Finnish Forest Research Institute, Joensuu Research Station
University of Joensuu, Faculty of Forestry

RootView — overview and manual

Pedro J. Aphalo* Aleksander Simonic†

*Current address: Faculty of Forestry, University of Joensuu, P.O. Box 111, FIN-80101 Joensuu, Finland; mailto:pedro.aphalo@joensuu.fi
†mailto:alex@winedt.com

First printing: March 1999
Second revised printing: June 1999
Third revised printing: June 2000

This manual was typeset with LaTeX.
The source file was edited with WinEdt.

RootView credits

Analysis: Pedro J. Aphalo
Design: Aleksander Simonic and Pedro J. Aphalo
Implementation: Aleksander Simonic
Documentation: Pedro J. Aphalo and Aleksander Simonic

Preface

This note describes RootView, a program for computer-aided measurement of plant roots. It also includes a reference manual to the commands available in the program, and gives some hints on how to capture the images needed as input, and how to most effectively process the data output files.

RootView is mainly intended for measurement of roots in images obtained from minirhizotrons, but could also be used for images obtained from rhizotrons, and "microcosms" (as used in studies of mychorrhizas). It is used for tracing, measuring and classifying roots and tips. It generates *raw* data which can be used to calculate not only average root length and diameters, but can also be used for studying the demography of fine roots.

RootView runs on PC compatible computers with Pentium family processors running WIN32 operating systems: Windows 95, Windows 98, and Windows NT 4.0.

RootView was developed for The Finnish Forest Research Institute (METLA), Joensuu Research Station.

We think this program fills a gap in the tools available to researchers studying the ecophysiology of roots by non-destructive methods. Any comments and bug reports are welcome.

Contents

1 Overview

1.1 Introduction

In contrast to what happens with above-ground plant parts, roots are difficult to study because they are included in the soil, a non-transparent medium. Different devices are in use to observe roots *in situ*: rhizotrons (below-ground tunnels or similar constructions with windows to the soil), minirhizotrons (tubes of a clear material such as glass or plastic) normally used to observe roots with borescopes or special video cameras, and pots or containers with clear or removable walls. All these devices provide two dimensional views of roots in the soil.

RootView is designed expressly for working with images from minirhizotrons to study the growth and demography of fine roots and mycorrhizas. At Joensuu, we take images through the wall of 54 mm inner diameter / 60 mm outer diameter acrylic tubes (or "minirhizotrons") with a special colour video camera. We use RootView to interactively measure roots as seen on two dimensional images obtained by digitizing the PAL colour video signal. We currently capture digital images with a Snappy device (Play Incorporated, distributed by Logitech) connected to the printer port of a portable computer. The Snappy frame grabber is capable of video-frame interpolation, and resolutions of more than 1024×1280. Due to the quality of the analogue video signal output by the video camera we use (BTC-100X, Bartz Technology Co., Santa Barbara, CA, USA.) it is not worthwhile using resolutions higher than 800×600 as the video camera has a CCD with resolution of 752×582 pixels. In some cases lower resolutions may be worth using to save disk space. JPEG file format is used, as compression reduces file size considerably.

We take pictures on successive dates (several weeks apart) at the same location, using a mechanical indexing handle to relocate the camera. Small registration errors occur. The size of the field of view is 18 mm $\times$ 13.5 mm. For example, to cover a 18 mm wide band along a 0.70 m long tube requires 52 images. In a small experiment one can have 80 such tubes. So, at each observation date one gets around 4 000 image files. Consequently, there can be as many as 16 000 images in a growing season.

RootView is a tool for computer-aided root measurement, not for automatic root measurement. RootView makes the work of an operator more efficient and faster. There already exists an MS-DOS program called ROOTS, functionally similar to RootView, but which requires the use of a specific frame grabber card. It is designed for analysing images stored on video tape and is available from Michigan State University. There is also a program for Mac computers called RooTracker, written with hypercard.

In Sweden, automatic analysis of root images taken *in situ* through flat glass windows on a below ground tunnel has been attempted using the image processing software system Khoros

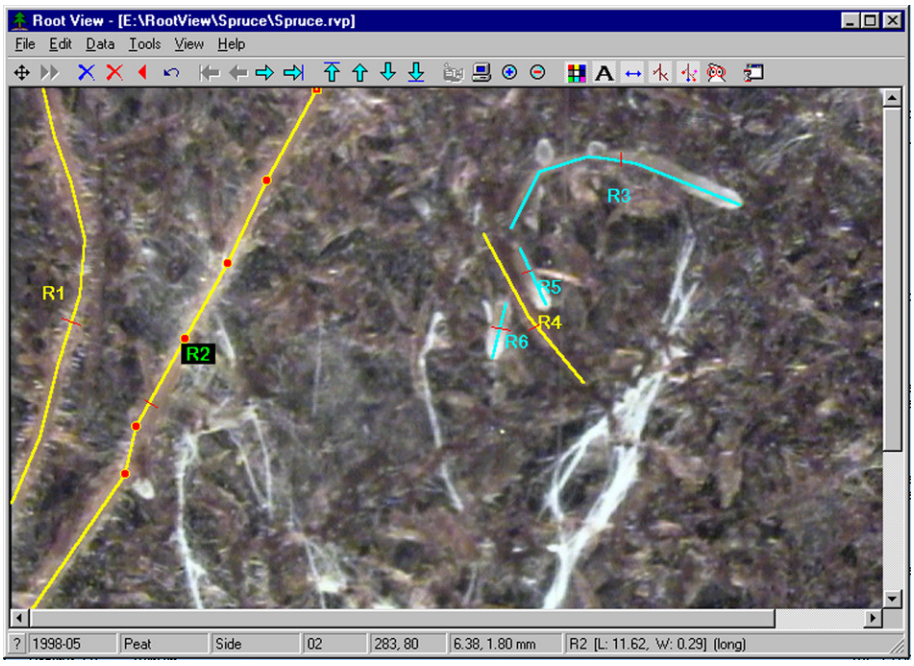

Figure 1.1: RootView displaying an annotated image: the tracings on roots classified as belonging to different categories are displayed in different colours. The root labelled R2 is selected, and the nodes of the traced line are also displayed.

(Khoral Research, Albuquerque, NM, USA. In the USA a special program for automatic root measurement in minirhizotron images has been developed (MR-RIPL 2.0, from the Root Image Processing Lab, Michigan State University). These attempts at automatic image analysis and measurement of roots had moderate success for white roots on black soil. Worse results should be expected when colour and brightness differences are small between background and roots.

1.2 Implementation

1.2.1 The user interface

RootView is a WIN-32 (Windows 95/98/NT) program (Fig. 1.1). It is based on the idea of having an *experiment* as the basis for organizing the data. Each experiment is described in a **project** file, images are organized in directories or folders, and the 'tracings' and annotations are stored in a text file for each image file. Finally the program generates, on request, an output file with data about each root. This last file is in a format easy to import into Excel or other worksheet or statistical programs, and also easy to parse with any custom written program.

Images are not modified by the program, so no images need to be saved. Saving of data files is automatic, and a backup copy of last previously saved data is kept. As it is not possible to print

```
plot     tube  frame     date    root     category  a  length   width
Peat     Side     02  1998-05      R1         long  0    7.99    0.38
Peat     Side     02  1998-05      R2         long  0   11.62    0.29
Peat     Side     02  1998-05      R3        short  0    5.08    0.27
Peat     Side     02  1998-05      R4         long  0    3.32    0.25
Peat     Side     02  1998-05      R5        short  0    1.14    0.21
Peat     Side     02  1998-05      R6        short  0    1.04    0.34
Peat     Side     02  1998-05      R7         long  0    2.74       *
```

Figure 1.2: The first few lines of an output file

the images with RootView, another program such as Photoshop should be used.

RootView has a graphical user interface (GUI) with menus, toolbar, keyboard shortcuts, and uses the mouse as input device for tracing (drawing) roots. It has on-line Help which can be accessed from a menu, and context sensitive Help exists for the different dialogue boxes.

Only one image is displayed at a time, but it is easy to navigate through a sequence of images taken at different times at a given location on a tube. It is also very easy to move from frame to frame along a tube. It is also possible to move randomly to any other image in the experiment.

1.2.2 Data

The data about date, plot number, and tube number is described in the project file (.rvp) and reflected in the directory structure used to store the files. The name of the files is not unique, but the location in the directory tree identifies the images (`.jpg`) and data (`.rvd`) files. Image and data files have a name which reflects the *frame* number or location along the tube. The data file is a text file where a user comment and data about the roots is stored. The data includes a list of root objects, each one with an ID, a category label, and a list of co-ordinates defining the straight line segments, a width, and a flag indicating whether the root is alive, dead or has disappeared. Data about root tips (coordinates, category, and *life* flag) is also stored.

IDs of objects are generated automatically and are consistent between successive images at the same location (images should always be analysed in chronological order from oldest to most recent).

Measurement data uses real world co-ordinates (in mm) rather than pixels. It is possible to measure within one time series images stored at different resolutions.

The output file summarises the data in the whole experiment, or part of it —e.g. one plot. It is a 'rectangular' text file, with data organized in columns and rows. The column separators, missing-data marker, and column headings are all user customizable (Fig. 1.2).

1.2.3 Measurement procedure

Normally, measurement by tracing is performed sequentially through all images taken at a given location. However, it is possible to continue from where analysis was stopped; for example, after adding more images to the sequence (i.e. once data for a new measuring date is added).

```
5␣Measurements
1998-05
1998-06
1998-07
1998-09
1998-11

2␣Plots

Plot_01
2␣Tubes
␣␣Side
␣␣␣␣1␣34␣18.00␣13.50␣First␣frame␣␣Last␣frame␣␣Width␣and␣Height
␣␣Up
␣␣␣␣1␣34␣18.00␣13.50␣First␣frame␣␣Last␣frame␣␣Width␣and␣Height

Plot_02
2␣Tubes
␣␣Side
␣␣␣␣1␣34␣18.00␣13.50␣First␣frame␣␣Last␣frame␣␣Width␣and␣Height
␣␣Up
␣␣␣␣1␣34␣18.00␣13.50␣First␣frame␣␣Last␣frame␣␣Width␣and␣Height
```

Figure 1.3: The project file for a very simple experiment. Spaces are shown as ␣.

Project set-up

1. The operator writes a project file (Fig. 1.3) using a text editor such as Notepad. The file includes data on measuring dates, number of plots, number of tubes per plot, first and last frame in each tube, and frame dimensions (in real world units such as millimetres).

2. The operator opens the project file with RootView, and accepts the prompt to generate the directory tree for the experiment.

3. The operator uses RootView to define the categories which will be used to classify roots and tips, choosing also the colours used to display the objects of each category. Categories can be renamed or added at any later time. Categories can be safely deleted only if they are not in use for any objects.

4. The operator does one of:

   a) Moves already available files to the correct location in the directory tree, if necessary renaming them with a file name which is the number of the frame along the tube (the number of digits to use is user selectable).

   b) Captures the images directly into the right directory.

First image

1. The user selects a plot and tube to work on.
2. The first image at the given position is displayed. Date, plot, tube number, are extracted from file name and directory. The operator can add a comment.
3. The operator traces roots and tips on the image, and assigns them to categories. RootView displays the image with the traced 'objects' and their labels as an overlay (Fig. 1.1).

Later images

1. The operator requests the next image in the series. The image is displayed on the screen.
2. The objects traced on the previous image in the time series for the current frame are *imported* and displayed as an overlay on the current image.
3. The user then adjusts registration taking a given feature of the image as reference, and dragging the marker into place.
4. The objects are edited by the operator using the mouse: objects are modified (roots which have grown), objects are added (new roots), objects are *killed* (dead roots), objects are changed from one category to another (e.g. white to brown), width is also changed if necessary.
5. Go to 1 until all images are done.

2 Manual

2.1 Introduction

In addition to this manual, information on how to use RootView is available in its help files accessed through the Help menu, and through Help buttons in dialog boxes.

In the sections below the procedures for project setup (page 15), image display and measurement of roots (page 17), data output (page 23), installation of add-on tools (page 23) and initial installation of the software (page 26) are explained. The hardware and software requirements are listed in page 26. Also some suggestions regarding the quality of images and general experimental procedures are given in page 25.

The following typographical conventions are used: `filename.tag`, Menu > Submenu, Key. The contents of ASCII text files are set in `typewriter` font.

2.2 The project and other configuration settings

2.2.1 The project file

In order to navigate through the large number of images belonging to one experiment, RootView needs a description of the physical and temporal structure of the experiment. This information is extracted from a RootView *project file* (`*.rvp`) and it is only after successfully reading this file that RootView becomes operational. The project file has an ASCII format and it can be maintained and created with any ASCII editor (eg. Notepad or WinEdt).

The layout of the project file is simple. Data consists of two parts: measurements and layout (Fig. 1.3). It must start with a line containing a (non-zero) number of measurements followed by the "names" of measurements (which are usually dates and are used as names for folders inside which data for each measurement is stored).

In the beginning one can start with just the first measurement and later add the new ones as they become available for processing and analysis. RootView helps you create, and later expand, the directory tree and monitors which data needs processing...

The list of measurements is followed by an empty line and then the second part of data describing the experiment's layout (Fig. 1.3).

Each Plot name (e.g. "plot_01") must be preceded by exactly one empty line, and followed by a line indicating the number of minirhizotrons or tubes[1] (e.g. "2 Tubes"). In contrast, there

[1] More accurately any strip of adjacent images, for example each row of images taken along one angular position of a tube. If images are taken for example on right and left sides of a tube, for the purpose of processing they should

should be no empty lines between the tube descriptions. However, *tube names* can be indented. Each tube description contains data giving the dimension of the visual field encompassed by the images and the index number for the first and last frames along the tube.

Copy and paste can be used to prepare such data fast. Just make sure that there are no errors (e.g. the number of plots and tubes, empty lines and such). Text following the numbers is ignored by the program, and can be used for comments.

There are no limits on the number of frames (all data in Root View is dynamic). For example, one can specify:

```
␣␣␣␣100␣999␣18.00␣13.50␣A␣very␣long␣minirhizotron!
```

to indicate that the first frame in this tube has index 100 and the last one has index 999.

Names of Dates, Plots and Tubes can consist of any characters that are acceptable in filenames (the Data Tree directories are named after them). However, it might be best to avoid spaces in filenames as this can make interaction with other utilities and batch files more complicated.

2.2.2 Names and location of image files

Image files should have as their name the index number of the frame, and a tag indicating the file format; for example, `01.jpg`. Leading zeroes in frame names are not really necessary[2]. In File > Preferences > Labels there is a field labelled "Frame Name". In this field it is possible to enter strings like 1, 01, 001, 0001, etc... to get the index expanded with no leading zeroes or one or more when an image file is fetched. The decision of how many leading zeroes are used should be made before the "jpeg" files are imported or annotated since it affects the filename convention for `.jpg` and `.rvd` files.

RootView assumes that data is organized in the directory tree as follows:

```
<project root>\<date>\<plot>\<tube>\<frame number>.jpg
```

where `<project root>` is the location of the `.rvp` project file. RootView's data browser has a command to create, and later expand, the directory tree and let you know how many images are present/missing and how many have been processed (a corresponding `.rvd` file exists).

2.2.3 Other configuration data

All other options are set through RootView, and are stored in two special files: `RootView.ini` and `RootView.cat`. The first file contains the values pertaining to general preferences (colours, labels and other settings accessible through File > Preferences). The second file contains the list of Root and Tip Categories and their attributes (File > Categories). By default RootView opens the files that are located in its base directory. However, if you make a copy of any (or both) of the above files to the directory where your RootView project (`*.rvp`) is located

be described as *two* tubes.

[2] The advantage of having file names with leading zeros is that when sorted in alphabetical order they become sorted in numerical order as well. This is handy when using Windows Explorer to look at the contents of directories.

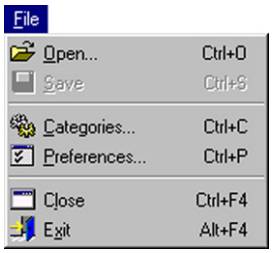

Figure 2.1: File and configuration commands in the File menu.

these files and the settings inside them become local to the project and RootView loads the local files after the project file is loaded. This makes it possible to work on more than one project. You should not attempt to modify these files directly (with an Editor): always use the File > Preferences and File > Categories dialogs to manipulate the values of data inside these files.

Categories to be used in the classification of roots and tips are set in the *Categories* dialog, accessed as File > Categories (Fig. 2.1). A few default categories are pre-defined, but the use of category definitions local to the current project is highly recommended (see above). Categories can be given almost arbitrary names, assigned a short-cut key, a display colour and line thickness. Categories can be later renamed[3] or even deleted if not used. New categories can be added later as needed.

Preferences related to the behaviour of RootView are set in the *Preferences* dialog, accessed as File > Preferences (Fig. 2.1). *Preferences* has several tabs. In the *Fonts and Colors* tab, the font used for displaying root labels is selected, and the colour palette can be edited. In the *Labels* tab, the prefixes used for automatic generation of root and tip labels can be set. The colour used for displaying labels is also set in this tab, as well as the format used for the image file names, as described above in section 2.2.2. In the *Options* tab, colours used to display nodes and the magnification used for zooming steps, and maximum[4] and minimum magnifications allowed when zooming are set. The *Options* tab is used to set how the program behaves on start-up. Finally the *Configuration* tab displays the location of the `RootView.ini` and `RootView.cat` files in use, as well as the base directory. (The name of the project file in use is displayed at the top of the main window.)

2.3 Viewing, tracing and measuring roots

2.3.1 Choosing an experiment

After creating a RootView project file, start RootView and open the project file of the experiment you want to start working on. The project file can opened by using File > Open... command.

[3] If a category is renamed, then all `*.rvd` files need to be scanned and fixed, so although RootView handles this more or less automatically, it can be a very time consuming operation in a large experiment.

[4] Do not increase the maximum magnification allowed unless the PC has lots of RAM.

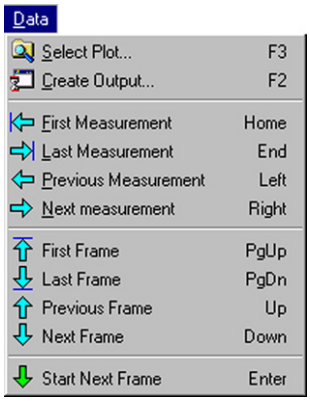

Figure 2.2: Commands in the Data menu.

Alternatively, you can drag and drop a project file into RootView's Icon or a running instance of the program. RootView also allows you to associate `*.rvp` files with its executable and thus you can open such files by double-clicking on them in Windows Explorer. Once the project file has been successfully loaded, RootView is ready to start working on the project's images and data.

2.3.2 Navigating through data

RootView displays in its status line Measurement, Plot, Tube and Frame name for the currently selected and displayed image. Furthermore, the status line panels containing this information respond to mouse clicks by displaying the *data browser* which allows the selection of an arbitrary frame to work on. The *data browser* also provides a command to create the directory tree needed to accommodate the data for the current project. This dialog also provides a command to scan all data and display the information on the number of required, present and processed images. Back and Next buttons in the *data browser* are used to move through the project's data tree: date → plot → tube → frame. Double-clicking on any item moves forward as well.

Navigating though consecutive measurements and frames in the same tube can be done directly with special commands, shortcuts and tool bar buttons (Fig. 2.2).

2.3.3 Tracing roots

Image editor

Root View's Editor has two modes: **adjusting registration error** and **object editing**. The objects are the tracings which represent roots and tips. The mode can be toggled by clicking the leftmost tool bar button or by using the Insert key or with Edit > Toggle Edit Mode. The current mode of the editor is shown by the corresponding toolbar button: depressed indicates registration adjustment mode.

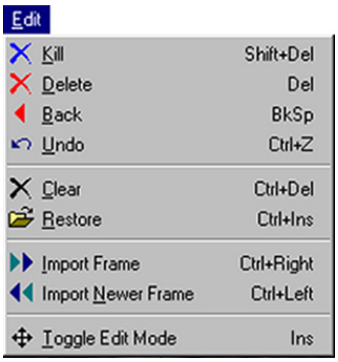

Figure 2.3: Commands in the Edit menu.

Error registration

Error Registration is typically adjusted after a tracing has been **imported** from the image from the previous measurement (date). When you enter this mode a marker (Cross hairs) is displayed. This marker can be positioned on any recognizable feature of the first image and can be later used to properly adjust the error after the tracing is imported into the next measurement. Normally this marker will be positioned on the image from the first measurement, but if needed it can be relocated later. The marker is there to make the adjustment easier, but in many cases the tracing itself provides enough reference points to achieve the adjustment.

To Position the marker (without moving the image) do the following: Press and hold the Ctrl key and click anywhere in the image where you want the marker to appear and possibly adjust its position by dragging it around (always holding the Ctrl key). For extra precision you can zoom in.

To register the error simply drag the image around (until the marker matches the image feature used as reference point). The cursor changes its shape while you are adjusting the error and the status line displays the actual error (compared to the image for the first measurement).

Object editor

A new Object (Root or Tip) is inserted in the image by holding the Ctrl key while clicking on its position. The Properties dialog is displayed allowing you to enter object's attributes. If the object is a root, you'll typically continue by Shift+Clicks to enter its nodes. The label initially positions itself in the "centre of gravity" but you can later drag it to the position where it does not obscure the view.

When tracing a series of similar Roots or Tips, displaying the dialog is an unnecessary distraction. To quickly insert a new object (with the same Category as the last inserted one) the operator can use Shift + Ctrl qualifier while clicking on a new object. To speed up the process even further, RootView allows each category to be assigned a shortcut key. Clicking with the mouse while holding down a shortcut key inserts an object (Root or Tip) belonging to the

associated category[5].

The generation of *object names* should be normally left to RootView in order to ensure consistent annotation from measurement to measurement. As the labels generated automatically can be customised in File > Preferences there should be no need to manually edit labels.

Clicking on any object (or its label) selects the whole object. A selected root displays its nodes. Clicking on a node of a selected root tracing selects the node. Pressing the Esc key, or clicking the right mouse button, or clicking on an empty spot de-selects any selected object.

Labels, nodes and tips can be dragged around. A Selected object can also be deleted (Toolbar button or Edit > Delete). New nodes can be added to a selected root tracing using Shift+Click. If a node is added outside the current tracing, then it is appended to the growing end (marked as a square node). If a node is added on top of the old tracing the new node is inserted in between the two adjoining nodes. The Backspace command deletes the last node at the tip.

If a node is selected then *Delete* removes just the selected node rather than the whole root tracing. A selected node can also be dragged to follow growth of a root. Colors of selected nodes (and other objects) can be adjusted through the *Preferences* dialog (see section 2.2.3, page 16).

Finally, each root has an attribute *average width*. The operator should spot the "typical" position which reflects the average root's width and mark the width at this position. This is done by selecting the root, pressing and holding the Alt key, clicking on one edge of the root and then dragging the mouse to the other edge (thus creating a visible width mark). For this procedure zooming in might be useful.

There are two commands which can be used for removing objects from an image; however, their purpose is different. *Delete* is used to correct mistakes while tracing a root, and *Kill* is used to mark a root or tip as dead. Delete removes the object from the data file, while Kill marks it as dead or gone. Consequently, objects which have been imported or exported between frames should **not** be deleted. Instead, such objects should be marked as "dead" using the *Kill* command or in the case when they disappear they should be marked as "gone" (Kill them twice). Dead objects are still visible (roots use dashed lines) while gone objects do not appear in the image. They remain in the data marked as gone. If the operator would (for some reason) like to see such objects he or she has to toggle the value of the "Show Ghost Roots & Tips" button in the Tool Bar.

Double clicking on any object brings the *Object Properties* dialog, which can be used to change the category assigned to an object, its life status or to add a text comment. In the *Object Properties* dialog the operator can explicitly change the 3-state life attribute by checking one of the radio buttons (Alive, Dead, Gone).

Double-Clicking on an empty spot brings up the *Frame Properties* Dialog. The only input field in this dialog is for comments, but it displays information about the size of the image and registration error.

Undoing is limited to the last change. Undoing twice redoes the change. This is enough to restore accidental deletions.

[5] After some practice an operator might consider taking advantage of this functionality in order to speed up the process of annotating images.

Figure 2.4: Commands in the View menu.

Save, restore and clear

The data are automatically saved to the corresponding `*.rvd` file when a new image is loaded and displayed. A backup file is created with the data current when the data was last saved. File > Save can be used to manually force a save and create a backup. The data in the backup file can be made current with Edit > Restore, with all later changes lost. Edit > Clear deletes all current data for the image displayed, but not the backup. *Undo* can be used to undo a restore or a clear.

2.3.4 Image display

Zooming

View > Real Size displays the image at its native resolution (one pixel in the image file is displayed as one pixel on the computer screen).

View > Fit Image to Client stretches or shrinks the image so that it exactly fits in the *current* size of RootView's main window. Aspect ratio is not preserved.

View > Zoom In and View > Zoom Out increases and decreases the size of the image, respectively. Aspect ratio is preserved. These commands can be used repeatedly, until the maximum or minimum size is reached[6].

Status line and toolbar

Root View displays the currently selected Measurement, Plot, Tube and Frame in its Status Line (Fig. 2.5). Furthermore, the status line panels containing this information **respond** to mouse clicks by displaying the *Data Browser* dialog which allows you to directly select a frame to work on.

The *Data Browser* dialog also provides a command to create the folders needed to accommodate data for the current project. Finally, the dialog provides a command to scan data and display the information on the number of required, present and processed images.

The toolbar gives fast access to most frequently used commands. The icons in the toolbar are the same ones as those in the menus (Fig. 2.6).

[6]How much the size of the image is changed each time a zooming command is applied, and the minimum and maximum magnification limits, can be changed in the *Preferences* dialog, *Options* tab. (see section 2.2.3, page 16).

a) Status bar with root R21 selected

b) Status bar with no objects selected

Figure 2.5: The *Status line*. Pressing the button with a question mark displays help about the status line. The first four panels display measurement, plot, tube and frame for the displayed image; the next two fields show the cursor position in pixels and in millimetres; in edit mode the last pane a) with one root tracing selected, shows root label, root length, root width and category, but b) with no objects selected, shows image size in pixels, and image size in mm.

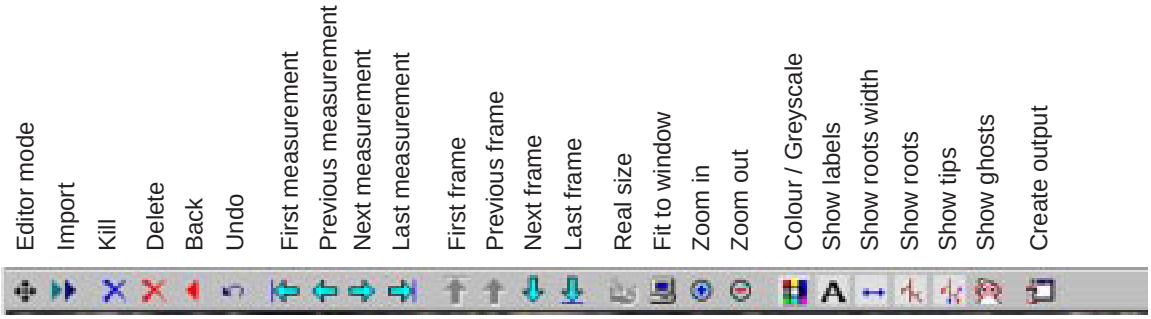

Figure 2.6: Commands in the toolbar.

2.4 Data output

Root View's roots and tips data is "scattered" in the experiment's tree directories in a format that is not suitable for analysis and summaries. For this reason RootView is also able to generate output files containing data summaries for all or part of an experiment. Separate output files are generated for roots and tips. The user can choose to generate either output file or both.

Data output files are generated only at the operator's request because gathering the data from all traced roots in an experiment is a time consuming task. Data > Create Output or the equivalent toolbar button opens the *Output Data Generator* dialog, which is used to request the generation of the file(s) from the data currently available in the `*.rvd` files. In the *Selection* tab of the dialog the user can choose to generate output files for the whole experiment or only for certain plot(s) or measurement(s).

The Output file(s) have a rectangular shape (Fig. 1.2, page 11). The columns for roots data look like this:

```
plot tube frame measurement root category a length width frame_area
```

and for tips:

```
plot tube frame measurement  tip category a frame_area
```

The frame_area column is optional, and not included by default as in most experiments all frames have the same field of view. Attribute (labelled 'a' by default) is a special parameter which can take one of three possible values: 0 for **alive**, 1 for **dead** or 2 for **gone**.

The actual labels used for the headings of the columns can be specified in the *Output Data Generator* dialog as well. Columns are always aligned to the right. If insufficient width is reserved by the length of a tag, the tag is automatically extended to accommodate the widest item in its column. However, after that a warning is displayed and the data has to be generated again. The changes to tags are saved for the next time if the dialog is exited through the OK button. Keeping the columns as narrow as they could be can significantly reduce the size of the output files. The *Output Data Generator* dialog also allows the operator to specify the column separator (usually a space or a comma followed by a space), and the missing data marker (usually '*' or '.').

The output data files are always placed in the same folder as the project file. However, their filenames can be chosen by the user. Since the program has to scan potentially a large number of *.rvd files to produce a long output file (e.g. 100K lines), a progress indicator has been added to the dialog.

2.5 Adding *tools*

2.5.1 Basics and special variables

The *Tools Menu Setup* dialog is used to configure the contents of the Tools Menu. Items in this menu usually refer to applications that are used as add-ons in RootView, providing additional functionality (e.g. moving the JPEG files or analyzing the output data).

variable	function	example
%B	Root View's Base Directory	
%P	Project's Base Directory	
%F	Project's (`*.rvp`) filename	`Experiment`
%R	Roots Output Data filename with tag	`Roots.dat`
%r	Roots Output Data filename only	`Roots`
%T	Tips Output Data filename with tag	`Tips.dat`
%t	Tips Output Data filename only	`Tips`
%p	location of currently selected image	`%P\Measuremet\Plot\Tube`
%f	Currently selected frame	`01`..n
~	modifier, use short (8+3) filename	`%~B`, `%~P`
/	modifier, use UNIX path style	`%/B`, `\%/P`

Table 2.1: Special variables available in the *Tools Menu Setup* dialog.

The definition of an Item consists of its menu name and the command line. Special parameters such as %P, %F can be used to pass values depending on the current project and selected frame to the accessory in its command line. If the check-box in front of the Item is checked then a special dialog displaying the exact command line that is about to be executed is displayed before the application is launched. Specifying a non-empty *Caption* instructs RootView not to execute the command line if the application with the specified caption is already running. The running instance gets in the foreground, instead. It is also possible to specify the initial directory for the application that is to be activated. Defining an *Item* as "-" (without quotes) is interpreted as a menu separator rather than a command.

RootView's intended functionality is limited to: navigating through an experiment's images, tracing roots and tips on the images and storing and displaying these tracings (Image Editor), and generating output (raw) data files.

Tools for capturing images, moving the JPEG files to RootView's project directory tree, performing data analysis and producing summaries is/will be implemented separately. However, RootView can act as a front end and application launcher for this purpose. Its Tools menu can be customized to include such add-ons.

Launching an application or a batch file would not be of much use unless Root View could also provide parameters pertaining to the current project and data files. For this purpose special % variables have been introduced (Table 2.1).

Example: A menu item that opens the project file in Notepad can be defined as: `notepad.exe "%P\%F.rvp"`. Frequently used applications can be assigned a shortcut and can thus be quickly activated from within Root View...

2.5.2 Examples

These examples (Table 2.2) assume that the commands refer to executables accessible through the PATH environment variable. If that is not the case the whole path should be included instead

Item	Command	Startup Folder
&Edit Project File	`notepad.exe "%P\%F.rvp"`	
&Capture Images	`snappy.exe`	`%p`
&Archive data	`WZzip.exe -u -o -yp -r -p "%P\%F.zip" "*.rvd"`	`%P`
&Add measurement	`perl.exe %B\perl\add_meas.pl "%P\%F.rvp"`	`%P`

Table 2.2: Examples of item definitions for the Tools menu.

of just file name. Notepad.exe is included with Windows, Snappy, Winzip and Perl should be installed separately.

2.6 Tricks-of-the-trade

2.6.1 Image quality

It is extremely important to get sharp images, so focusing should be done with great care on a good monitor. It is important also to minimize registration errors by careful set up of the camera, and especially by using a correctly sized drill bit for the index holes in the minirhizotron tubes. Cleanliness is also very important to avoid scratches in the walls of the minirhizotrons as this also degrades image quality.

For capturing images, we recommend the use of a resolution similar to the resolution of the video camera, but in some cases the use of lower resolutions may speed-up image capture and reduce storage space at the cost of lower precision (more guessing) in the measurements.

RootView reads images in JPEG format. This format usually uses lossy compression; in other words, the file is compressed in such a way that not all the information is recovered during decompression. This is not a big issue as long as not too much important detail is lost. When creating JPEG it is possible to choose the degree of compression used. There is always a trade-off between size after compression and image quality. It is best to use the medium to high quality range when capturing images.

RootView can work with JPEG images from any source, although we currently use a Snappy still video capture device. This device has the advantage of grabbing images of the highest possible quality for a given analogue video source; however, it is rather slow. The Snappy device does frame interpolation; in other words, it uses information from several frames of the analogue video to synthesize a single high resolution digital still image. It is important to use the right settings in Snappy for the video source in use. In our case: signal from a video camera (as opposed to broadcast signal) and still subject (as opposed to a moving subject).

2.6.2 Calculating summary statistics

Importing into Excel. Importing into SPSS. Using Perl or AWK.

2.6.3 Murphy's Law

Finally we strongly recommend making regular back-ups of image and data files, and keeping them in a safe place. There is too much time and effort spent in this kind of experiments to have them ruined by a failure in a PC or a human error.

2.7 Hardware and software limits

RootView is written in Delphi 4 (Professional Edition). All data is dynamic — there is no imposed constraint on the amount of data except for a computer's resources and capabilities.

The program requires at least a Pentium 90, with 16 Mbytes of RAM, and an 800 $\times$ 600 colour display, running WinNT 4.0/ Win98 or Win95. For smooth performance Pentium 166 with 32 MBytes (or better) is strongly recommended. Images consume the computer's memory very fast and some design decisions have been made in order to keep the program resource friendly. In particular, only one image is loaded in the computer's memory at each moment. A good sharp colour monitor is also a must for precise work, and/or long working hours.

A RootView data file for each image uses 3-5 KBytes of hard drive space (twice as much with the backup copy). This should not cause any problems even when the experiment consists of 10K+ images. However, an average 600 $\times$ 800 pixels colour JPEG file has a size of more than 100 KBytes, so for a large experiment it might be necessary to remove the old JPEG files. RootView is designed to function correctly even after the JPEG files for processed frames have been removed: it is no longer possible to view or edit such images, but its objects (roots and tips) can still be included in the output data generated by RootView as well as being imported into the next measurement.

2.8 Installation

The program is delivered either as a compressed file (`RootView.zip`) or as an uncompressed directory structure on a CD-ROM.

Either...

- Extract the contents of `RootView.zip` into a directory, for example `C:\RootView`, preserving the directory information stored in the archive. For extraction you will need WinZip.

- Assuming your CD-ROM drive is `D:`, copy `D:\RootView\` and all its contents to your machine's hard disk, for example `C:`.

Once the files are installed RootView can be started by clicking on the icon labelled 'RootView' or 'RootView.exe' in the installation directory (e.g. `C:\RootView\`. However it is recommended that you create a shortcut to RootView on your desktop by dragging the icon while pressing Alt. (The 'Target field' should be for example `C:\RootView\RootView.exe` and the 'Start in' field `C:\RootView`.)

After RootView is installed, it is also convenient to associate `.rvp` "RootView project files" with the RootView executable, so that they can be opened by double clicking on them in the Windows Explorer. (You do this by choosing View > Options... > File Types and pressing the 'New Type...' button. For description of type put 'RootView project'. For Associated extension put 'rvp'. For action 'open' put `C:\RootView\RootView.exe` as application, and make sure that 'Use DDE' is not selected. See the Windows help for details.) It is suggested that the Tools menu is customised to the utilities available.

To completely uninstall RootView simply delete the `C:\RootView` directory and all its contents.

Acknowledgements

Dr. Leena Finér and Dr. Tarja Lehto got P.J.A. interested and involved in the problem of measuring roots. P.J.A. got A.S. interested. Dr. Finér also obtained funding from the Finnish Forest Research Institute, which made possible the development of RootView.

The development of RootView and the preparation of this manual was in addition partly funded by the Academy of Finland (grants 58 238 and 37 964) and the Maj and Tor Nessling Foundation (grant 99027).

Notes