate process outside the direct control of rigiedit.

☛ **Tip**: If a node in a non-SHriMP window is a leaf in the subsystem hierarchy, you can double-left-click on it to edit the associated text file.

4.10.8 Opening a URL for a node

Each node can have a Uniform Resource Locator (URL) associated with it. This may be used to launch a web browser and connect to hypertext pages or the World Wide Web. This URL is specified by the nodeurl attribute for the node, prepended by the string in the configuration parameter `WEBROOT`. The web browser, which must be running, is named in the configuration parameter `WEBBROWSER` (§4.3.8).

If the nodeurl attribute is not empty, then to follow the URL for a node:

- **Choose Open URL from the Node menu for the node.**

  The web browser is a separate process outside the direct control of `rigiedit`.

4.10.9 Changing node type colors

To change the color of a node type:

1. **Choose Node Colors from the Options menu.**
   An Node Colors dialog appears.
2. **Pick a node type from the dialog.**
3. **Adjust the color for the specified node type using the sliders.**
   All nodes of the given type are immediately changed to the new color.
   The color model used is RGB; a higher value for a color component adds more of that color.
   If necessary, pick other node types and change their colors.

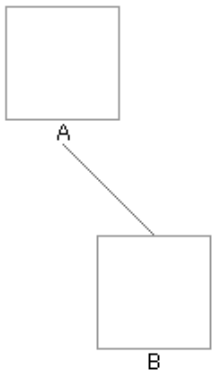
   △ **Note:** The windows display the new color scheme only as they are redrawn; you may need to explicitly refresh the windows to see the new colors (§4.8.5).
4. **Click Save to permanently save the node colors to the `Rigicolor` file of the current domain.**

   This step is optional.
5. **Click Done to dismiss the dialog.**

△ **Note:** You cannot change the color of a particular node independently; colors are tied to node *types*.

4.11 Working with Arcs

Arcs or relationships connecting nodes in the graph are displayed as lines. Arcs can be of various types, as specified in the domain model; they are distinguished with customizable colors. An arc is only drawn if both node endpoints are visible in the window.
Arcs are also directed. An arc *from* source node A *to* destination node B is represented as a line from the *bottom* of node A to the *top* of node B. Node A is called a *client* of node B and node B is called a *supplier* of node A. The arc is an *outgoing* arc of node A and an *incoming* arc of node B. A node may have an arc going to itself, for a recursive relationship. You see this as a line from the bottom of a node to its top.



When working with arcs, you need to select them before applying an operation.

4.11.1 Arc types

In a `rigiedit` operation, you may be required to specify a particular arc type (through the Arc Type palette) or a set of arc types (through the Arc Type Set popup menu in the Settings dialog).

Most arc types are domain-specific; following is a description of the domain-independent arc types that arise when producing a subsystem containment hierarchy.

- level

  A level arc spans two adjacent levels in a subsystem hierarchy.

- composite

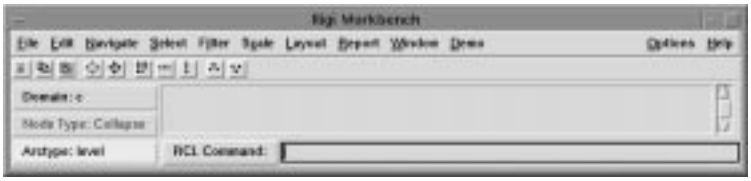
  A composite arc represents a bundle of one or more arcs of different types.

  Subsystem nodes generally have composite arcs incident to them.

The level and composite arc types are automatically added if not present in the loaded domain model.

★ **Technical:** Multiple types of level and composite arcs are supported through RCL commands. Essentially, any arc type can become the current level or composite arc type. By default, the current level and composite arc types are the ones named, respectively, level and composite.

4.11.2 Changing current arc type



To change the global current arc type (used as a parameter in many `rigiedit` operations):

1. **Click the Arc Type button in the Workbench window.**
   An Arc Type palette appears.

2. **Pick the desired arc type from the palette.**
   Or move the pointer outside this palette to cancel.

   This palette causes certain operations to consider only specific arc types. The any choice in the palette matches any arc type.

4.11.3 Changing the type of an arc

To change the arc type of an arc:

1. **Choose Set Type from the Arc menu for the arc.**
   A palette appears, presenting a choice of arc types.

2. **Pick a new arc type by clicking on the appropriate choice.**
   Or move the pointer away to cancel.

4.11.4 Editing attributes of an arc

To edit the attributes of an arc:

1. **Choose Edit Attributes from the Arc menu of the arc.**
   An Attributes dialog appears, listing the available arc attributes and their values.

2. **Pick an arc attribute from the list and click Edit.**
   A dialog appears for changing the value of the attribute.
3. **Type in the desired value and press the enter key (or click Change).**
   The new value appears in the Attributes dialog.
4. **Click Done to commit the changes and dismiss the dialog.**
   Or click Cancel to cancel.

4.11.5 Editing annotation for an arc

Each arc can have an annotation file linked to it. This file is specified by the annotate attribute for the arc. The value of this attribute can be modified (§4.11.4). The annotation files are stored in the directory named in the configuration parameter `DBDIR`.

To edit the annotation for an arc:

- **Choose Edit Annotation from the Arc menu of the arc.**
  A Text editor window appears, after loading the annotation file for the arc. If the annotate attribute is empty, a new filename is created and entered as the attribute value before loading. The editor is a separate process outside the direct control of `rigiedit`.

▲ **Warning:** The `DBDIR` parameter must be set to an existing, writeable directory (§4.3.6); otherwise, the annotations will not be saved properly.

4.11.6 Opening a URL for an arc

Each arc can have a Uniform Resource Locator (URL) associated with it. This may be used to launch a web browser and connect to hypertext pages or the World Wide Web. This URL is specified by the arcurl attribute for the arc, appended to the string in the configuration parameter `WEBROOT`. The web browser, which must be running, is named in the configuration parameter `WEBBROWSER` (§4.3.8).

If the arcurl attribute is not empty, then to follow the URL for an arc:

- **Choose Open URL from the Arc menu for the arc.**
  The web browser is a separate process outside the direct control of `rigiedit`.

4.11.7 Changing arc type colors

To change the color of an arc type:

1. **Choose Arc Colors from the Options menu.**
   An Arc Colors dialog appears.
2. **Pick an arc type from the dialog.**
3. **Adjust the color for the specified arc type using the sliders.**
   All arcs of the given type are immediately changed to the new color.
   The color model used is RGB; a higher value for a color component adds more of that color. If necessary, pick other arc types and change their colors.

   △ **Note:** The windows display the new color scheme only as they are redrawn; you may need to explicitly refresh the windows to see the new colors (§4.8.5).
4. **Click Save to permanently save the arc colors to the `Rigicolor` file of the current domain.**
   This step is optional.
5. **Click Done to dismiss the dialog.**

△ **Note:** You cannot change the color of particular arcs independently; colors are tied to arc *types*.

4.12 Opening windows

You can open new canvas windows to present other perspectives on the graph. Unless otherwise specified, these windows

- allow and preserve arrangements of nodes;
- can be saved in reloadable views.
- support graph modifying operations such as collapse, expand, cut, copy, paste, create node, and create arc;

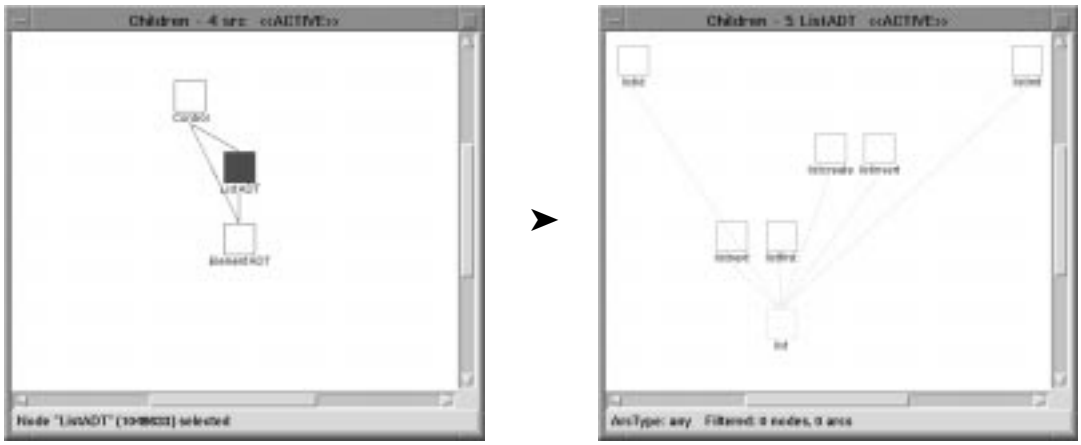
4.12.1 Presenting the children of nodes

To present the children of nodes in a new window:

1. **Select one or more nodes.**
2. **Choose Children from the Navigate menu.**

   The outgoing level arcs of the selected node(s) are followed one level to obtain the children nodes.

   A new Children window appears, presenting all the children nodes of the selected node(s), with relationships among the children nodes shown by various types of arcs from one child to another.



☛ **Tip:** If the node is a non-leaf node in the subsystem hierarchy, you can double-left-click on it to present the children.

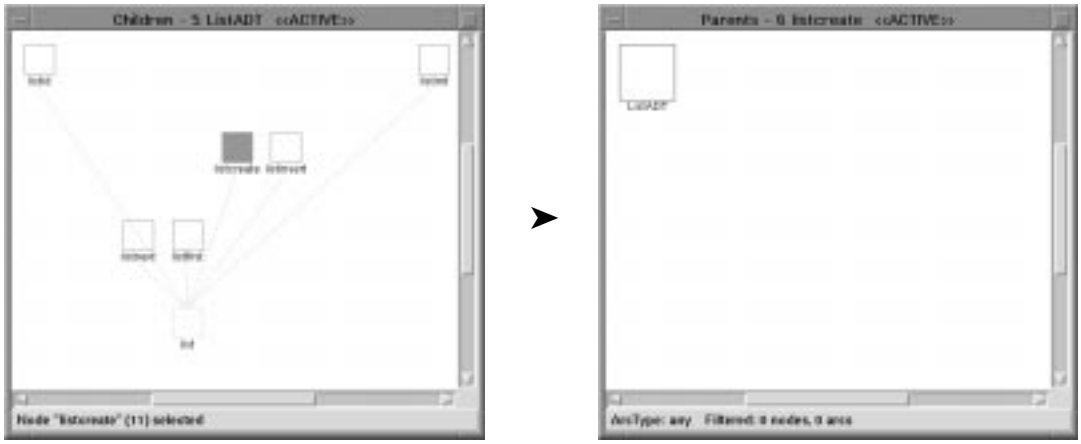
4.12.2 Presenting the parents of nodes

To present the parents of nodes in a new window:

1. **Select one or more nodes.**
2. **Choose Parents from the Navigate menu.**

   The incoming level arcs of the selected node(s) are followed one level to obtain the parent nodes.

   A new Parents window appears, presenting all the parent nodes of the selected node(s), with relationships among the parent nodes shown by various types of arcs from one node to another.



4.12.3 Presenting the neighbors of nodes

To present the neighbors of nodes in a new window:

1. **Select one or more nodes.**
2. **Choose Settings from the Options menu.**
3. **Adjust the Tree Depth slider to specify the distance of the neighboring nodes from the selected nodes.**
   If the slider is -1, the depth is infinite and the full reachability tree would be laid out.

4. **Pick the set of arc types to follow from the Arc Set popup menu in the dialog.**
5. **Click Done to dismiss the dialog.**
6. **Choose Neighbors from the Navigate menu.**

   The incoming and outgoing arcs of the types specified by the arc set are followed up to the given distance to obtain the neighboring nodes.

   A new Neighbors window appears, presenting all the neighbor nodes of the selected node(s), with relationships among the neighbor nodes shown by various types of arcs from one node to another.

4.12.4 Presenting selected nodes in a new window

To present selected nodes in a new window:

1. **Select one or more nodes.**
2. **Choose Selection from the Navigate menu.**

   A new Selection window appears, presenting all the previously selected nodes and the relationships among them.

4.12.5 Presenting a projection

You can show the descendants of a selected group of nodes (at a certain depth) by creating a *projection*. The descendants are presented in a projection window. To produce a projection:

1. **Select one or more nodes to be the roots of the projection.**
2. **Choose Settings from the Options menu.**

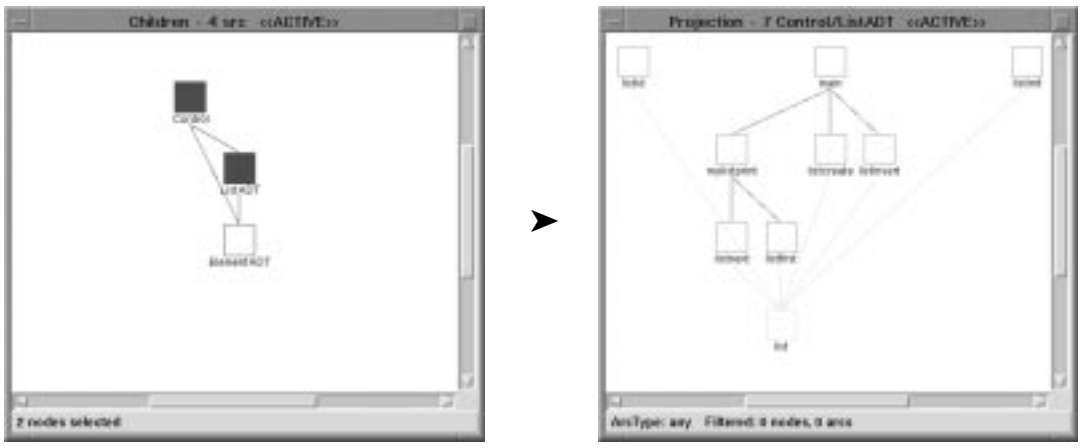
   A Settings dialog appears.
3. **Adjust the Projection Depth slider to the depth you want.**

   If the slider is -1, the projection depth is infinite and a projection would display the "leaf" nodes of the hierarchies rooted at the selected root nodes. If the slider is 0, a projection would display only the selected root nodes.

   Otherwise, a projection displays children nodes at the specified depth. Leaf nodes are included in the projection if the slider value is set too deep for certain branches of the hierarchy.
4. **Choose Projection from the Navigate menu.**

   A new Projection window appears, containing a union of all nodes that are exactly at the specified depth below the selected nodes. The names of the selected nodes that were projected appear on the title bar of the projection window.



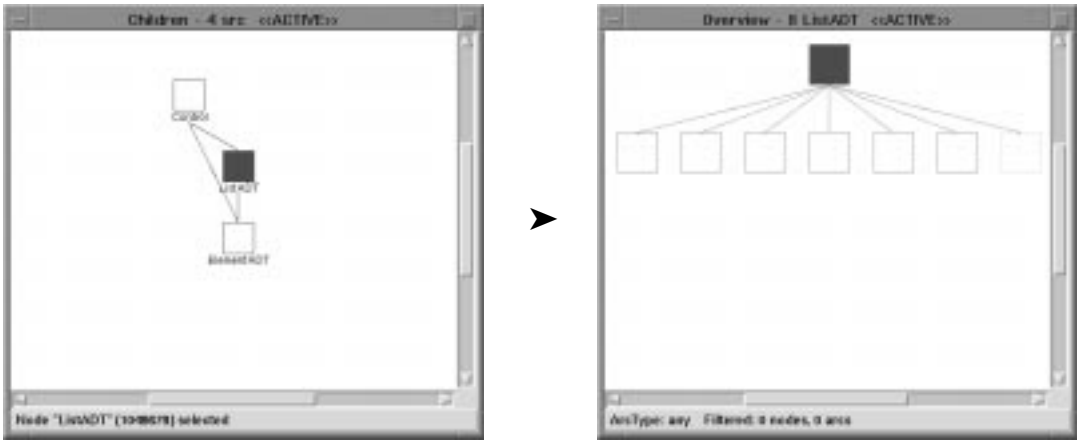
△ **Note:** Projection windows do not support graph modifying operations.

4.12.6 Presenting an overview

You can view the layered, hierarchical subsystem structure rooted at a node by creating an *overview*. The hierarchy is presented in an overview window. To produce an overview:

1. **Select a node to be the root of the overview.**
2. **Choose Overview from the Navigate menu.**

   A new Overview window appears, presenting the tree-like subsystem structure below the specified root node The root node is at the top of the tree in the new window. An Overview window presents a vertical "slice" of the hierarchy. The arcs that span levels in the hierarchy are known as *level* arcs. For clarity, the arcs within a level and the node labels are filtered in an Overview window.



☛ **Tip:** It's useful to resize this window and place it in a corner of the screen while you work.

△ **Note:** Overview windows do not support graph modifying operations.

4.12.7 Presenting a fisheye view

See §4.19.1.

4.13 Editing the Graph

4.13.1 Creating a new node

To create a new node:

1. **Pick a node type for the new node from the Node Type palette.**

2. **Place the pointer at the location where the new node should be added, hold down the shift key, and double-right-click.**

   A node, named `new`, of the specified type is created in the canvas at the given location. You should give the new node a unique name.

   The current selection set is not disturbed.

`rcl_create_node`

4.13.2 Creating a new arc

To create a new arc:

1. **Pick an arc type for the new arc from the Arc Type palette.**

2. **Place the pointer over the starting node, hold down the shift key, and press the right mouse button.**

3. **Drag the pointer to the ending node and release the mouse button.**

   An arc of the specified type is created from the starting node to the ending node.

   The current selection set is not disturbed.

   ☛ **Tip:** To create a self arc, when the starting and ending nodes are the same, drag the pointer to the top of the node and release.
   Trying to “create” an already existing arc merely selects the arc.

△ **Note:**
You cannot directly create level arcs in any window; level arcs are only created when you collapse nodes into a subsystem.
Only up to one arc is permitted between a given source and destination; multi-arcs are not supported.

`rcl_create_arc`

4.13.3 Deleting nodes

To delete nodes:

1. **Select one or more nodes to be deleted.**
2. **Choose Cut from the Edit menu.**

   The selected nodes and the arcs among them are removed from the active window (and placed on the clipboard). The arcs connecting the nodes to the rest of the graph are discarded.

4.13.4 Deleting an arc

To delete an arc:

1. **Select the arc to be deleted.**
2. **Choose Cut from the Edit menu.**

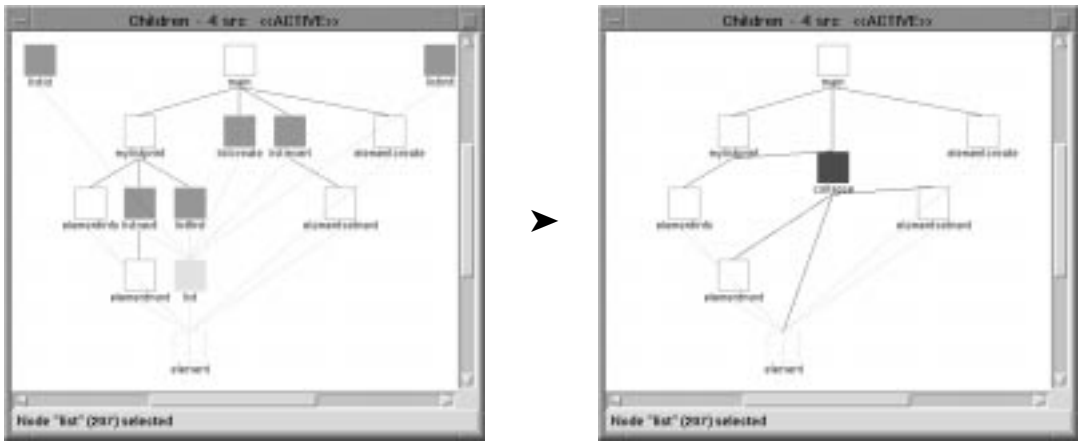
   The selected arc is removed from the active window.

4.13.5 Collapsing a subsystem

To collapse nodes into a subsystem:

1. **Select one or more nodes for the subsystem.**
2. **Choose Collapse from the Edit menu.**

   A new subsystem node is created that has all of the selected nodes as its children, thus simplifying the graph in the active window.



   The previously selected nodes are moved to a lower level in the hierarchy (and are deselected). The new node, named `collapse`, becomes selected; you should provide a more meaningful name.

`rcl_collapse`

4.13.6 Expanding a subsystem

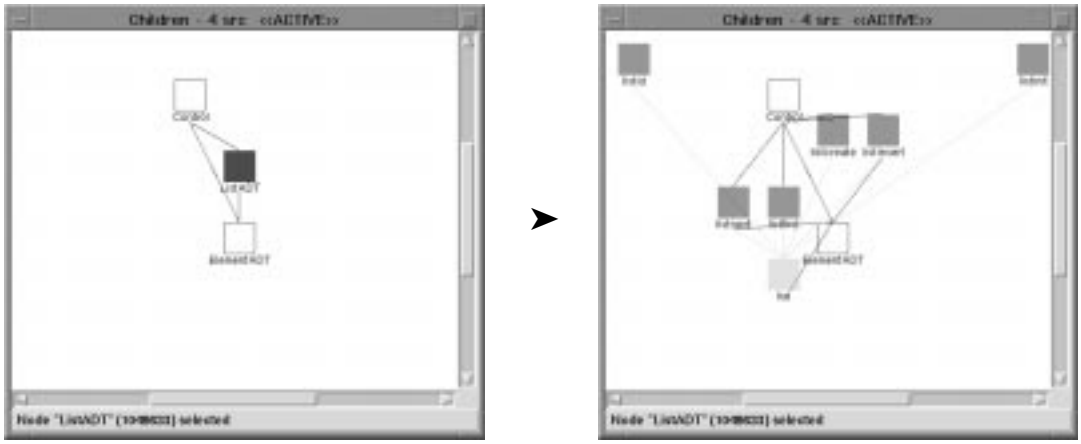
You can perform the opposite of collapsing a subsystem. To expand a subsystem:

1. **Select a subsystem node.**

   A subsystem node contains other nodes. That is, it is a non-leaf node in the subsystem (containment) hierarchy.

2. **Choose Expand from the Edit menu.**

   The selected subsystem node is replaced by the nodes it contains.



△ **Note:** You can only expand one subsystem at a time with the Expand menu command.

`rcl_expand`

4.13.7 Cutting a subgraph

To cut a subgraph:

1. **Select one or more nodes of the subgraph to be cut.**
2. **Choose Cut from the Edit menu.**
   The selected nodes and the arcs among them are removed from the active window and placed on the clipboard. The arcs connecting the subgraph to the rest of the graph are discarded.

The accelerator key for this operation is Ctrl-x.

`rcl_cut`

4.13.8 Copying a subgraph

To copy a subgraph:

1. **Select one or more nodes of the subgraph to be copied.**
2. **Choose Copy from the Edit menu.**
   The selected nodes and the arcs among them are copied to the clipboard.

The accelerator key for this operation is Ctrl-c.

`rcl_copy`

4.13.9 Pasting a subgraph

To paste a subgraph:

- **Choose Paste from the Edit menu.**
  The subgraph stored on the clipboard is added to the active window.

The accelerator key for this operation is Ctrl-v.

`rcl_paste`

4.13.10 Showing the clipboard

To show the clipboard:

- **Choose Show Clipboard from the Edit menu.**

  A window appears presenting the subgraph stored on the clipboard (the most recently cut nodes and the arcs among them).

`rcl_clipboard`

4.13.11 Clearing the clipboard

To clear the clipboard:

- **Choose Clear Clipboard from the Edit menu.**

4.14 Using Filters

You can selectively filter out detail that you wish to hide. Filters do not modify the graph model. A window may have a different set of filters applied to its contents than that of another window.

4.14.1 Hiding names of nodes

You can hide the node labels to reduce the visual clutter when there are many nodes. To hide the names of nodes:

1. **Select one or more nodes whose names are to be hidden.**
2. **Choose By Selection ... from the Filter menu.**
   A Filter by Selection dialog appears.
3. **Click Hide Names from the dialog.**
   The node labels for the selected nodes are hidden in the active window.
4. **Click Done to dismiss the dialog.**

`rcl_filter_hide_name`

4.14.2 Showing names of nodes

To show the names of nodes:

1. **Select one or more nodes whose names are to be shown.**
2. **Choose Filter by Selection ... from the Filter menu.**
   A Filter by Selection dialog appears.
3. **Click Show Names from the dialog.**
   Node labels for the selected nodes are shown in the active window.
4. **Click Done to dismiss the dialog.**

`rcl_filter_show_name`

4.14.3 Hiding selected nodes

To hide a selected group of nodes:

1. **Select one or more nodes to be hidden.**
2. **Choose Filter by Selection ... from the Filter menu.**
   A Filter by Selection dialog appears.
3. **Click Hide Selection from the dialog.**
   The selected nodes and their incident arcs become hidden in the active window.
4. **Click Done to dismiss the dialog.**

▲ **Warning:** The selected nodes remain selected even after filtering. You should left click on a clear area of the canvas to make sure the filtered nodes are deselected.

`rcl_filter_selection`

4.14.4 Showing previously hidden nodes

To show nodes previously hidden by Hide Selection:

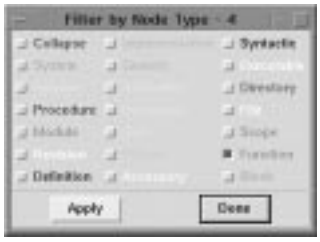
1. **Choose Filter by Selection ... from the Filter menu.**
   A Filter by Selection dialog appears.
2. **Click Unfilter from the dialog.**
   All nodes that had been filtered by Hide Selection become visible in the active window, subject to any node type filters in effect.
3. **Click Done to dismiss the dialog.**

4.14.5 Showing and hiding nodes by type

To show or hide nodes by their node types in the active window:

1. **Choose By Node Type ... from the Filter menu.**

   A Filter by Node Type dialog appears.

   △ **Note:** Settings made in this dialog only affect the window that was active at the time the dialog was brought up; the ID of the relevant window appears in the title bar of the dialog.

2. **Toggle on the node types to hide or toggle off the node types to show in the dialog.**

3. **Click Apply.**

   Nodes in the active window are hidden or shown according to the chosen node type filter settings.

4. **Click Done to dismiss the dialog.**

☛ **Tip:** Use the Filter by Node Type dialog as a legend to the node types in the current domain model.
To reveal this dialog if covered by other windows, choose Raise Active from the Window menu or choose By Node Type ... from the Filter menu again.

4.14.6 Showing and hiding arcs by type

To show or hide arcs by their arc types in the active window:

1. **Choose By Arc Type ... from the Filter menu.**

   A Filter by Arc Type dialog appears.

   △ **Note:** Settings made in this dialog only affect the window that was active at the time the dialog was brought up; the relevant window appears in the title bar of the dialog.

2. **Toggle on the arc types to hide or toggle off the arc types to show in the dialog.**

3. **Click Apply.**

   Arcs in the active window are hidden or shown according to the chosen arc type filter settings.

4. **Click Done to dismiss the dialog.**

☛ **Tip:** Use the Filter by Arc Type dialog as a legend to the arc types in the current domain model.
To reveal this dialog if covered by other windows, choose Raise Active from the Window menu or choose By Arc Type ... from the Filter menu again.

4.14.7 Inheriting filter settings

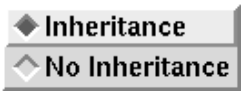
To inherit the filter settings of the active window when opening new windows:

1. **Choose Settings from the Options menu.**

   A Settings dialog appears.

2. **Pick the desired choice from the Filter Inheritance popup menu.**

   The Inheritance choice passes on the node and arc type filters of the active window when opening new windows.



3. **Click Done to dismiss the dialog.**

△ **Note:** The filters are only inherited by children, parents, neighbors, and selection type windows.

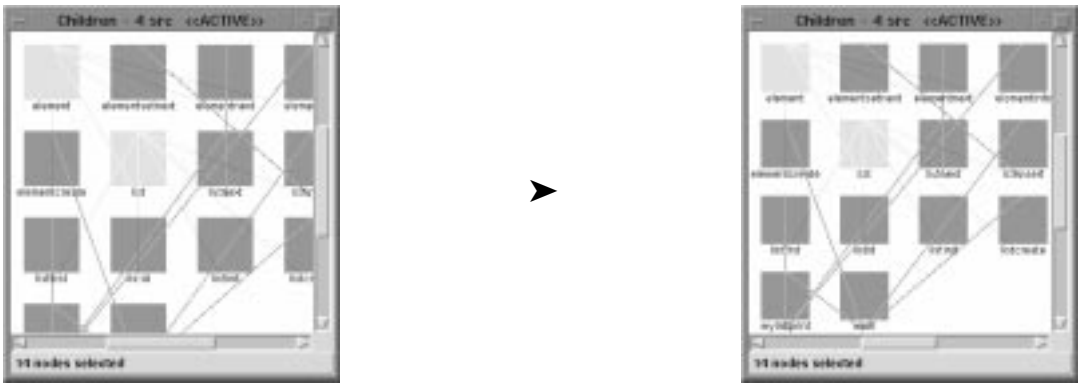
4.15 Scaling the Focus

You can control how much of the graph structure you want to see in the active window by scaling the nodes.

4.15.1 Fitting nodes within a window

Nodes are drawn to a canvas area that is often larger than the actual boundaries of the window. You can scale the nodes to fit.

- **Choose To Fit from the Scale menu.**



Nodes in the active window are shifted and scaled, if necessary, to stay within the boundaries of the window.

`rcl_scale_to_window`

4.15.2 Fitting selected nodes within a window

Nodes are drawn to a canvas area that is often larger than the actual boundaries of the window. You can scale a selected set of nodes to fit.

1. **Select one or more nodes to scale.**
2. **Choose Selection from the Scale menu.**

   The selected nodes in the active window are shifted and scaled, if necessary, to stay within the boundaries of the window.

`rcl_scale_selection`

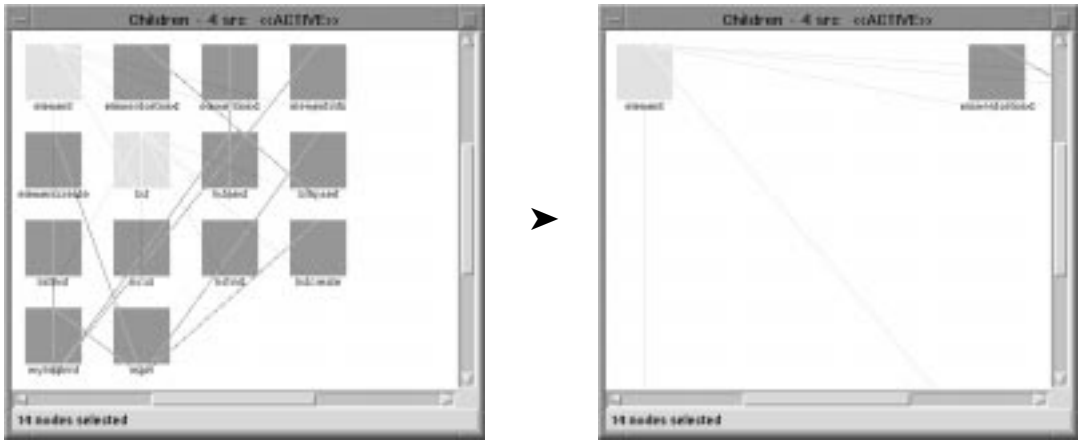
4.15.3 Zooming in

To scale nodes larger:

1. **Choose Settings from the Options menu.**
2. **Adjust the Scale Factor slider to a value more than 100 percent (up to 400 percent).**

3. **Choose By Factor from the Scale menu.**

   The current sizes of the nodes in the active window are expanded by the specified factor. Some parts of the graph may go beyond the boundaries of the active window.



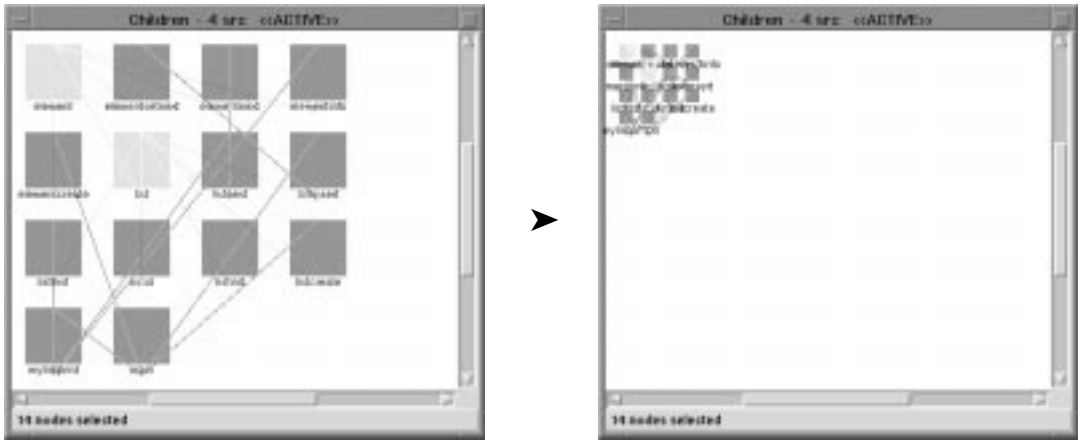
4.15.4 Zooming out

To scale nodes smaller:

1. **Choose Settings from the Options menu.**
2. **Adjust the Scale Factor slider to a value less than 100 percent (down to 25 percent).**

3. **Choose By Factor from the Scale menu.**

   The current sizes of the nodes in the active window are reduced by the specified factor.



4.15.5 Restoring the focus

To stop scaling of nodes:

- **Choose Normal Size from the Scale menu.**

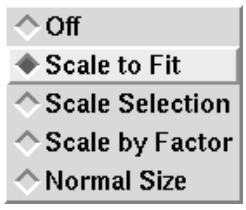
`rcl_scale_none`

4.15.6 Automatic scaling

To automatically perform a scaling operation after making an automated layout:

1. **Choose Settings from the Options menu.**
2. **Pick the desired choice from the Automatic Scaling popup menu.**

   The Off choice turns off automatic scaling. The Scale to Fit choice resizes all the nodes to fit in the boundaries of the window. The Scale Selection choice resizes only the selected nodes to fit in the boundaries. The Scale by Factor choice resizes nodes according to the Scale Factor slider. The Normal Size choice sets nodes to their normal size, 64 pixels square, even if you may need to scroll to see certain nodes.



4.16 Making Arrangements

The initial layout of nodes in a window is a grid. When arranging nodes, you need to select them before applying a layout operation.

4.16.1 Moving a node

To move a single node:

- **Place the pointer over the node, press the left mouse button, drag the node, and release.**

4.16.2 Moving several selected nodes

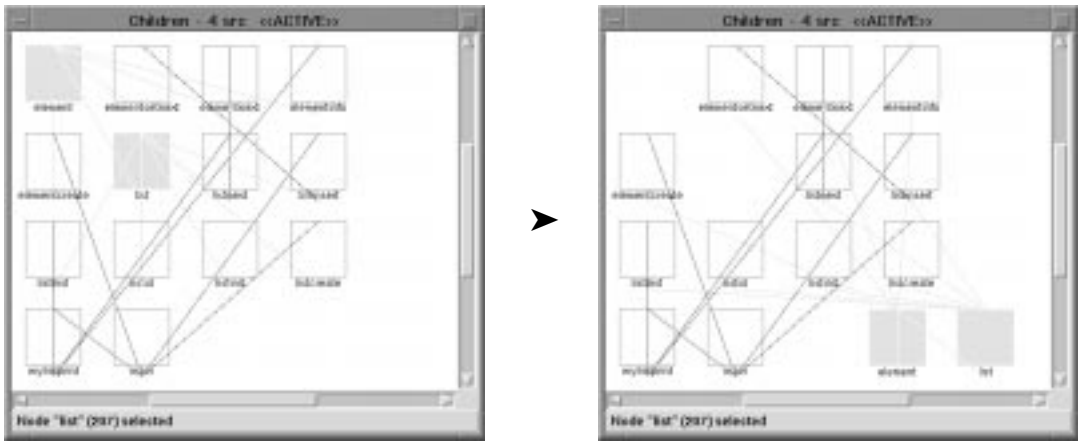
To move several selected nodes:

1. **Select the nodes to be moved.**
2. **Hold down the shift key, press the left mouse button over a selected node, drag the nodes, and release.**

4.16.3 Arranging nodes horizontally

To arrange nodes in a horizontal line:

1. **Select one or more nodes to be arranged horizontally in a line oriented from left to right.**
2. **Right-click on the canvas, where you want the horizontal line to begin.**
   Right-clicking does not disturb the current selection.
3. **Choose Horizontal from the Layout menu.**
   The selected node(s) are arranged horizontally, starting from the point on the canvas where you clicked, and remain selected.



`rcl_group_horizontally`

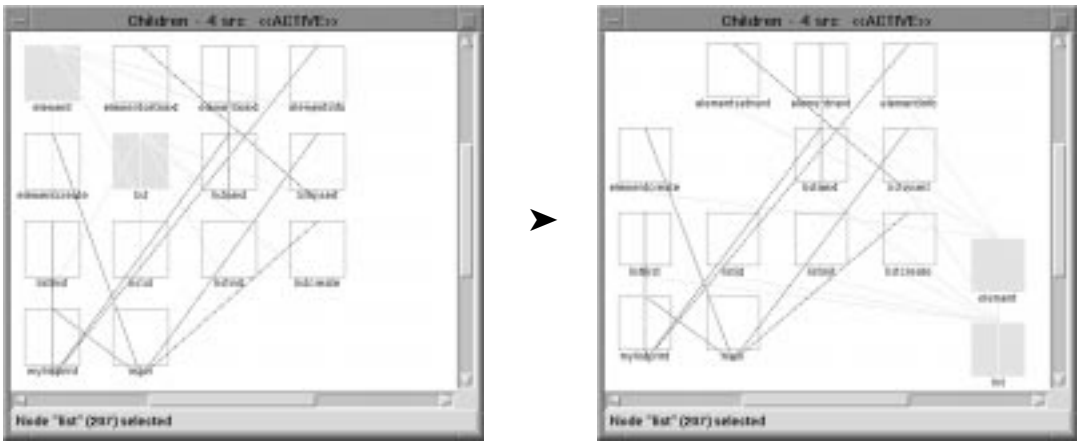
4.16.4 Arranging nodes vertically

To arrange nodes in a vertical line:

1. **Select one or more nodes to be arranged vertically in a line oriented from top to bottom.**
2. **Right-click on the canvas, where you want the vertical line to begin.**

   Right-clicking does not disturb the current selection.
3. **Choose Vertical from the Layout menu.**

   The selected node(s) are arranged vertically, starting from the point on the canvas where you clicked, and remain selected.



`rcl_group_vertically`

4.16.5 Arranging nodes into a grid

To arrange nodes in a grid.

1. **Select one or more nodes to be arranged into a grid.**
2. **Right-click on the canvas, where you want the top-left corner of the grid to begin.**
3. **Choose Grid from the Layout menu.**

   The selected node(s) are arranged in a grid, starting from the point on the canvas where you clicked, and remain selected.

`rcl_group_grid`

4.16.6 Arranging all nodes into a grid

To arrange all the nodes in the active window into a grid:

1. **Choose Grid All from the Layout menu.**

   The current selection is not disturbed.

`rcl_grid_all`

4.16.7 Arranging reachable nodes along outgoing arcs into a tree

You can arrange, into a tree layout, all the nodes on which a selected node depends. The tree is laid out coming down the active window; the reachable nodes appear lower than the root.

1. **Select the root node for the tree layout.**
2. **Pick the appropriate arc type for the outgoing arcs from the Arc Type palette.**

   The any choice in the palette matches any arc type.

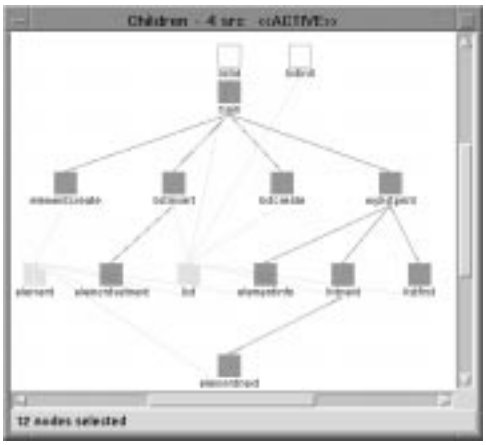
   Since composite arcs may contain (elided) non-composite arcs of the specified arc type, the traversal may pass through these composite arcs to build the tree. The composite arc type choice matches only composite arcs.
3. **Choose Settings from the Options menu.**

   A Settings dialog appears.
4. **Adjust the Tree Depth slider to the depth you want.**

   If the slider is -1, the depth is infinite and the full outgoing reachability tree would be laid out.

5. **Click Done to dismiss the dialog.**
6. **Choose Forward Tree from the Layout menu.**

   Nodes that are reachable along outgoing arcs of the specified arc type to the given depth from the selected root node are arranged into a tree in the active window.



`rcl_forward_tree`

4.16.8 Arranging reachable nodes along incoming arcs into a tree

You can arrange, into a tree layout, all the nodes which depend on a selected node. The tree is laid out going up the active window; the reachable nodes appear higher than the root.

1. **Select the root node for the tree layout.**
2. **Pick the appropriate arc type for the incoming arcs from the Arc Type palette.**

   The any choice in the palette matches any arc type.

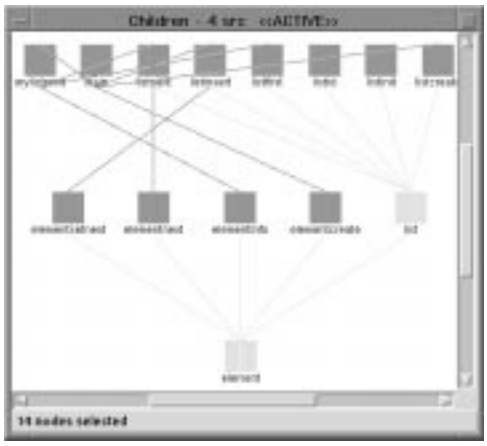
   Since composite arcs may contain (elided) non-composite arcs of the specified arc type, the traversal may pass through these composite arcs to build the tree. The composite arc type choice matches only composite arcs.
3. **Choose Settings from the Options menu.**

   A Settings dialog appears.
4. **Adjust the Tree Depth slider to the depth you want.**

   If the slider is -1, the depth is infinite and the full incoming reachability tree would be laid out.

5. **Click Done to dismiss the dialog.**
6. **Choose Reverse Tree from the Layout menu.**

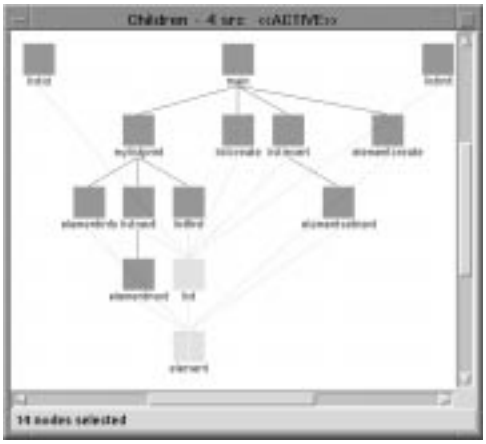
   Nodes that are reachable along incoming arcs of the specified arc type to the given depth from the selected root node are arranged into a tree in the active window.



`rcl_reverse_tree`

4.16.9 Arranging all nodes in a Sugiyama layout

To arrange nodes in a Sugiyama layout:



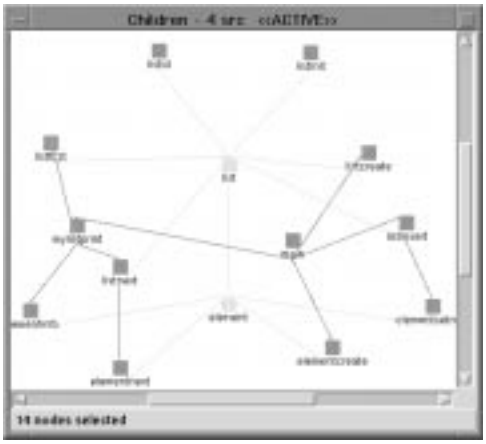
- **Choose Sugiyama from the Layout menu.**
  All nodes in the active window are arranged according to a Sugiyama layout, a layered, tree-like layout that tries to minimize crossings.
  △ **Note:** The graph in the active window cannot have cycles.

▲ **Warning:** If the number of nodes in the tree is too great, or the hierarchy is too deep, or you run out of virtual memory, the Sugiyama implementation fails.

★ **Technical:** An external program called `gel-sugiyama` is used to implement this layout.

4.16.10 Arranging all nodes in a spring layout

To arrange nodes in a spring layout:



- **Choose Spring from the Layout menu.**
  All nodes in the active window are arranged according to a spring layout. In this layout, arcs are modeled as springs so that highly connected nodes tend to pull each other together and more isolated nodes tend to push each other apart.
  △ **Note:** The graph in the active window must be connected.

★ **Technical:** An external program called `gel-spring` is used to implement this layout.

4.16.11 Moving nodes to a pile

To manage a lot of nodes, you can pile them on top of each other.

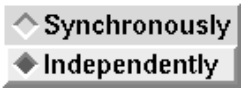
1. **Choose Settings from the Options menu.**
   A Settings dialog appears.
2. **Adjust the Grid Size slider to value** 0**.**

3. **Click Done to dismiss the dialog.**
4. **Select one or more nodes to be moved to a pile.**
5. **Right-click on the canvas, where you want the pile to be located.**
6. **Choose Grid from the Layout menu.**
   The selected nodes are moved to a single pile.

4.16.12 Moving nodes in synch

Because of multiple perspectives on the same graph model, the same essential node(s) may appear multiple times but in separate windows. You can have mouse-based dragging of such node(s) occur only within the active window or in all windows.

1. **Choose Settings from the Options menu.**
   A Settings dialog appears.
2. **Pick the desired choice from the Node Movement popup menu.**
   The Synchronously choice causes synchronous node movement in all windows. That is, dragging a node causes relative movement in all windows that display this node. The Independently choice causes individual movements.



3. **Click Done to dismiss the dialog.**
4. **Drag the node(s) as desired.**

4.16.13 Moving nodes with constraints

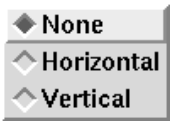
You can have mouse-based dragging of nodes be constrained horizontally, vertically, or not at all.

1. **Choose Settings from the Options menu.**

   A Settings dialog appears.

2. **Pick the desired choice from the Constraint Type popup menu.**

   The Horizontal choice causes node movement to be only vertical; the Vertical choice causes node movement to be only horizontal; the None choice allows free movement.



3. **Click Done to dismiss the dialog.**

4. **Drag the node(s) as desired.**

4.17 Viewing Reports

4.17.1 Reporting numbers of nodes and arcs

To report the number of nodes and arcs in the active window:

- **Choose Window Statistics from the Report menu.**

  The report appears in a Text editor window with numbers of nodes and arcs broken down by the various types and whether they are visible or filtered; this editor is a separate process outside the direct control of `rigiedit`.

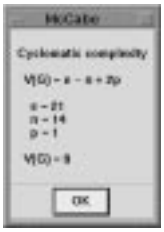
4.17.2 Reporting cyclomatic complexity

The McCabe cyclomatic complexity $V(G)$ of a control flow graph measures the maximum number of linearly independent paths through it. The complexity typically increases because of branch points.

To compute the cyclomatic complexity:

- **Choose Cyclomatic Complexity from the Report menu.**

  A report appears with the value of $V(G)$



If e is the number of arcs, n is the number of nodes, and p is the number of connected components, then $V(G) = e - n + 2p$.

4.17.3 Viewing node neighborhood and dependency information

To view information on the immediate neighborhood around a node as it is presented within a window:

1. **Choose View Information from the Node menu of the node.**

   A detailed Information window appears, presenting information about the node (in the window just activated).

   This information includes the node's:

   - internal node ID,
   - node type,
   - incoming and outgoing arcs by arc type, and
   - neighboring nodes along these arcs (with their node name and type).

   Some of this information is dimmed for nodes and arcs not visible in the active window.

   Some of this information may be dimmed for any of several reasons:

   - an arc is filtered,
   - an arc relates a node that is filtered,
   - an arc relates a node that is not in the window,
   - a node is filtered,
   - a node is not in the window.

   In short, information is dimmed for any node or arc not visible in the active window.

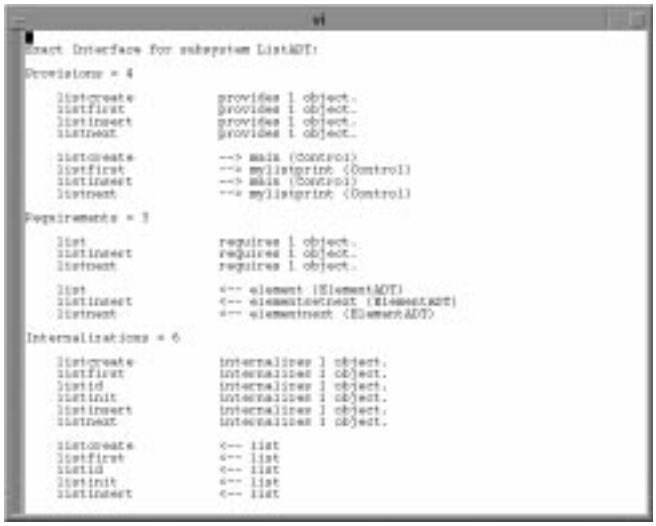
2. **Click Done to dismiss the Information window.**

4.17.4 Reporting subsystem information

You can produce an *exact interface* report of the dependencies to, from, and within a selected group of nodes.

1. **Select one or more nodes.**
2. **Choose Exact Interface from the Report menu.**

   The report appears in a Text editor window; this editor is a separate process outside the direct control of `rigiedit`.



The report includes three kinds of information for each selected subsystem: *provisions*, *requirements*, and *internalizations*. A provision is a dependency from a node *inside* the subsystem to a node *outside* the subsystem; the internal node *provides* at least one object. A requirement is a dependency from a node *outside* the subsystem to a node *inside* the subsystem; the internal node *requires* at least one object. An internalization is a dependency between two nodes inside the subsystem.

4.17.5 Viewing information for an arc

To view information on an arc:

1. **Choose View Information from the Arc menu of the arc.**

   A textual Information window appears, presenting information about the arc (in the window just activated).

   This information includes the arc's:

   - internal arc ID,
   - source and destination nodes (with their name), and
   - constituent arcs if the arc is composite.

2. **Click Done to dismiss the Information window.**

4.17.6 Reporting information for a composite arc

You can produce an *exact interface* report for a composite arc between two nodes. A composite arc may represent one or more arcs of different types between nodes at lower levels in the hierarchy.

1. **Select a composite arc.**
2. **Choose Exact Interface from the Report menu.**

   The report appears in a Text editor window; this editor is a separate process outside the direct control of `rigiedit`.

4.17.7 Reporting graph quality

You can produce a *graph quality* report which evaluates the quality of a selected subsystem according to a set of software modularity measures. Each measure is normalized to a range from 0 to 1. Higher values are "better."

The overall quality is based on the:

- *partition* quality,
- *control encapsulation* quality, and
- *data encapsulation* quality.

The partition quality measure *increases* as the number of interfaces between nodes in the subsystem *decrease*. This is the principle of low coupling in modular design. The interfaces are classified into high-, medium-, and low-strength interfaces. The thresholds for this division can be adjusted.

The control encapsulation quality measure *increases* with the number of control flow dependencies between nodes inside the subsystem, and *decreases* with the number of control flow dependencies from nodes inside the subsystem to nodes outside. This favors localized control and small interfaces.

The data encapsulation quality measure *increases* with the number of local references to data types, and *decreases* with the number of external references to data types. This favors data encapsulation and object-oriented designs.

To produce a graph quality report:

1. **Choose Settings from the Options menu.**

   A Settings dialog appears.

2. **Adjust the High Threshold slider to set the threshold for high-strength interfaces.**

   A composite arc is a high-strength interface if the number of dependencies it represents is greater than this threshold.

3. **Adjust the Low Threshold slider to set the threshold for low-strength interfaces.**

   A composite arc is a low-strength interface if the number of dependencies it represents is lower than this threshold.

   △ **Note:** The parameter changes are immediate.

4. **If desired, click Done to dismiss the dialog.**

5. **Select one or more nodes.**

6. **Choose Graph Quality (C) from the Report menu.**

   The report appears in a Text editor window; this editor is a separate process outside the direct control of `rigiedit`.

   The summary averages the individual measures for the selected subsystems.

△ **Note:** The graph quality report only works for the provided simplified C domain model.

4.18 Working with Views

One way to document the graph is to create, save, and load `rigiedit` *views*. A `rigiedit` view is a snapshot of the layout of one or more windows and their contents at a given point in time. A view records visual perspectives on a graph, including appearances such as node positions. After loading a view, you can still interact with its windows. Views provide a flexible way to focus attention on important facets of the subject software.

△ **Note:** A view and the underlying graph model on which the view is based must correspond. If the graph in memory changes, older views may not work correctly.

△ **Note:** Text editor windows and their report contents, SHriMP windows, and informational windows, cannot be saved in a view.

4.18.1 Saving a view

To save a `rigiedit` view of the canvas windows on the screen:

1. **Open and arrange the contents of the windows as desired.**

   Locations of nodes, filter settings, and current selections (anything you see) are part of the view.

2. **Move and resize the windows of your view as desired.**

   Position, size, and scroll settings are recorded.

3. **Save the graph on which the view depends.**

   See §4.7.2.

   This ensures that the view to be saved corresponds to the right graph model.

4. **Choose Save View As ... from the File menu.**

A File dialog appears for saving the view.

5. **Type a filename for the view.**
   ☛ **Tip:** A suffix of `.view` is useful for distinguishing view files. If no file suffix is specified, `.view` is added automatically.
6. **Click OK to save the view.**
   Or click Cancel to cancel.

`rcl_save_view`

4.18.2 Loading a view

▲ **Warning:** When loading a `rigiedit` view, you must ensure that the graph in memory is the same as the graph on which the view was based.

To load a `rigiedit` view:

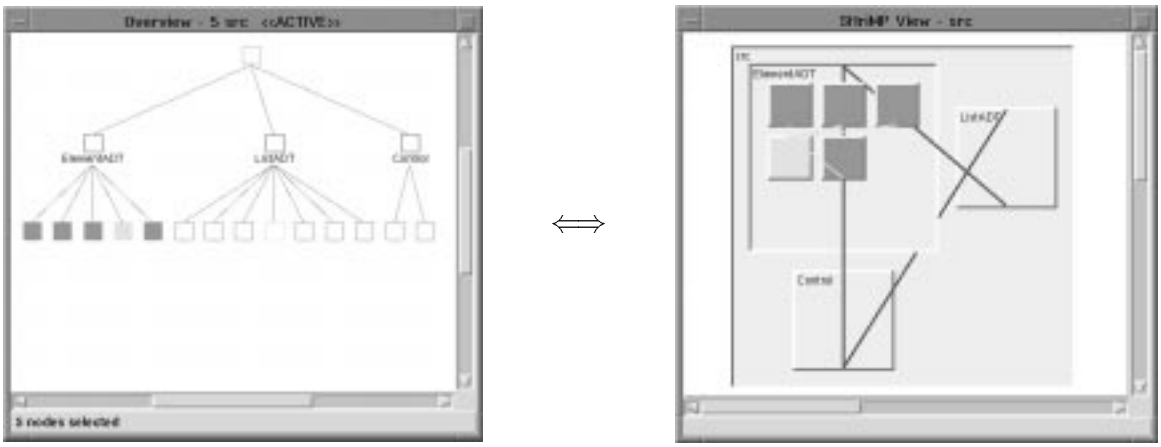
1. **Choose Close All from the Window menu.**
   All `rigiedit` windows become closed except the root window.

2. **Load the graph on which the view depends.**
   See §4.7.3.
3. **Choose Load View ... from the File menu.**
   A File dialog appears for loading the view.
4. **Select the view to load and click OK.**
   Or click Cancel to cancel.

`rcl_load_view`

4.19 Using SHriMP Windows

SHriMP (Simple Hierarchical Multi-Perspective) windows show the subsystem hierarchy through the nesting of boxes that represent nodes.



You progressively reveal what a subsystem contains by opening its box, showing its children inside. Several boxes can be opened to show global, contextual information while exploring the details in a particular subsystem. The boxes can be moved around and individually enlarged or reduced. This section describes the specific operations supported in a SHriMP window.

△ **Note:** Manual arrangements are allowed, but not preserved. You cannot save a SHriMP window as part of a `rigiedit` view. A SHriMP window does not support selections or graph modifying operations.

4.19.1 Presenting a SHriMP window

To open a SHriMP window of the hierarchy rooted at a node:

- **Choose Open SHriMP View from the Node menu for the node.**

  A SHriMP window appears, presenting the root node in a closed state and the name of the node on the title bar.

  ☛ **Tip:** Enlarge the root node to full size for more working room (§4.19.5).

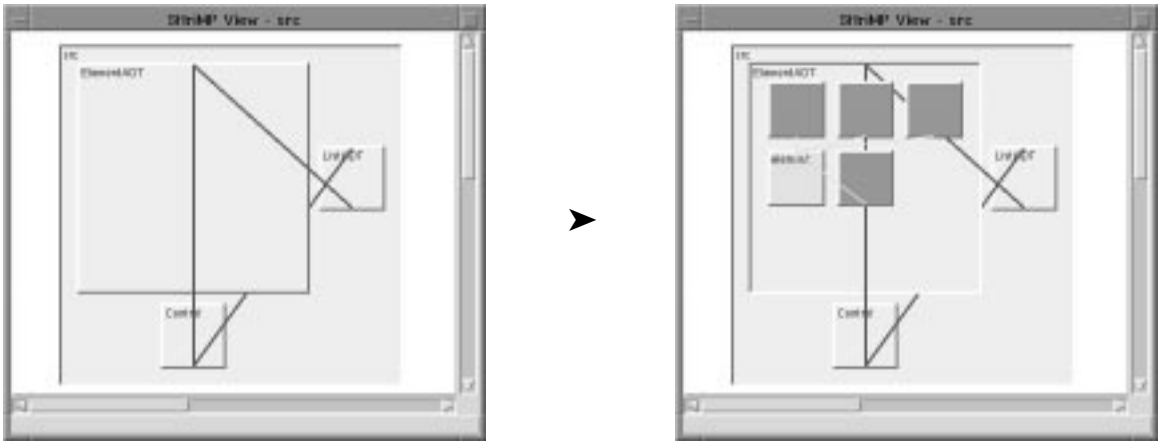
△ **Note:** Only one SHriMP window can be displayed at a time.

4.19.2 Revealing the children of a node

To open a closed, non-leaf node to reveal its children:

- **Double-left-click on the non-leaf node.**

  The node is opened, showing its children uniformly sized in a grid layout. Visually, the node looks sunken.



4.19.3 Eliding the children of a node

To close an opened, non-leaf node to elide its children:

- **Double-left-click on the non-leaf node.**
  The node is closed. Visually, the node looks raised.

4.19.4 Filtering children

To filter children nodes in a particular opened, non-leaf node by type:

1. **Choose Node Settings ... from the Node menu for node.**
   A SHriMP Node Settings dialog appears.
2. **Toggle on the node types to hide or toggle off the node types to show in the dialog.**
   

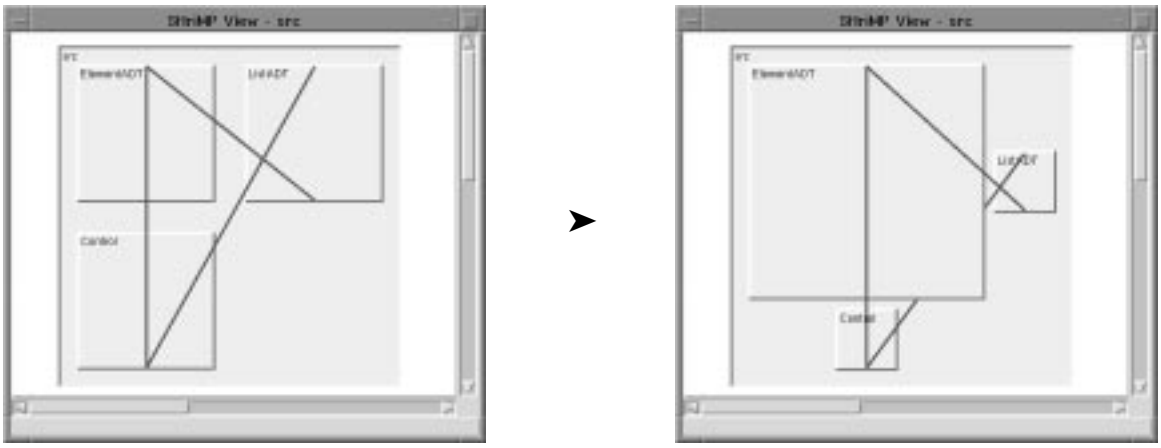
   Children nodes within the non-leaf node are hidden or shown according to the chosen node type filter settings. Filtering is immediate.
3. **Click Done to dismiss the dialog.**

4.19.5 Enlarging the size of a node

To enlarge the size of a node:

- **Hold down the control key and press the left mouse button on the node until the desired size then release.**

  The node is enlarged (along with its children if opened). This may reduce the size of sibling nodes (and their children) to provide room.



4.19.6 Reducing the size of a node

To reduce the size of a node:

- **Hold down the control and shift keys and press the left mouse button on the node until the desired size then release.**

  The node is reduced (along with its children if opened). This may enlarge the size of sibling nodes (and their children).

4.19.7 Seeing the node name

If a node is too small, its name is automatically hidden.

To see the name of the node:

- **Move the pointer over the node.**

4.19.8 Adjusting the step size

The step size for the enlargement and reduction of nodes can be adjusted.

To adjust the step size:

1. **Choose SHriMP Settings from the Options menu.**

   A SHriMP Settings dialog appears.
2. **Adjust the Scaling Increment slider to the desired value (in pixels).**
3. **Click Done to dismiss the dialog.**

4.19.9 Overlapping children

To allow or disallow the overlapping of children nodes in a particular opened, non-leaf node:

1. **Choose Node Settings ... from the Node menu for the node.**

   A SHriMP Node Settings dialog appears.
2. **Click on the desired choice from the Overlapping Children part of the dialog.**

3. **Click Done to dismiss the dialog.**

4.19.10 Layout constraints

To set layout constraints for the children nodes in a particular opened, non-leaf node:

1. **Choose Node Settings ... from the Node menu for the node.**
   A SHriMP Node Settings dialog appears.
2. **Click the desired choice from the Layout Constraint part of the dialog.**
   The None choice means no constraints; the Proximity choice preserves proximity relationships among nodes when sizing; the Orthogonality choice preserves orthogonality relationships.

3. **Click Done to dismiss the dialog.**

4.19.11 Presenting a Children window

To open a Children window on a particular opened, non-leaf node:

- **Choose Open Rigi View from the Node menu for the node.**
  A Children window appears.

4.19.12 Viewing the annotation for a node

To view the annotation file linked to a leaf node:

- **Double-left-click on the leaf node.**

  If there is an annotation file linked to the node, a Text editor window appears with its contents.

  See also §4.10.6.

4.19.13 Editing the source text for a node

To edit the source file linked to a leaf node:

- **Choose Open Source Text from the Node menu for the node.**

  If there is a source file linked to the node, a Text editor window appears with its contents.

  See also §4.10.7.

4.19.14 Printing a SHriMP window

To save the contents of a SHriMP window as PostScript:

1. **Choose SHriMP Settings from the Options menu.**
   A SHriMP Settings dialog appears.
2. **Enter a filename for the PostScript file.**
   ☛ **Tip:** Like the C shell, a leading ∼ in the filename can be used to refer to a user home directory.
3. **Click Take Snapshot to generate the file.**
   The generated file contains an image of the SHriMP window contents, without the frame.
4. **Click Done to dismiss the dialog.**

4.20 Using the Toolbar

4.20.1 Toolbar Buttons

The icon buttons on the toolbar are shortcuts for common operations from the menubar.

From left to right, these operations are:

Cut from the Edit menu	(§4.13.7)
Copy from the Edit menu	(§4.13.8)
Paste from the Edit menu	(§4.13.9)
To Fit from the Scale menu	(§4.15.1)
Selection from the Scale menu	(§4.15.2)
Grid from the Layout menu	(§4.16.5)
Horizontal from the Layout menu	(§4.16.3)
Vertical from the Layout menu	(§4.16.4)
Forward Tree from the Layout menu	(§4.16.7)
Reverse Tree from the Layout menu	(§4.16.8)

Appendix A

A.1 Directory Structure

This section outlines the main parts of the distribution directory structure.

```
Rigi/
        db/                     database directory
                arixi-d/                SQL/DS demo files
                list-d/                 list demo files
                ray-d/                  ray demo files
        domain/                 domain directory
                c/                      simple C domain files
                cparse/                 cparse C domain files
                plas/                   PL/AS domain files
        icons/                  toolbar icons
        rcl/                    Rigi Command Library
        tmp/                    temporary files (Windows only)
bin/
        sun4-sunos4/            executables (SPARC SunOS only)
        rs6000-aix4/            executables (RS/6000 AIX only)
        ix86-linux2/            executables (Intel Linux only)
lib/
        tcl7.4/                 Tcl 7.4 library files
        tk4.0/                  Tk 4.0 library files
        tix4.1/                 Tix 4.1.0 library files
doc/
        cparse/                 parser documentation HTML pages
        rcl/                    RCL documentation HTML pages
        util/                   utilities HTML pages
```

A.2 Mouse Actions

This section lists the mouse actions in a canvas window.

	single	left	click	canvas	deselects all	§4.9.8
	⋮	⋮	⋮	node	selects node	§4.9.1
	⋮	⋮	⋮	arc	selects arc	§4.9.2
	⋮	⋮	drag	canvas	draws selection rectangle	§4.9.3
	⋮	⋮	⋮	node	moves node	§4.16.1
	⋮	right	click	canvas	activates window	§4.8.2
	⋮	⋮	⋮	node	brings up node menu	§4.2.1
	⋮	⋮	⋮	arc	brings up arc menu	§4.2.2
	double	left	click	node	opens node	§4.10.7, §4.12.1
shift	single	left	click	node	extends selection	§4.9.4
⋮	⋮	⋮	drag	node	moves nodes	§4.16.2
⋮	⋮	right	drag	node	creates arc	§4.13.2
⋮	double	right	click	canvas	creates node	§4.13.1

A.3 Keyboard Shortcuts

This section lists the main accelerator keys.

Ctrl-a	All from the Select menu	§4.9.5
Ctrl-x	Cut from the Edit menu	§4.13.7
Ctrl-c	Copy from the Edit menu	§4.13.8
Ctrl-v	Paste from the Edit menu	§4.13.9
Alt-f	Bring up the File menu	§A.4.1
Alt-e	Bring up the Edit menu	§A.4.2
Alt-n	Bring up the Navigate menu	§A.4.3
Alt-s	Bring up the Select menu	§A.4.4
Alt-i	Bring up the Filter menu	§A.4.5
Alt-c	Bring up the Scale menu	§A.4.6
Alt-l	Bring up the Layout menu	§A.4.7
Alt-r	Bring up the Report menu	§A.4.8
Alt-w	Bring up the Window menu	§A.4.9
Alt-d	Bring up the Demo menu	§A.4.10
Alt-o	Bring up the Options menu	§A.4.11
Alt-h	Bring up the Help menu	§A.4.12
Tab	Step focus through dialog items	
Enter	Click dialog item in focus	
←	Scroll left	
→	Scroll right	
↑	Scroll up	
↓	Scroll down	

Each item in a menu has an associated key that appears underlined. After bringing up a menu from the menubar, choose an item by pressing its associated key. For example, the Exit command can be invoked by pressing Alt-f then x. For ease of typing, the Alt key may be held down through the entire shortcut combination; to exit, press Alt-f Alt-x (denoted Alt-f-x).

A.4 Menu Commands

This section lists the provided menu commands and the relevant subsections describing them. The underlined characters are used in keyboard shortcuts (*see* §A.3).

A.4.1 File menu

Load Graph	§4.7.3
Save Graph As …	§4.7.2
Load View	§4.18.2
Save View As …	§4.18.1
Initialize	§4.7.4
Exit	§4.6.1

A.4.2 Edit menu

Cut	§4.13.7
Copy	§4.13.8
Paste	§4.13.9
Collapse	§4.13.5
Expand	§4.13.6
Show Clipboard	§4.13.10
Clear Clipboard	§4.13.11

A.4.3 Navigate menu

Children	§4.12.1
Parents	§4.12.2
Neighbors	§4.12.3
Selection	§4.12.4
Projection	§4.12.5
Overview	§4.12.6

A.4.4 Select menu

All	§4.9.5
None	§4.9.8
Complement	§4.9.6
Outgoing Nodes	§4.9.13
Incoming Nodes	§4.9.14
Forward Tree	§4.9.15
Reverse Tree	§4.9.16
By Attribute …	§4.9.10
By Structure …	§4.9.11
By Name …	§4.9.9

A.4.5 Filter menu

By Node Type …	§4.14.5
By Arc Type …	§4.14.6
By Selection …	§4.14.1, §4.14.2, §4.14.3, §4.14.4

A.4.6 Scale menu

To Fit	§4.15.1
Selection	§4.15.2
By Factor	§4.15.3, §4.15.4
Normal Size	§4.15.5

A.4.7 Layout menu

Grid All	§4.16.6
Grid	§4.16.5, §4.16.11,
Horizontal	§4.16.3
Vertical	§4.16.4
Forward Tree	§4.16.7
Reverse Tree	§4.16.8
Spring	§4.16.10
Sugiyama	§4.16.9

A.4.8 Report menu

Window Statistics	§4.17.1
Graph Quality (C)	§4.17.7
Exact Interface	§4.17.4, §4.17.6
Cyclomatic Complexity	§4.17.2

A.4.9 Window menu

Raise Active	§4.8.3
Cascade	§4.8.4
Refresh	§4.8.5
Update	§4.8.6
Close Active	§4.8.7
Close All	§4.8.8

A.4.10 Demo menu

List Demo (C)	§2.2
Ray Demo (C)	§2.3
SQL Demo (PLAS)	§2.4

A.4.11 Options menu

Settings	§4.8.9
SHriMP Settings	§4.19.8
Node Colors	§4.10.9
Arc Colors	§4.11.7
Configuration	§4.3.2, §4.3.3

A.4.12 Help menu

About Rigi 5.4.4

A.4.13 Node menu

View Information	§4.17.3
Edit Attributes	§4.10.5
Edit Annotation	§4.10.6
Edit Source	§4.10.7
Rename	§4.10.3
Set Type	§4.10.4
Open SHriMP View	§4.19.1
Open Rigi View	§4.19.11
Open URL	§4.10.8

A.4.14 Arc menu

View Information	§4.17.5
Edit Attributes	§4.11.4
Edit Annotation	§4.11.5
Set Type	§4.11.3
Open URL	§4.11.6

Index

`.rsf` suffix, 29, 62
`.view` suffix, 29, 131

aborting the editor
  under Unix, 59
  under Windows 95, 59
abstract data type, 18
  access functions of, 19
  identification of, 18–19
activating a window, 12, 64, 66
active window, 11, 15, 64
  associated dialogs, 68
  closing the, 22, 68
  filter dialog for, 18, 68, 106
  raising the, 66
  refreshing the, 67
  updating the, 20, 67
analysis, *see* opening *and* reporting
annotation
  annotate arc attribute, 91
  annotate node attribute, 85
  defining location of files, 85, 91
  editing for a node, 85
  editing for an arc, 91
  viewing for a node, 138
arc
  adding a type of, 50
  annotate attribute of, 91
  arcurl attribute, 92
  changing the global type, 90
  changing the type of, 90
  color of, 50, 92
  creating an, 98–99
  cutting a, 102
  deleting an, 99
  directed, 76, 89
  editing annotation for, 91
  editing attributes of, 91
  getting information about, 26, 126
  hiding by type, 35, 107
  opening a URL for, 92
  selecting an, 16, 70
  types of, 89–90
  working with, 89–92
Arc menu, 26, 40
Arc Type button, 11, 19, 90
arc type set, 89
arranging, 16–17, 113–122
  all nodes into a grid, 116
  nodes horizontally, 16, 114
  nodes into a forward tree, 117
  nodes into a grid, 116
  nodes into a reverse tree, 118
  nodes vertically, 32, 115
  spring layout, 119–120
  Sugiyama layout, 17, 35, 119
attribute
  adding an, 50
  annotate for a node, 85
  annotate for an arc, 91
  arcurl, 92
  binding a value to, 60
  editing for a node, 84
  editing for an arc, 91
  file, 60, 85
  lineno, 60, 85
  nodeurl, 87
automatic scaling, 17, 112

backing store, 47

call arc
in an RSF stream, 60
inferring functions of, 61
type, 15, 60
call graph
producing a, 35
canvas
backing store of, 47
color of, 42, 47
cursor location in, 32
dimensions of, 42, 47
menus in, 20, 39
reset scaling in, 111
right-clicking on, 20
window, 65
window limitations, 93
zooming in, 110
zooming out, 111
`CANVASCOLOR`, 41, 42, 47
cascading windows, 66
change analysis, *see* exact interface
changing a configuration, 44
Children window, 14, 65, 93
double-clicking to open, 21
filter inheritance by, 108
opening a, 13–14, 21, 93, 137
clearing
a graph, 63
the clipboard, 103
client node, 14, 89
identification of, 19
clipboard, 65
clearing the, 103
showing the, 103
closing
all windows, 68
the active window, 22, 68
cluster, *see* subsystem
Collapse node
added automatically, 82
multiple types of, 82
type, 82
collapsing a subsystem, 19–20, 100
color
in Arc menu, 40
in Node menu, 40
of arc types, 50, 92
of canvas background, 42, 47
of node types, 50, 88
`columns`, 32–34
command
button, 11, 56, 57
entering a, 11, 31–32, 54, 56
history, 11, 32, 54
line, 11, 31, 54
listing available, 56
retrieving a previous, 11, 32, 54
running a periodic, 38
composite arc
added automatically, 89
dependencies in, *see* exact interface
formation of, 20
matching within, 76, 78–81, 117, 118
multiple types of, 90
type, 15, 51, 89
conceptual modeling, *see* domain
configuration
changing a, 44
commonly changed parameters, 41
creating a new, 43
default canvas color of, 47
default database directory of, 45
default domain of, 45
default text editor of, 46
default web browser of, 46
fonts in, 48
number of backing stores of, 47
overriding a parameter in, 45
parameters, 41
connected graph, 119
constraint type, 122
control encapsulation, *see* graph quality
copying a subgraph, 102
coupling, 1, 28, 128

creating
a new configuration, 43
a node, 98
a subsystem, 19–20, 100
an arc, 98–99
customization, *see* configuration *and* script
cutting a subgraph, 102
cycles in a graph, 119
cyclomatic complexity, *see* reporting

data arc
filtering, 35
in an RSF stream, 60
recursive, 21
type, 15, 60
data encapsulation, *see* graph quality
Data node
type, 14, 60
data type, 14
access to, 15
containment of, 15
encapsulation quality of, 128
recursive dependencies in, 21
reference to, 15
relationships of, *see* data arc
`DBDIR`, 41, 42, 45, 85, 91
`DBREFDIR`, 42
deleting
a node, 99
a subgraph, 102
an arc, 99
`DEMOFONT`, 42
deselecting
a node, 73
all nodes, 15, 73
directory structure, 142
domain
defining the default, 45
files for modeling, 50–51
switching the current, 12, 52
working with, 49–52
Domain button, 11, 12, 52

editing the graph, 98–103
editor, 1
aborting the, 59
command-line options of, 38
configuring the, 41–48
exiting the, 36, 58
preferences of, *see* configuration
running the, 38
enlarging a SHriMP node, 135
exact interface
internalization information, 26, 125
of a composite arc, 26–27, 127
of a subsystem, 25–26, 125
provision information, 26, 125
requirement information, 26, 125
exiting the editor, 36, 58
expanding a subsystem, 101

file format, *see* Rigi Standard Format
filter inheritance, 108
filtering, 104–108, *see* hiding *and* showing
finishing, 36, 58–59
fisheye view, *see* SHriMP window
fonts, *see* configuration
function, 14
call, *see* call arc
containing file of, 60
line number location of, 60
name of, 60, 61
Function node
in an RSF stream, 60
type, 15, 60

`gel-spring`, 120
`gel-sugiyama`, 119
graph
clearing a, 63
connected, 119
cycles in, 119
editing the, 98–103
layout of, *see* arranging
loading a, 12, 62–63

saving a, 62
visualization of, 10, 14, 89
working with, 60–63
graph quality, 27–28, 128–129
control encapsulation measure, 28, 128
data encapsulation measure, 28, 128
partition measure, 28, 128
`GRAPHFONT`, 41, 42
grid size, 121

hiding
arcs by type, 35, 107
children in a SHriMP window, 134
names of nodes, 104
nodes by type, 18, 106
selected nodes, 105
high threshold, 28, 128, 129
high-strength interface, 129

`ICONDIR`, 42
impact analysis, *see* exact interface
infinite projection, 31, 96
initializing, *see* clearing
internalization, *see* exact interface

keyboard shortcuts, 144–145
for copying, 102
for cutting, 102
for pasting, 102
for selecting all, 72

layout, *see* arranging
layout constraints, 137
level arc
added automatically, 89
incoming, 94
limitations on, 99
multiple types of, 90
outgoing, 93
type, 13, 51, 89, 97
linking
annotation, *see* annotation
source text, *see* source text
web page, *see* Uniform Resource Locator
loading
a graph, 12, 62–63
a script, 34, 55
a view, 30–31, 131
low threshold, 28, 128, 129
low-strength interface, 129

matching, *see* selecting
`MAXCANVASDIM`, 42, 47
McCabe complexity, *see* reporting
menu
bar, 39
commands, 145–148
for a node, 40
for an arc, 40
working with, 39–40
`MESSAGEFONT`, 41, 42
metrics, *see* reporting
modeling, *see* domain
mountain in Switzerland, *see* Rigi
mouse actions, 143
moving
a node, 113
nodes in synch, 121
nodes into a pile, 121
nodes with constraints, 122
several nodes, 17, 113

Neighbors window, 65, 95
filter inheritance by, 108
opening a, 95
`netscape`, 42
node
adding a type of, 50
annotate attribute of, 85
arranging all into a grid, 116
arranging horizontally, 16, 114
arranging into a grid, 116
arranging into a tree, 117–118
arranging vertically, 32, 115

changing the global type, 83
changing the type of, 84
color of, 50, 88
copying a, 102
creating a, 98
cutting a, 102
deleting a, 99
deselecting a, 73
deselecting all, 15, 73
editing annotation for, 85
editing source text for, 85–86, 138
editing the attributes of, 84
enlarging a SHriMP, 135
file attribute, 60, 85
getting information about, 25, 124
hiding by type, 18, 106
hiding name of, 104
hiding selected, 105
inferring type of, 61
lineno attribute, 60, 85
movement, 121
moving a, 113
moving in synch, 121
moving into a pile, 121
moving several, 17, 113
moving with constraints, 122, 137
nodeurl attribute, 87
opening a URL for, 87
pasting a, 102
enlarging a SHriMP, 135
renaming a, 20, 83
scaling to fit, 109–110
selecting a, 16, 70
selecting all, 15, 72
selecting by attribute value, 75
selecting by dragging, 16, 71
selecting by name, 19, 74
selecting by shift-clicking, 16, 71
selecting by structure, 76
selecting by type, 32, 77
selecting complement, 72
selecting incoming neighbors, 19, 79
selecting incoming reachable, 81
selecting outgoing neighbors, 78
selecting outgoing reachable, 80
showing name of, 24, 104, 136
showing previously hidden, 105
SHriMP, *see* SHriMP window
spring layout of, 119–120
Sugiyama layout of, 119
types of, 82
viewing annotation for, 138
working with, 82–88
Node menu, 20, 40
Node Type button, 11, 83
`notepad.exe`, 42
`NUMBACKSTORES`, 41, 42, 47

opening, 93–97
a Children window, 13–14, 21, 93
a Neighbors window, 95
a Parents window, 22, 94
a Projection window, 22–23, 96
a Selection window, 95
a SHriMP window, 133
an Overview window, 13, 23, 97
overlapping children, 136
overriding a configuration parameter, 45
Overview window, 65, 97
hidden aspects of, 13, 97
limitations of, 97
opening an, 13, 23, 97
updating of, 20, 67

Parents window, 65, 94
filter inheritance by, 108
opening a, 22, 94
partition, *see* graph quality
pasting a subgraph, 102
pattern matching, *see* selecting
periodic, 38

platforms supported, 2
pointer focus, 12, 64
polling, 38
PostScript, 138
preferences, *see* configuration
projection depth, 22, 23, 31, 96
Projection window, 22, 65, 96
    infinite, 31
    limitations of, 23, 96
    opening a, 22–23, 96
provision, *see* exact interface

querying, *see* selecting

raising the active window, 66
rc.rcl, 42
RCL, *see* Rigi Command Library
RCL Command, 11, 56, 57
rcl_clipboard, 103
rcl_close, 68
rcl_close_all, 68
rcl_collapse, 100
rcl_copy, 102
rcl_create_arc, 99
rcl_create_node, 98
rcl_cursor_set, 32, 33
rcl_cut, 102
rcl_expand, 101
rcl_filter_apply, 35
rcl_filter_arctype, 35
rcl_filter_hide_name, 104
rcl_filter_selection, 105
rcl_filter_show_name, 104
rcl_forward_tree, 117
rcl_get_node_type, 33
rcl_grid_all, 116
rcl_group_grid, 116
rcl_group_horizontally, 114
rcl_group_vertically, 32, 33, 115
rcl_load, 63
rcl_load_view, 131
rcl_node_rename, 83
rcl_paste, 102
rcl_poll_proc, 38
rcl_quit, 58
rcl_quit_no_verify, 58
rcl_refresh, 67
rcl_reverse_tree, 118
rcl_save, 62
rcl_save_view, 131
rcl_scale_none, 111
rcl_scale_selection, 110
rcl_scale_to_window, 33, 109
rcl_select_all, 33, 72
rcl_select_forward_tree, 80
rcl_select_get_list, 33
rcl_select_invert, 72
rcl_select_none, 33, 73
rcl_select_reverse_tree, 81
rcl_select_type, 32, 33
rcl_update, 67
rcl_win_canvas_width, 33
README, 3
enlarging a SHriMP node, 135
refreshing the active window, 67
renaming a node, 20, 83
reporting, 123–129
    arc information, 26, 126
    composite arc information, 26–27, 127
    cyclomatic complexity, 123
    graph quality, 27–28, 128–129
    McCabe complexity, 123
    node information, 25, 124
    numbers of arcs, 123
    numbers of nodes, 123
    subsystem information, 25–26, 125
requirement, *see* exact interface
reverse engineering, 1, 7, 9
RIGI, 41, 42
Rigi, 1–2
Rigi Command Library
    redefining primitives of, 53
    scripting with, *see* script

Rigi Standard Format, 12, 60–61
    dialects of, 60
    limitations with, 61
    structured, 60
    unstructured, 60
`Rigiarc`, 50
    composite arc type in, 51
    level arc type in, 51
`Rigiattr`, 50
`RIGIBIN`, 42
`rigicfg.env`, 41, 43
`Rigicolor`, 50, 88, 92
`RIGIDBHOST`, 42
`RIGIDBPORT`, 42
`RIGIDOMAIN`, 41, 42, 45
`rigiedit`, *see* editor
`RIGIINIT`, 42, 45, 50, 53
`RIGILIB`, 42
`Riginode`, 50
    Collapse node type in, 50
    Unknown node type in, 51
`RIGIRCL`, 42, 53
`Rigircl`, 50, 53
`RIGISTY`, 42
`RIGITITLE`, 42
`RIGIURCL`, 41, 42, 53
`RIGIUSER`, 41, 42
`RIGIUSTY`, 42
root, *see* subsystem hierarchy
root window, *see* window
`ROOTFRAMEDIM`, 42
`ROOTLOCATION`, 42
`ROOTWINDOWDIM`, 42
RSF, *see* Rigi Standard Format
running
    a command, 54
    a script, *see* script
    the editor, 38

saving
    a graph, 62
    a view, 29–30, 130–131
    arc type colors, 92
    node type colors, 88
scale factor, 110–112
scaling, 109–112
    automatic, 112
    nodes to fit, 109
    reset, 111
    selected nodes to fit, 110
scaling increment, 136
script, 31–35, 53–57
    `columns` example, 32–34
    loading a, 34, 55
    running on domain switch, 50, 53
    running on startup, 38, 53
    using Tcl, 53
searching, *see* selecting
selecting, 15–16, 70–81
    a node, 16, 70
    after filtering, 105
    all nodes, 15, 72
    an arc, 16, 70
    complement nodes, 72
    incoming neighbor nodes, 19, 79
    incoming reachable nodes, 81
    nodes by attribute value, 75
    nodes by dragging, 16, 71
    nodes by name, 19, 74
    nodes by shift-clicking, 16, 71
    nodes by structure, 76
    nodes by type, 32, 77
    outgoing neighbor nodes, 78
    outgoing reachable nodes, 80
Selection window, 65, 95
    filter inheritance by, 108
    opening a, 95
`setenv`, 45
Settings dialog, 69
showing
    arcs by type, 107
    available commands, 56
    children in a SHriMP window, 133
    global Tcl variables, 57

names of nodes, 24, 104, 136
nodes by type, 18, 106
previously hidden nodes, 105
script body, 56
the clipboard, 103
SHriMP window, 132–138
adjusting step size of, 136
constraining children in, 137
editing source text, 138
hiding children in, 134
opening a, 133
opening a Children window for, 137
overlapping children in, 136
printing a, 138
showing children in, 133
viewing annotation, 138
SIGINT, 59
slice, 13, 14, 97
`source`, 34, 55
source text
defining location of files, 85
editing for a node, 85–86, 138
file attribute, 60, 85
lineno attribute, 60, 85
spring layout, *see* arranging
`SRCDIR`, 41, 42, 85
stacking windows, 66
structure definition, *see* data type
structured RSF, *see* Rigi Standard Format
subgraph
copying a, 102
cutting a, 102
deleting a, 102
pasting a, 102
subsystem, 1, 5, 10
creating a, 19–20, 100
dependencies of, *see* exact interface
expanding a, 101
identification of, 7, 18–21
metrics on, *see* graph quality
multiple types of, 82
uses for, 1, 18
subsystem hierarchy, 5, 10
confusion with, 17
double-click on leaf, 85, 86
double-click on non-leaf, 93
overview of, *see* Overview window
projection of, *see* Projection window
root of, 12, 13
traversing in, 13–14, 21–24
windows on, *see* window types
`sugiyama`, 35
Sugiyama layout, *see* arranging
supplier node, 14, 89
switching domain model, 12, 52

text editor
defining the default, 46
Text editor window, 25–27, 29, 85, 91, 123, 125, 127, 129, 138
`TEXTEDITOR`, 41, 42, 46
`TEXTFONT`, 41, 42
`TMPDIR`, 42
toolbar icons, 139
tree depth, 95, 117, 118

Uniform Resource Locator
arcurl attribute, 92
defining the root page, 87, 92
nodeurl attribute, 87
opening for a node, 87
opening for an arc, 92
unstructured RSF, *see* Rigi Standard Format
updating the active window, 20, 67
URL, *see* Uniform Resource Locator

`vi`, 42, 46
view
and graph model, 29, 130
limitations of, 130
loading a, 30–31, 131
saving a, 29–30, 130–131
working with, 29–31, 130–131

warning, 2, 17, 62, 85, 91, 105, 119, 131

web browser
    defining the default, 46
`WEBBROWSER`, 41, 42, 46, 87, 92
`WEBROOT`, 42, 87, 92
window
    activating a, 12, 64, 66
    active, *see* active window
    basics, 64–69
    canvas area in, 11, 64
    cascading, 66
    closing all, 68
    externally controlled, 65
    message area in, 11, 64
    opening a, *see* opening
    root, 6, 11, 13, 30, 39
    stacking, 66
    title of, 11–14, 22, 23, 35, 42, 64, 65, 96, 106, 107, 133
    types of, 65
Workbench window, 6, 11, 39
`WORKBENCHFONT`, 41, 42

X font specification, 48
`xfontsel`, 48
`xterm`, 42, 46

zooming
    in, 110
    out, 111