MatrixPro - User's Manual

Version 1.2

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1 Introduction

MatrixPro is a tool for visualizing and animating data structures and algorithms. It can be used by teachers for demonstrating algorithms and by students for experimenting with algorithms and solving exercises. The most widely taught tree and graph algorithms are built-in, so that creating a visualization can be done interactively without programming. Visualizations can be saved and reloaded, and can be exported in SVG or LaTeX formats.

A novel feature of MatrixPro is the ability to simulate algorithms by direct interaction.

The website of MatrixPro is `http://www.cs.hut.fi/Research/MatrixPro/`.

2 Installing MatrixPro

This section describes how to download and run MatrixPro. Advanced material on building and installing the software can be found in Appendix C.

MatrixPro requires Version 1.4 of the Java SDK or JRE be installed.

Download the file `matrixpro-full.jar` from the MatrixPro website. On many platforms you can create an icon for this file and then run the program simply by double-clicking on the icon. Alternatively, you can start the tool by typing the following at a command prompt:

```
java -jar matrixpro-full.jar
```

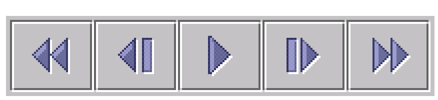
For this to work, the Java JRE or SDK must be in the search path.

3 Quick start

This chapter gives you a brief explanation of how to use MatrixPro. Only a few of the features will be presented, but it should be enough to get you started without reading more than a few pages.

3.1 Interacting with MatrixPro

Figure 1 shows the main window of MatrixPro. Along the top is the menu bar (Section 5). Below it on the left is the *animator* containing VCR-like controls for the visualization:



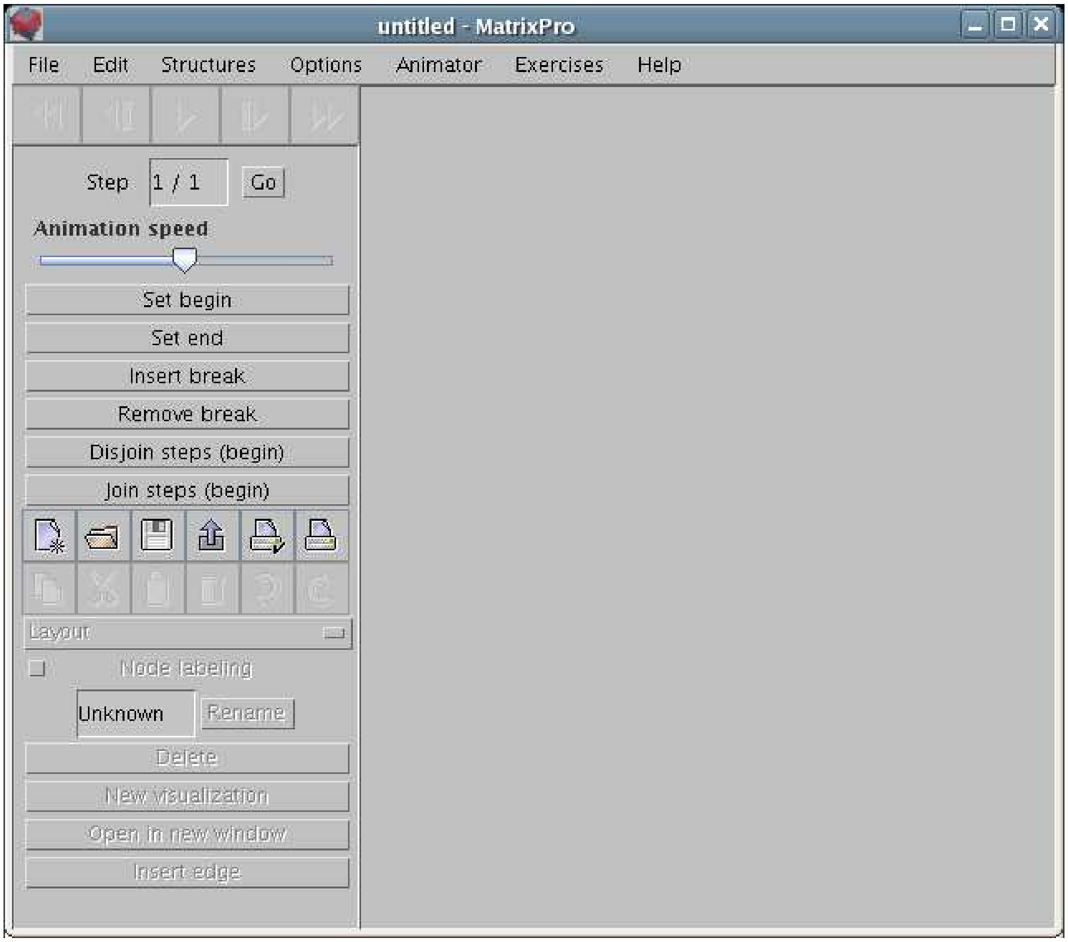


Figure 1: The MatrixPro main window.

and below the animator is the *toolbar* with additional controls (Section 9). On the right is the structure panel where all the visualizations appear; these are explained in Sections 7 and 8. Not shown are context-sensitive popup menus (Section 6).

The functions of the animator buttons (from left to right) are:

- Begin will undo all operations in the history.
- Backward will undo one operation.
- Play will run the animation continuously from the current position to the end of the scenario. The button will change to a Stop button that stops the animation.
- Forward will redo one operation.
- End will redo all operations in the current scenario.

3.2 The structure panel

The Structures menu contains four submenus for creating various data structures:

Fundamental data types (FDT) These are "raw" data types that have no predefined semantics, for example, binary trees or graphs. The elements of FDTs are normally *keys*, though they can also be other FDTs.

Conceptual data types (CDT) These are data structures that have constrained values and operations defined upon them. For example, binary search trees are constrained so that values in the left subtree of a node are less than values in right subtree, and the operations of insert, delete and search are defined upon them.

Utilities These are primarily structures containing keys for use in FDTs and CDTs.

Datatype with data These are pairs of array of keys and commonly used CDT structures.

Multiple data structures can be created in the structure panel; the panel can be scrolled or resized as needed.

Let us work through an example. Select Structures/Utilities/Array of Random Keys. The array will appear in the upper part of the structure panel. Next, select Structures/Conceptual data types/Binary Search Tree. An empty BST will appear below the array in the structure panel. Drag the keys one-by-one from the array of keys and drop each one *onto the title bar* of the BST. While an object is being dragged, a frame appears around it. The keys are inserted into the correct positions, according to the definition of a BST (Figure 2). Instead of dragging keys one by one, you can drag the entire array of keys (from its title bar) and drop it onto the title bar of the tree. All the keys in the array will be inserted one by one into the binary search tree.

Now you can step through the animation by clicking the Backward and Forward icons of the animator; clicking Begin will start the animation from the beginning and clicking Play will run it without stopping.

Move the mouse over a node until **the node label is highlighted** (e.g. turns red). Press the right mouse button and select Delete from pop-up menu. The node will be deleted from the tree according to the definition of BSTs. Alternatively, move the mouse over a node until **the node background is highlighted** (e.g. turns blue) and select Delete; the subtree rooted at that node is deleted.

In the next section, we will desribe in detail how to interact with data structures.

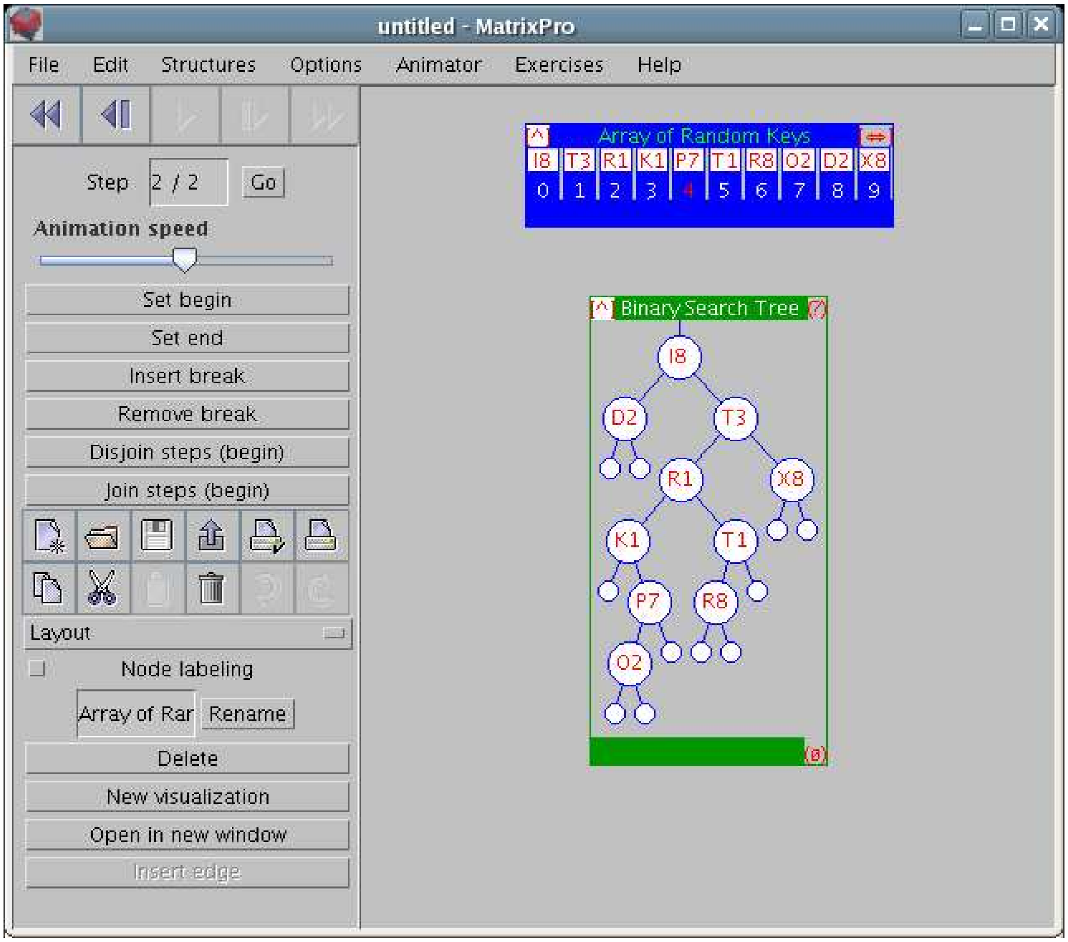


Figure 2: Inserting keys into a Binary Search Tree.

4 Interaction

4.1 Hotspots

Data structures with a visible title have a hotspot in the left corner of the title bar, denoted by a square containing a red "[^]". The popup menu can be opened by left-clicking on this hotspot (Section 6).

Arrays contain another hotspot (two-headed arrow) in the right corner of the title bar. The number of elements displayed in the array can be changed by dragging this hotspot left or right.

There are also two additional hotspots. In the top right corner of the CDT structures there is the search hotspot "(?)" which can be used to call the search method of the CDT structure by dropping the searched key on the hotspot. In the bottom right corner of structures (except arrays) there is the null hotspot "(0)" which can be used to modify references point to empty nodes. To use it, drag and drop a reference to the hotspot and update references from Options menu.

See Figure 2 for examples of the hotspots.

4.2 Inserting keys into a data structure

In the example of the binary search tree, we showed how keys can be inserted into a data structure by dropping them onto the title bar of the data structure. The insertion routine of the corresponding data structure will then be invoked and the visualization will be updated. It is also possible to insert a key in a *specific* node of a data structure, by dragging and droping the new key into the desired node.

For example, create an array of keys and an AVL tree and insert `M` into the tree. You can now experiment with dragging and dropping another key (say `P`) either onto the title bar or into the root node or one of the leaves (Fig. 3). In each case the results will be different.

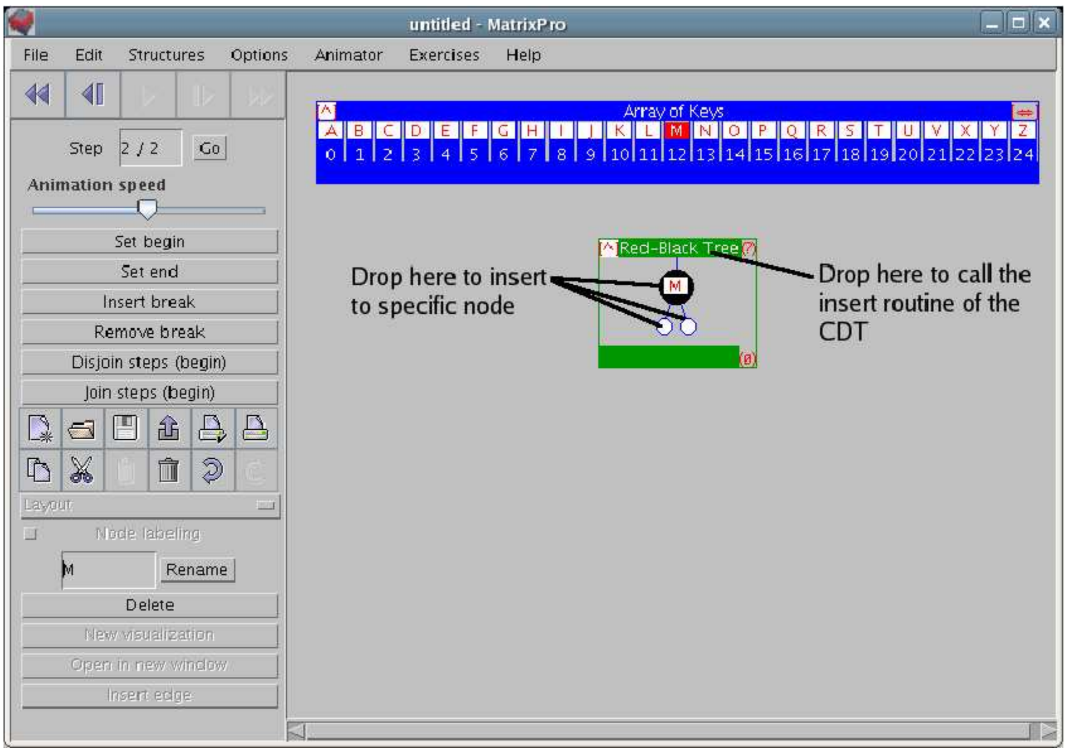


Figure 3: Inserting keys into a specific node or by invoking the insert routine

MatrixPro supports nested data structures of arbitrary complexity. You can store an array inside a node of a graph or a tree in as an array element; for example, the B-tree implementation (2-3-4 Tree) uses arrays nested within trees to hold the keys. Some fundamental data types, such as arrays or binary trees, have no semantics for inserting keys "into the structure." For such structures, keys must be inserted at a specific position; in case of inserting a set of keys, the entire set will be inserted as a unit.

4.3 Deleting keys and nodes

Elements can be deleted from a data structures by using the Delete command in the popup menu. What the Delete command actually does depends on the data structure or structure component upon which it was invoked. Deleting a data structure will remove the whole structure, including its visualization from the current frame; it is not possible to undelete it by going backward in the animation. Deleting a tree node removes the subtree rooted at the deleted node, while deleting a graph node causes that node and all references to or from it to be deleted. Deleting a node in a linked list will remove that node from the list. Some components of structures, such as array indices, cannot be deleted.

The effects of deleting a node from a CDT depend on the CDT in question. The two ways to delete an item described above both act as if the deletion were performed on the FDT upon which the CDT is based. A different way to delete an item from a CDT is to hold the Shift key down while dragging the item away from the CDT and dropping it somewhere else (such as an empty part of the animation window). This deletes the item from the CDT, and if the item is dropped on another structure, it is inserted as usual. Note that the CDT's delete routine is used to perform the delete in with Shift held down; for example, Shift-dragging an item from a stack will always cause the topmost item on the stack to be deleted regardless of which item was dragged.

Elements can also be deleted by dragging and dropping them in a trash can, which can be created by selecting Structures/Utilities/Trash.

4.4 Other operations

To copy a subtree, drag the root node of the subtree to the desired position. If you copy a subtree to a different position in the same tree, the first subtree (that will be found in a DFS) will be displayed, and the other copies will be shown minimized. The copied tree points to the original tree, so changes in either of the visualizations affect both the original and the copy.

References in graphs and trees can be moved to point to another node by dragging and dropping them on the new target node. Tree nodes that have no references are removed. References must be explicitly updated after a drag and drop operation by selecting Options/Update References.

In MatrixPro operations are grouped into animation steps that can contain other, smaller, steps. The smallest possible steps (atomic steps) may not have any visible effect on the visualizations. Normally, the animation control buttons work on non-atomic steps, but they work on atomic steps if Shift is pressed when selecting Backward or Forward.

5 Menu commands

5.1 File menu

New Window (Ctrl+N): Opens a new animation window.

Open (Ctrl+O): Opens a new data structure. Java class files, saved Matrix animations and text files containing the string representation of a data structure can be opened. MatrixPro knows how to visualize saved animations and strings automatically, but Java classes must implement the visualization interfaces correctly. Appendix A describes the text file formats as well as an extended text file format. Animations are saved as serialized Java objects, so there will be problems if an object's class has changed after it was saved. Customizations to the visualization are not saved with the serialized animations.

Open recent: Opens one of the recently opened or saved files.

Save As...: Saves the data structures either as Serialization or ASCII. The type can be set from the Files of Type drop-down list.

Close (Ctrl+W): Closes the current window; if there is only one window, this is the same as Exit.

Clear: Clears the current active structure panel.

Export...: Exports the current animation or the view of one step of the animation in one of the formats selected from Files of Type. These are described in Appendix B.

Page Setup...: Opens the page setup dialog for printers.

Print...: Prints the current window.

Print animation...: Prints the entire animation, each step on its own page.

Exit: Exits the program.

5.2 Edit menu

Font: Changes the font used by visualizations.

Font size: Changes the font size used by visualizations.

Show: Selects the visible user interface components: either the toolbar *including* the animator or only the animator.

Copy (Ctrl-C): Copies the selected structure to the clipboard.

Cut (Ctrl-X): Copies the selected structure to the clipboard and then deletes the original structure.

Paste (Ctrl-V): Pastes the structure from the clipboard. This calls the insert routine of the selected structure, so the behaviour depends on the implementation of that structure. Note that the pasted structure and the original structure are both visualizations of the same structure, so modifications done to one change the other.

Paste as duplicate: Pastes the structure from the clipboard as a new visual structure; only whole structures can be pasted this way, not keys or nodes. A structure can be selected by clicking on its title bar. Changes in the new visualization affects the original and vice versa.

Delete: Deletes the selected structure. Again, the effect depends on the underlying structures.

Undo: Undoes the last user interface operation. Not all operations can be undone and visualization customizations such as rotations are lost.

Redo: Redoes the last undone user interface operation. Visualization customizations are lost.

5.3 Structures menu

The Structures menu is used to instantiate the data structures built into MatrixPro. For more information about the different structures, see Section 7.

5.4 Options menu

The options menu contains special commands for simulation purposes

Update references: Updates the references between elements and repaints the visualized data structures. You can change several references at a time by moving them to point to the desired target. The underlying structure (and thus, the visualization) is not updated until the update references operation is called, as described in Section 4.4.

Swap: Changes the semantics of drag and drop. The default semantics is Insert which moves an element from the source location to the destination but does not change the original source structure. The semantics of Swap cause the source and target elements to be swapped. Swap is intended for use on keys in arrays and FDTs.

Preferences..: This opens a dialog with two tabbed panes.

- **Toolbar** Customizes the toolbar (Figure 4). A component can be hidden by selecting it from the list of visible components and clicking Hide, and a hidden component can be made visible by selecting it and clicking Show. Components can be moved up or down in the toolbar by selecting them and clicking Move up or Move down. Add opens a dialog for adding a component; you have to select its class file.

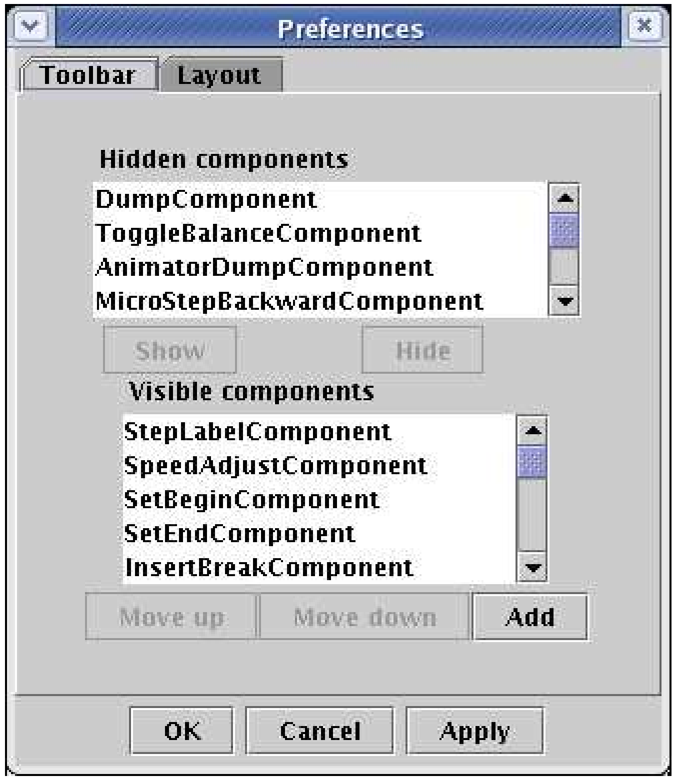


Figure 4: Customizing the toolbar.

Layout Customizes the positions and insets of the visualizations.

The values that can be set for each visualization are:

- *gridx* — x position of the visualization (left=0)
- *gridy* — y position of the visualization (top=0)
- *gridheight* — number of rows for the visualization
- *gridwidth* — number of columns for the visualization
- *ipadx* — space to add to the components' width
- *ipady* — space to add to the components' height
- *weightx* — how to distribute extra horizontal space
- *weighty* — how to distribute extra vertical space
- *top inset* — amout of external padding above the visualization
- *bottom inset* — amout of external padding below the visualization
- *left inset* — amout of external padding left of the visualization
- *right inset* — amout of external padding right of the visualization

5.5 Animator menu

The Animator menu contains commands to control and modify the animator. In addition to menu equivalents of the buttons on the animator, there are two additional selections:

Set beginning here: Sets the current state to be the beginning of the animation. The previous states can no longer be reached.

Set end here: Sets the current state to be the end of the animation. The following states can no longer be reached.

5.6 Exercises menu

This menu contains a large number of algorithms and data structures, categorized in submenus. Selecting one of them causes a new window to be displayed containing a random instance of an exercise for that topic. On the left a panel appears with instructions on the exercise, while on the right a structure panel is initialized.

For example, select Exercises/Basic algorithms/Binary search. The structure panel is initialized with an array of keys and an empty linked list; the instruction panel contains the value to search for, and the instructions are to drag the visited keys from the array to the linked list. When you have finished select actions from the Exercise menu:

Reset: Resets the exercise to a new instance.

Model answer: Displays an animation of the correct answer to the exercise.

Grade my solution: Displays a frame with the number of correct steps in the solution.

5.7 Help menu

Help: Displays information about where to find MatrixPro User's manual and some tutorials.

About: Displays the copyright notice and the version.

6 Popup menu

Popup menu can be opened by right-clicking on a component. That component can be a structure, a node or a key. The available operations in the popup menu depend on the component which was right-clicked.

New visualization: Creates a new visualization of the data structure in the current animation window. Changes in the new visualization affects the original and vice versa.

Delete: Invokes the delete method for this object. By default this removes the selected structure or component from the underlying data structure.

Change layout: Changes the layout for the data structure.

Visualization: This submenu (described in Section 6.1) contains commands that directly modify how the data structure is visualized.

Filters: This submenu (described in Section 6.2) contains commands that—depending on the data structure—filter out the structure's details or select only a part of it to be represented.

Rename: Renames a data structure. This only affects keys, data structures with a header, or labeled nodes. This command is also used to modify the value of a key.

Rename all keys (arrays only): Opens a dialogue to rename all keys of the array. The keys must be separated by spaces.

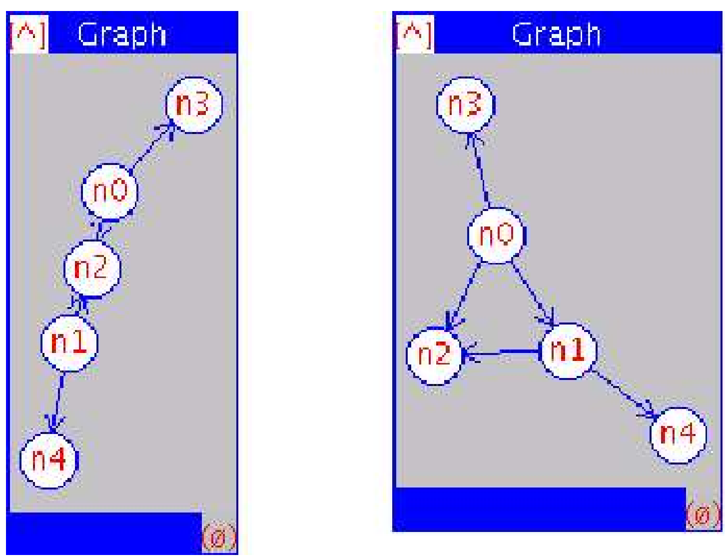
Labeled (nodes only): Chooses whether labels next to nodes are displayed.

InsertEdge (graph vertices only): Inserts an edge between two vertices after the destination vertex has been clicked.

Refresh: Refreshes the visualization. It will also create new keys for an array of random keys.

Call: Calls a user-defined method (without parameters) if they have been defined for this object.

Change Edge Length: (For graphs using either the Kamada-Kawai or the Fruchterman-Reingold layout.) Opens a popup window where you can type a new edge length used in the algorithm. Changing its value can have dramatic effect on the layout:



6.1 Visualization Menu

The visualization menu contains commands that modify the way the structure is visualized:

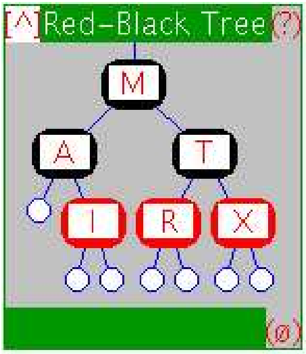
Minimized: Minimizes or maximizes a visualization.

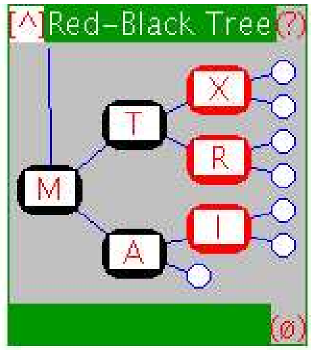
Alive: Enables and disables a visualization's response to simulation operations such as dragging and dropping.

Enable: Enables and disables direct access to the subcomponents of a visualization.

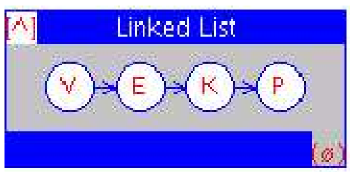
Titled: Displays the title bar in a data structure.

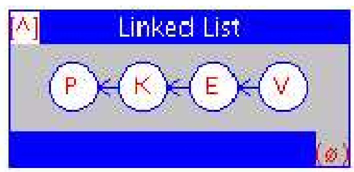
Rotated: Rotates the visualization:



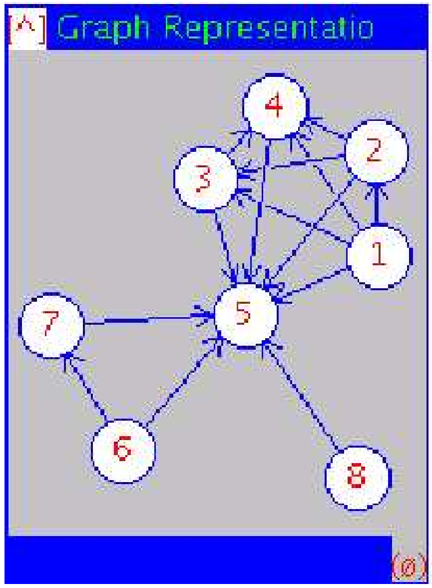


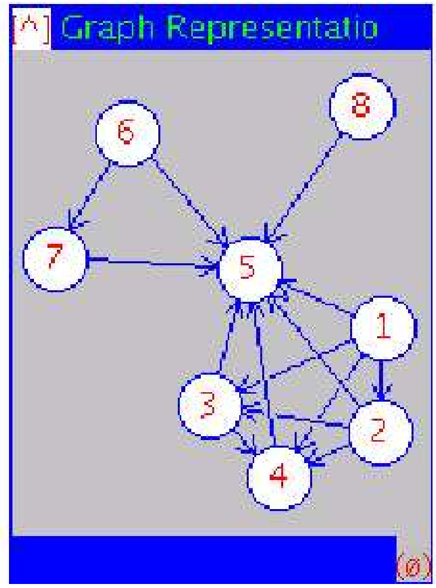
FlipX: Flips the X coordinates of the visualization:





FlipY: Flips the Y coordinates of the visualization:





Indexed (arrays only): Displays or hides the indices of an array.

6.2 Filters menu

The filters menu depends on the data structure.

Directed (trees and graphs only): Edges are directed.

EmptyLeaves (trees only): Show empty leaves.

DFSvalidate (graphs only): Validate the graph in DFS order; otherwise, validate in BFS order.

BackEdges: Show back edges for graphs.

ForwardEdges: Show forward edges for graphs.

CrossEdges: Show cross edges for graphs.

Increment (arrays only): Increment the size of an array.

Decrement (arrays only): Decrement the size of an array.

Double (arrays only): Double the size of an array.

Halve (arrays only): Halve the size of an array.

RaiseIndex (arrays only): Shift array indexes right by one.

LowerIndex (arrays only): Shift array indexes left by one.

7 Structures

7.1 Fundamental data types

Fundamental data types (FDT) include the basic structures like binary trees, arrays, linked lists and graphs:

Array Inserting keys in an array can be done by dropping them either on the key (initially empty) or the index.
Default layout: array
Possible layouts: array

Linked List Inserting keys in the list can be done by dropping them onto the structure. This always inserts the keys as the first element of the list. To insert a key in the middle of the list, drop the new key onto the node *after* which you want the new key to be inserted.
Default layout: list
Possible layouts: list

Dynamic Binary Tree A dynamic binary tree starts with a single node that is the root. Dropping a key into a leaf, creates a node with two leaves, enabling construction of arbitrary binary trees.
Default layout: layered tree
Possible layouts: array, layered tree, leaf tree, layered graph vertex

Static Binary Tree (8) This is a binary tree with exactly eight nodes. This is an array representation of a tree.
Default layout: layered tree
Possible layouts: array, layered tree, leaf tree

Common Tree This can be used to construct arbitrary trees. A new node is inserted as a child of an existing node by dropping a key onto the existing node. Be sure to drop the key on the *node* (the background turns blue), not onto the *key* (the key turns red).
Default layout: layered tree
Possible layouts: layered tree, leaf tree, layered graph vertex

Directed Graph Nodes can be inserted by dropping them onto the graph. Inserting edges can be done in three ways:

- Select Insert edge from the source node's popup menu and then click on the target node.
- Select the source node, click Insert node on the toolbar and then click on the target node.
- Select the source node with Shift key held down and then click on the target node.

Default layout: layered graph
Possible layouts: layered graph, Kamada-Kawai graph, Fruchterman-Reingold graph, dummy graph, array

Undirected Graph Nodes and edges are inserted in the same way as for directed graphs.

Default layout: layered graph

Possible layouts: layered graph, Kamada-Kawai graph, Fruchterman-Reingold graph, dummy graph, array

7.2 Conceptual data types

Conceptual data types (CDT) are more complex structures that have a predefined set of operations whose implementation depends on the CDT. Inserting keys should be always done by dropping the keys on the title bar of the CDT. Keys can be deleted by selecting either Delete from the popup menu of a key, or by selecting a key and then deleting it using toolbar button, or by holding the Shift key while dropping them outside the structure. For more information on deleting parts of the structure see Section 4.3.

Binary Search Tree

Default layout: layered tree

Possible layouts: array, layered tree, leaf tree, layered graph vertex

2-3-4 Tree

Default layout: layered tree

Possible layouts: layered tree, leaf tree

Red-Black Tree

Default layout: layered tree

Possible layouts: array, layered tree, leaf tree, layered graph vertex

Digital Search Tree

Default layout: layered tree

Possible layouts: layered tree, leaf tree

Radix Search Tree

Default layout: layered tree

Possible layouts: array, layered tree, leaf tree, layered graph vertex

Binary Heap

Default layout: layered tree

Possible layouts: array, layered tree, leaf tree

AVL Tree

Default layout: layered tree

Possible layouts: array, layered tree, leaf tree, layered graph vertex

Splay Tree

Default layout: layered tree

Possible layouts: array, layered tree, leaf tree, layered graph vertex

Stack(list)

Default layout: list
Possible layouts: list

Stack(array)

Default layout: array
Possible layouts: array

Queue

Default layout: list
Possible layouts: list

7.3 Utilities

Trash Visual objects that are dragged and dropped onto the Trash are deleted.

Array of Keys An array of all the (capital) letters of the alphabet.

Array of Random Keys An array of random keys of three alphanumeric characters.

7.4 Datatype with data

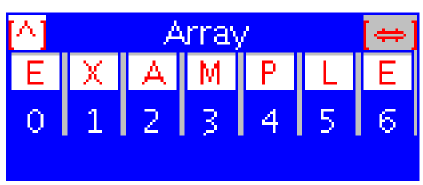
Array of Keys + ... A shortcut to create both a Array of Keys and one of the CDTs.

8 Layouts

There are several different layouts that can be used to visualize the data structures. The layout of a structure can be changed using the Change layout submenu of the popup menu or using the Layout toolbar component.

8.1 Array

The layout Array can be used to represent arrays and trees:



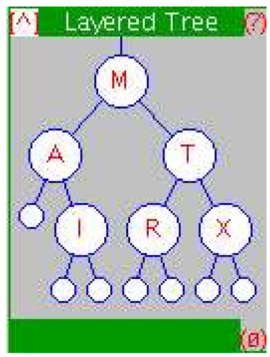
See Section 4.1 for information on the hotspot used to change the size of an array; the size can also be changed using the popup menu's submenu Filters (see Section 6.2).

8.2 List

The layout List can be used to represent linked lists, stacks and queues:

8.3 Trees

Layered Tree The Layered Tree layout:

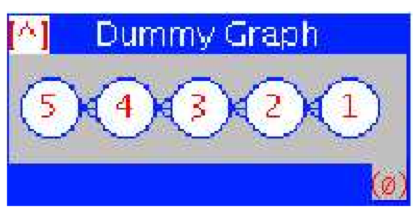


draws a tree using the Layered-Tree-Draw algorithm, extended to support non-binary trees and variable-size nodes.

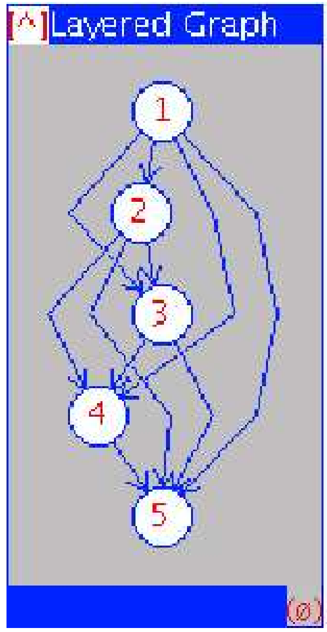
Leaf Tree

8.4 Graphs

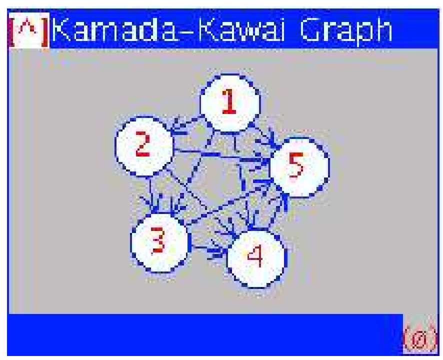
Dummy Graph The dummy graph layout is a simple layout, where all the nodes are positioned in a horizontal line:



Layered Graph The layered graph layout uses a directed acyclic graph algorithm supporting arbitrary graphs and variable-size nodes:

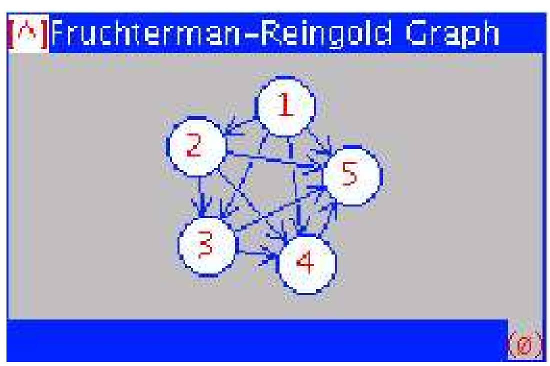


Kamada-Kawai Graph This layout uses the Kamada-Kawai layout algorithm:



The layout can be modified by Change edge length from the graph's popup menu.

Fruchterman-Reingold Graph This layout uses the Fructerman-Reingold layout algorithm:



The layout can be modified by Change edge length from the graph's popup menu.

9 Toolbar

The contents of the toolbar can be customized (Section 5.4) and not all components described here appear by default. The toolbar components are described in a set of tables:

Animation control Table 1.

Animation modification Table 2. All these commands can be undone by selecting undo.

Structure modification Table 3. If no structure is selected, these buttons will be disabled (unless otherwise noted).

Miscellaneous Table 4.

Developer features Table 5.

Some structures can have operations that can be added as buttons to the toolbar. There is a special toolbar component for these components called ContextualPanel. The components for the operations appear in this toolbar component.

Some toolbar components appear or are enabled if they are relevant to the structures appearing in the structure panel; however, the toolbar is not updated until after moving the mouse outside a structure.

Table 1: Animation control

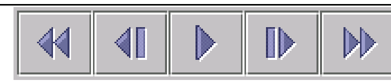
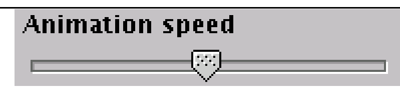
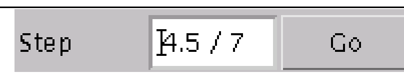
Component	Explanation	Picture
Animator	Begin undoes all the operations. Backward undoes one operation (one enclosed animation step). If the data structure is modified while there are undone operations, these operations can no longer be redone. Holding Shift when pressing Backward undoes one atomic step at a time. Play executes the animation from the current state to the last one. Play changes to Stop for stopping the animation. Forward redoes one operation, or one atomic operation if Shift is held. End redoes all.	
Animation Speed	The speed of the animation can be controlled: right for faster and left for slower.	
Step View	The current step and the number of steps in the animation are shown. Enter a step number and press Enter or click Go to jump to the desired step in the animation.	
Microstep backward	Move one atomic operation backward	
Microstep forward	Move one atomic operation forward	

Table 2: Animation modification

Component	Explanation	Picture
Set begin	Sets the current state to be the beginning of the animation. The previous states can no longer be reached.	
Set End	Sets the current state to be the end of the animation. The following states can no longer be reached.	
Insert break	Add a new break in the animation: the animation will promote the given step to a top level step and make the animator stop at this position when moving Backward or Forward.	
Remove break	Remove a break in the animation so that Backward and Forward no longer stop at this step.	
Join steps	Join several steps in the animation into one step: (1) Go to the step you want to start the join at; (2) Press Join steps; (3) Go to the step you want to end the join at; (4) Press Join steps again. It does not matter which of the selected steps comes first in the animation.	
Disjoin steps	Break up several steps in the animation into distinct steps: (1) Go to the step you want to start the disjoin at; (2) Press Disjoin steps; (3) Go to the step you want to end the disjoin at; (4) Press Disjoin steps again. It does not matter which of the selected steps comes first in the animation. (This command might have no visible effect on the animation.)	

Table 3: Structure modification

Component	Explanation	Picture
New visualization	Creates a new visualization of the selected data structure in the current animation window. Changes in the new visualization affect the original and vice versa.	
Open in new window	Opens a new visualization of the selected data structure in a new animation window. Changes in the new visualization affect the original and vice versa.	
Delete	Invokes the delete method for the selected object. By default this removes the selected structure or component from the underlying data structure.	
Insert edge	Adds edges to graphs. First select the source node, then click Insert edge and finally click on the destination node. If something else than a node of a graph is selected, this button is disabled.	
Rename	Renames a data structure. This affects only keys, data structures with a header and labeled nodes.	
Layout	Changes the layout for the selected data structure; select a layout from the drop-down list.	
Set Edge Length	Enter a new edge length and press Enter or Set edge length. Enabled only for graphs using either the Kamada-Kawai or the Fruchterman-Reingold layout.	
Label Nodes	Automatically label the nodes in a structure with unique numbers beside every node. For an example, see Figure 5. For arrays this feature is available but it does nothing.	

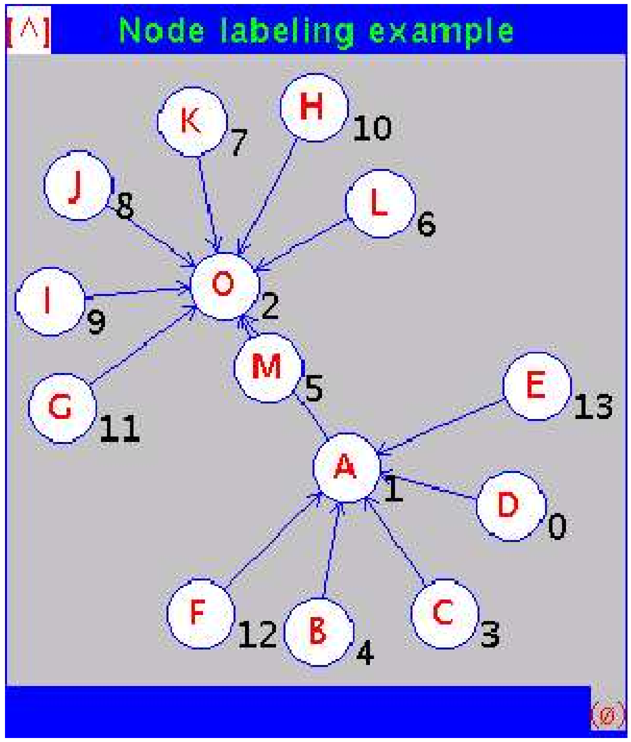


Figure 5: Example of the automatic node labeling.

Table 4: Miscellaneous components

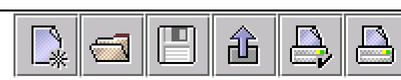
Component	Explanation	Picture
Edit	Quick access to Copy, Cut, Paste, Delete, Undo and Redo operations.	
File	Quick access to New, Open, Save animation, Export, Page Setup and Print.	
Save	Saves the current structures.	

Table 5: Developer's components

Component	Explanation	Picture
Animator dump	Shows debug information for the animator.	
Debug	Switches debug output on or off.	
Dump	Shows debug information for a selected structure or for all objects if no structure is selected.	

A Text File Formats

Section 5.1 described the three representations supported by MatrixPro text files. All examples in this appendix can be found in the `$MATRIX/code/examples/` directory.

edge list The edges of the graph are listed with one node pair per line; each node pair corresponds to an edge in the graph. (Default.)

```
#matrix graph
1 2
1 3
1 4
1 5
2 3
2 4
2 5
3 4
3 5
4 5
```

adjacency-list Each line contains a node and the nodes adjacent to that node; the node and its list of adjacent nodes define edges in the graph.

```
#matrix graph adjacency-list
A:B C D
B:C
C:E
D:E
E:B
F:G
G:H
H:F
```

array Each line contains one key, starting from index 0.

```
#matrix array
A
B
C
D
E
F
```

There is also an extended text file representation which makes it possible for one file to contain an arbitrary number of structures. It also enables keys in the structures to contain special characters like spaces. With this representation, structures can be nested. For example:

```
#matrix structures                //header of the file
test#1                            //name of the first main structure
#matrix graph adjacency-list      //header of the structure
a:test#1_1 c                      //keys in adjacency-list format
test#1_1:e                        //test#1_1 is an inner structure
c:d
e:test#1_2
#EOS                              //end of structure -character
  test#1_1                        //description of the inner structure
  #matrix array
  a
  b
  c
  #EOS
  test#1_2                        //another inner structure
  #matrix graph adjacency-list
  key1:key2 key3 key4
  key2:test#1_2_1
  key4:key6 key7
  #EOS
    test#1_2_1
    #matrix array
    d
    e
    f
    #EOS
test#2                            //another main structure
#matrix array                     //header of the structure
asdf                              //keys in array format
test#2_1
qwerty
#EOS
  test#2_1                        //inner structure
  #matrix array
  aa
  bb
  cc
  dd
```

```
#EOS
```

The names of the main structures must end with a number (for example, `structure#1`) to distinguish them inner structures. Names of the inner structures should be chosen so that it is easy to recognize their parent structures (for example, `structure#1_1`). The description of the structure comes after its name. This can be either in adjacency-list or in array representation. The end of a structure is marked by `#EOS`.

If the keys contain special characters like spaces, _ or #, they must be preceded by a single quote `'` (for example, `inner' structure`, `a'_b`, `'#matrix`). The quote character is removed when the keys are used. If many nodes have the same key in graph, these duplicates can be marked by adding a number at the end (for example, `key`, `key_2`).

Indentation can be freely used, for example, to set off inner structures from outer structures. Comments start with string `//`. Space is also removed from the end of each line.

Some information about the visualization of each structure (representation, rotated, minimized, and name) can be saved into a file. For example:

```
test#1                              //name of the structure in ASCII file
#representation layered graph
#rotated true
#minimized false
#name Binary Tree                   //title of the opened structure
#matrix graph adjacency-list        //header of the structure
```

The structure created from a text file can be visualized as either a tree or a graph. However, if a structure is saved to a text file, its functionality is not saved, only its structure. Additional information can be saved about some structures. Currently, this works only for binary trees: if a BST is saved to a text file and then reopened, it is opended as a binary tree not as a general structure. For example:

```
#matrix structures
structure#1
#name Binary Tree
#matrix autopolymorph matrix.structures.FDT.probe.BinTree   //header
Ns1:5QH BpW
5QH:null s8J
s8J:null GFc
GFc:null null
BpW:Ns1_2 Ddv
Ns1_2:null null
Ddv:null null
#EOS
```

This header contains information about what structure should be loaded, in this case, a binary tree. Structures that are implemented as binary trees (AVL Trees, Red-Black Trees, Splay Trees, etc.) can be saved and loaded as a binary trees.

The first key in the structure description (`Ns1` in this example) becomes the root node of the binary tree. The string `null` is recognized while loading the ASCII file and will be replaced with an empty node in the structure. This is only necessary when the left child of a node is empty and the right child contains some key.

B Exporting

MatrixPro can export visualizations in one of the following formats:

LaTeX Export the current view in LaTeX format. The Complete document checkbox selects whether or not to export a complete LaTeX document or just a document fragment. Exporting in LaTeX creates a TeXdraw representation of the current view. TeXdraw can be found at `http://ctan.org`.

SVG Export the animation in SVG format. Exported SVG animations can be viewed with the Adobe SVG Viewer browser plug-in that can be obtained from `http://www.adobe.com/svg`. The SVG can be configured (Fig. 6). It can be compressed with gzip that is supported by Adobe's SVG plug-in, an animator panel can be included (Fig. 7), and the animation can be scaled. If the animator panel is not added to the animation two more options are available: the length of the pause between steps (in seconds), and the length of one step of animation (in seconds).

PNG Export the current view or the animation in PNG format. You can select whether to export the current view (default) or the entire animation as a series of pictures. If the picture series is selected, the files will be named `<name><step>.png`.

For more information about exporting TeXdraw pictures and SVG animations, see the tutorial at `http://www.cs.hut.fi/Research/MatrixPro/tutorials/export_tutorial.shtml`.

C Advanced Installation

If you already have a copy of the Matrix framework that is suitable for this version of MatrixPro, you can download this type of release. If you have the matrix.jar file in the same directory as matrixpro.jar, you can start it by typing:

```
java -jar matrixpro.jar
```

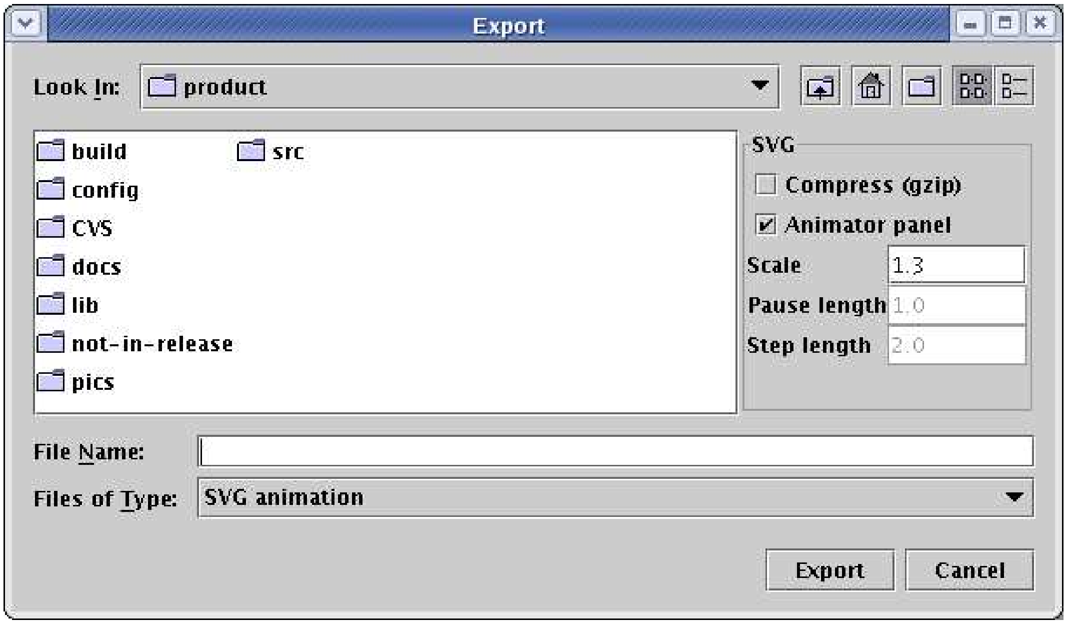


Figure 6: SVG export dialog

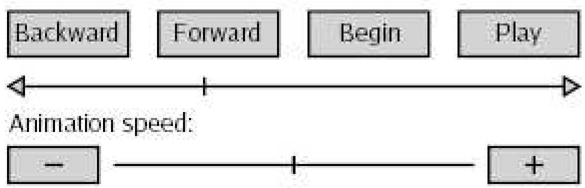


Figure 7: Animator panel in SVG animation

In general, you can start it by typing:

```
java -classpath <path-of-matrix.jar>:matrixpro.jar
matrixpro.ui.MainFrame <configuration-file>
```

Substitute the path of the matrix.jar file for <path-of-matrix.jar> and the path and filename of the configuration file for <configuration-file>. You can get the configuration file from the download page.

The source release does not contain the Matrix framework. To be able to compile the system, you should download an appropriate version of Matrix. By default, the MatrixPro lib directory is expected to contain matrix.jar. The source release of MatrixPro is available as a gzipped TAR or as a ZIP file. To build MatrixPro you should have Apache Ant installed. The build file (`build.xml`) contains the following targets:

clean Removes the compiled class files.

compile Compiles all source code.

javadoc Generates the Java API documentation for the system.

run Compiles and runs the application.

manual Compiles PDF, PS and HTML versions of the manual from LaTeX source (LaTeX, dvips, ps2pdf and latex2html must be in the path).

The important directories are:

build/classes This directory contains the compiled classes, and is created only if you use the Ant build file provided with the source.

docs/javadoc Contains the Java API documentation of the system.

docs/manual Contains the user's manual.

lib Empty. This directory is where the ant build file searches for the matrix.jar file.

src Contains the source code of MatrixPro.

If you don't want to copy the matrix.jar file into the lib directory (or create a symbolic link if your file system supports them), you can modify the build.xml file. Change the value of the property named matrix.jar:

```
<property name="matrix.jar" value="\${lib.dir}/matrix.jar"/>
```

If you don't have Ant and you don't want to install it, you can try the following in the MatrixPro root directory (in Unix):

```
javac -classpath src:lib/matrix.jar src/*/*/*.java src/*/*/*/*.java
java -classpath src:lib/matrix.jar matrixpro.ui.MainFrame
```

Windows users should change the colons in the above commands to semicolons and the slashes to backslashes.

D Acknowledgements

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