Technical Publication

Direction 2407688
Revision 2.1

GE Healthcare
eXplore MicroView v. 2.1 Software Guide

http://www.gehealthcare.com

1 Using MicroView 1

1.1 Introducing MicroView 1

1.1.1 Getting Help 1
1.1.2 Support 1
1.1.3 Revision History 1

1.2 Installing MicroView 2

1.2.1 Minimum Windows System Specifications 2
1.2.2 Minimum Linux System Specifications 2
1.2.3 Minimum Mac System Specifications 3
1.2.4 Learning MicroView 3

2 Using MicroView 5

2.1 Starting MicroView 5

2.2 Using MicroView 6

2.2.1 Main MicroView Window 6
2.2.2 Tools & Applications 7
2.2.3 Loading a File 14
2.2.4 Importing 2-D Image Slices 14
2.2.5 Saving Complete Image File 17
2.2.6 Saving 2-D Images 17
2.2.7 Exporting Images as 2-D Image Slices 17

3 Working with CT Image 19

3.1 MicroView Tools 19

3.1.1 Point Measurement (1-D) 19
3.1.2 Line Measurement & Analysis (2-D) 19
3.1.3 Viewing Line Profiles 20
3.1.4 Defining a Region of Interest Volume 2D / 3D 23
3.1.5 Sub-Volume Analysis 24
3.1.6 Region Of Interest (ROI) Selection - Standard 28
3.1.7 Selecting a Region of Interest (ROI) - Advanced 30
3.1.8 Cortical ROI 34
3.1.9 Region Grow 35
3.1.10 DICOM Data Transfer 37
3.1.11 CT Calibration Tool 38
3.1.12 Image Information Tool 39

3.2 MicroView Processes 40
3.2.1 Downsampling the Image 40
3.2.2 Inverting the Image 40
3.2.3 Applying Gaussian Smoothing 41
3.2.4 Flipping the Image 42
3.2.5 ROI Blanking 42
3.2.6 Resampling the Volume 44
3.2.7 Reorienting the Volume 44

3.3 MicroView Visualization Tools 46
3.3.1 Creating a MIP 46
3.3.2 Rendering Volume 49
3.3.3 Display Isosurface 50
3.3.4 Overlay Geometry 53
3.3.5 Make Movie 54

4 Bone Analysis - Basic & Advanced 55
4.0.1 Using the Advanced Bone Analysis Application 55
4.0.2 Analysis Results and the MicroView Spreadsheets 59
4.0.3 Advanced Bone Analysis Options 63

5 Plugins 69
5.0.1 Registration 69
5.0.2 Measurement Tool 75

6 Appendix 77
6.0.1 Supported File Formats 77
6.0.2 Memory Performance under Windows 78
6.0.3 MicroView's Support for Raw Image Data 79
6.0.4 References 81
6.0.5 Glossary 82
6.0.6 Frequently Asked Questions 83
6.0.7 Copyright Information 85

Chapter 1 Using MicroView

Section 1.1 Introducing MicroView

Welcome to **MicroView** 3-D volume viewer & analysis tool. **MicroView** is a visualization and quantification tool for 2-dimensional and 3-dimensional data. It complements GE Healthcare's MicroCT systems by offering a number of visualization and analysis tools for MicroCT data.

1.1.1 Getting Help

MicroView has context-sensitive help attached to most dialog boxes and windows, including the main **MicroView** window. Press **F1**, select **MicroView** Help... from the Help menu, or **h** at any time to view the **MicroView** quick-reference guide.

1.1.2 Support

For additional help installing and using **MicroView** and its features please contact GE Healthcare Software Support.

GE Healthcare
1-1510 Woodcock Street, London, ON N6H 5S1 Canada
Tel: 1.800.682.5327
Email: preclinical_imaging@ge.com
http://gehealthcare.com/preclinical_imaging

1.1.3 Revision History

Revision v1.02002-12-18jdg	Initial release
Revision v1.12003-06-05jdg	Updated with screenshots and new info
Revision v1.2.0-b22004-07-16jdg	Updated for CUI-compliant **MicroView** 1.2.0-b2
Revision v2.0 - 2005-02-02	**MicroView** 2.0 release
Revision v2.1 - 2005-12-10	**MicroView** 2.1 release

Section 1.2 Installing MicroView

To install **MicroView**.

1. Insert CD and follow online instructions in the install-notes.html file to install program.

The **MicroView** installation routine will place a **MicroView** launcher in the Applications folder of the Finder application, under Windows and Mac specific info.

1.2.1 Minimum Windows System Specifications

- Windows 98, NT 4.0, 2000, XP
- Processor: Pentium III, 450MHz, (P4, 2.6 GHz recommended
- RAM: 256MB (2GB recommended)*
- Hard Drive Space: 60MB
- SVGA monitor and graphics capabilities (1280x1024 resolution recommended)
- Video: 3-D accelerated video card with 64MB of texture memory** (128 MB recommended)
- 3 Button Mouse

* The RAM required depends on the size of the files being loaded. Under Windows™ 2000, the maximum file size that can be loaded is 854 MB, so roughly 1-2 GB of RAM is recommended for normal use. See note in Appendix 6.0.2 on enhancing performance while running under Windows™ XP.

** **MicroView** will run using a video card with only 16MB of video RAM, however, a video card with 128MB of video RAM and on-board texture mapping support is recommended.

1.2.2 Minimum Linux System Specifications

- Processor: Pentium III, 450MHz, (P4, 2.6 GHz recommended)
- RAM: 256MB (1GB recommended)
- Hard Drive Space: 60MB
- SVGA monitor and graphics capabilities (1280x1024 resolution recommended)
- Video: 3-D accelerated video card with 64MB of texture memory (128 MB recommended)
- 3 Button Mouse

For Linux™ computers, **MicroView's** computer and memory requirements are identical to the requirements above, however, a minimum of 200 MB of available hard disk space is required.

NOTE - The MicroView memory capabilities under Linux™ is typically better than under Windows™.

1.2.3 Minimum Mac System Specifications

- G3 computer
- MAC OS X 10.3 and higher
- Optional X11 components installed
- RAM: 256MB (1GB recommended)*
- Hard Drive Space: 70MB
- a 3-D accelerated video card with 64MB of texture memory (128MB recommended)**
- 3 Button Mouse
- SVGA monitor and graphics capabilities (1280x1024 resolution recommended)
- The user installing **MicroView** must have administrator privileges on the system where it will be installed.

* The amount of RAM required depends on the size of the files you wish to view.

** **MicroView** will run using a video card with only 16MB of video RAM, however, a video card with 128MB of video RAM and on board texture mapping support is recommended.

The maximum file size limitation noted above for Windows™ does not exist for the Macintosh™ version of **MicroView**. The maximum file size is constrained by the available memory.

1.2.4 Learning MicroView

This manual, together with the online will help you learn **MicroView**.

MICROVIEW USER MANUAL

This guide contains information on using the **MicroView** commands and features.

The manual assumes you have a working knowledge of your computer and its operating conventions, including how to use a mouse and standard menus and commands. It also assumes you know how to open, save, and close files. For help with any of these techniques, please see your operating system documentation.

HELP FUNCTION

While running the program the help function is always available. Press **F1**, select **MicroView Help...** from the Help menu or the **h** key at anytime and a help screen appears in a web browser. The help screen lists the commands, features, and program shortcuts.

POP-UP HELP

Pop-up help is available for most fields in **MicroView**.

1. Select "Enable balloon help" box from the Edit??Application Settings... Miscellaneous box.

Chapter 2 Using MicroView

Use **MicroView** to view and analyze image files obtained using MicroCT.

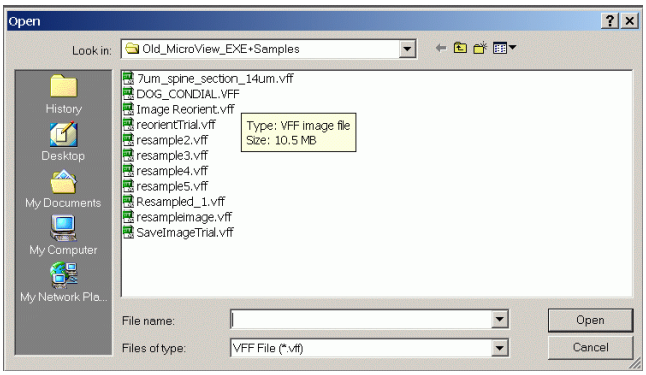
Section 2.1 Starting MicroView

WINDOWS

1. Double-click **MicroView** icon located on the desktop. 

   Alternatively, open Start Menu and select **MicroView** from Programs/GE Healthcare/ **MicroView**/**MicroView**.

   Alternatively, double-click the icon of any supported image file from within Windows Explorer or any file browser. **MicroView** is launched, and the selected image file is automatically loaded.



LINUX

When using **MicroView** under Linux, ensure X11 is installed, and an X session (e.g. KDE or Gnome) has been started. Start **MicroView** by:

1. Run /opt/GEHC/bin/MicroView from an xterm, or similar console.
2. Select Graphics/**MicroView** from the system menu (applies to Gnome 2.6 desktops; KDE menu entries may differ slightly).

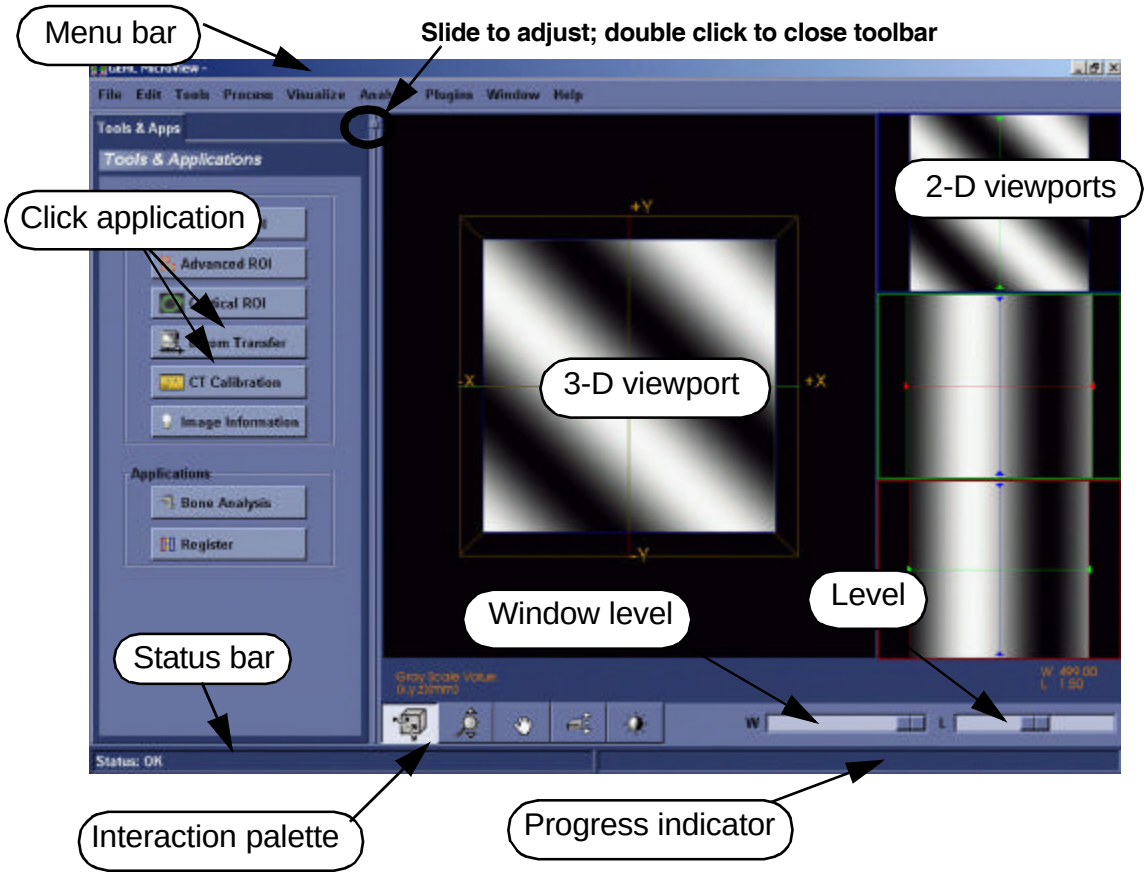
MAC

1. Find the **MicroView** application icon in the Applications folder from the Finder window.

2. Double click on the **MicroView** application icon to start the program.

Section 2.2 Using MicroView

2.2.1 Main MicroView Window



The default **MicroView** display consists of an application toolbar on the left side of the screen, a 3D image viewport in the centre of the screen, and three 2D viewports on the right side of the screen.

It also contains a menu at the top of the application window, Window and Level adjustment slide bars, the interaction palette, and a status and progress indicator at the bottom of the window.

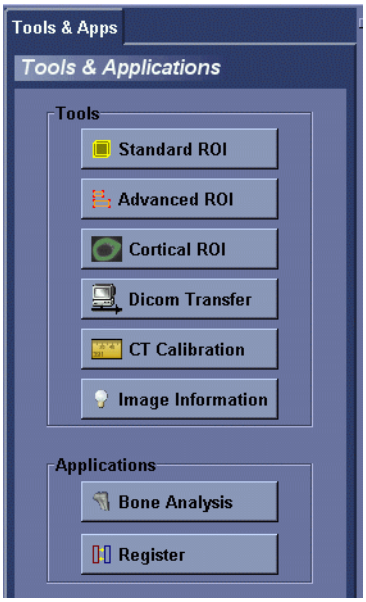
NOTE - If the volume loads into MicroView and the viewports seem to be empty you may have to adjust the Window / Level values and/or move through the planes to see the data.

2.2.2 Tools & Applications

The tools and applications available in **MicroView** vary depending on which version of the program you have.

Available Tools and Applications

MicroView Basic

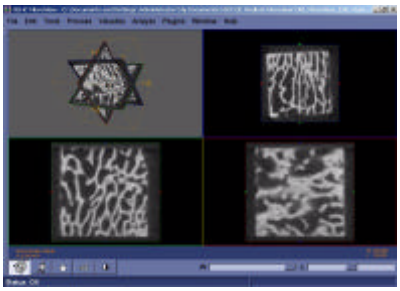


MicroView with Advanced Bone Application

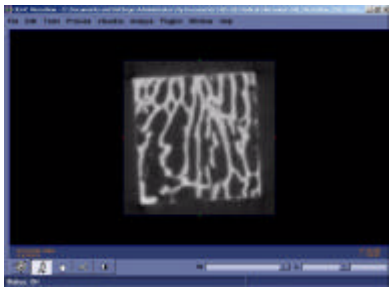
The **MicroView** tools and applications are explained in detail later on.

2.2.2.1 Modifying the display

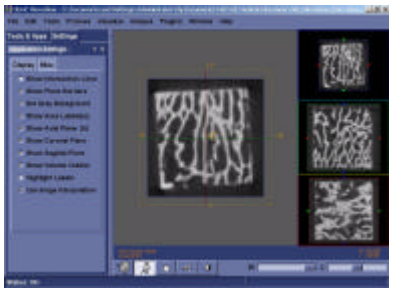
Each viewport in **MicroView** can be individually maximized or expanded by double-clicking mouse button **1** over the viewport. Restore the display by double-clicking mouse button **1** again.



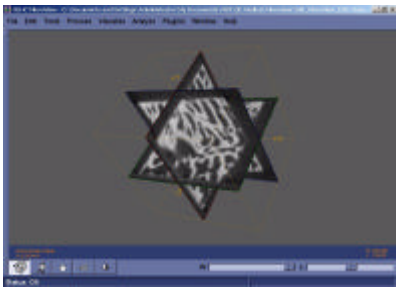
2 by 2 display



Maximized view 2D



1 by 3 display



Maximized view 3D

The basic layout of **MicroView** can also be changed. Select Window??Set Layout to 2-by-2 to display **MicroView** as a 2-by-2 grid of viewports. Select Window??Set Layout to 1-by-3 to switch back to the default arrangement.

The toolbar on the left of the screen can be resized or closed as required.

2.2.2.2 Image viewing

If you are not familiar with 3-dimensional digital image manipulation it may take some time to become comfortable with rotating and manipulating your data.

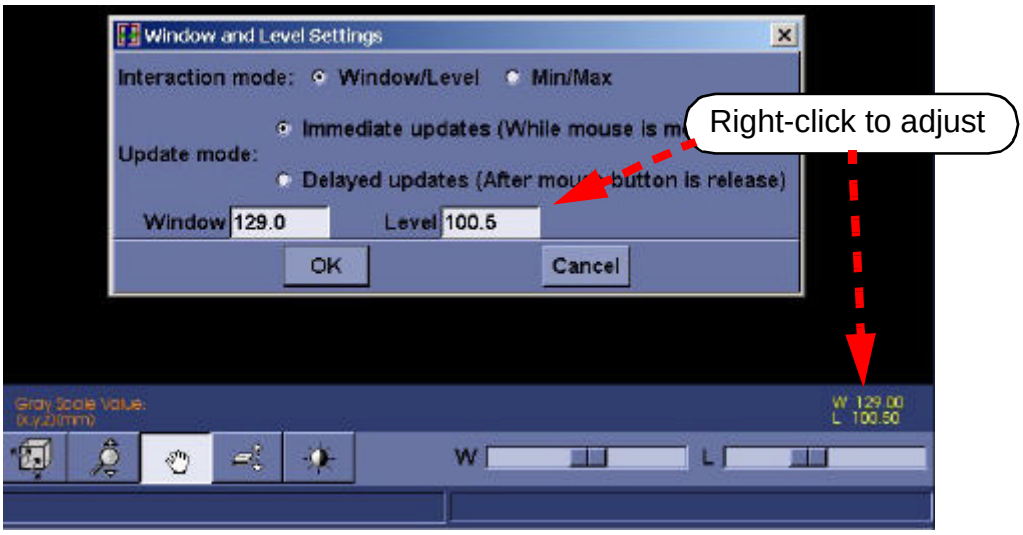
VIEWING DATA

Once the file is loaded into **MicroView** you may need to adjust the Window / Level values to properly view the data.

1. Use cursor to slide Window and Level bars to an appropriate value. The image adjusts accordingly.

Choose from Window / Level or Min/Max values

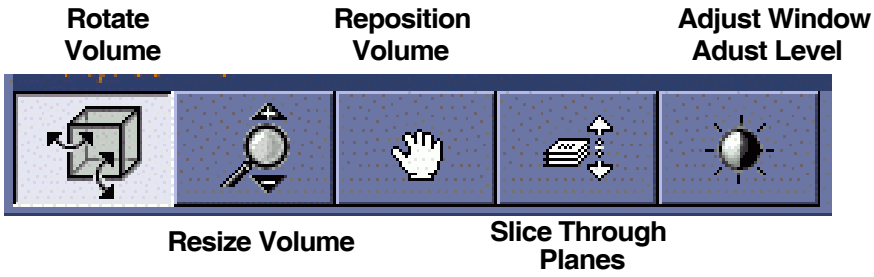
2. Right-click on the Window / Level values shown in the lower right-hand corner of the screen to open a window that can be used to further adjust the Window/Level parameters.



- Display either Window / Level or Min/Max values on the scrollbars.
- Immediate Updates: Window and Level values adjust as you scroll.
- Delayed Updates: Changes to Window and Level values occur once you release the mouse button. This feature is useful for slow displays.

INTERACTION PALETTE

MicroView's Interaction Palette contains convenient buttons that change the default mode of interaction with the application. Using the Interaction Palette is useful in one or two mouse button environments.

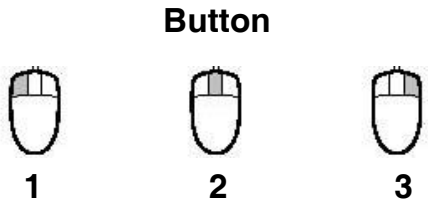


1. Using the left-most mouse button, click on one of the palette tools.
2. Use the left-most mouse button to manipulate the volume as required.
   The selected mode remains effective until changed.

MOUSE & CURSOR

MicroView supports the use of a 3-button mouse.

Button **1** is left-most button and button **3** is right-most button. The mouse can be used at any time to perform the functions described below.



CURSOR

The **MicroView** cursor changes appearance depending on where it is on the screen and what you are doing.


appears when using button **2** to move planes through the volume

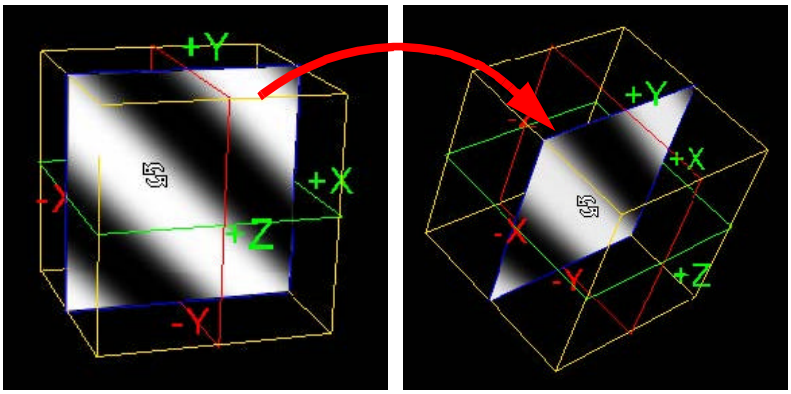

appears when using button **1** to rotate 3-D volume


appears when using shift and button **1** to pan / re-position 2-D images


appears when using button **3** to zoom 3-D volume or 2-D images

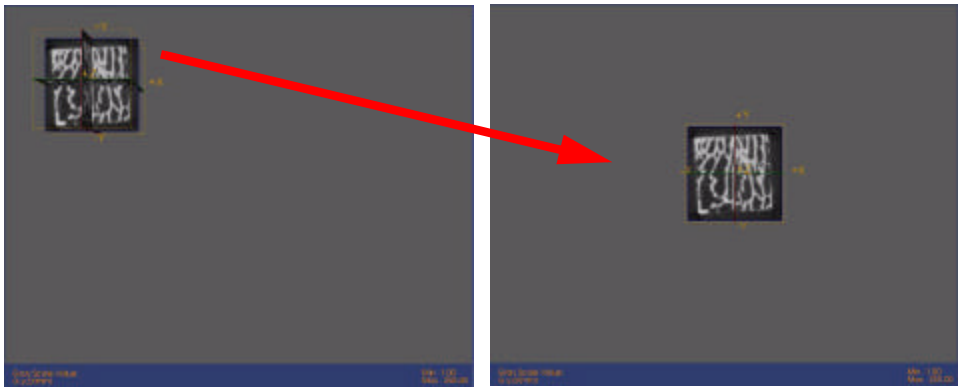
2.2.2.3 Rotating volume

1. Hold button **1**  and move cursor to rotate the volume.
   Press **r** key at any time to reset volume to starting position.



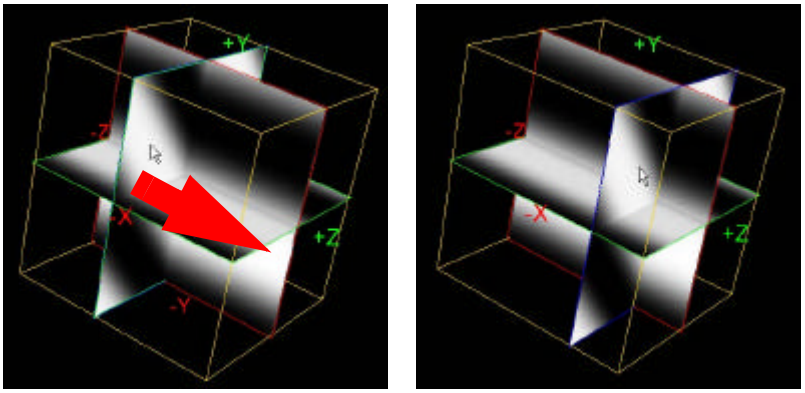
2.2.2.4 Panning volume

1. Use Shift + button **1** and drag cursor to re-position volume on the screen.
   Press **r** key at any time to reset volume to starting position.



2.2.2.5 Slicing through selected planes

1. Use button **2** with cursor in the inner area of the plane to move selected plane across volume.



   Press the z key as required to toggle integer stepping. This causes the planes to move in increments that have been determined by the volume spacing value.

   Alternatively, move though selected planes by positioning cursor on a plane within 3-D or 2-D viewport and press arrow keys to move plane back and forth through volume. Plane moves one voxel.

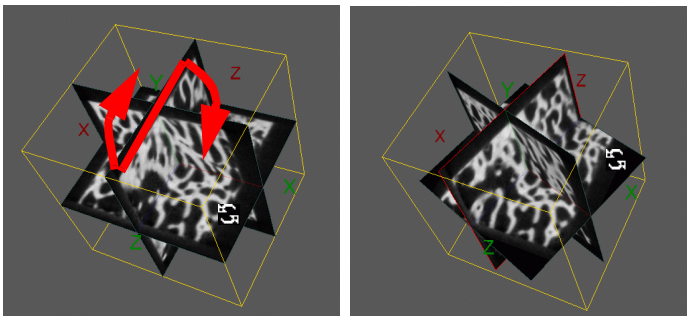
2. Position cursor on a plane within 3-D or 2-D viewport and then press Page Up or Page Down key to move plane back and forth through the volume ten voxels at a time.
3. Pressing the Home or End key will move the selected plane out to the edge of the volume.

2.2.2.6 Rotating plane around its axis

Use button **2** with cursor at the edge of the plane.

1. Hold button **2** and drag cursor to rotate plane around its plane axes.

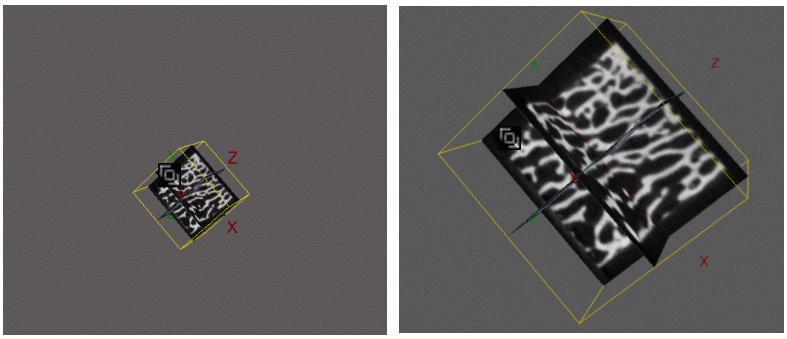
   Depending on whether the cursor is located inside or outside the volume, the rotation behavior will vary.



2.2.2.7 Zooming image

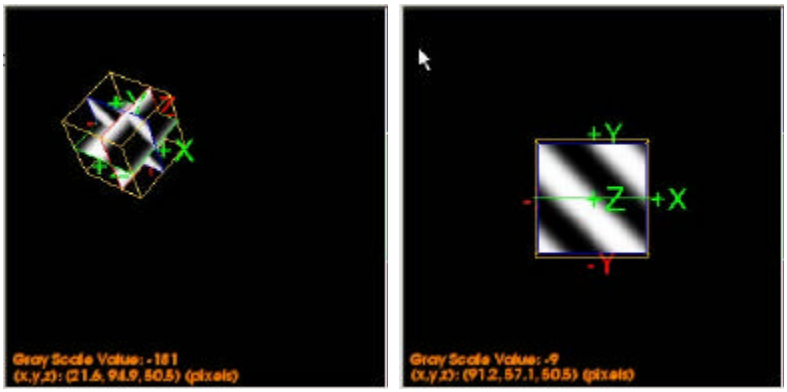
Use Button **3**  with cursor within 3-D or 2-D Viewport.

1. Hold button **3** and move cursor up and down to zoom image in and out.



RESETTING IMAGE

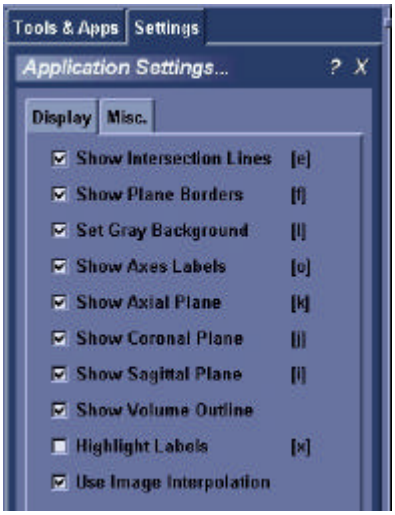
Press **r** key at any time to reset volume to starting position.



2.2.2.8 Changing MicroView options

MicroView allows you to control how the information on the screen is displayed.

1. Select Application Settings… from Edit menu.
   The **MicroView** Application Settings dialog boxes appear.



2. Select or de-select from among the display or miscellaneous features using checkboxes or shortcut keys shown adjacent to the options list.

The display and miscellaneous options for which there are shortcut keys are shown below.

DISPLAY OPTIONS

Key / Option	Result
e	Toggles the intersection lines on the 2-D images on or off.
f	Toggles the borders around the planes on or off.
l	Toggles the screen background in the main window from black to gray.
o	Toggles the axes labels (X, Y, Z) on or off.
k	Toggles the axial plane on or off in the main window.
j	Toggles the coronal plane on or off in the main window.
i	Toggles the sagittal plane on or off in the main window.
x	Highlights the labels on the screen.
Show Volume Outline	If enabled, shows an outline around the outside edge of the volume.
Use Image Interpolation	If enabled, **MicroView** uses bilinear interpolation when displaying image data. When disabled, program uses nearest neighbor interpolation instead.

MISCELLANEOUS OPTIONS

Key / Option	Result
Show measurements in mm	The alternative unit of measure is in pixels.
z / Enable Integer Stepping	If enabled, **MicroView** prevents the display of bilinearly interpolated slices between actual data slices.
Use Min/Max for W/L control	Controls how image brightness / contrasted are manipulated. You can use either Minimum / Maximum values or Window / Level values.
Update W(indow)/L(evel) immediately	If enabled, **MicroView** updates the image as the Window/ Level settings are changed.
Display Splash at Startup	If enabled, **MicroView** displays a splash screen at program start up.
Enable balloon help	If enabled, **MicroView** displays popup help text over all dialog boxes when the cursor is stationary for a few seconds.

2.2.3 Loading a File

NOTE - A list of supported file formats appears in the Appendix.

1. Locate and select file and click Open to load file. Depending on the size of the selected volume this may take a few moments.

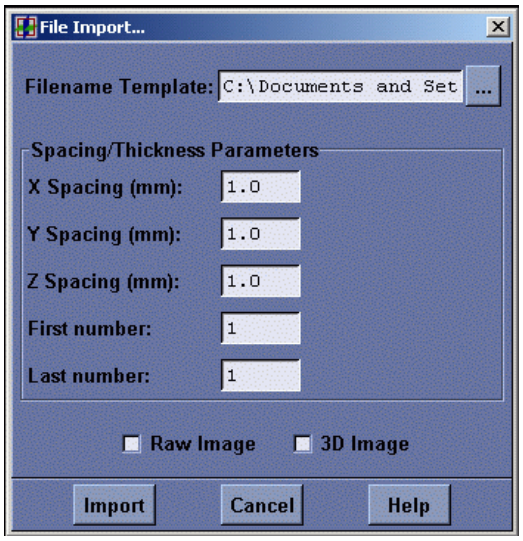
NOTE - Files sizes that exceed the system RAM will not open.

Once the file is loaded the volume appears on the screen. You now are ready to view and analyze the image data.

2.2.4 Importing 2-D Image Slices

MicroView is able to import a sequence of 2-D images in a variety of common image formats, and assemble them into a 3-D image.

1. To do this each 2-D image file must be named with consecutive numbers.
2. Select Image Import... from the File menu. File Import window appears.



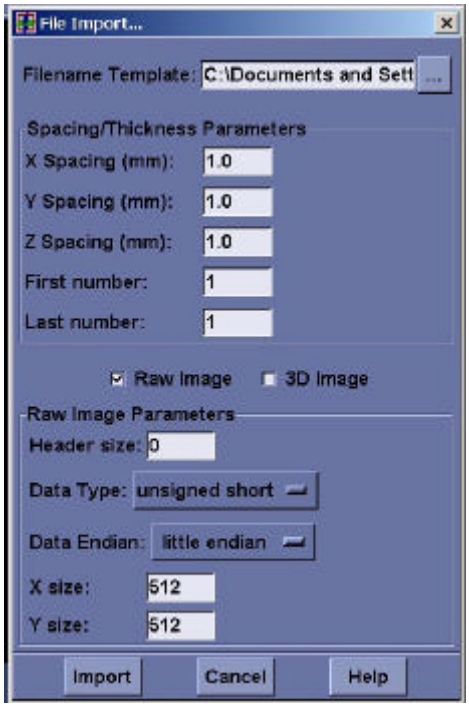
3. Enter a filename template name, in the format import-####.png, where # denotes characters that are automatically replaced by index numbers.

   The … (browse) button to the right of the template box can be used to locate a file.
4. Enter first and last index numbers in the appropriate entry boxes (e.g. if the template chosen is "import-##.gif" and the first and last numbers are set to 3 and 7, respectively, **MicroView** loads import-03.gif, import-04.gif... import-07.gif).
5. Enter desired spacing between image slices, in millimeters for each of the x, y, and z axes.
6. Enter the first and last number in the series of images to be imported.
7. Press Import button to import and display the image sequences in **MicroView**.

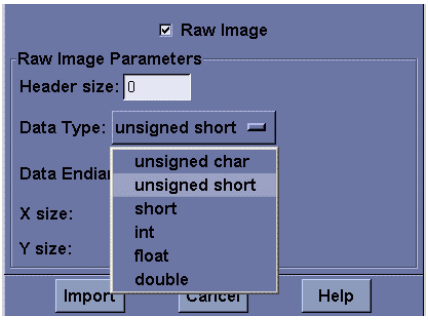
2.2.4.1 Importing raw 2D images

MicroView can also import raw data in a variety of formats.

Select Raw Image button on File Import window to display additional import options.



8. Specify the offset from the beginning of each file to the raw image data (in case an image header is present), the data type, byte ordering (for 16-bit image data) and the dimensions of the raw image data.

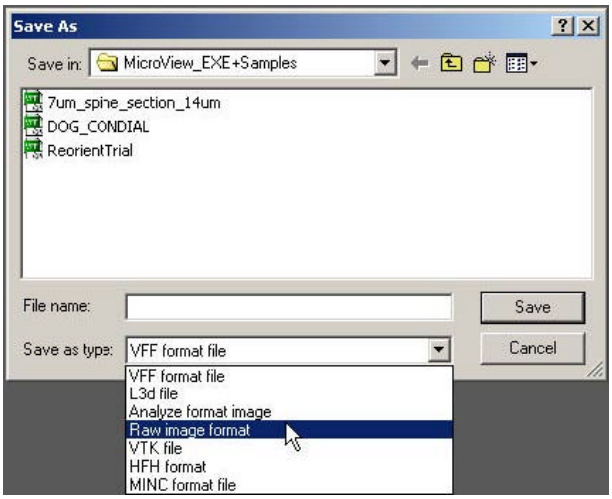


9. Click on Import button to import the file.

2.2.5 Saving Complete Image File

The complete image file can be saved in a variety of different formats from within **MicroView**.

1. Select Save As from File menu.



2. Select destination folder, named and desired file format. Press Save.

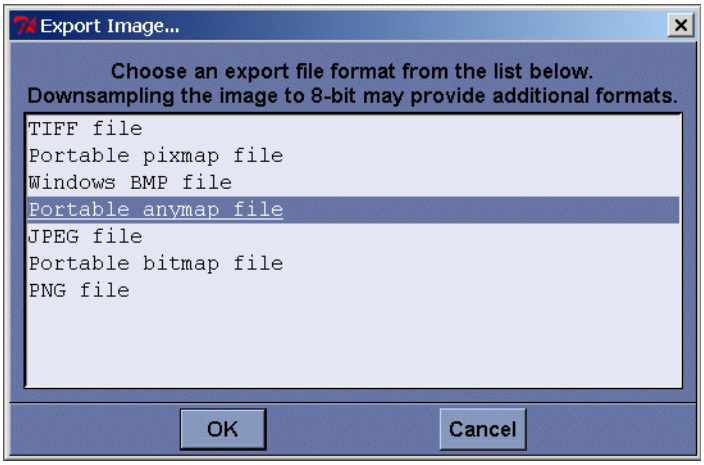
2.2.6 Saving 2-D Images

2-D images from **MicroView** can be saved in a number of different file formats.

1. Position cursor over 2-D plane or main 3-D volume and press **t** key.
2. Select name and destination location to which the .tif file is to be saved. Press Save.

2.2.7 Exporting Images as 2-D Image Slices

1. Select Image Export... from File menu.



2. Choose an image file format from the list provided. The available choices depends on the image depth of the selected image.
3. Click OK.
4. Select a directory to which to save the files. **MicroView** automatically saves individual image slices that make up the volume as individual files.
5. The filename extension depend on the selected file format, and a prefix of "export-" (e.g. export-0001.gif, ...) appears.
6. Click OK.

Chapter 3 Working with CT Image

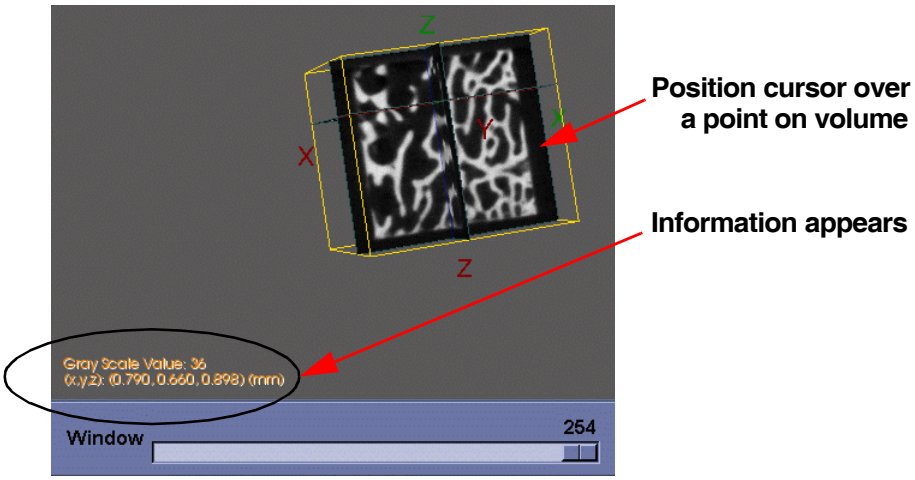
MicroView contains a number of standard and optional tools to help you analyze two and three-dimensional data. These are described below. Optional tools are noted, and may be purchased by contacting GE Healthcare. See contact information at front of manual for further information.

Section 3.1 MicroView Tools

3.1.1 Point Measurement (1-D)

MicroView provides location and grayscale information for individual points on either 2-D or 3-D images.

1. Place cursor on any point on 3-D volume or on 2-D plane.



The coordinates and grayscale value of the point are continuously displayed in the bottom left-hand corner of the main **MicroView** window.

3.1.2 Line Measurement & Analysis (2-D)

MicroView allows you to create lines on the 2-D planes for later analysis. Define a line using the following method.

DEFAULT LINE

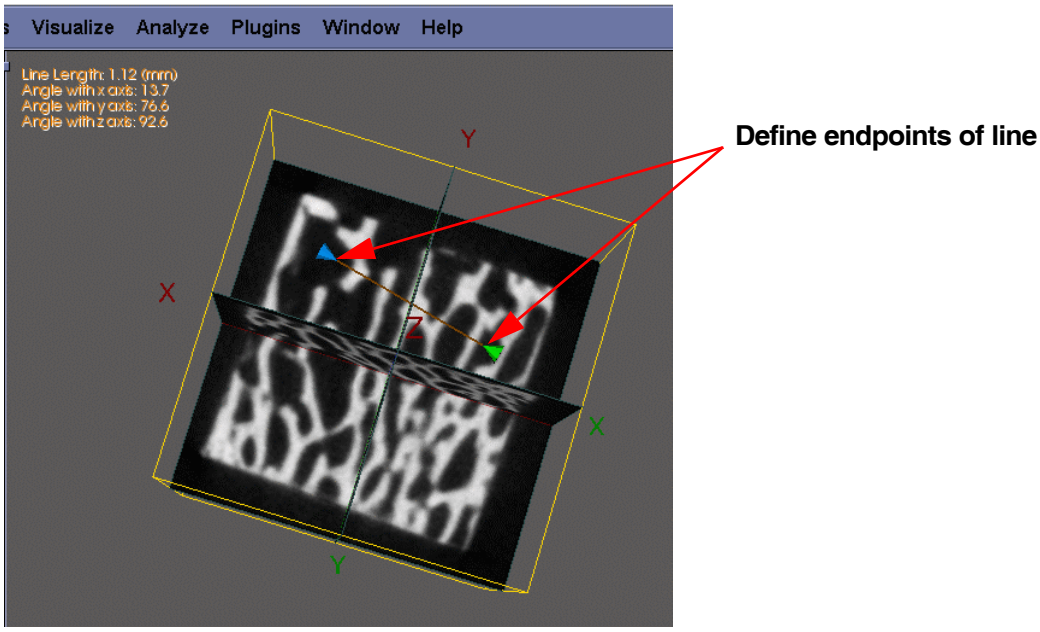
1. Select Show Line from the Edit menu.

   A line will appear in the middle of the volume. The line may be repositioned as described below.

CUSTOM LINE

1. Position cursor over an image plane in any of the viewports. Press **1** key to mark beginning of line.
2. Re-position cursor over same plane to mark end of the line. Press **2** key.

   Green and blue indicate the end points of the new line and information about it appears in the upper-left corner of the screen.



3. Using the middle mouse button, select and reposition the line as required.
4. Define new endpoints at any time by pressing either of the **1** and **2** keys.
5. Clear line by pressing the **y** key, or selecting Edit??Clear Line.

Once a line has been defined, use any of the following keys to perform 2-D analysis:

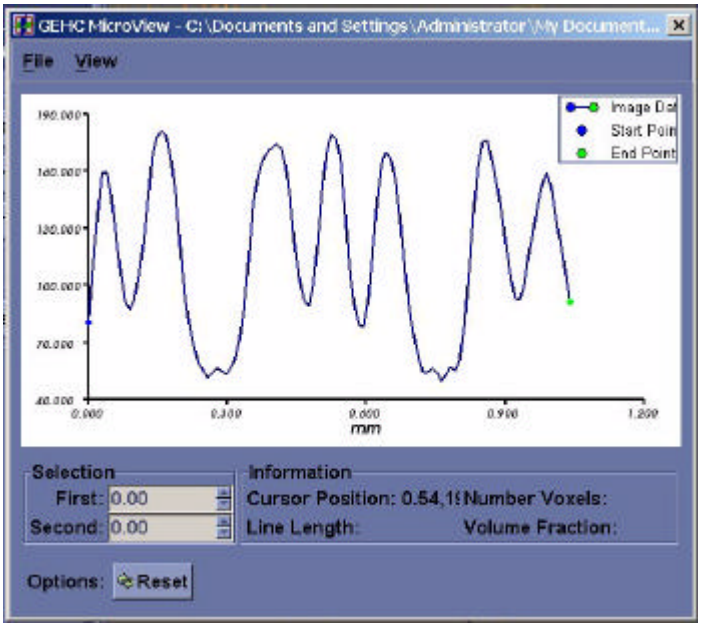
Key	Result
a	Saves grayscale values along the selected line to a text file.
p	Plots the grayscale values along the selected line.
0	Saves the end points of the selected line to a text file.
y	Removes the line.

3.1.3 Viewing Line Profiles

The system can calculate and display a profile of the grayscale values along the line.

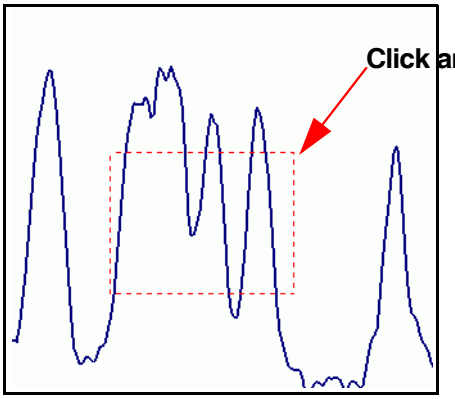
1. Press **p** key or select Plot... from Tools menu to generate line profile.

   A typical window is shown below.



ZOOMING IN ON A REGION OF INTEREST (ROI)

1. Use button **1** to click and drag a region of interest along the line profile and zoom in on the plotted data.



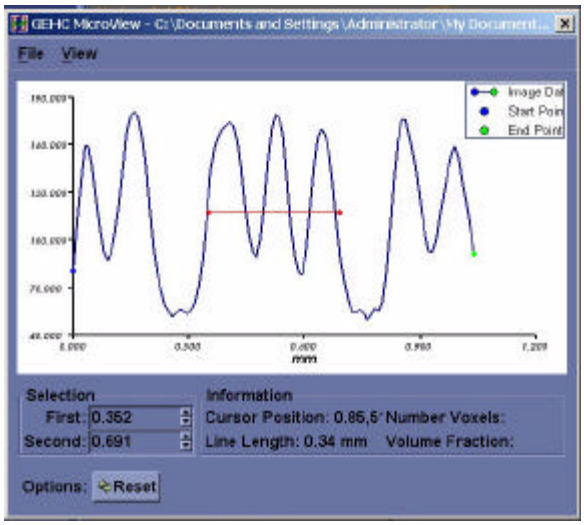
   Multiple levels of zooming can be achieved by repeating the click-and-drag method.
2. Zoom out by clicking button **3**.
3. Reset plot window at any time by clicking Reset button on plot window, or using **r** key.

MEASURING ALONG 2D PIXEL PROFILE

This feature allows you to make measurements along a line much more accurately than can be done while working from the 3D volume itself.

1. Position the mouse cursor over a feature within the plot window and press the **1** key, then select a second feature and press the **2** key.

   A horizontal red line is drawn between the two features. Mouse cursor position and selected line length are displayed in the bottom centre of the plot window.



3.1.3.1 Line profile options

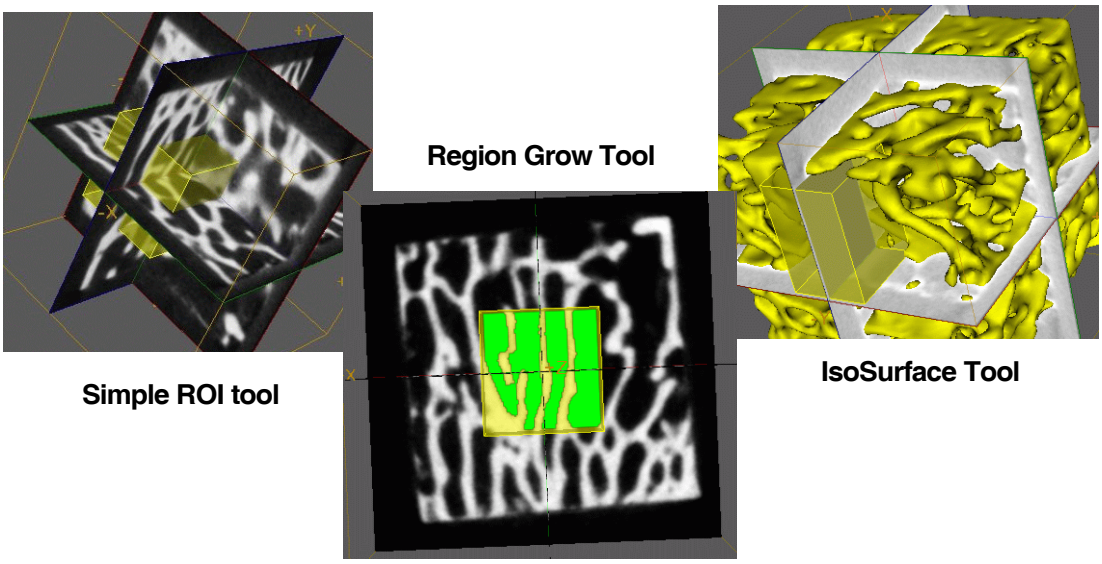
The line profile tool contains a number of options, described below.

Options	Result
File??Save Data	Saves the line plot data to a .txt file. System prompts for a file name and destination for the file. Press Save.
File??Save Snapshot...	Takes a snapshot of the plot window and saves it to disk as an image file. System prompts for a file name, file type and destination for the file. Press Save.
View??Symbols	Toggles the display of symbols at each data point along the profile.
Reset	Resets the view of the plot window.

3.1.4 Defining a Region of Interest Volume 2D / 3D

INTRODUCTION

For many operations in **MicroView**, the starting point is the selection of a 2D or 3D Region Of Interest (ROI). ROIs define the portion of the volume to be analyzed. For instance, an ROI can be created around a feature in an image in order to compute the mean and standard deviation of just that feature or perform some form of analysis.



The active ROI in **MicroView** is typically displayed in yellow to differentiate it from other surfaces and voxel highlight tools. The ROI may appear as a transparent yellow surface, or as a grouping of yellow voxels in the displayed image plane, depending on the tool used to generate the ROI.

There are five tools that can be used to generate a ROI in **MicroView**. These are:

- Standard ROI Tool,
- Advanced ROI Tool,
- Region Grow Tool,
- Overlay Geometry Tool,
- Cortical Bone ROI Tool.

These are explained in detail in the following section.

INSTRUCTIONS

MicroView allows you to create a 2D or 3D ROI from within the larger image volume.

1. Using cursor, mark start point on a plane within the volume. Press **7** key.
2. Reposition cursor and mark an end point on a plane within the volume. Press **8** key.
   A yellow rectangle defining the sub-volume is drawn.

Once a ROI is selected use the tools described below to do 2D/3D analysis on the volume.

3.1.5 Sub-Volume Analysis

Once a sub-volume has been defined, a number of analyses can be performed using either the shortcut keys described below or the buttons on the histogram window.

Key	Result
g	Plots the histo**g**ram and computes the mean and standard deviation of the grayscale values within the ROI
m	Calculates **m**ean and standard deviation for sub-volume. Value is displayed in lower right-hand corner of screen.
s	**S**aves the sub-volume coordinates to a file called SubVolumeCoordinates (in the loaded file's directory).
v	Saves the sub-**v**olume file. System prompts for a file name, format and location. Click Save or Cancel upon completion.
c	**C**lears the volume.
d	**D**umps the grayscale values to an ASCII file. System prompts for a file name, format and location. Click Save or Cancel upon completion.
If the sub-volume is a rectangular area (an area on single plane) the **u** key can be used to perform the following.	
u	Save the area file. System prompts for a file name, format and location. Click Save or Cancel upon completion.

3.1.5.1 Plot histogram of sub-volume

1. Press **g** key to plot and display histogram from sub-volume.
2. Select a box ROI as described previously, or select the entire image volume from within the Standard ROI Tool.
3. Select Histogram… from Tools menu or press the **g** key. A histogram of the current Region of Interest is automatically calculated and shown in a separate window.

ZOOM IN FOR FURTHER ANALYSIS

1. Using mouse button **1** click and drag an area of the histogram for further analysis. The blue graph will turn red where selected and the selected area will be displayed.
2. Reset plot window at any time by clicking Reset button on plot window, or using **r** key.

AUTO THRESHOLD

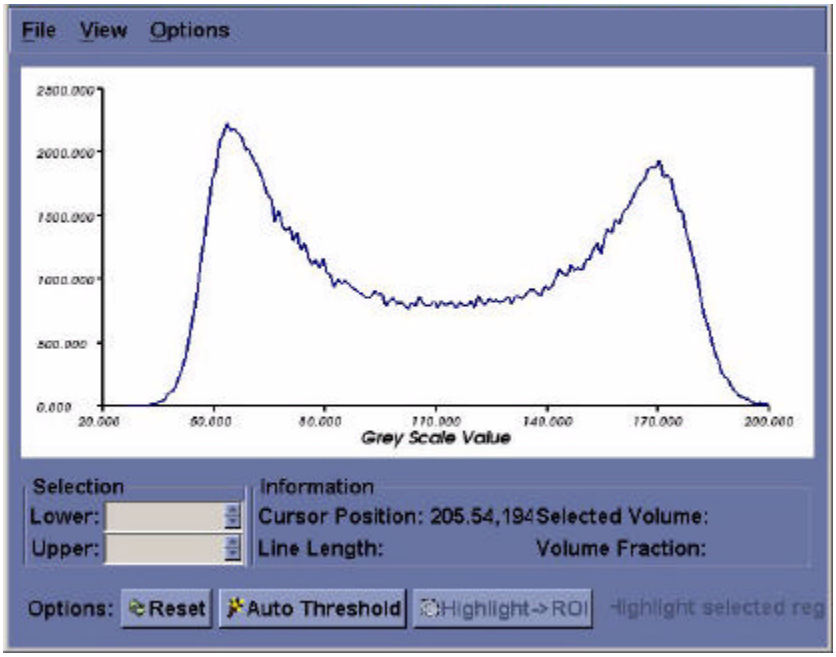
The Auto Threshold button can be used to automatically determine an optimal threshold value for the isosurface tool or stereology tool.

SELECT RANGE OF VOXEL VALUES

You can select a range of voxel values, and the system will report the number of voxels in the selected range and the volume fraction.

1. Place cursor on the graph in the plot window, press and hold down the middle mouse button and use the mouse to define the desired range of values. Release button to select.

   Volume and volume fraction information for the selected area are generated and displayed on screen.

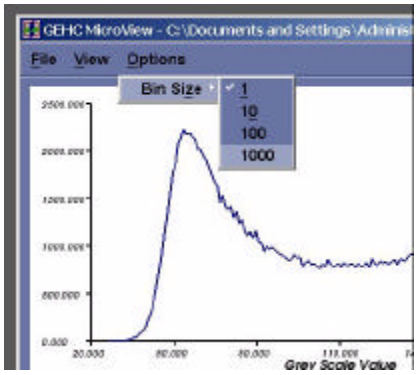


The controls in the histogram window are similar to the controls in the 2D profile plot window. The histogram window does have some additional features, described below.

2. Check the Highlight selected region checkbox to adjust the texture mappings so that voxels corresponding to the selected value range are highlighted.

SELECT BIN SIZE

The user can select the bin size. The bin size is the width of each of the bars in the histogram. The default bin size is 1.

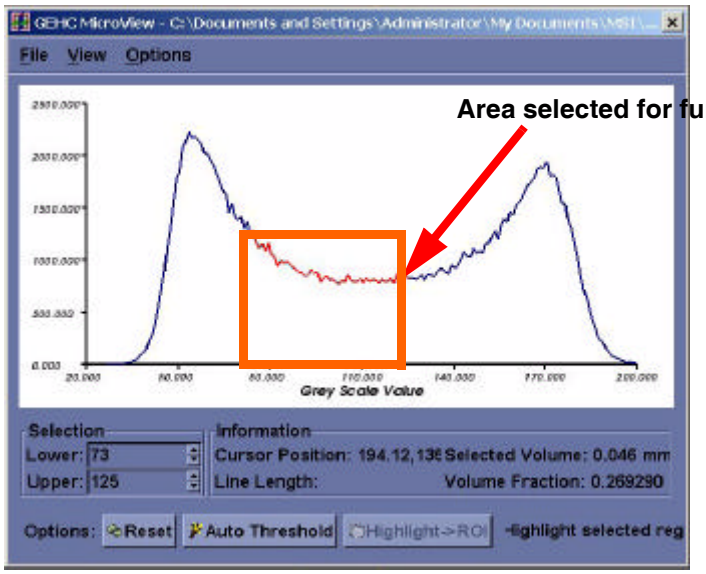


The following commands and options are available on the histogram window.

Menu / Function	Result
File?? Save Data	Saves the histogram data to a .txt file. System prompts for a file name and destination for the file. Press Save or Cancel upon completion.
File?? Save Snapshot	Takes a snapshot of the histogram window and saves it to an image file. System prompts for a file name and destination for the file. Press Save or Cancel upon completion.
View?? Reset	Resets the view of the histogram window to the starting position.
Options??Bin Size	User can select appropriate bin size for histogram.
Auto Threshold	System automatically calculates and displays an optimal threshold value for use in the Isosurface tool.
Highlight Selected Region	When selected, provides a visual indication of the selected area on the original image in red.

ZOOMING IN ON A REGION OF INTEREST (ROI)

1. Use button **1** to click and drag a region of interest along the histogram plot and zoom in on the plotted data.



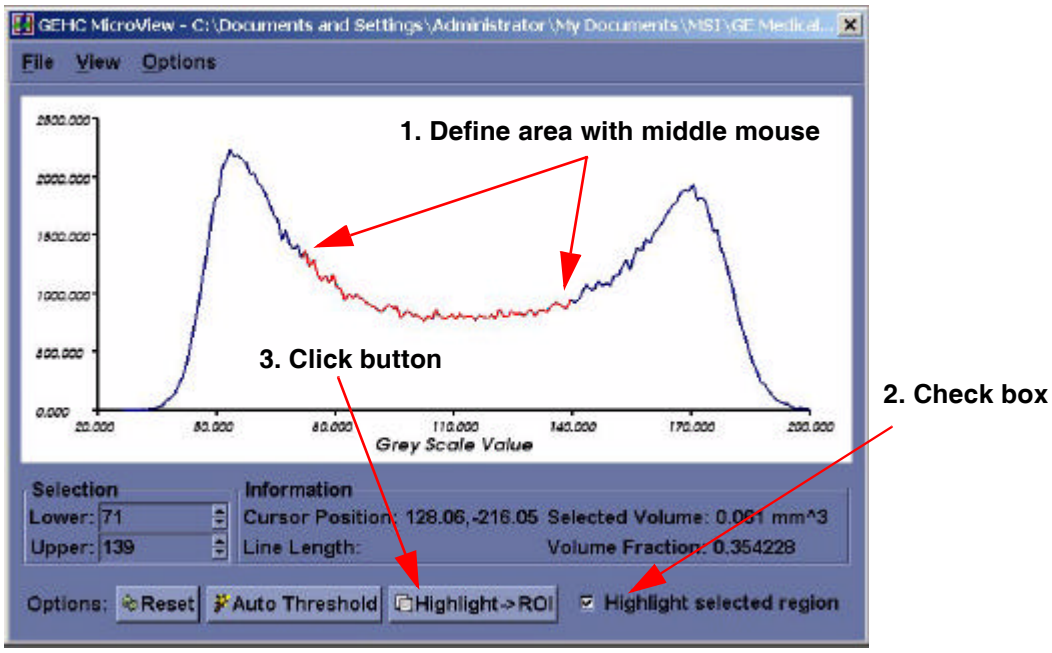
Multiple levels of zooming can be achieved by repeating the click-and-drag method.

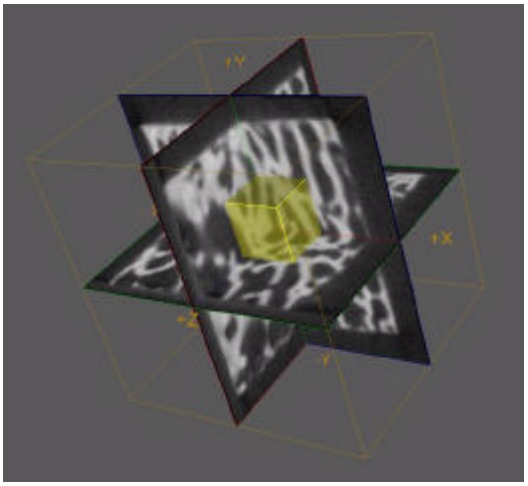
2. Zoom out by clicking button **3**.
3. Reset plot window by clicking Reset button or press **r** key.

HIGHLIGHT SELECTED REGION

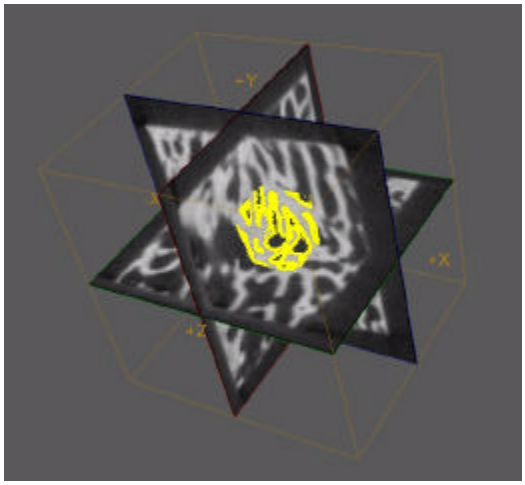
Selected ranges can be converted to an active ROI.

1. Define an ROI and plot the histogram as described above.
2. Highlight a region on the graph using the middle mouse button.
3. Check Highlight selected region box.
4. Click the Highlight?? ROI button. The highlighted red region will become yellow, indicating that the selected values are now the active ROI.





Before



After

3.1.6 Region Of Interest (ROI) Selection - Standard

In addition to using the **7** and **8** keys (or Control-7 and Control-8) to quickly define a rectangular ROI, **MicroView** provides you with complete control over the size and location of the ROI using the Standard ROI tool.

1. Select Standard ROI… from Tools menu. The Standard ROI toolbar appears.

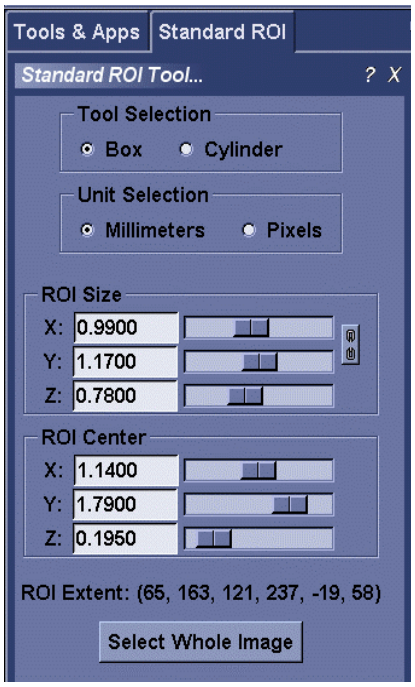
1. Choose ROI shape

2. Select units

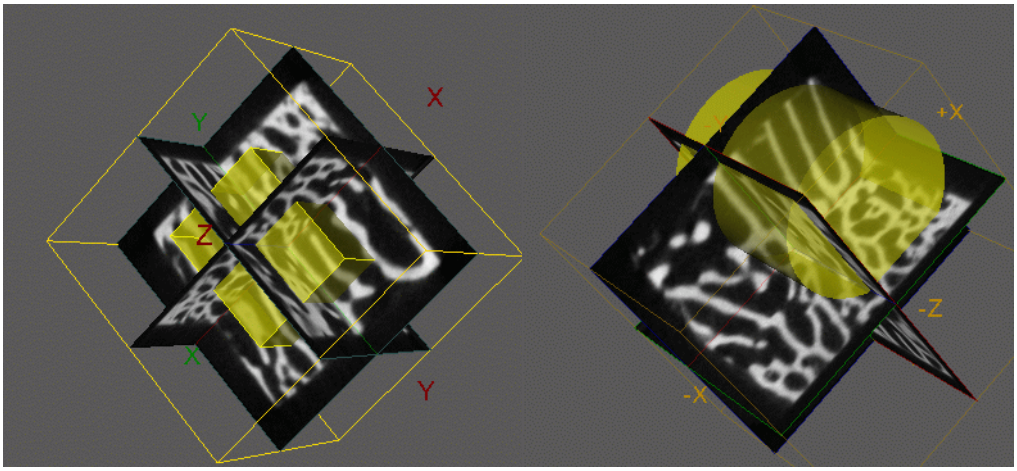
3. Adjust ROI size

4. Adjust ROI location

5. Select Whole Image



A yellow elliptical cylinder or parallelepiped appears in the volume.



Define a ROI within the volume for analysis.

1. Select either an elliptical cylinder or a parallelepiped volume for analysis.
2. Select preferred unit of measure, millimeters or pixels.
3. Adjust ROI size by dragging cursor along the X, Y or Z slider bars, or by entering an exact value in the text box. The ROI area changes automatically and the new values are displayed.

The selected ROI in the volume adjusts accordingly.

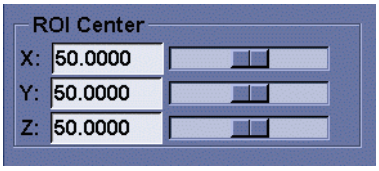
ADJUSTING ROI SIZE

The ROI size and position can be adjusted to suit.

1. Click and drag cursor over the slider bar to shift the location of the ROI within 3-D volume. The yellow ROI in the volume shifts accordingly.
2. Alternatively, adjust ROI size by clicking and dragging within the ROI using mouse button 2.

ADJUSTING ROI POSITION

To change the location of the ROI center within the 3-D volume;



1. Hold button **1** and drag mouse over any of the text boxes labeled, X Position, Y Position, or Z Position, to shift the corresponding position, or, press and hold the **3** key and use the mouse to reposition the area. Release the **3** to set the new coordinates.

NOTE - Adjust the position of the ROI by moving the mouse to a new location in the volume and pressing 3. The ROI will move accordingly.

NOTE - Adjust the position of the ROI by pressing the shift key and dragging the mouse along one of the volume faces.

Once you have correctly defined the ROI you can begin the calculations using any of the optional plug-in analysis tools.

3.1.7 Selecting a Region of Interest (ROI) - Advanced

The Advanced ROI Tool can be used to generate a 3D ROI from a series of stacked 2D ROIs. It also allows you to manually select an arbitrary ROI or to define different shaped regions of interest such as spline-fitted surfaces.

Once a ROI is selected, analysis such as calculating mean and standard deviation, generating an isosurface, calculating BMD, etc. can be performed.

1. Select Advanced ROI… from Tool tab or Tools menu. The Advanced ROI toolbar appears.

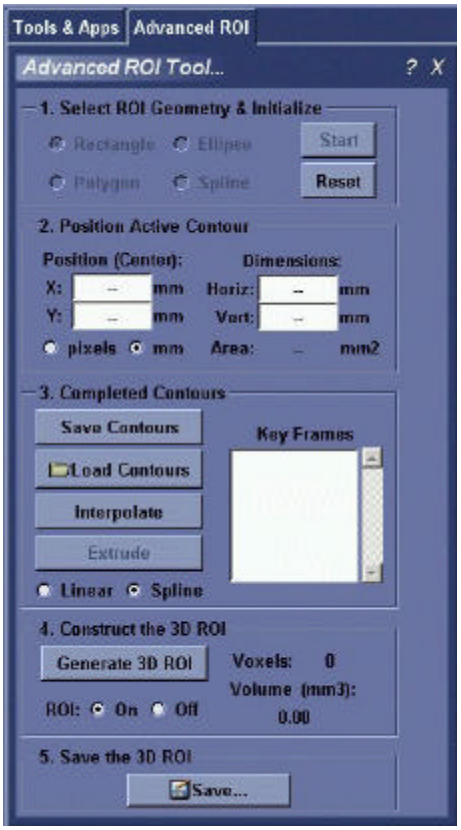
1. Choose shape

2. Position contour

3. Manage contours

4. Construct the 3D ROI

5. Save the 3D ROI



2. Choose desired shape from the available options, (Rectangle, Ellipse, Polygon or Spline).
3. Click Start button to draw the 2D image.

   At any time, click Reset to delete all 2D and 3D ROIs. This action may not be undone.

ROI AS RECTANGLE OR ELLIPSE

1. Position mouse within one of the 2D image panes, press mouse button **1** and drag to desired size.
2. To adjust the size of the 2D ROI place mouse on any corner of the ROI, press button **1** and drag to suit.

   Release button when proper size is reached.
3. To adjust position of 2D ROI, place mouse inside of ROI, press and hold button **1** and drag.

   Release mouse button when the 2D ROI is positioned properly.
4. Click mouse button **1** outside of 2D ROI to re-select and inside of the 2D ROI to drag it around.
5. Push the 2D plane with the middle mouse button to a new location and draw another 2D ROI

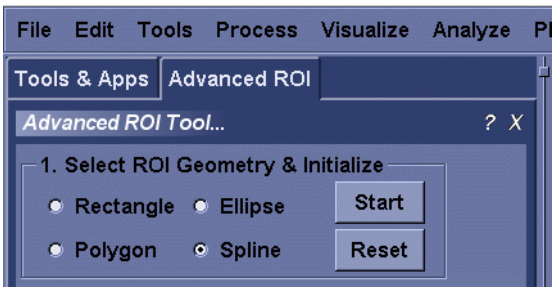
as described above.

6. Click Generate 3D ROI button to draw the 3D ROI. Save, load and interpolate the contours as required.

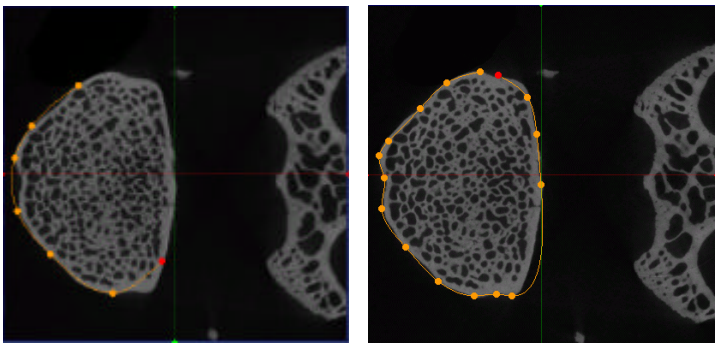
ROI AS POLYGON OR SPLINE

This free-hand mode is used to define a ROI as either a polygon or spline.

1. Check either Polygon or Spline and Start button.



2. Using the cursor and mouse button **1** pick and click the points which define your shape on the 2D image pane. The points are connected automatically with line segments.



Select and click points with button 1

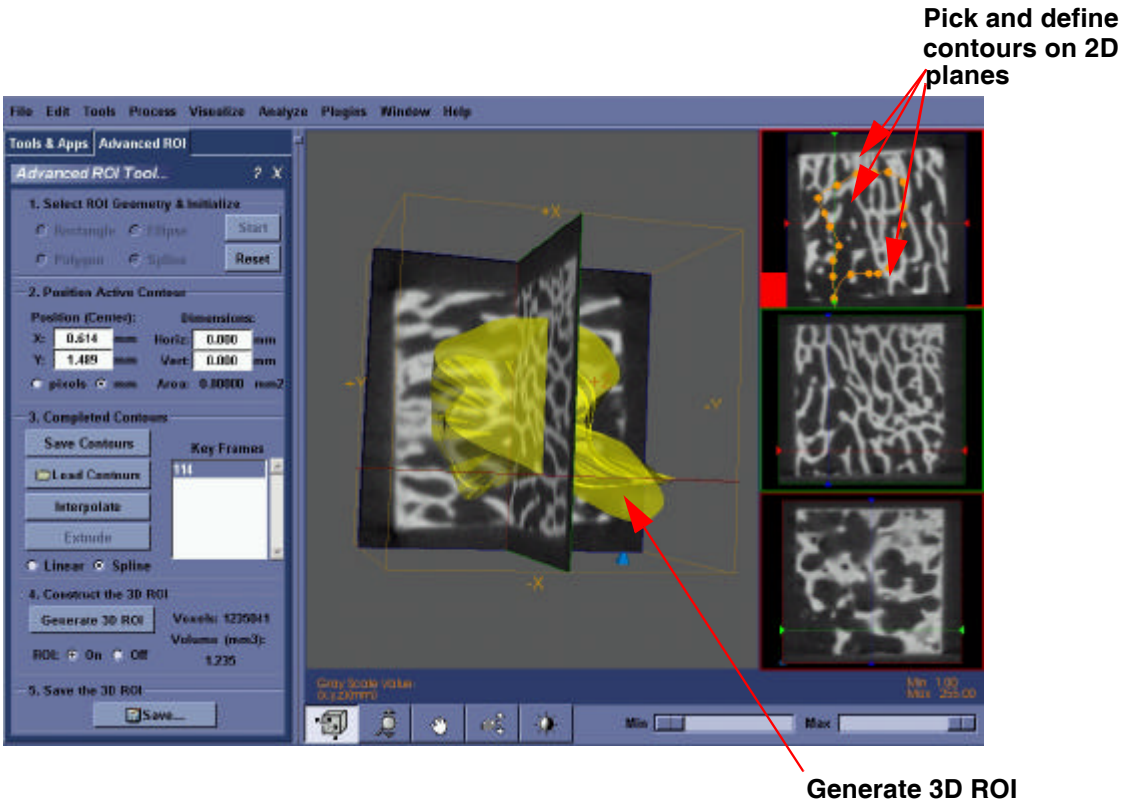
3. Once fully defined, click again on the first point to enclose the ROI.
4. To delete a point, select it with the cursor and hit the delete key.

   After the 2D ROI is enclosed, it can be edited by dragging a point to re-position it, clicking on a line segment to add a point, clicking inside the ROI to drag the whole ROI, or clicking outside of the ROI to erase the ROI and start all over.

NOTE - For each user-drawn 2D ROI there is a number in the Key Frames section. A Key Frame is a number that indicates the image slice index where the 2D ROI was drawn. Click the Interpolate Contours button to generate 2D ROIs on every empty slice between the minimum and maximum Key Frames. There are two options for the interpolation: Linear or Spline.

5. Push the 2D plane with the middle mouse button to a new location and define another shape as described above. Repeat as required until the boundaries of the new ROI have been completely defined.

6. Click Generate 3D ROI button to draw the 3D ROI. Save, load and interpolate the contours as required.



7. After the interpolation, you can edit any frames to fine-tune the ROIs. Every edited frame becomes a Key Frame in addition to the existing Key Frames. Clicking on the Interpolate button will do the interpolation again using the updated Key Frames.
8. Click Save Contours button at any time to save the stack of 2D ROIs.

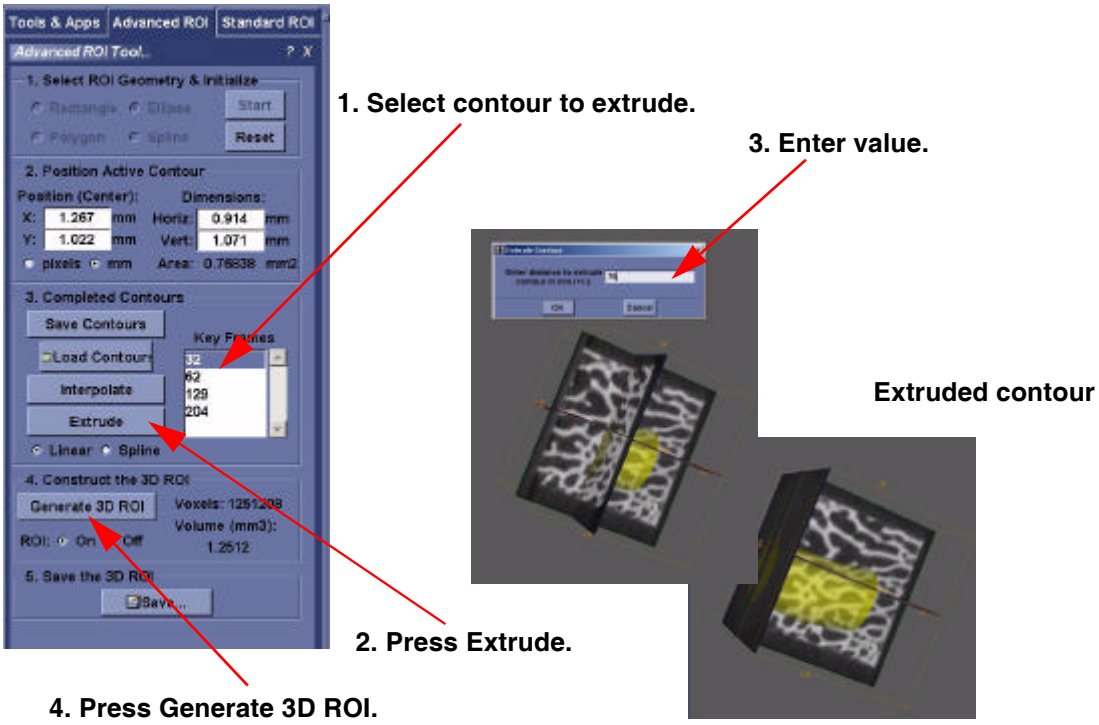
   The 2D ROIs can be reloaded by clicking Load Contours button.
9. To generate a 3D ROI from a stack of 2D ROIs and display the 3D ROI click the Generate 3D ROI button.
10. Click on the ROI On or Off radio button to show or hide the 3D ROI.
11. Press Save... button to save the 3D ROI.

    This can be used by Overlay Geometry module.
12. Click the **x** button in the top right hand side of the notebook tab to close this tab and remove ROIs from all image panes. This action may not be undone.

EXTRUDE TOOL

The extrude tool allows you to extrude (or project) a selected contour along the z-axis a fixed distance.

1. Create or load contours as described previously.
2. Select the contour to be extruded in the Key Frames window.
3. Click the Extrude button.
4. Enter a value in the pop-up window. Press Ok.
5. Click on Generate 3D ROI button. New ROI is generated automatically and shown on the screen.



3.1.8 Cortical ROI

Use this tool to select an ROI corresponding to either the cortical shell or the trabecular space of the bone in a CT image. It uses a series of morphological operators to semi-automatically select cortical bone components. The trabecular space is found within the cortical bone region. Once the cortical bone components have been selected, they can be converted to an ROI for use in the Advanced Bone Application. The image planes can also be rotated so that the axes of the planes are aligned with the principal axes of the cortical bone.

Before running this tool, select an ROI to be used for segmentation; otherwise the tool will automatically select the entire image and perform segmentation on the resulting ROI.

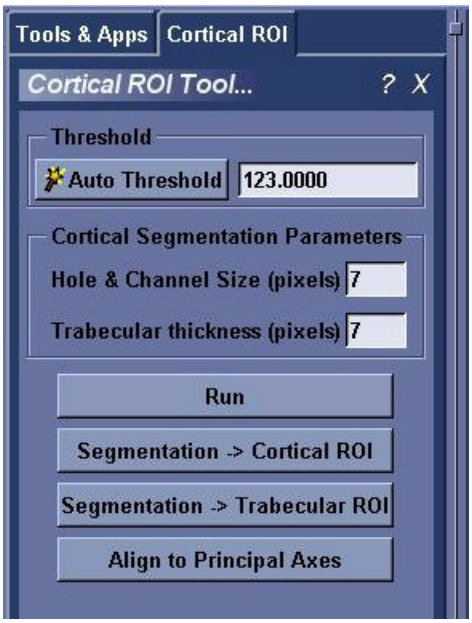
1. Select a box ROI as described previously, or select the entire image volume.
2. Select Cortical ROI... from Tools menu. The Cortical ROI toolbox appears.

1. Set Threshold or Run Auto Threshold

2. Select segmentation parameters

3. Run segmentation

4. Convert results to an ROI



3. Set a graylevel value that selects bone versus non-bone, or select Auto Threshold button. The system automatically computes a threshold value and displays it on-screen.
4. Select hole & channel size in pixels and trabecular thickness in pixels. 7 is the default value.

   The hole and channel size specifies the largest size, in pixels, of any holes and channels through the bone that you would like the algorithm to fill.

   The trabecular thickness specifies the largest size, in pixels, of trabeculae that you would like the algorithm to remove from the ROI. For bones where the cortical thickness is similar to the trabecular thickness, the segmentation algorithm may also eliminate the cortical bone making it less suitable for use in these circumstances.
5. Select Run, to start the segmentation algorithm. Results are displayed on the screen in green.
6. Select Segmentation ? Cortical ROI to convert the segmentation results to an ROI for use with the bone analysis tool. Results are displayed on the screen in yellow.
7. Select the Segmentation ? Trabecular ROI button to invert the ROI selection -- i.e. select the trabecular bone region as an ROI. Results are shown in yellow on the screen.
8. Select Align to Principal Axes buttons to align the volume to the principal axes of the segmented cortical bone.

3.1.9 Region Grow

INTRODUCTION

The Region Grow Tool is used to define a ROI based on connected voxels with similar graylevel values.

Connected voxels can be grouped together using one of three rules:

- all voxels with graylevel values greater than a user-defined threshold,
- all voxels with gray level values lower than a user-defined threshold, or
- all voxels with gray level values within a range of values centered on a user-defined threshold.

While it can be used to select an ROI the tool can also operate within the confines of a pre-existing ROI, or can be applied to the whole image.

Region growing is a method of segmentation where an initial seed voxel and criteria for connectivity are provided, and then 26 neighboring voxels are examined to see if each one meets the criteria for connectivity. If a voxel meets the criteria for connectivity its neighbors voxels are examined in turn. For this tool, the criterion for connectivity is a threshold.

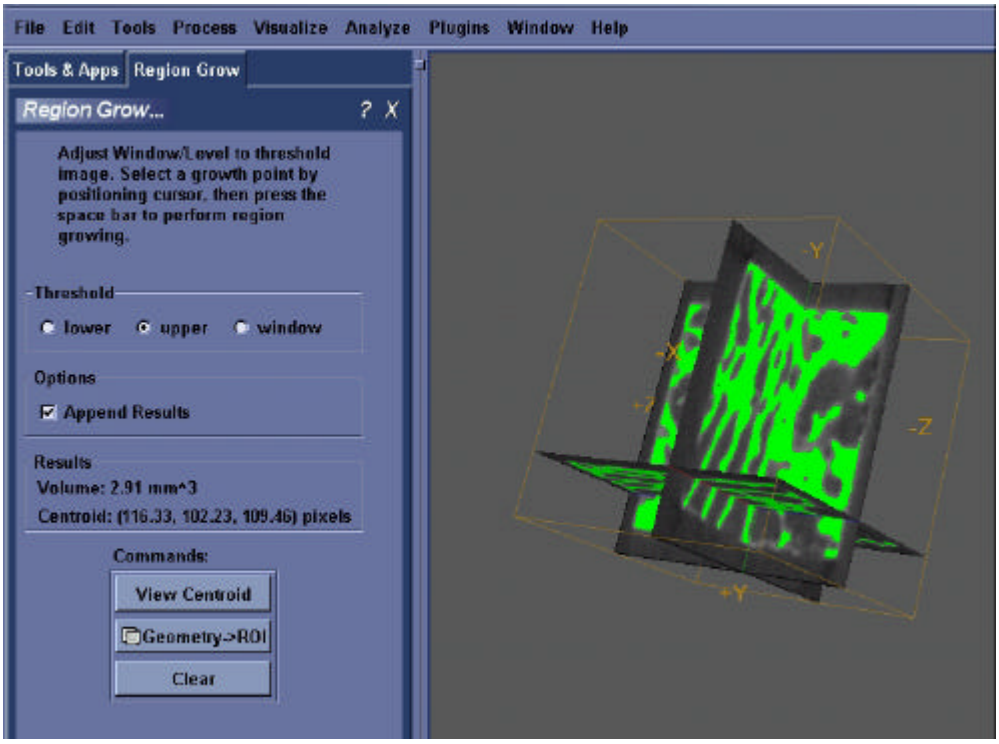
Region growing is useful tool for segmenting tumors.

INSTRUCTIONS

Typically a simple ROI is selected to constrain the region growing process. Selecting a small rectangular ROI around the object to be segmented will reduce the memory and time required to perform the region grow operation.

Region Grow can be used without selecting a constraining ROI, but the time and memory required are greater.

1. Select Region Grow… from the Tools menu.



1. Move one of the 3D viewplanes so that it intersects the constraining ROI. Select a plane that clearly shows a slice of the object you wish to segment.
2. Temporarily set the Window value for the main window to 1.
3. Adjust the Level value so that the loaded image is displayed in black and white. Choose a setting so that the feature to be segmented is displayed in white.
4. Select a threshold option from the available list. If segmenting
   - a **bright object** from a darker background, select **upper** threshold. The system then selects connected voxels with values higher than the current level setting.
   - a **dark object** from a brighter background, select **lower** threshold. The system then selects connected voxels with values lower than the current level setting.
   - Choose **window** threshold to segment connected pixels in a range of graylevel values surrounding the current level scrollbar value (+/- half the window setting).
5. Pick a starting point (e.g. a pick point) for the region grow operation by positioning the mouse cursor over the object of interest within the constraining ROI.
6. Hit the space key to select the 3D point.

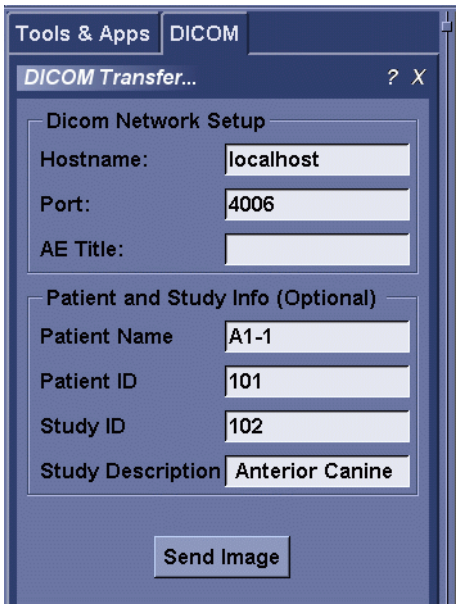
   The region grow tool will determine a set of connected voxels and will highlight these voxels in green in both the 3D and 2D viewports. In the results section of the region grow tool, the volume and centroid of the group of voxels are displayed.
7. Press View Centroid to move the 3D cutplanes so that they intersect at the centroid of the selected ROI.
8. Press Geometry->ROI to assign the results of this tool to the default ROI for further analysis. Once assigned, the green highlighted voxels will turn yellow, indicating the new choice of system-wide ROI.
9. Save as required using the options from the File menu tab.

3.1.10 DICOM Data Transfer

MicroView allows you to transfer a loaded image to a compatible DICOM viewing station for viewing, archiving or printing.

MicroView uses either the CTN third-party command line "send_image" tool send_image, or the DCMTK toolkit tool storescu to transfer a loaded image to a compatible DICOM viewing station. See http://wuerlim.wustl.edu/DICOM/ctn.html for further information.

1. Select Dicom Transfer... from Tools menu. Dicom Transfer toolbox appears.



2. Enter hostname and port number of the destination server in the text entry boxes.
3. Optionally, select a DICOM application name (AE Title) for servers that require communication from a specific application name.

   For servers that do not require a specific application name, leave this field blank.

   Check with your DICOM vendor, or user's manual to determine what the AE (Application Entity) title should be.
4. Enter values for Patient Name, Patient ID, Study ID and Study Description, as required.

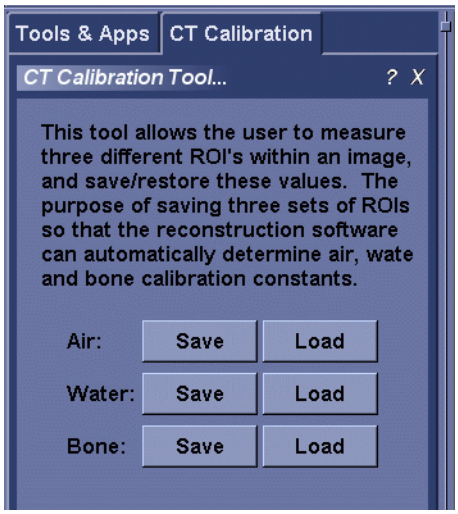
   In some cases **MicroView** may provide default values based on the image loaded.
5. Press Send Image button to transfer the image.

To learn more about CTN and send_image, visit the CTN web site at http://dicom.offis/de/dcmtk/php.en.

3.1.11 CT Calibration Tool

This tool is used to measure three different ROIs within an image, and save/restore these values. The three ROIs are saved so that the reconstruction software can automatically determine air, water and bone calibration constants.

1. Select CT Calibration Tool... from Plugins menu. CT Calibration toolbar appears.

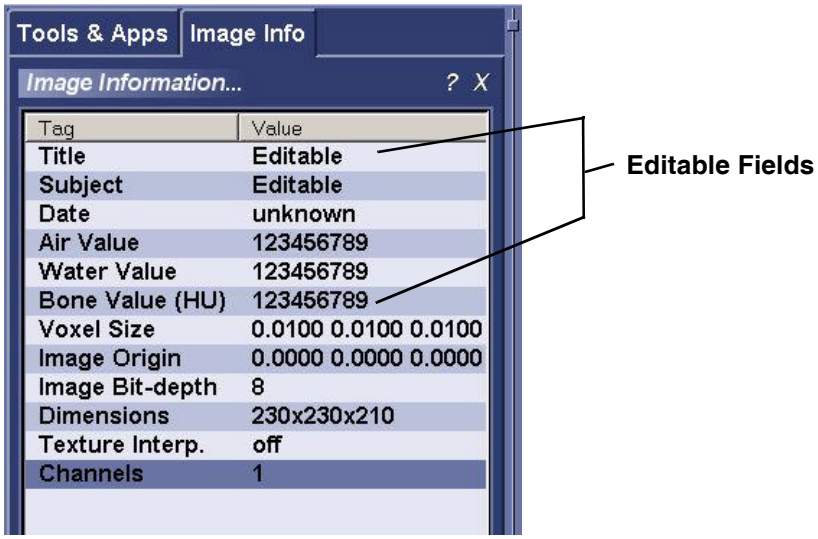


2. Define a ROI on the volume with only air using either the 7 & 8 keys, (or by using the ROI Selection Tool... on the **MicroView** menu) and
3. Clicking the corresponding Save button.
4. Do the same for water and bone. Click Save.
5. Once a ROI for each of air, water, and bone are selected and the settings have been saved, click Load buttons and the corresponding ROI appears.

3.1.12 Image Information Tool

The Image Information Tool displays information about the image, such as title, date of creation, size, spacing, bits, air density, etc. The information is obtained from the header portion of the image file.

1. Select Image Information... from Tools menu. Image Info window appears.

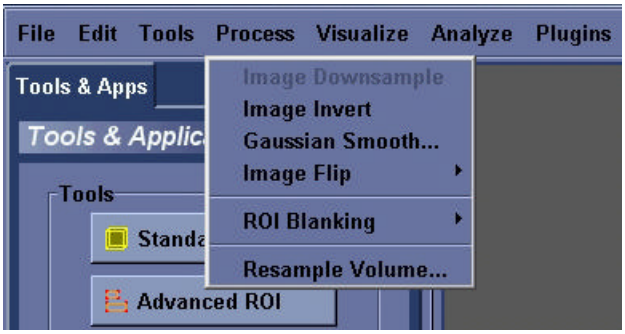


NOTE - Bone Value is expressed in Hounsfield Units.

Information for certain of the fields can be edited directly in this window.

2. Click **x** to close window.

Section 3.2 MicroView Processes



MicroView allows you to perform a number of image manipulation routines on the image. These are shown on the "Process" tab, and include:

- Downsampling the image,
- Inverting the image,
- Smoothing the image (Gaussian smoothing),
- Flipping the Image
- Blanking out or masking the area inside or outside the ROI,
- Resampling the volume,
- Reorienting the volume.

Each of these is explained further below.

3.2.1 Downsampling the Image

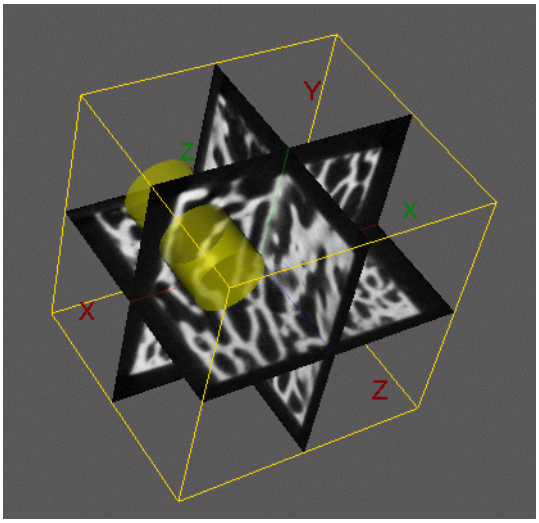
This feature allows you to downsample a 32-bit or 16-bit image into a 8-bit image. This reduces both file size and pixel dimensions.

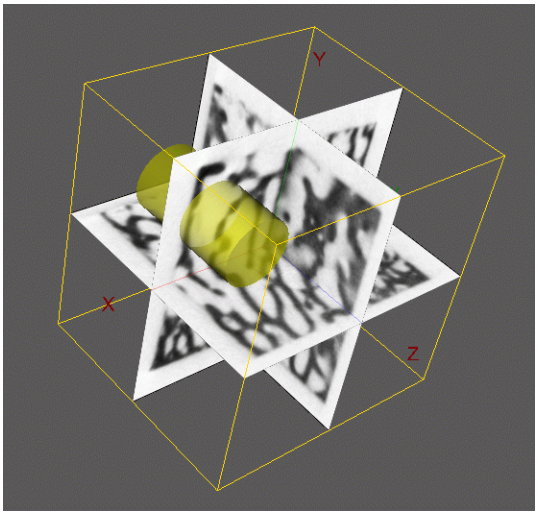
1. Select Image Downsample from Process menu. Process begins automatically and downsampled image is shown on the screen.

3.2.2 Inverting the Image

This tool allows you to create a negative of the selected image.

1. Select Image Invert from Process menu. Process begins automatically and may take a few seconds to complete. Inverted image is shown on the screen.



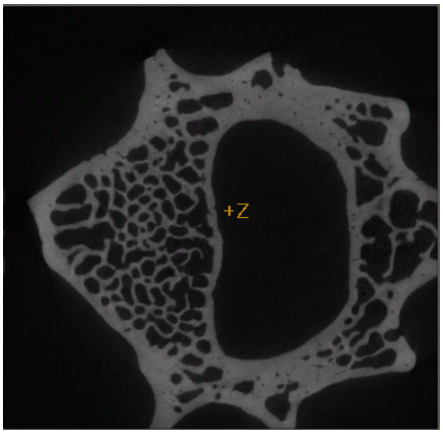


2. Apply Image Invert again to restore the image to its original state.

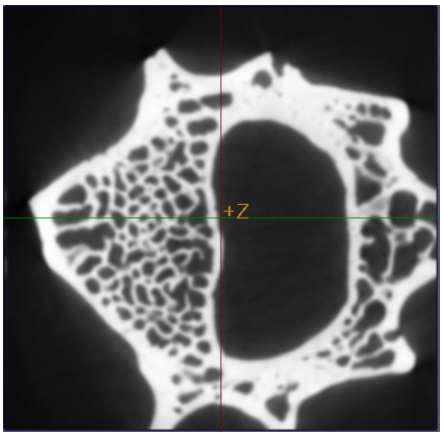
3.2.3 Applying Gaussian Smoothing

When selected, applies Gaussian smoothing to the image data and redraws the image.

NOTE - This process cannot be undone by re-selecting the button. The image must be closed and re-opened.

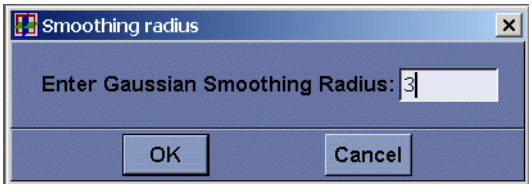


Non-smoothed



Smoothed

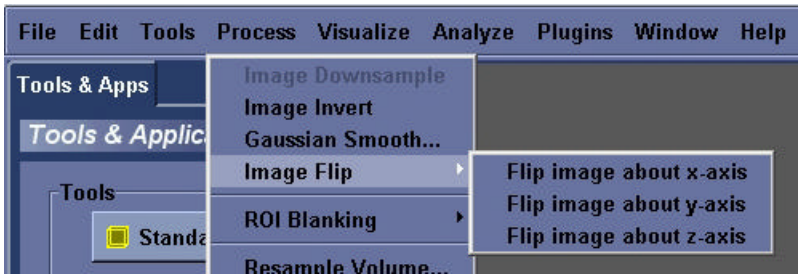
1. Select Gaussian Smooth from the Process Menu.
   System prompts for a Smoothing Radius. Default value is 3.



2. Press OK to continue.
3. Process begins automatically and may take a few seconds. New results are shown onscreen.

3.2.4 Flipping the Image

This tool allows you to flip the image about either the x, y or z axis.



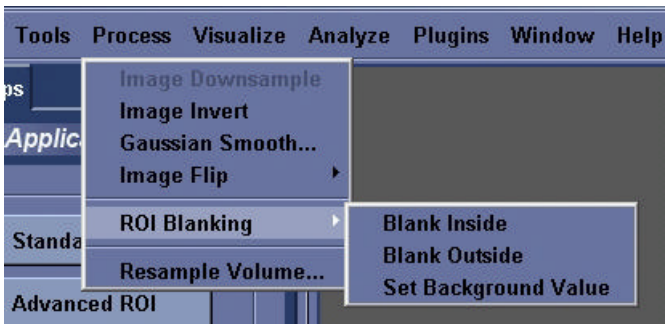
1. Select Process?? Image Flip and the axis you want to flip the image about.
2. Save the flipped image at any time by through the File?? Save Image As... command.

3.2.5 ROI Blanking

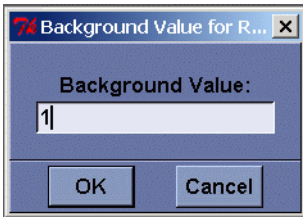
This process allows you to blank (erase) image data from either inside or outside the defined ROI. You may also define a background value to blank.

NOTE - This process cannot be undone by re-selecting the button. The image must be closed and re-opened.

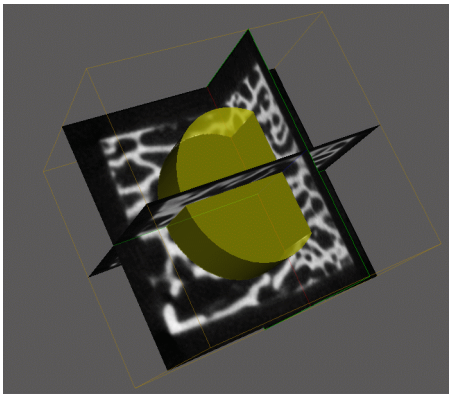
1. Select ROI Blanking from Process menu. A sub-menu appears.



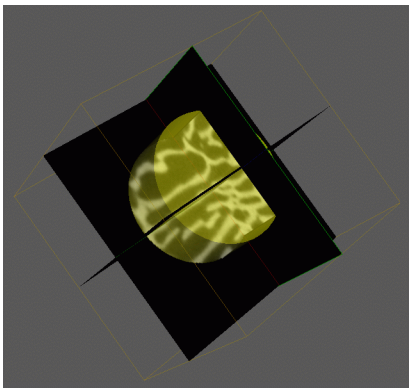
2. Set the Background value as required. Click OK to continue.



3. Select either Blank Inside, Blank Outside.
   Process begins automatically and results are displayed onscreen.



Inside Blanked



Outside Blanked

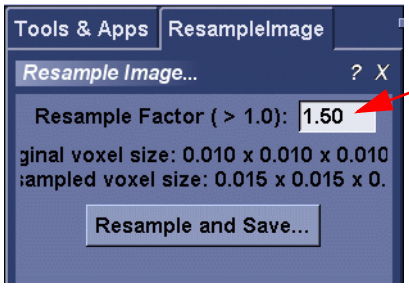
3.2.6 Resampling the Volume

MicroView can perform image downsampling on a loaded image in order to decrease the disk space and memory needed to store an image.

The technique involves tri-cubic interpolation.

NOTE - Resampling will result in reduced image resolution.

1. Select Resample Volume... from Process menu. Resample Image window appears.



Defines the factor used for binning pixels and hence the output image size

2. Enter desired resampling factor in the text field.
3. Press Resample and Save... button to resample the image and save it to disk.

   You are then prompted to name and save the new image file.

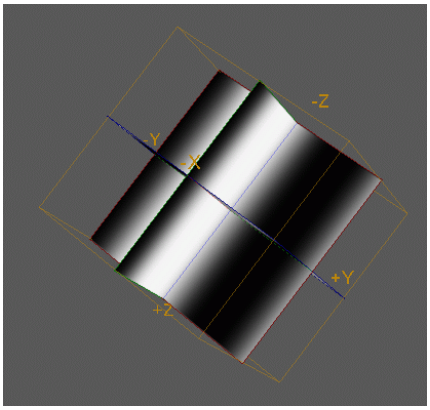
3.2.7 Reorienting the Volume

MicroView allows you to reorient the volume to some new view and then save the reoriented image separately.

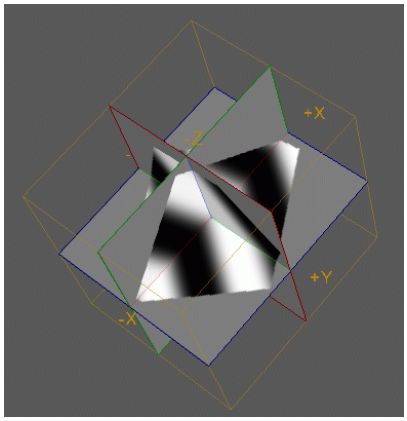
1. Center and orient the cut planes in the 3-D viewport until the desired orientation is achieved.
2. Select Save Reoriented Image... from the File menu to save the reoriented image.

   System prompts for a file name and location to save the file to. Click Save or Cancel upon completion.

   When the new file is re-opened it will display the new axes.

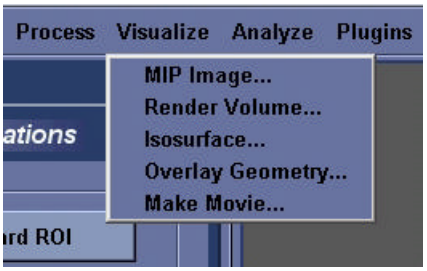


Non-Reoriented



Reoriented

Section 3.3 MicroView Visualization Tools



MicroView provides a number of image visualization tools. These allow you to:

- Create a MIP (Maximum Intensity Projection) image,
- Render the volume,
- Create an isosurface from the image,
- Overlay Geometry onto the image,
- Make a movie.

Each of these tools is described below.

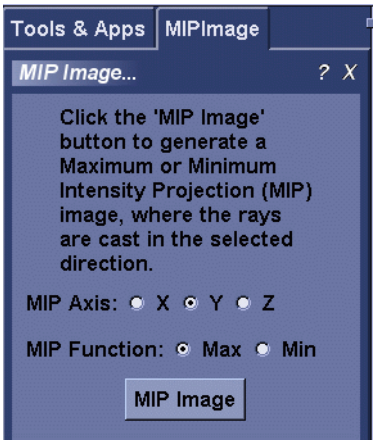
3.3.1 Creating a MIP

A MIP or Maximum Intensity Projection image is a volume rendering technique used to visualize high-intensity structures within volumetric data. For example, a MIP can be used to extract vascular structures from medical data sets.

The MIP image is produced by casting parallel rays through the image along one of the X-, Y-, or Z-axes. Each output pixel in the MIP image represents the maximum intensity value found along the corresponding ray cast through the original image.

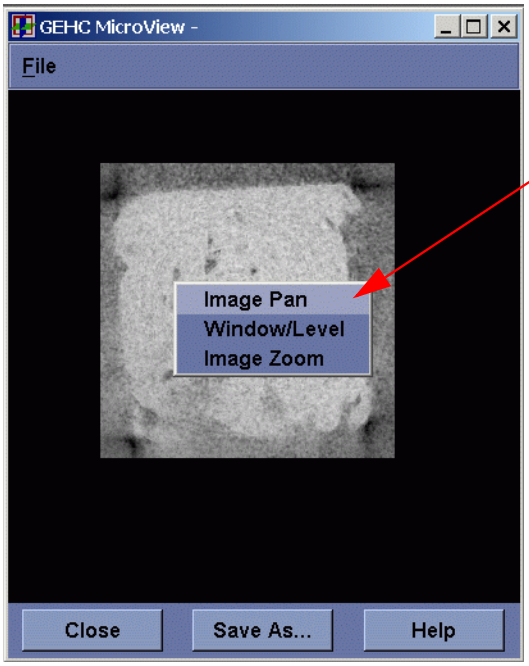
This tool is useful when registering a 3D image onto a 2D image. This can be accomplished by first finding the MIP of the 3D image.

1. Select Visualize??MIP Image... The MIP Image... window appears.



2. If desired, select an ROI using one of the available ROI Tools. The ROI is used to mask the image prior to generating the MIP image. This is useful for cropping out high-intensity borders surrounding an image, which may otherwise confound the MIP image.
3. Select desired MIP axis X, Y or Z axis along which to project the image data.
   Oblique MIP-ing is currently not supported.
4. Click MIP Image button to generate the MIP.

5. Use the left mouse button inside the popup MIP window to control the window and level settings of the MIP image.



6. Click the right mouse button to display options for panning, zooming and adjusting window and level values for MIP'ed image.
7. Close or Save As... upon completion.

3.3.2 Rendering Volume

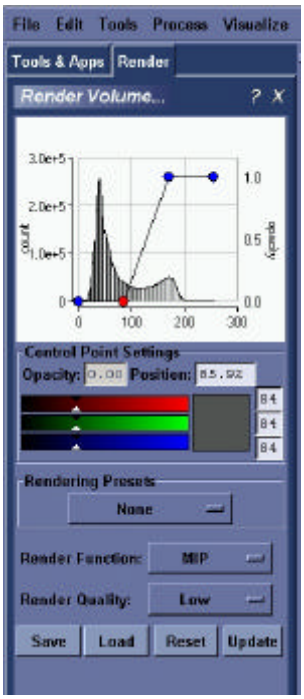
The **MicroView** volume rendering tool is used to produce photo-realistic 2D semi-transparent representations of 3D image data. It uses one of three raycast techniques.

Raycast volume rendering is especially common in the medical imaging community where three dimensional volume data is easily available. To understand raycasting, think of voxels within a 3D image as possessing a density which corresponds to the graylevel value of the voxel. Imagine that for each pixel in the rendered image scene, a ray is drawn from the observer's eye, through the image pixel, then through the entire 3D image data set. Each ray will intersect a number of voxels before leaving the 3D image data. For each image pixel in the rendered scene, a color is determined by accumulating information derived from the intersecting voxels along the corresponding raycast ray. In particular, for each voxel in the 3D image data, the "density" or graylevel value of the voxel will be transformed into a corresponding voxel color and transparency. This color and transparency information will be combined, according to a raycast function to determine the final pixel color in the image scene.

MicroView currently supports three styles of raycast volume:

- **Isosurface Rendering** - a raycast method where surfaces of similar density objects are rendered, and the remaining materials are hidden. For this rendering mode, a density threshold value must be selected that defines the surface, and the color of the surface selected.
- **MIP (Maximum Intensity Projection) Rendering** - a method where the color of the densest object along each raycast path is used to determine the final color of each pixel. This method is particularly useful to extract, e.g. contrast-enhanced vessels, or bone from images.
- **Composite Rendering** - a general raycast method, which gives the greatest level of control over the raycast scene.

1. Select Render Volume … from the Visualize menu. The Render Volume window appears.



3. Adjust image histogram, opacity & color ramp
Look-Up table defines the mapping between the gray scale values in the image and the color used displayed for each gray scale value.

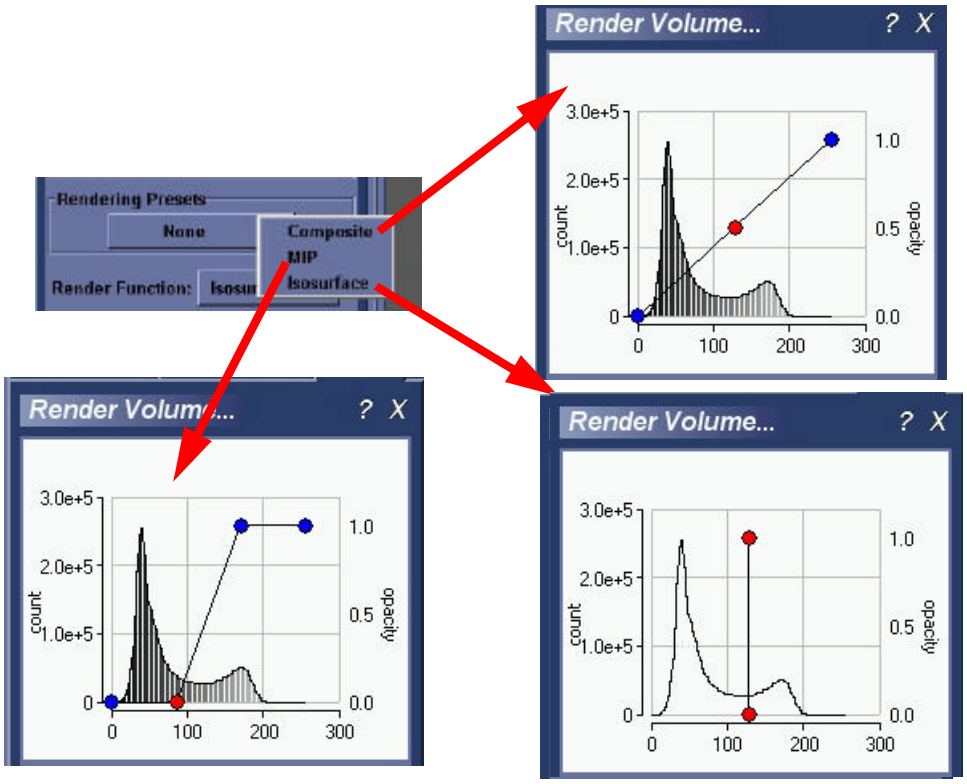
2. Adjust control point settings

1. Select type of rendering

4. Select rendering quality

5. Select Update, Load or Save as required.

2. Select from among the available Render Functions (Composite, MIP, Isosurface).



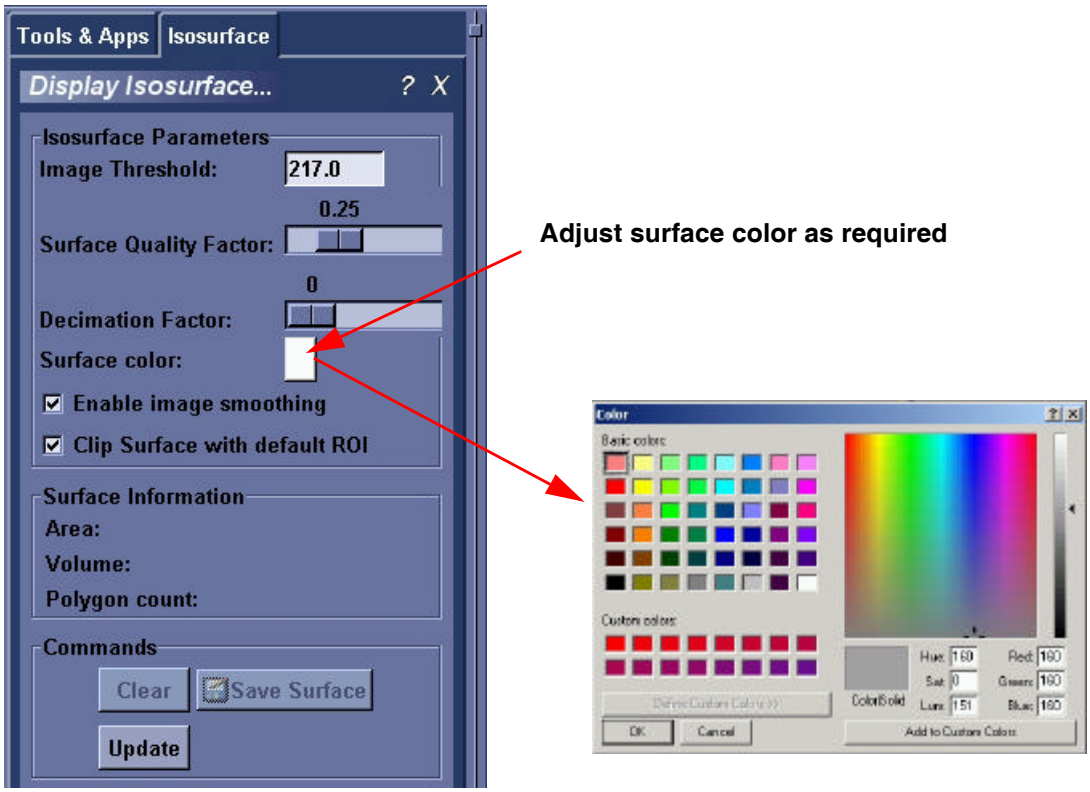
3. Adjust the appearance of the rendered volume by editing the opacity and color assigned to each gray level value in the image.

   Edit opacity by either entering opacity values directly into the three data fields, by adjusting the sliders or by moving the red control points on the graph with the mouse and cursor.
4. Select from among the available Rendering presets (None, Bone, Soft Tissue/Bone).
5. Choose the Render Quality (High, Low).
6. Click the Update button again once opacity editing is complete. Volume is updated automatically and displayed.
7. Upon completion, save the rendered volume, or load an existing one.
8. Choosing Reset cancels the previous rendering action.
9. Closing the Rendering Tool cancels any rendering action performed on the volume.

3.3.3 Display Isosurface

MicroView's isosurface tool can be used to extract a surface from a 3D image that corresponds to a user-defined graylevel value.

1. Select Isosurface... from the Visualize menu. Display Isosurface... tool appears.

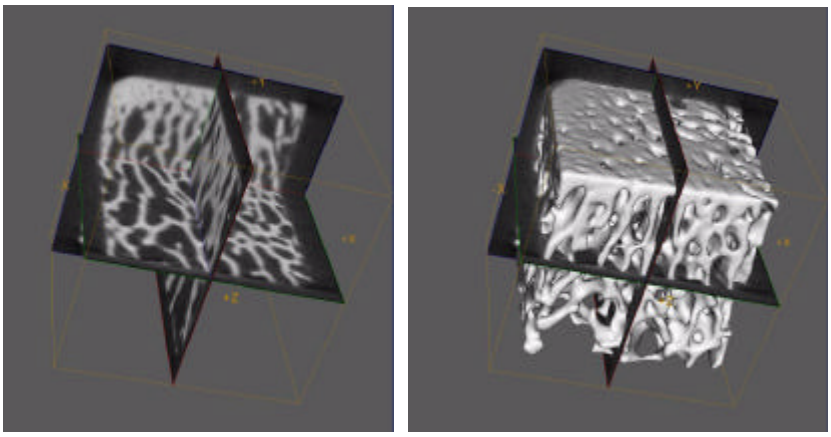


2. Select an image threshold value in the Isosurface Parameters text box. This grayscale value is used for generating the isosurface.
3. Select a surface quality factor. This factor is used to resample the image prior to extracting an isosurface. Use a small value (e.g. 0.25) initially to extract a coarse surface, then refine the surface by increasing the factor to 1.0.
4. Select a decimation factor as required using the slider.

   MicroView will attempt to reduce the surface complexity of the final isosurface by this user-defined amount. Setting a value of "0.1" means that MicroView will attempt to reduce the surface polygon count by 10%, while minimizing the impacting on surface topology, surface area and volume contained within the isosurface. A value of "0" indicates that no decimation shall be attempted, while values approaching "1" will significantly impact the quality of the final surface.
5. Press the Surface Color button as required to select a new color for the surface.
6. Select Enable image smoothing as required.

   If selected, the input image is smoothed before the isosurface is generated. Enabling this option will generally result in less noisy surfaces.
7. Select Clip Surface with default ROI as required.

   If selected, determines an isosurface for only (that) portion of the input image within the ROI.
8. Press Show Surface button to display the isosurface.
9. Press Save Surface button to save the surface geometry to disk. The system will prompt for a file name and format. Click Save button.



3.3.4 Overlay Geometry

INTRODUCTION

The Overlay Geometry Tool is used to define, display, and manipulate 3D surface geometry objects onto an ROI.

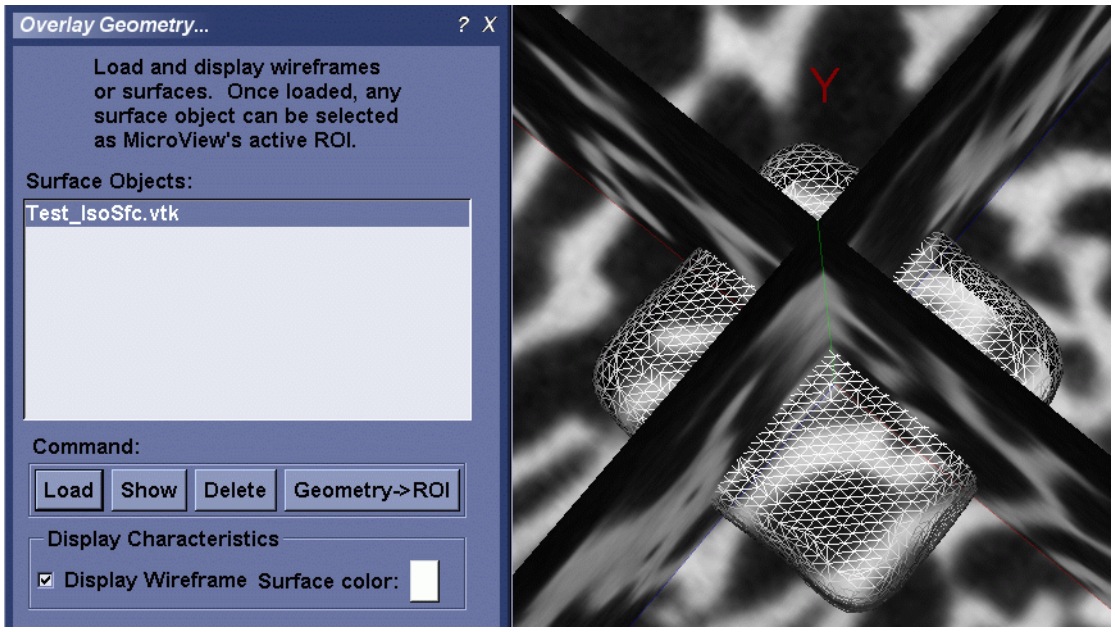
Three dimensional (or surface) geometries, including those generated using other software tools (such as **MicroView** Isosurface) and other formats (STL, PLOT3D and PLY) can be loaded and used in **MicroView** as a ROI and displayed over top of the loaded image.

Loaded geometries may be superimposed on top of the current 3D image data. Surface characteristics, such as color and whether the object is displayed as a closed surface or a wire mesh can be adjusted for each loaded surface.

Finally, each surface may be selected and assigned as the default ROI for **MicroView**. This permits advanced ROI selections to be saved and restored, as well as allowing third-party tools to be used to generate ROI objects.

INSTRUCTIONS

1. Select Overlay Geometry... from the Visualize menu. The Overlay Geometry tool appears.



2. Click Load button and select a geometry file to load.
3. Click Show or Delete to show or hide the geometry.
4. Click the Geometry??ROI button to assign the currently selected surface as the default ROI for **MicroView**.
5. Adjust the display characteristics as required by clicking on the Display Wireframe Surface Color button.

   System will prompt to choose a color from the palette. Click OK to continue.

NOTE - Multiple ROIs can be loaded simultaneously, each with their own color.

3.3.5 Make Movie

This tool allows you to make and save a movie of a sequence of screen snapshots while the loaded image is either rotated 360 degrees about an axis, or sliced along a cutplane

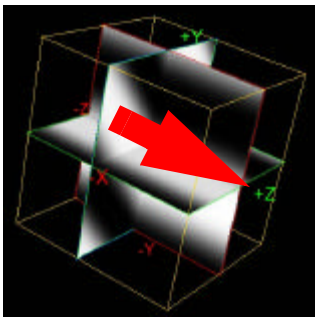
1. Select Make Movie... from the Visualize menu. The MovieMaker / Make Movie window appears.

2. Select type of animation to produce.

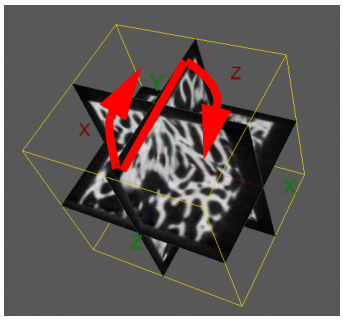
   The X/Y/Z slicing option generates an animation of the image slicing along the selected image axis. The X/Y/Z rotation option generates an animation of the image rotating about the selected axis.
3. Select from among the available movie file types.
4. Enter number of images to capture while the image travels along the entire axis or rotates through 360 degrees.
5. Select the desired frame rate.

   For movies with only a few frames it often is useful to reduce the frame rate to ensure the video doesn't play too quickly.

   Not all movie file formats support modified framerates.
6. Enter a filename and location for the new file and click the Make Movie button.



Slicing along axis



Rotating about axis

Chapter 4 Bone Analysis - Basic & Advanced

INTRODUCTION

MicroView's Bone Analysis Application allows you to perform a variety of analysis, and visualization techniques upon a selected ROI. It also allows you to organize, file and store your data for future reference.

Users choose which functions to perform on a given ROI, what type of visualization output is required, and in what format the outputted results should be written in prior to any calculation.

AVAILABLE ANALYSIS TOOLS

The Bone Analysis Application contains the following tools:

- **BMD** - calculates Bone Mineral Density, Bone Volume Fraction (BVF), bone mineral content, and various other statistics,
- **SMI*** - calculates Structure Model Index which in turn provides information about the curvature of the surface,
- **Anisotropy*** - determines the degree of symmetry and orientation of a trabecular structure,
- **Cortical Analysis*** - determines slice-by-slice thickness, area, moment of inertia, and BMD values for cortical bone. It is used in conjunction with the Cortical ROI tool to perform analysis on the cortical shell of a bone.
- **Stereology** - reports Euler index, bone volume fraction, bone surface to bone volume ratio, trabecular plate thickness, trabecular plate number, trabecular plate separation and various other measures. The Euler index is a measure of the connectivity of a trabecular structure.
- **Topology*** - categorizes each voxel in a trabecular structure as being a member of either a surface, curve, or junction and provides a visual representation of this classification, and;
- **Direct Measures*** - determines the local trabecular thickness of a bone, and provides a visual representation of this local thickness.

***** Denotes optional tools available with the Advanced Bone Analysis package.

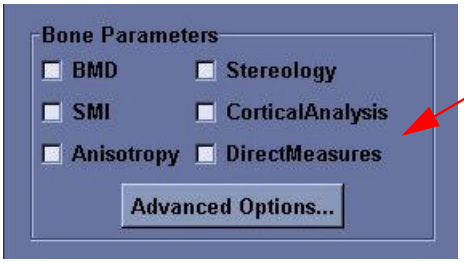
4.0.1 Using the Advanced Bone Analysis Application

Detailed instructions for using the advanced bone analysis tools are shown below.

1. Activate the Advanced Analysis Tool by selecting Advanced Analysis Tool… from the Analyze menu or the Bone Analysis tab on the Tools & Applications toolbar.
2. If a ROI has not already been selected, select one by clicking either Standard ROI or Advanced ROI button. Use Standard ROI to select a box or cylinder ROI. Use Advanced ROI to manually select an arbitrary ROI.

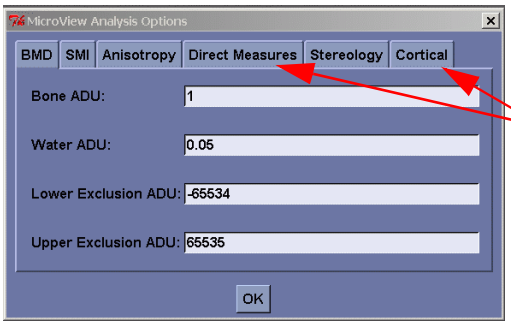
3. Either type in a threshold value in the entry field in the Threshold section or click the Auto Threshold button to generate one.

4. In the Cancellous Bone Parameters section select the number and type of analyses you wish to run.



Select which analyses to run

5. Click the Advanced Options button to modify the default settings for each of the parameters to be run. Click OK to proceed.



Adjust settings for each analysis

NOTE - Advanced Options are discussed in more detail following this section.

6. In the Output Options section select the type of file and name of the file the results should be written to.

4.0.1.1 Output options and project management

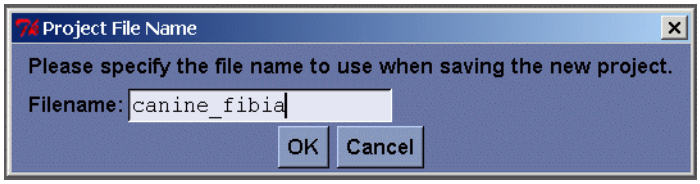
MicroView provides a number of options to help manage your project files and analysis results. These are explained below.

1. Load an existing project or create a new one. The system prompts you for project name, description and project parameters.

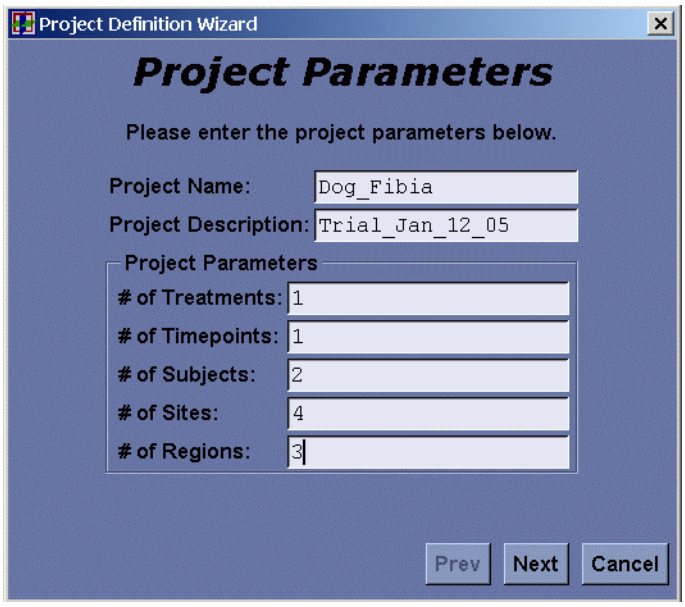
   The project file is stored as .xml.

CREATING AND LOADING PROJECTS

The output data generated by **MicroView** can be kept as part of a project. If there is an existing project in memory, the "New Project" button will unload that project, and allow the user to define a new project for immediate use.



2. Enter the initial project parameters including the name, description and the number of points on each study axis.
3. Press Next to advance, Previous to return or Cancel to exit.
4. Enter the names for each axis point in the remaining windows of the wizard.



5. Press Show Results button to have the results of the analyses displayed in a dialog box upon completion.

6. In the Visualization Options from the available options, RAW, Topology, Anisotropy, or Direct Measures.

NOTE - Certain options are only available for selection if they have been selected earlier in the Cancellous Bone Parameters section.

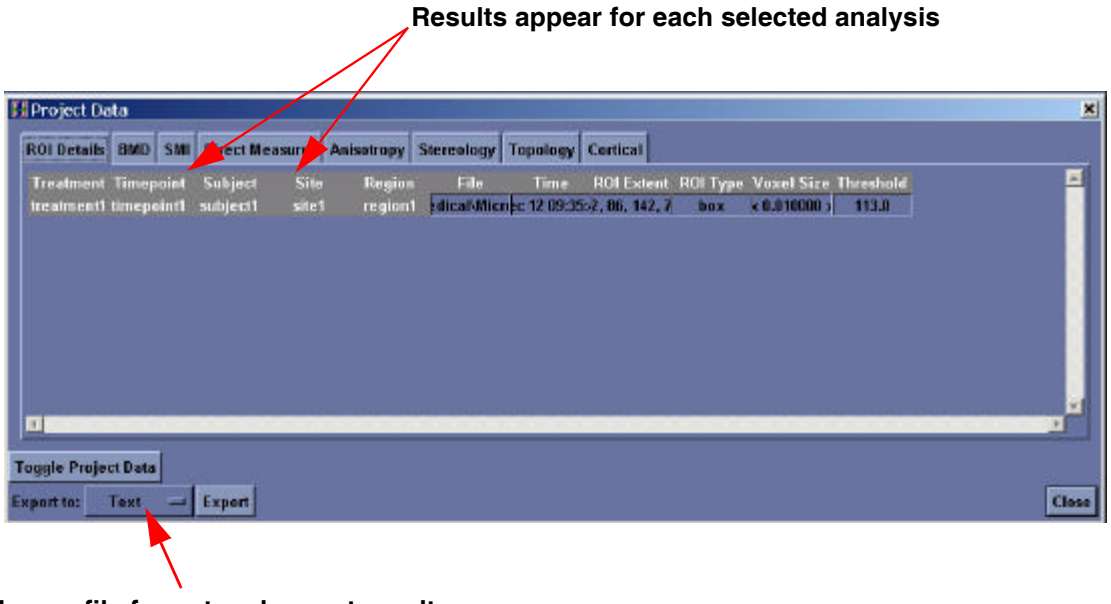
If any one of these options is selected, **MicroView** will shift focus from the Advanced Analysis dialog to the appropriate dialog for visualization when the Run button is clicked.

7. Click Run to begin the analysis. Depending on the number of analyses selected, it may take a few moments to complete.

4.0.2 Analysis Results and the MicroView Spreadsheets

INTRODUCTION

The results generated by the Advanced Bone Application are shown in a spreadsheet window. A typical screen is shown below.



At the top of the view are tabs which correspond to the available analysis tools. The "ROI Details" tab provides general information about the region of interest used to generate the analysis. The other tabs display the individual results of each analysis in tabular form.

NOTE - If the analysis was not chosen in the Cancellous Bone Parameters window, the corresponding spreadsheet table will be empty.

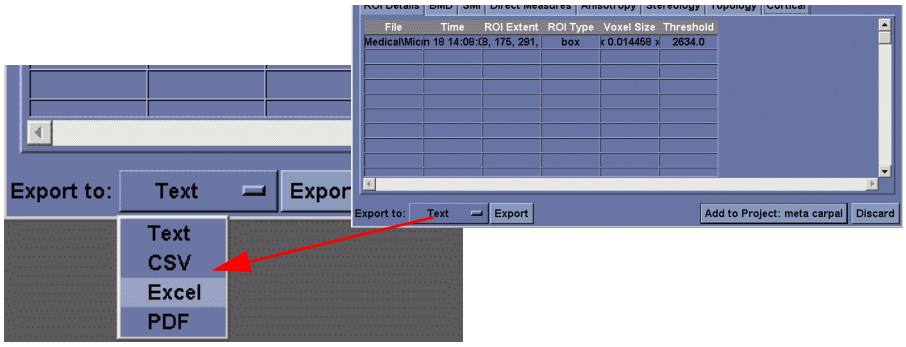
The tables for the Direct Measures, Stereology and Cortical tools have an additional features on dropdown menus.

- **Direct Measures** the additional information that can be displayed is a histogram (bin counts) of the thickness and spacing data.
- For the **Stereology**, the additional information is the morphological data by axis.
- For the **Cortical** tool, the additional information is both the slice-by-slice detailed data, and the detailed thickness data.

At the bottom of the spreadsheet window are a number of buttons and other controls, which change depending on the type of data being viewed.

4.0.2.1 Data export options

MicroView provides different file export options and these appear at the bottom of the spreadsheet as shown.



Because and these file types organize the data in different ways, these differences are explained in detail below.

TEXT AND CSV

The text and CSV files are organized in the similar fashion, and simply use a different delimiter between the different data fields. Text files are tab delimited and the CSV files are comma delimited.

All of the data fields are exported to the file. The file organizes the data output according to the tabs that appear in the spreadsheet viewer, so the ROI Details appear first, followed by BMD and so on. In the cases where there is additional data (Direct Measures, etc), the additional data begins on a new line within the section that it relates to. Each data section begins with a title, and a header row (including units) followed by the data row.

If the data exported is the entire project, then each section contains all of the data for the entire project and the lines begin with the project parameters for the specific line.

NOTE - That respective lines may not match up from data section to data section, depending on whether a particular analysis was performed for a given project entry.

EXCEL

The Excel file is organized in a fashion that is nearly identical to the spreadsheet viewer in **MicroView**. Each tab in the spreadsheet view is given a separate worksheet in the Excel file.

Further, the additional data components (Direct Measures, etc) are given their own worksheet. The rows are alternately highlighted to allow for easier separation of the data. The header rows are fixed so that they do not disappear when scrolling the data.

In the ROI Details worksheet, there is an additional column that contains a snapshot of the region of interest used to generate the data.

The organization of the rows for exporting data from the entire project into the Excel worksheet is the same as described previously for the text and CSV files.

PDF

The PDF file does not contain all of the available data, but presents a one or two page summary view of the data. It is not intended for detailed data analysis. The top of the page contains a large view of the snapshot of the region of interest that generated the data. Below the snapshot is a table that contains selected data points from each of the different analyses that can be performed on the image data.

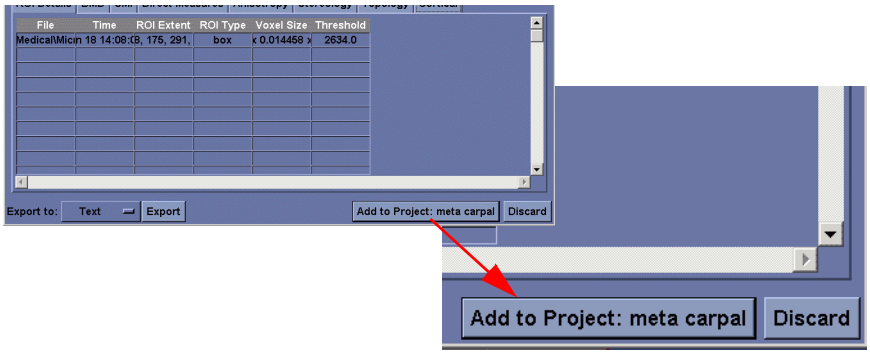
When exporting the data for an entire project to PDF, each individual project entry generates a separate report, contained in the same file. The data is thus separated, and cannot be compared easily.

1. Select from among the available Export options.
2. Press the Export button and the system will prompt you to enter a file name, location and file type. Press Save to continue.

4.0.2.2 Adding to existing project

MicroView allow you to keep the analysis data as part of a project.

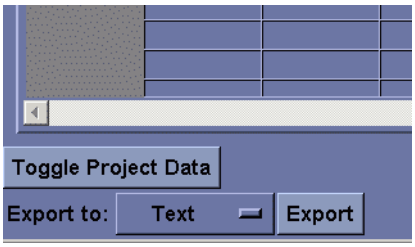
1. Click on the "Add to Project: <project name>" button if they have an existing project.



NOTE - If there is no project loaded, the Add to Project button will not appear.

If the analysis data is to be kept as part of a project, the user is prompted to identify the project parameters that apply to this analysis. Once this is done, the user is presented with the spreadsheet view containing all of the data in the project. The data in this view can again be exported to any of the four file formats, but in this case, will include all of the different analyses that were performed as part of the project.

When viewing the entire project, a new button will appear - "Toggle Project Data". In the default view, each entry in the project is simply assigned a line number. However, internally, the program remembers the project parameters that are associated with each entry. By pressing the "Toggle Project Data" button, the view changes so that the project parameters are explicitly shown in the spreadsheet table, or removes them from view if they are present.



NOTE - The "Discard" button will throw away the current results and they are lost forever. If you want to export the results to another file, or keep them in a project, do not use Discard.

The "Close" button closes the spreadsheet view when looking at the data for the entire project. The data is saved to the XML file, and can be viewed again using the "Show Results" button from the Advanced Bone Application window.

LOADING EXISTING PROJECTS

1. Use Load Project button to load an existing project. Provided the project file has the correct format, it is loaded together with all the existing data in the file and the project definition.
2. Click on Edit Current Project button and the project wizard will display all of the parameters for the loaded project.
3. If you had opened an existing project, the "Show Results" button will show the data contained in the entire project using the spreadsheet viewer.
4. Click on Add to Project: <project name> once a project has been defined.

   A dialog is displayed which allows you to select the different project parameters to use when filing the output data. The window contains five drop down boxes in the dialog corresponding to the five study axes. By selecting the arrow at the right of the drop down, a list of all of the different point labels on that axes is presented and the user can select the appropriate values for the analysis being added to the project.

4.0.3 Advanced Bone Analysis Options

The Advanced Options allow you to modify the default bone analysis settings.

1. Click the Advanced Options button.

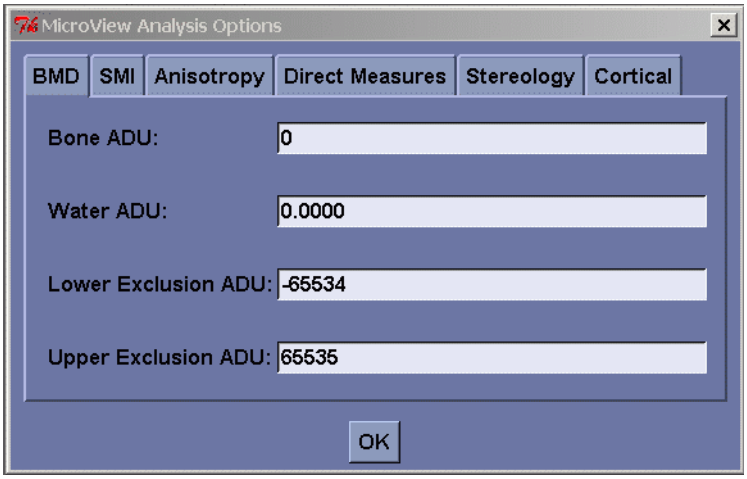
The Advanced Options dialog contains several tabs which are explained below.

4.0.3.1 BMD - Bone Mineral Density

INTRODUCTION

This tool performs a virtual biopsy and "ashing" to determine bone mineral content non-destructively. Image data derived from the Locus family of CT scanners may be calibrated to standard CT number, measured in Hounsfield Units (HU), and furthermore calibrated to permit determination of equivalent mass of hydroxyapatite (bone mineral). Results are reported as bone volume fraction (BVF) or bone mineral density (BMD) in units of mg (HyAp)/cm^3.

FEATURES



The BMD tab has several variables that can be edited manually. These are:

- Bone and Water ADU (Arbitrary Density Unit) - By default the values for Bone ADU and Water ADU are set to the calibration constants found in the header of image file.
- Lower Exclusion ADU -The Lower Exclusion ADU is a grey scale value below which voxels are not included in the bone equivalent mass calculation.
- Upper Exclusion ADU - The Upper Exclusion ADU is a grey scale value above which voxels are not included in the bone equivalent mass calculation.

The upper and lower exclusion ADU should be set to exclude air and metal, respectively, in the bone mass calculation.

INSTRUCTIONS

1. Adjust the values in any of the fields to suit and click OK to continue.

4.0.3.2 SMI (Structure Model Index)

INTRODUCTION

Structure model index (SMI) is a parameter used to measure how "rod-like" or "plate-like" trabecular architecture is. With aging and disease, cancellous bone architecture in some sites deteriorates from plate-like to rod-like. SMI for ideal plates and rods is 0 and 3, respectively. SMI calculated for specimens with high bone volume fraction (BV/TV) can be negative.

HOW IT WORKS - ALGORITHM

The SMI parameter is discussed in detail in [Hillebrand97a]. SMI is calculated as 6* (S' * V) / S^2, where S' is the surface area derivative, V is the trabecular bone volume, and S is the surface area. The factor of 6 is used to obtain integer values for ideal plate, cylinder, and sphere models (plate = 0, cylinder = 3, sphere = 4).

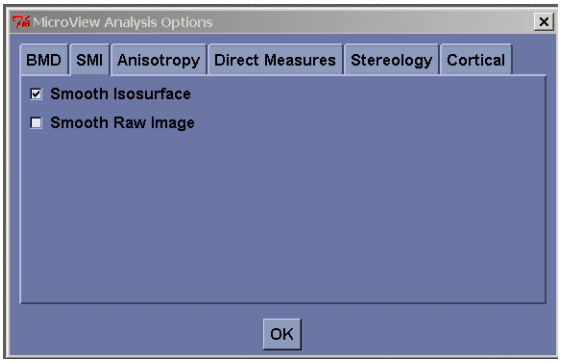
The first step in calculating SMI is to create an isosurface of the trabecular bone within the ROI. The surface area and volume are directly calculated from this isosurface. The surface area derivative is estimated by calculating the change in surface area of the isosurface when the vertices are translated a small amount along their normal directions and normalizing by the magnitude of the displacement.

NOTE

SMI was initially used to describe structures with very few intersections between the structure elements (i.e., rods and plates) while the BV/TV is low. SMI parameter is always positive for these structures. However, if SMI analysis is applied on a dense structure with lots of intersections between the structure elements, it may give negative SMI values. This results from the surface area decreasing when dilating the surface vertices along the normals and consequently a negative S' in the equation for SMI. For example, take a plate with a hole in the center. The hole becomes smaller after the vertices are translated in the normal direction and the corresponding change in surface area is negative.

For ROI with more than 22,000,000 (300 x 300 x 300) voxels, the ROI image is resampled by shrinking factors 2 x 2 x 2 to reduce memory consumption and speed up calculation.

INSTRUCTIONS



The SMI tab has options to smooth the image prior to the generation of an isosurface and to smooth the isosurface prior to the calculation of SMI.

1. Select or deselect the SMI options as required and click Ok to continue.

4.0.3.3 Anisotropy

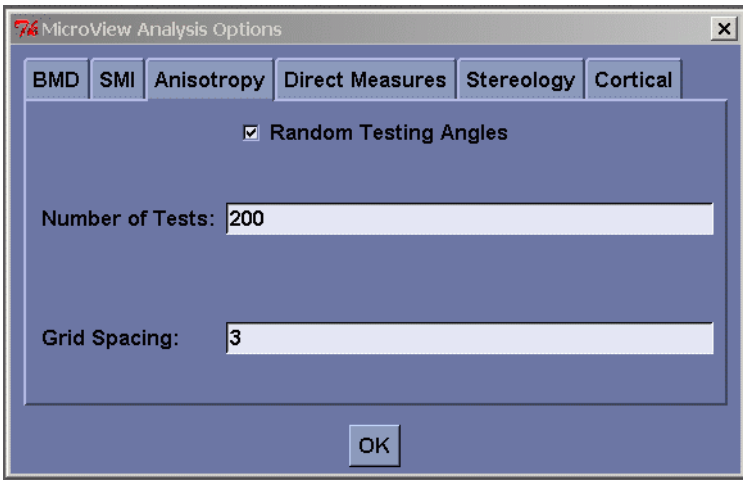
INTRODUCTION

Anisotropy measures the orientation of the trabecular architecture. This orientation affects the mechanical behavior of trabecular tissue and is affected with age and disease. **MicroView** uses the mean intercept length (MIL) method to calculate the structural anisotropy. This method measures the intersections of a test grid with the trabecular structure and calculates the fabric ellipsoid (3D ellipse) [Whitehouse74][Harrigan84]. Trabecular structures with no preferred orientation have a spherical ellipsoid, while structures with more alignment in one direction have the major axis of the ellipse aligned in that direction.

HOW IT WORKS - ALGORITHM

A grid of parallel test lines is passed though the ROI and the number of intersections of the test lines with the bone/marrow interface is calculated. This procedure is performed for the number of test rotations listed in the advanced options. Each rotation of the test grid is described by two angles (theta, phi) in spherical coordinates. For each rotation, MIL is calculated as 2* BV/TV / (number of intersections / test line length). The MIL data are then fit to the equation of an ellipse using least squares. The least squares analysis provides the 6 coefficients for the best fit ellipse. An eigen analysis of the second rank tensor formed by these coefficients provides the length of the axes of the ellipsoid and their corresponding directions. The degree of anisotropy is then defined as the ratio of the lengths of the maximum and minimum axes.

FEATURES



The Anisotropy analysis tab has several variables that can be edited manually. These are:

- Random Testing Angles - When selected, determines whether the direction of the lines used when calculating MIL are randomly chosen.
- Number of Tests - Represents the number of lines used to calculate mean intercept length (MIL).
- Grid Spacing - Determines how finely the ROI is to be resampled prior to any calculations.

INSTRUCTIONS

1. Adjust Anisotropy options as required and click Ok to continue.

4.0.3.4 Direct Measures

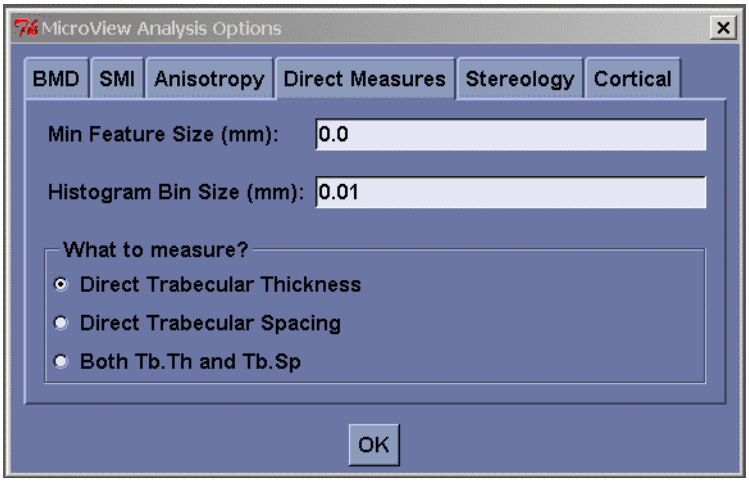
INTRODUCTION

Direct Measures calculates the trabecular thickness (Tb.Th) and separation (Tb.Sp) by fitting maximal spheres to the trabecular structure. The diameters of the spheres within the bone and marrow regions provide estimates of Tb.Th and Tb.Sp, respectively.

HOW IT WORKS - ALGORITHM

The algorithm is discussed in detail in [Hildebrand97b]. The first step is to binarize the data based on the selected threshold. For trabecular thickness, the Euclidean Distance Transform of the bone region is calculated. This results in each bone voxel being assigned a value corresponding to the distance to the nearest non-bone voxel. Next, for each bone voxel the largest sphere that fits within the bone structure is determined. Tb.Th and Tb.Sp are then calculated as the mean value assigned to all bone and marrow voxels, respectively.

FEATURES



The Direct Measure tab contains several options, described below.

- The Minimum Feature Size in pixels can be specified. Structures less than this size will not be used in calculating direct trabecular thickness and direct trabecular spacing.
- In the Direct Measures tab, the user has an option of what measures to compute - direct trabecular thickness, direct trabecular spacing, or both.

NOTE - There is a limitation for ROI dimension which is 650 x 650 x 650. The accuracy of the Tb.Th and Tb.Sp calculation is 0.01 voxel.

INSTRUCTIONS

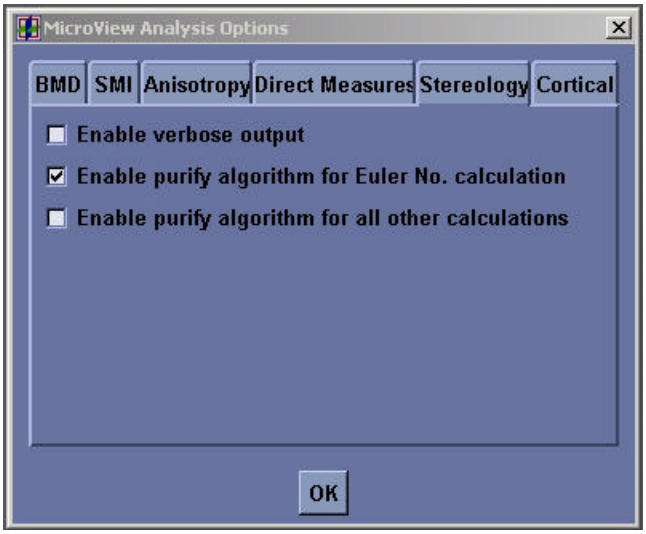
1. Adjust Direct Measures options as required and click Ok to continue.

4.0.3.5 Stereology

INTRODUCTION

MicroView can perform simple stereology analysis of a 3D bone image. The stereology tool measures trabecular structure using similar techniques as those implemented in classical histomorphometry. 2D techniques determine estimates of trabecular thickness, spacing and density. At the same time, trabecular connectivity is quantified by calculating the Euler number for the trabecular structure. Finally, the bone surface area to volume ratio is also calculated.

FEATURES



The Stereology tab contains three options, described below.

- An option to enable verbose output which displays additional measures when selected.
- The Enable purify algorithm for Euler number calculation.
- The third option, The purify algorithm removes isolated bony spicules and fills encapsulated marrow spaces. To obtain meaningful results from Stereology, the image should be passed through this purification filter first.

INSTRUCTIONS

1. Select Enable purify algorithm for all other calculations first, before performing the other calculations.

Note: When the purify algorithm is enabled, select an ROI where at least one of the voxels at the boundary of the ROI is equal to or above the threshold (i.e. the trabecular bone must intersect the boundaries of the ROI). Passing a clipped image, through the purify filter, which has no boundary voxels equal to or above the threshold will produce a blank image from the filter.

2. Adjust the remaining Stereology options as required and click Ok to continue.

4.0.3.6 Cortical

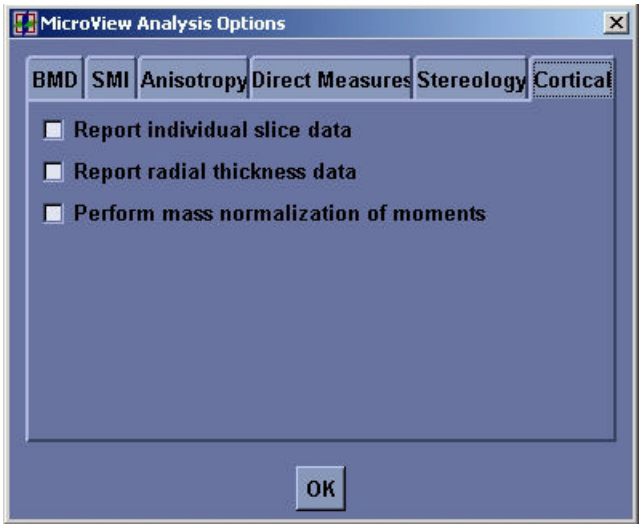
INTRODUCTION

Use this tool to select an ROI corresponding to the cortical shell of the bone. The tool uses a series of morphological operators to semi-automatically select cortical bone components.

A graylevel threshold value, and two scaling size parameters may be tuned in order to improve the accuracy of this ROI tool.

Note: The cortical analysis tool assumes that the bone is aligned with the long axis parallel to the z-axis defined in **MicroView**. If your sample is not oriented in this way, it must be reoriented for the results to be meaningful.

FEATURES



The Cortical tab contains three options, shown below.

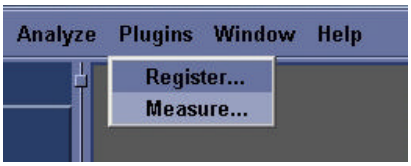
- Report individual slice data - turns on reporting of all output measures listed above but on a slice-by-slice basis rather than for the entire volume.
- Report radial thickness data - turns on reporting of cortical thickness measurements at ten degree intervals around the circumference of each slice.
- Perform mass normalization of moments - normalizes all of the moment measures by the total mass of cortical bone.

INSTRUCTIONS

1. Select Cortical options as required and click Ok to continue.

Chapter 5 Plugins

MicroView has a number of optional tools to help you analyze MicroCT data. These are shown on the **MicroView** Plugins menu. They are:



5.0.1 Registration

INTRODUCTION

Image registration is the process of finding a spatial transform that co-aligns two images, such that homologous features in both images (i.e. identical landmarks in the two distinct images) are given the same spatial coordinate. This allows two images to be superimposed together (i.e. fused) in a way that makes corresponding features easy to view, identify and compare.

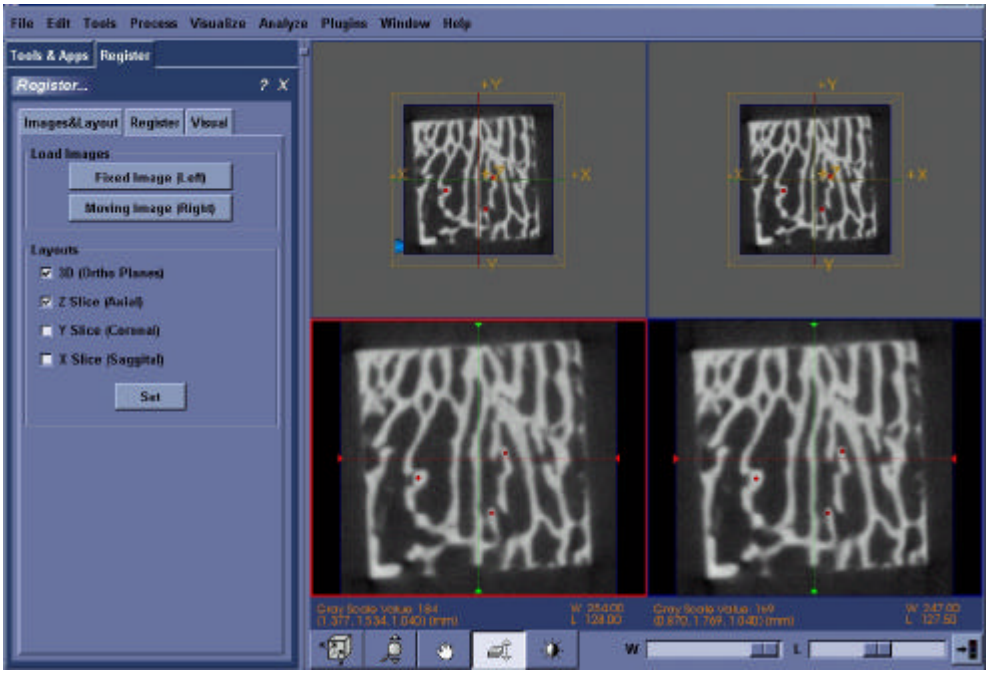
The **MicroView** registration tool is designed for manual landmark registration. Manual landmark registration involves picking two sets of homologous landmarks from so-called "fixed" and "moving" images. A simple sum of least squares fitting algorithm is then used to determine the transformation to map the moving image to the coordinate system of the fixed image based on the landmarks selected.

There is an option in the registration tool to allow users to select the type of transform to be performed. The options are:

- rigid body,
- similarity, and
- full affine transformations.

Once images are registered they can be visualized through synchronization and/or fusion. For example, an image gathered from a positron emission tomography (PET) scanner provides functional information whereas an image obtained from a computed tomography (CT) scanner provides information regarding the structure and anatomy of the specimen. Synchronization and fusion will correlate the structural and functional information.

INSTRUCTIONS



The registration process consists of 3 main steps:

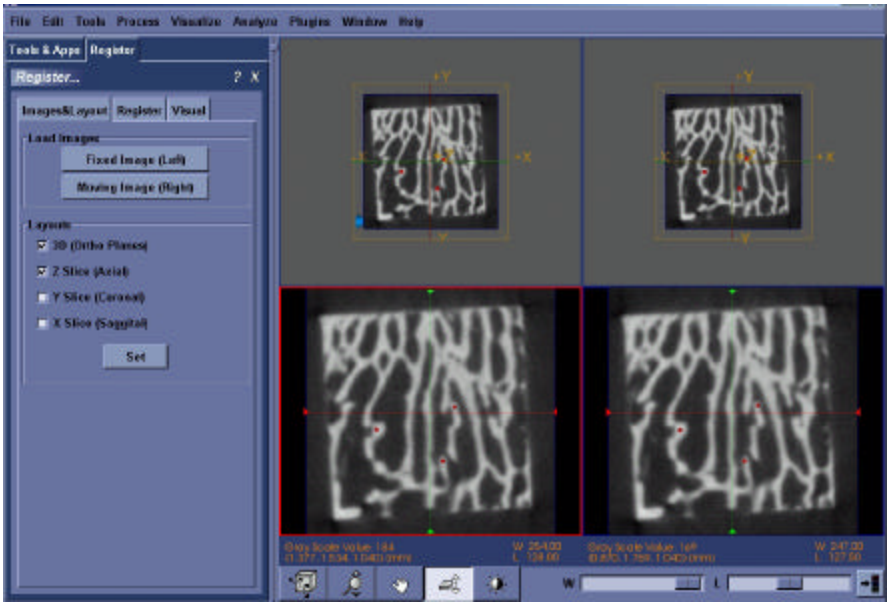
- Loading Images and Layout Setup
- Landmark Registration
- Visualization

1. Click on Plugins... Register.

LOAD IMAGES / SETUP LAYOUT

Load two images

Select layout to display

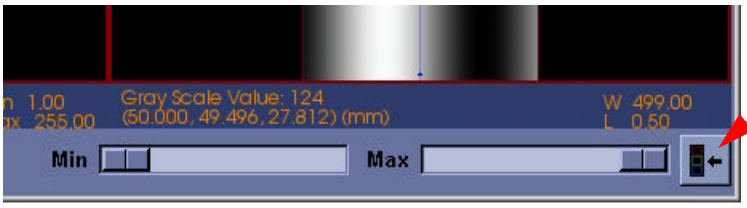


2. Load a fixed image into the left-hand pane and load a moving image into the right-hand pane.

3. Pick the view you want to work with from the available Layouts and click Set. The view settings can be changed at any time during the registration process.

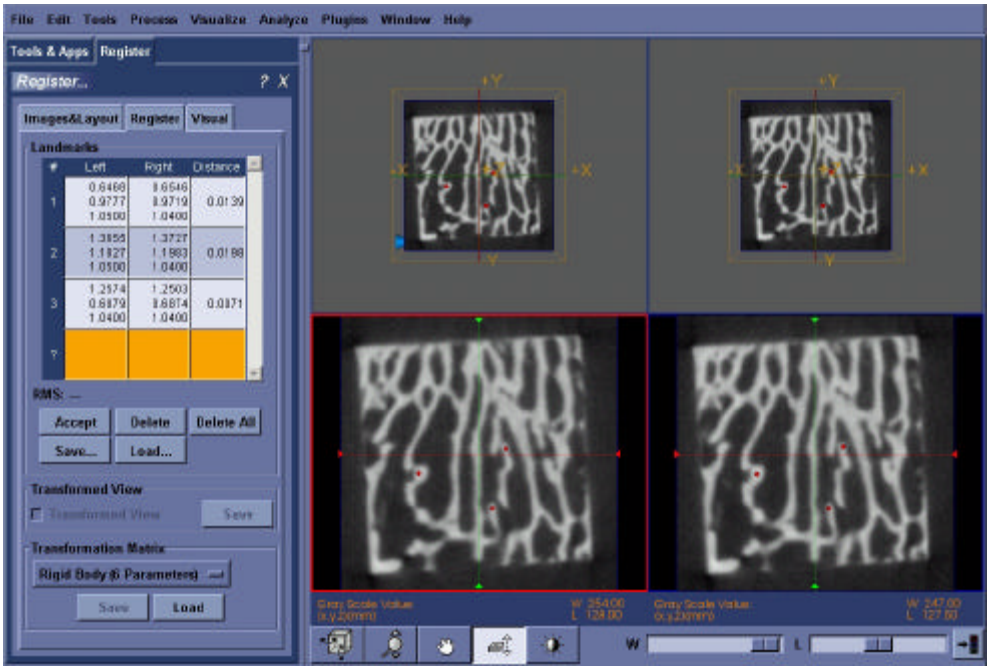
   The toggle button in the lower right corner allows you to adjust the between window/level values for each image in turn.

Toggle between right & left images to adjust Window / Level



REGISTER TAB

1. Click on Register tab.



2. Select common landmarks (on both images) by positioning the cursor over the landmark and pressing the spacebar on the keyboard.

   The coordinates of the landmarks are displayed on a row in the table on the left panel highlighted in orange and shown with a ? mark.

3. Mark the corresponding landmark on the other image with the cursor and press the spacebar.

   The selected pair of landmarks are shown as orange marks.

   The landmarks can be moved around by moving the mouse to new positions and then pressing the space bar.

4. Zoom in on the images as required to fine-tune the landmarks locations. Sometimes, it may be easier to locate the corresponding landmarks in a oblique view. Use the 3D view to manipulate the image and get oblique views.

5. Click the Accept button, or press the Enter key to record the pair of landmarks selected in previous step.

   Landmarks will be shown in red to indicate that they are accepted and recorded. The recorded landmarks may not be moved around but they can be deleted and replaced by a new ones.

6. Repeat the above steps to mark additional pairs of landmarks.

   NOTE - There is no upper limit for the number of landmarks that may be selected. However, a minimum of 3 pairs of landmarks must be selected for 2D images and at least 4 pairs must be selected for 3D images. Once enough landmarks have been selected a transformation matrix is automatically calculated to register the moving image on left to the fixed image on the right. The initially disabled Transformed View check box becomes enabled.

7. Check the Transformed View check box to switch the moving image to the transformed view.

   At this stage, it may be sufficient to skip to the visualization section and examine the registration result. If the result is not satisfactory, continue on to the following steps.

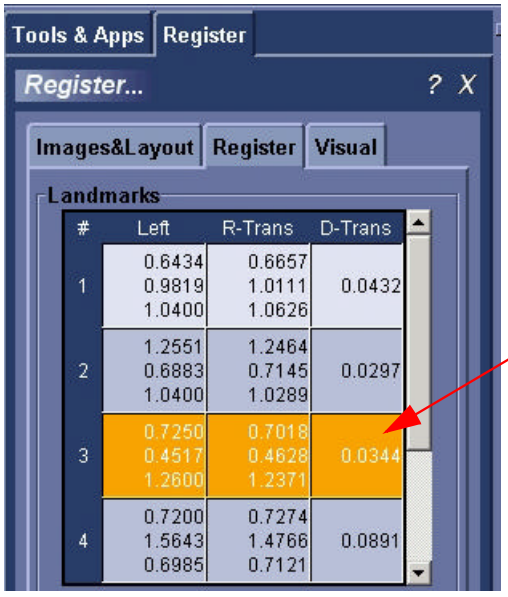
8. Select more landmarks to improve the registration as required.

   The additional landmarks on the moving image can be picked either in the original view or the transformed view. Switch back and forth between original and transformed views by checking and unchecking the Transformed View check box. Notice the contents of the second (landmark coordinates on the right) and third (distance) columns also change when the view is changed.

   Examining the distance column in the transformed view could help one to find the pair of landmarks that contribute the largest RMS error for the registration. The RMS value is the root mean square of the distances between each landmark pairs. This value is displayed under the Landmarks table.

DELETE OR EDIT LANDMARKS

Landmarks can be reviewed and/or deleted by selecting the corresponding row in the Landmarks table. Click the left mouse button on a row to highlight it. Click the Delete button to delete the highlighted row and the corresponding landmarks on the images.



Select and edit landmarks as required

All of the landmarks can be deleted at once by clicking the Delete All button.

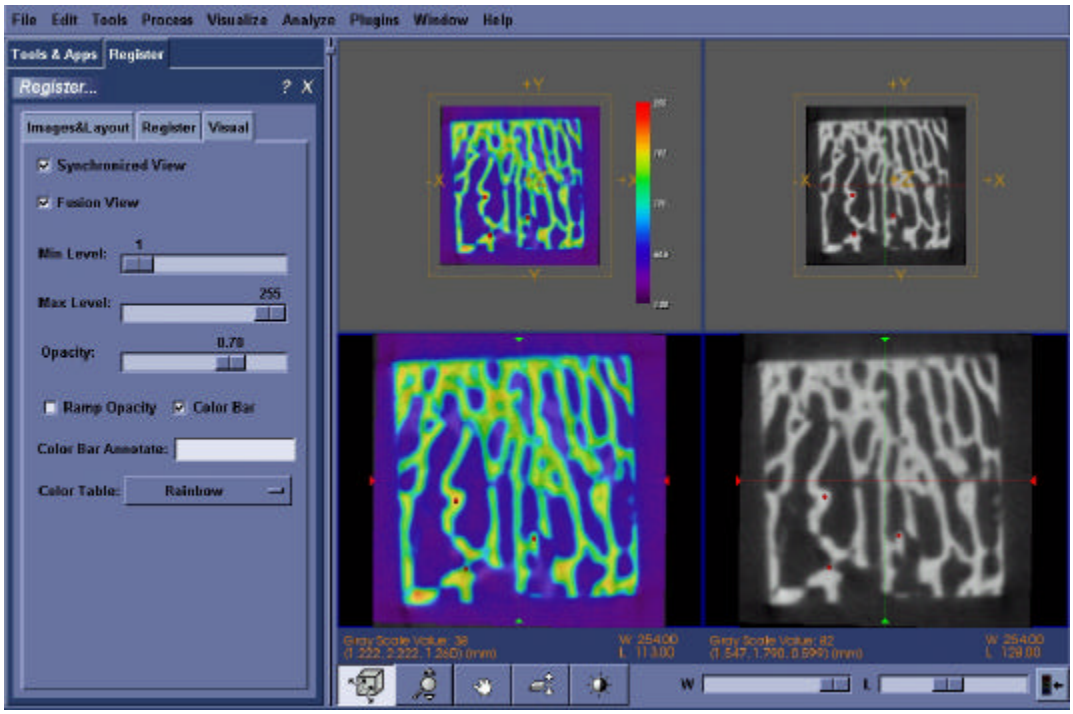
SELECT TRANSFORMATION TYPE

By default, the rigid-body transform is used for the registration. If the rigid-body transform is not sufficient for the registration, select a different type of transform from the drop-down selection from the Transformation Matrix section.

- **Rigid Body** (6 Parameters) is a type of transformation with 6 degrees of freedom (i.e. 3 for rotation and 3 for translation).
- **Similarity** (7 Parameters) is a type of transformation with 7 degrees of freedom (i.e. 3 for rotation, 3 for translation, and 1 for uniform scale).
- **Full Affine** (12 Parameters) is a transformation with 12 degrees of freedom (i.e. 3 for rotation, 3 for translation, 3 for scale, and 3 for shear).

NOTE - that the more parameters the transformation matrix uses, the more landmarks are needed to get a good result.

9. Once selected, the transformation takes place automatically, and the results are shown onscreen.
10. Click on the Visual tab to review the registration result.



VISUAL TAB

The visualization tools in this application serve two purposes:

- They allow you to visually evaluate the registration result, and
- They help you to correlate the information from the two images, e.g., the structural and functional information.

SYNCHRONIZED VIEW

Checking the Synchronized View check box synchronizes the two displayed images. The synchronized interactions on the images include:

- Gray scale values for both images are displayed when moving the cursor.
- Synchronized viewing angle.
- Synchronized zooming and panning.
- Synchronized slicing through the images (including Page-Up and Page-Down).
- Synchronized landmarks. Moving the cursor over a point of interest in either the fixed or moving images and then pressing the Space Bar on the keyboard will activate the pair of orange colored landmarks. This feature can be used to do point-by-point comparison for the two registered images.

NOTE - Remember to uncheck the Synchronized View check box before going back to the landmark page and selecting additional landmarks.

FUSION VIEW

The moving image can be fused on to the fixed image by checking the Fusion View check box. Once the Fusion View check box is checked, additional controls will appear in the dialog.

- The Min Level and Max Level sliders determine the range of gray scale values that get mapped to colors. The moving image will be transparent outside this range.
- If the Ramp Opacity option is checked then the opacity of the moving image is ramped exponentially. Otherwise the opacity is constant and is determined by the Opacity slider.
- There are several different color tables to select from. A color table is a mapping of gray scale values to RGB color values.

Synchronized view and fused views are designed to be used for two registered images, or at least two spatially overlapped images in the world-coordinates (the patient space). Trying to synchronize or fuse two spatially unrelated images will result in unexpected behaviors.

NOTE - Synchronized view and fused views are designed to be used for two registered images, or at least two spatially overlapped images in the world-coordinates (the patient space). Trying to synchronize or fuse two spatially unrelated images will result in unexpected behaviors.

OPTIONS FOR SAVING

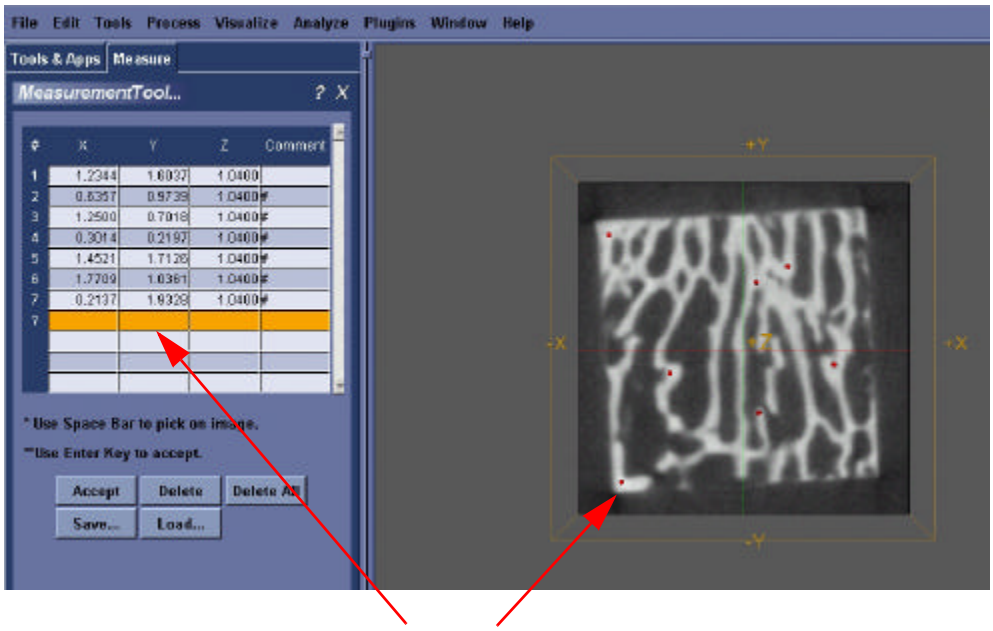
When satisfied, the results can be saved in one, two or all of the following three ways:

- **Save Landmark tags** Save the landmark coordinates by clicking the Save... button in the Landmarks section of the dialog. The landmarks can be loaded at a later time by clicking the Load... button in the Landmarks section.
- **Save Resampled image** Save the transformed (i.e., registered) moving image on the right pane to a file by clicking the Save... button in the Transformed View section. Tri-cubic interpolation is used to resample the transformed image.

- **Save Transformation matrix** Save the transformation matrix by clicking the Save... button in the Transformation Matrix section. This saved transformation can be applied at a later time to the moving image by clicking the Load... button in the Transformation Matrix section.

5.0.2 Measurement Tool

MicroView's measurement tool can be used to make a set of landmark measurements on an image, and to save these measurements to disk.



Pick points on image, accept and save

1. Start the tool by selecting Plugins??Measurement... from the main menu.
2. Pick points on the image using cursor; hit spacebar to accept.
3. Type comments directly into field as required and save measurements.

Chapter 6 Appendix

6.0.1 Supported File Formats

- Supported Image File Formats
- VFF - SUN™ TAAC file format
- DCM - DICOM version 3.0, part 10 image format
- VTK - The Visualization Tool Kit image format
- PPM/PBM/PGM - Portable pixmap/bitmap/graymap image format
- JPG - jpeg image format
- PNG - Portable network graphics format
- BMP - Windows™ bitmap file format
- TIFF - Tagged image file format (uncompressed, 8-bit format only)
- HDR/IMG - Analyze™ image format
- MNC - MINC image format
- NFO/RAW - A simple raw image format
- Interfile - A Nuclear medicine file format

SUPPORTED GEOMETRY FILE FORMATS

- vtk - Native VTK format
- obj - Alias Wavefront™ file format
- stl - Stereo Lithography File format
- bin - PLOT3D file format
- ply - PLY file format
- vtp - VTK XML file format
- oogl - Geomview OFF format file
- gts - GNU Triangulated Library file format
- tec - Tecplot™ file format

6.0.2 Memory Performance under Windows

MicroView memory performance can be improved by running under certain version of Windows operating systems, where the large memory aware boot option is available. Windows XP Professional and Windows 2003 versions both support this boot option. The method for increasing available memory for **MicroView** involves modification of the file C:\boot.ini to add "/3GB /PAE" to the boot line:

1. Log on as a user with Administrative privileges
2. Select Start?? Settings?? Control Panel?? System?? Advanced?? (Startup and Recovery) Settings, then click the "Edit" button.
3. Duplicate the first line under [operating systems]
4. Change the name of the new entry (the text between quotes), then add a "/3GB /PAE" switch at the end of the line.
5. Save and Exit. The file should look something like the following:

```
[boot loader]

timeout=5

default=multi(0)disk(0)rdisk(0)partition(1)\WINNT

[operating systems]

multi(0)disk(0)rdisk(0)partition(1)\WINNT="Microsoft Windows XP
Professional" /fastdetect

multi(0)disk(0)rdisk(0)partition(1)\WINNT="Microsoft Windows XP
Professional" /fastdetect /3GB /PAE
```

6. Reboot your computer. As your computer boots, a screen will be displayed giving you the choice of selecting between different boot options. Select the new boot option corresponding to the name you entered in C:\boot.ini. Once the computer finishes booting, you will be able to take advantage of up to 3GB of virtual memory in each instance of **MicroView**, rather than the default of 2GB.

6.0.3 MicroView's Support for Raw Image Data

MicroView reads and writes a variety of 2D and 3D image formats, summarized in the appendix above. In particular, the ".nfo" image format is a simple format that can be easily used to import and export raw images with **MicroView**. It is a two-file format that consists of a raw image, contained in a file named something like rawfile.img, and a text-based header file with the same base name, but with a ".nfo" extension (i.e. rawfile.nfo). Header files are simple ascii text files, that contain a set of name-value pairs, separated by a colon, one pair per line of the file.

An example header file is listed below:

EXAMPLE

```
width: 336
height: 283
numFrames: 160
shear_angle(rad): 0.000000
xVoxelSize: 0.1
yVoxelSize: 0.1
zVoxelSize: 0.2
dataType: 4
```

This header file describes a 336x283x160 raw image with voxels that are 0.1mm x 0.1mm x 0.2mm in dimension. The shear_angle(rad) entry should be present in the header, but is ignored by **MicroView** -- it can safely be set to zero. The dataType entry defines the numeric type of the data contained within the raw image file, rawimage.img. The value should be selected from the table below:

IMAGE DATATYPE CODES

Value	Type
2	Signed 8-bit char
3	Unsigned 8-bit char
4	Signed 16-bit short integer
5	Unsigned 16-bit short integer
8	Signed long integer
9	Unsigned long integer
10	Floating-point data

Given a raw image for import, first rename the file to have an extension of ".img". Determine the image dimensions, voxel size and image format. Using the text editor of your choice, create a corresponding header file with the same base name, but an ".nfo" extension. Copy and edit the entries listed Example 1 into this file, customize to match your image and save. Load **MicroView** and select the ".nfo" for reading.

6.0.4 References

JOURNAL ARTICLES

1. A Odgaard and HJG Gundersen. “Quantification of Connectivity in Cancellous Bone, with Special Emphasis on 3-D Reconstructions”. Bone. 14. 113-152. 1993.
2. N Otsu. “A threshold selection method from gray-level histograms”. IEEE Trans. Systems, Man, and Cybernetics. 9(1). 62-66. 1979.
3. T Hildebrand and P Rüegsegger. “Quantification of bone microarchitecture with the structure model index”. Comp Meth Biomech Biomed Eng 1. 15-23. 1997.
4. T Hildebrand and P Rüegsegger. “A new method for the model-independent assessment of thickness in three-dimensional images”. J Microsc 185. 67-75. 1997.
5. WJ Whitehouse. “The quantitative morphology of anisotropic trabecular bone”. J Microsc 101. 153-168. 1974.
6. TP Harrigan and RW Mann. “Characterization of microstructural anisotropy in orthotropic materials using a second rank tensor”. J Mat Sci 19. 761-767. 1984.

6.0.5 Glossary

Comma-separated value (CSV) file

A commonly used text-based spreadsheet format. Many spreadsheets can read and write this file format.

Computed Tomography (CT)

The science of generating tomographic x-ray images of an object or subject.

DICOM

DICOM is an acronym for The Digital Imaging and Communications in Medicine standard. The standard was created by the National Electrical Manufacturers Association (NEMA) to aid the distribution and viewing of medical images.

Hounsfield Unit

An x-ray attenuation scale commonly used for interpreting CT images.

Hydroxyapatite

A crystalline form of calcium found in bone.

Look Up Table (LUT)

A table that defines the mapping between the gray scale values found in the CT image and the coloration to be displayed for each gray scale value.

Region of interest (ROI)

A 2D or 3D region, within an image, used to define the extent of an analysis or computation.

Voxel

The 3D analog of a pixel, or picture element. The smallest, box-shaped element in any 3D image.

6.0.6 Frequently Asked Questions

Q: Where can I download the latest version of MicroView?

A: Go to the website http://microview.sourceforge.net. Click the link "Download" located in the upper left corner of the browser. Then click the link "MicroView-setup.exe" to download the latest version of **MicroView**.

Q: Where can I get source code for MicroView and instructions on how to build it?

A: There is a document at the sourceforge website that describes how to get and build the latest CVS **MicroView** source code. Go to the URL http://microview.sourceforge.net and click the link "Download" in the top left corner. Then click the "Docs" link. Then click the "Installation Instructions (win32)" link.

Q: Is MicroView available for Mac OS X?

A: Yes. With the release of **MicroView** 2.1, Mac OS X is fully supported. In particular, **MicroView's** movie maker and volume renderer are now supported on all platforms.

Q: Yes. With the release of MicroView 2.1, Mac OS X is fully supported. In particular, MicroView's movie maker and volume renderer are now supported on all platforms.

A: MicroView can automatically select an optimal threshold value by examining a histogram of pixel values in a user defined region of interest. This value is useful as input to the isosurface, stereology, and volume rendering plugins. To automatically threshold an image, first select a region of interest, using either the ROI plugin or the 7/8 keys. Next, generate a histogram of the pixel values within this region of interest by hitting the g key. Finally, click on the Auto Threshold button on the histogram plot window to automatically determine an optimal threshold. **MicroView's** automatic thresholding is based upon the "Otsu" method[Otsu79].

Q: When selecting Image Export from the File menu, the only option that comes up for export is DICOM (no jpeg or other file format options). Is this option no longer being offered in the current version of MicroView or do I need to do something else to convert my .vff file into jpeg slices?

A: The image export feature gives a list of appropriate file formats, depending on the image depth of the image you've loaded. If, for instance, you have a 16-bit image, only DICOM format will be available. For 8-bit images, different formats will be available, including jpeg, png, gif, etc. To handle the export of 16-bit images to formats such as jpeg, you need to first rescale the images to 8-bit. Under the Process menu, select Image Downsample in order to convert your image from 16-bit to 8-bit, then select Image Export from the File menu.

Q: How do I make movies in MicroView?

A: MicroView has a rudimentary movie making facility, which permits generation of movies. For more complex movie making, there are numerous screen capture applications that can export to e.g. AVI movies. One such utility is hypercam™ .

Q: Is MicroView scriptable?

A: Yes. There is a document at the sourceforge website that describes how to write scripts for **MicroView**. Go to the URL http://microview.sourceforge.net and click the link "Documentation" in the top left corner. Then click the "MicroView Scripting HOWTO" link.

6.0.7 Copyright Information

MicroView may be freely distributed to multiple computers.

MicroView is an open-source program, written in the C++ and Python-based programming language VTK. To learn about Python please visit http://www.python.org. To learn about VTK please visit the Kitware website, the developers of VTK, at http://www.kitware.com.

MicroView is based on a number of open source software packages. Individual copyright and license statements from their respective owners follow.

GE Healthcare Systems Copyright

Copyright (c) 2000-2005 GE Healthcare.

EXCEPT WHEN OTHERWISE STATED IN WRITING BY THE COPYRIGHT HOLDERS AND/OR OTHER PARTIES, THE COPYRIGHT HOLDERS AND/OR OTHER PARTIES PROVIDE THE SOFTWARE "AS IS" WITHOUT EXPRESSED OR IMPLIED WARRANTY INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. IN NO EVENT UNLESS AGREED TO IN WRITING WILL ANY COPYRIGHT HOLDER OR OTHER PARTY WHO MAY MODIFY AND/OR REDISTRIBUTE THE SOFTWARE UNDER THE TERMS OF THIS LICENSE BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL OR CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO, LOSS OF DATA OR DATA BECOMING INACCURATE OR LOSS OF PROFIT OR BUSINESS INTERRUPTION) ARISING IN ANY WAY OUT OF THE USE OR INABILITY TO USE THE SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGES.

ATAMAI INC. LICENSE

Portions of **MicroView** are based on code provided by Atamai Inc. The Copyright and license statement follows:

Copyright (c) 2000 Atamai, Inc.

Use, modification and redistribution of the software, in source or binary forms, are permitted provided that the following terms and conditions are met:

1. Redistribution of the source code, in verbatim or modified form, must retain the above copyright notice, this license, the following disclaimer, and any notices that refer to this license and/or the following disclaimer.
2. Redistribution in binary form must include the above copyright notice, a copy of this license and the following disclaimer in the documentation or with other materials provided with the distribution.
3. Modified copies of the source code must be clearly marked as such, and must not be misrepresented as verbatim copies of the source code.

THE COPYRIGHT HOLDERS AND/OR OTHER PARTIES PROVIDE THE SOFTWARE "AS IS" WITHOUT EXPRESSED OR IMPLIED WARRANTY INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. IN NO EVENT SHALL ANY COPYRIGHT HOLDER OR OTHER PARTY WHO MAY MODIFY AND/OR REDISTRIBUTE THE SOFTWARE UNDER THE TERMS OF THIS LICENSE BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL OR CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO, LOSS OF DATA OR DATA BECOMING INACCURATE OR LOSS OF PROFIT OR BUSINESS INTERRUPTION) ARISING IN ANY WAY OUT OF THE USE OR INABILITY TO USE THE SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGES.

VTK COPYRIGHT

ITK COPYRIGHT

THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDER AND CONTRIBUTORS ``AS IS'' AND ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE DISCLAIMED. IN NO EVENT SHALL THE AUTHORS OR CONTRIBUTORS BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.

See also the ITK web site: http://www.itk.org for more information.

PIL COPYRIGHT

The Python Imaging Library (PIL) is

Copyright © 1997-2005 by Secret Labs AB

Copyright © 1995-2005 by Fredrik Lundh

By obtaining, using, and/or copying this software and/or its associated documentation, you agree that you have read, understood, and will comply with the following terms and conditions:

Permission to use, copy, modify, and distribute this software and its associated documentation for any purpose and without fee is hereby granted, provided that the above copyright notice appears in all copies, and that both that copyright notice and this permission notice appear in supporting documentation, and that the name of Secret Labs AB or the author not be used in advertising or publicity pertaining to distribution of the software without specific, written prior permission.

SECRET LABS AB AND THE AUTHOR DISCLAIMS ALL WARRANTIES WITH REGARD TO THIS SOFTWARE, INCLUDING ALL IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS. IN NO EVENT SHALL SECRET LABS AB OR THE AUTHOR BE LIABLE FOR ANY SPECIAL,INDIRECT OR CONSEQUENTIAL DAMAGES OR ANY DAMAGES WHATSOEVER RESULTING FROM LOSS OF USE, DATA OR PROFITS, WHETHER IN AN ACTION OF CONTRACT, NEGLIGENCE OR OTHER TORTIOUS ACTION, ARISING OUT OF OR IN CONNECTION WITH THE USE OR PERFORMANCE OF THIS SOFTWARE.

NUM ARRAY COPYRIGHT

Copyright (C) 2003 Association of Universities for Research in Astronomy (AURA)

Redistribution and use in source and binary forms, with or without modification, are permitted provided that the following conditions are met:

1. Redistributions of source code must retain the above copyright notice, this list of conditions and the following disclaimer.
2. Redistributions in binary form must reproduce the above copyright notice, this list of conditions

and the following disclaimer in the documentation and/or other materials provided with the distribution.

3. The name of AURA and its representatives may not be used to endorse or promote products derived from this software without specific prior written permission.

THIS SOFTWARE IS PROVIDED BY AURA ``AS IS'' AND ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE DISCLAIMED. IN NO EVENT SHALL AURA BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.

Symbols
(ROI) - Advanced 30
(ROI) Selection 28
Numerics
2-D Image Slices 14
2D images 15
2D pixel profile 21
A
Adding to existing project 61
Adjusting ROI Position 29
Adjusting ROI size 29
Advanced Bone Analysis Application 55
Advanced Bone Analysis Options 63
Algorithm 64
Alpha Blend 54
Analysis 24, 59
Analysis (2-D) 19
Analysis Results 59
Anisotropy 55, 65
Appendix 77
Auto Threshold 24
B
balloon help 3
Bin Size 25
BMD 55
BMD - Bone Mineral Density 63
Bone Analysis Application 55
Bone Mineral Density 63
C
Calibration Tool 38
Cortical 68
Cortical Analysis 55
Cortical ROI 34
Creating a MIP 46
Creating and Loading Projects 57
CSV 60
CT Calibration 38
Cursor 9, 10
Custom Line 20
D
dark object 36
Data Transfer 37
Datatype codes 79
Defining a Region of Interest Volume 2D / 3D 23
Delete or Edit Landmarks 72
DICOM 37
DICOM Data Transfer 37
DICOM Data Transfer Tool 37
Direct Measures 55, 66
display and miscellaneous options 13
Display Isosurface 50
Display Options 13
Downsampling 40
E
Edit Landmarks 72
Excel 60
export options 60
Exporting 17
Exporting Images 17
Exporting Images as 2-D Image Slices 17
Extrude Tool 33
F
File Formats 77
Flipping the Image 42
Formats 77
G
Gaussian Smoothing 41
Geometry 53
Geometry File Formats 77
Getting Help 1
H
Help Function 3
Highlight Selected region 27
histogram 24
histogram of sub-volume 24
I
Image Datatype codes 79
Image Information 39
Image viewing 8
Importing 2-D Image Slices 14
Importing raw 2D images 15
individual slice data 68
Installing MicroView 2
Interaction Palette 9
Inverting 40
Inverting the Image 40
L
Learning MicroView 3
Line Measurement & Analysis (2-D) 19
Line profile options 22
Line Profiles 20
Linux System Specifications 2
Loading a File 14
Loading Existing projects 62
Loading Projects 57
M
Mac System Specifications 3
Main MicroView Window 6, 7

Make Movie 54
Manual 3
Measurement Tool 75
Measures 66
Measuring along 2D pixel profile 21
Memory Performance under Windows 78
MicroView options 13
MicroView Processes 40
MicroView Window 6
MIP 46
Modifying the display 7
Mouse 9
Mouse & Cursor 9
Movie 54
Moving through selected planes 11
O
options 13
Output options 57
Overlay Geometry 53
P
Panning volume 11
parameters 58
PDF 61
Performance under Windows 78
Plot histogram 24
Plot histogram of sub-volume 24
Plugins 69
Point Measurement (1-D) 19
Polygon 31
profile options 22
Profiles 20
project management 57
project parameters 58
R
radial thickness 68
range of voxel values 25
Raw Image Data 79
Rectangle or Ellipse 30
References 81
Region Grow 35
Region of Interest (ROI) - Advanced 30
Region Of Interest (ROI) Selection - Standard 28
Region of Interest Volume 2D / 3D 23
Register Tab 71
Registration 69
Rendering 49
Rendering Volume 49
Reorienting the Volume 44
Resampling 44
Resampling the Volume 44
Resetting image 12
Revision History 1
roi as Rectangle 30
ROI Blanking 42
ROI Position 29
ROI size 29
Rotating plane 11
Rotating volume 10
S
Saving 2-D Images 17
Saving Complete Image File 17
Select Bin Size 25
Select range of voxel values 25
Selecting a Region of Interest (ROI) - Advanced 30
Slices 14
SMI 55
SMI (Structure Model Index) 64
Smoothing 41
Spline 31
Spreadsheets 59
Starting 5
Stereology 55, 67
Sub-Volume Analysis 24
Support 1
Support for Raw Image Data 79
Supported File Formats 77
System Specifications 2
T
Text 60
Threshold 24
Tools 19
Topology 55
Transformation Type 73
U
Using the Advanced Bone Analysis Application 55
V
Viewing data 8
Viewing Line Profiles 20
Visualization Tools 46
Volume Analysis 24
voxel values 25
W
Windows System Specifications 2
Z
Zooming image 12
Zooming in on a Region of Interest 21, 26