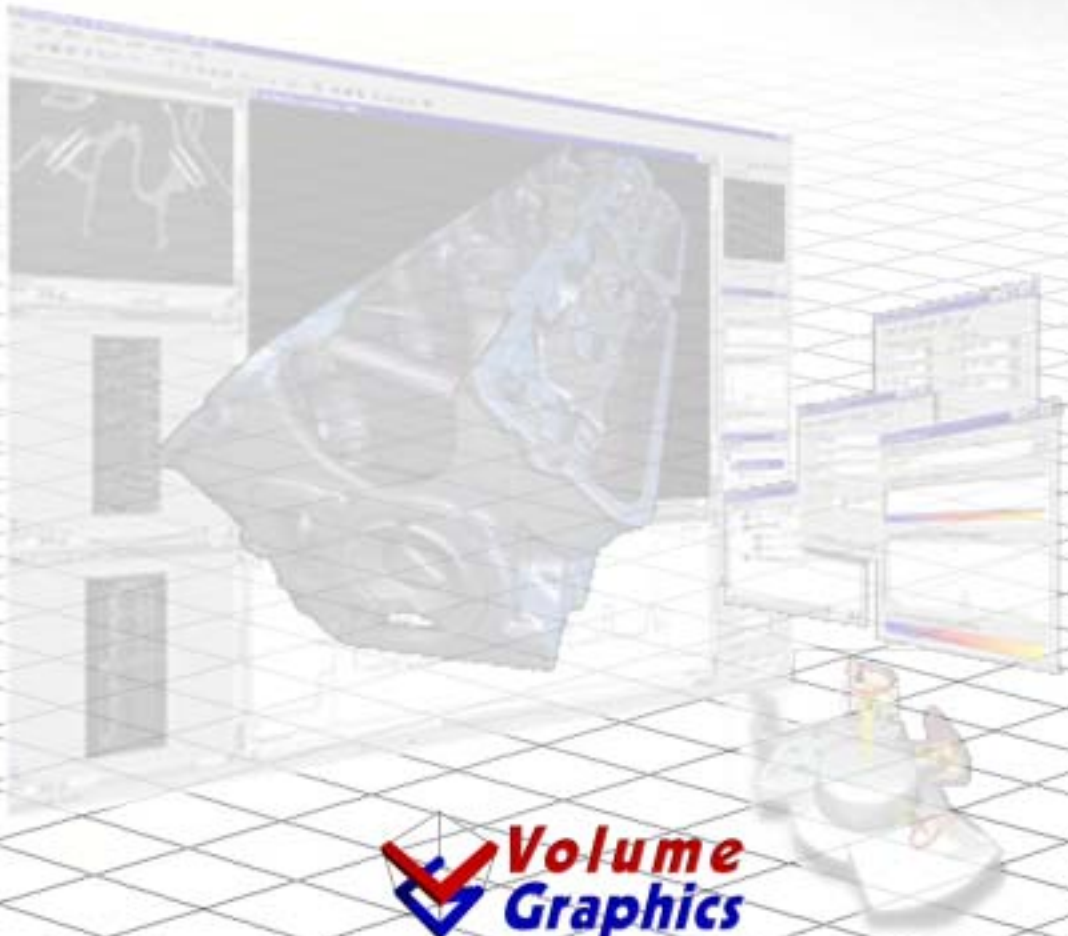
VGStudio MAX 1.0

User's Manual



Volume Graphics

Solutions about Voxels

www.volumegraphics.com

Volume Graphics GmbH
Wieblinger Weg 92a
D-69123 Heidelberg
Germany
Tel: +49 / 6221 / 73920 60
Fax: +49 / 6221 / 73920 88

Printed in Germany. First printing, March 2001.

Reach us on the Internet:

e-mail: vgstudio@volumegraphics.com

world wide web: http://www.volumegraphics.com

User's Manual

Solutions about Voxels

Table of Contents

Welcome to VGStudio MAX 1.0 User's Manual

VGStudio MAX 1.0 is a software system designed to support interactive analysis of three dimensional/volumetric data, the so called "voxel data" or three dimensional images. The term *voxel* is used to characterize a volume element; it is a generalisation of the notion of *pixel* that stands for a picture element. Volume data described with voxels represent therefore the result of some sampling process of a three dimensional object or structure. Typical sampling systems are X-Ray CAT, MRI, PET and SPECT, Confocal Laser microscopy.

VGStudio MAX 1.0 is a highly sophisticated image analysis and visualization software and was developed to provide the user with a powerful but easy-to-use interface to process and visualize voxel/volume data with high-performance analyzing and volume rendering algorithms. VGStudio MAX 1.0 includes Volume Graphics unsurpassed VGL® rendering technology which allows to render largest volume data sets at an interactive performance on every modern PC. VGStudio MAX 1.0 is the worldwide first application providing an intuitive standard graphical user interface in combination with the most advanced visualization and image processing technology. Apart from volume data analysis, VGStudio MAX 1.0 may also be used for documentation and presentation purposes. You may render high quality images and animations of your data under investigation.

Today VGStudio MAX 1.0 is used by professionals in healthcare, industry and science all over the world.

All terms you might be unfamiliar with here will be explained throughout this manual.

Medical Use Restrictions

We wish to thank you for your past support and continued usage of the VGStudio voxel data visualization and analysis program. We have many future plans for the product, and we will advise you through the appropriate channels as these enhancements become available.

At the same time, however, we wish to remind you that the VGStudio products are "for research use only" or "for investigational use only." The Department of Health and Human Services (DHHS) National Institute of Health (NIH) defines "research" as...

" ... a systematic investigation, including research development, testing and evaluation, designed to develop or contribute to generalizable knowledge... " (Cf. 45 CFR 46.102(d))

The "human subject" in research is...

" ... a living individual about whom an investigator... conducting research obtains (1) data through intervention or interaction with the individual, or (2) identifiable private information. Intervention includes both physical procedures by which data are gathered and manipulations of the subject or the subject's environment that are performed for research purposes. Interaction includes communication or interpersonal contact between the investigator and subject... " (Cf. 45 CFR 46.102(f))

Similarly, the DHHS Food and Drug Administration (FDA) defines an "investigation" as... "... a clinical investigation or research involving one or more subjects to determine the safety or effectiveness of a device... " (Cf. 21 CFR 812.3(h))

The FDA definition of a "subject" is...

" ... a human who participates in an investigation, either as an individual on whom... an investigational device is used or as a control. A subject may be in normal health or may have a medical condition or disease... " (Cf. 21CFR.812.3(p))

Within this regulatory framework, then, a clinical investigation can be argued to be a more restrictive form of research, in which the data and information collected are intended to be used to support the claims of a device's safety or effectiveness (the FDA regards software used in medical applications to be a medical device).

At the present time, Volume Graphics makes no representation that the VGStudio product is either safe or effective for any intended use for which research may currently be performed.

If you are conducting research or clinical investigations, by law, you are required to obtain prior Investigational Review Board (IRB) approval of

the clinical study protocol and of the patient informed consent documents, and to provide each patient/subject with a copy of the completed informed consent document. Similarly, if you are conducting research or clinical investigations using animal subjects, you are obligated to follow Good Laboratory Practices, and to observe the ethical treatment of the animals. If your facility or academic institution receives funding from NIH, or if your IRB has DHHS- approved assurances on-file, then you are obligated to follow the NIH rules, in addition to the FDA rules.

As a consequence of the regulatory status of the VGStudio products, you are reminded of the Login Acceptance Screen, reprinted below, in which you acknowledge the regulatory status of the product prior to using its functionality:

Disclaimer: VGStudio IS NOT FOR CLINICAL USE.

VGStudio or data derived from VGStudio may be used only for research and may not under any circumstances be used for clinical purposes. Pressing the 'Accept' during the VGStudio installation procedure indicates your consent NOT to use VGStudio for anything other than research purposes.

You are encouraged to contact your governing IRB or clinical risk manager should you have any additional questions or concerns. We hope that this information clarifies your understanding of the regulatory status of the VGStudio product, and look forward to continued dialog with you.

To acknowledge the conditions regulating the use of VGStudio, please sign this letter in the space provided below and fax a copy of page 8 and 9 to us at +49 621 181 2634.

We wish you continued success in your research activities.

—
Volume Graphics GmbH

I agree to the above restrictions on the use of VGStudio.

_____
Customer's Signature

_____
Customer's Name (Printed)

_____
Organization

1 Introduction to VGStudio MAX 1.0

This chapter will help the user in getting accustomed with the program and its functions, and gives an overview of some basic concepts the user should keep in mind when using the program.

This chapter covers the following topics:

- Volume graphics and VGStudio MAX
- About this manual
- Conventions used in this manual
- Where to get additional help
- Where to send feedback

1.1 Volume Graphics and VGStudio MAX 1.0

Volume rendering or, to use a more general term, volume graphics, is a sub-specialty of 3D computer graphics which deals with the discrete representation and visualization of objects represented as sampled data in three or more dimensions. Volume graphics differs from traditional 3D graphics in that 3D graphics primarily deals with the representation of object surfaces, whereas volume graphics deals with the representation of both object surfaces and interiors. In volume graphics, for example, sample points such as CT or MRI scans are taken from the real world, assigned color and transparency levels, and are then projected directly onto the computer screen.

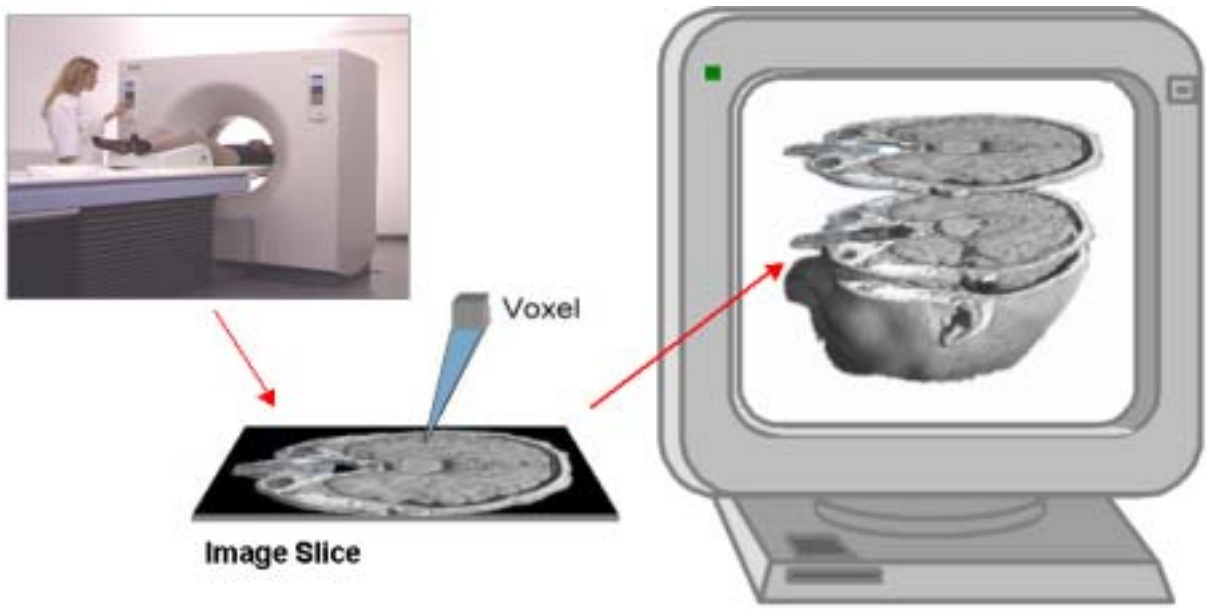


Fig. 1 Color and transparency levels are assigned to CT or MRI scans and are then projected directly onto the computer screen.

In recent years, the popularity of volume graphics has grown considerably. A few years ago, volume graphics was still limited by the large amount of computational power and memory required for real-time volume rendering. In contrast to classical or advanced 2D image processing, volume visualization and analysis produces huge amounts of data, so that memory, processor performances and algorithms are critical. Due to the highly sophisticated algorithms used in VGStudio MAX 1.0 and the increase in PC computing power, volume graphics and volume analysis became accessible to everybody as the program runs on a standard PC. The adoption of efficient solutions in VGStudio MAX 1.0, e.g. the multiprocessor (SMP) capable implementation of nearly every VGStudio MAX 1.0 feature, allows the user to apply a trial and error approach to the analysis of 3D data; the user can apply an operation or a transformation to the data and control the result in an interactive and real-time environment, and may thus select the best suited operation for his/her needs. By using VGStudio MAX 1.0, everybody can take advantage of volume graphics technology which has inherent advantages for applications that need visualization of irregular objects, or where the interior structure and a high-quality detail representation are essential, e.g. representations of the human body.

1.2 Images Rendered by VGStudio MAX 1.0 Users

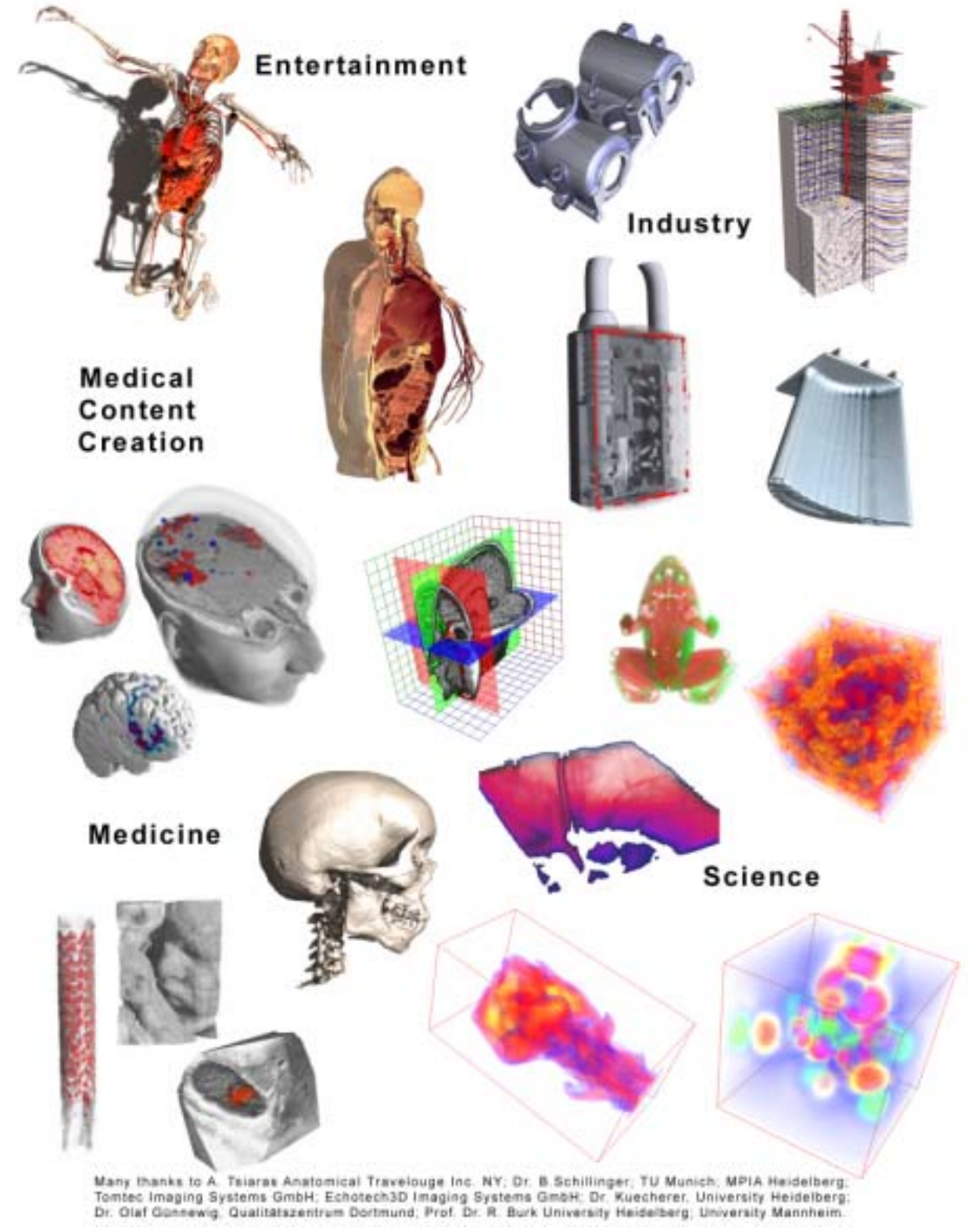


Fig. 2 Here are example images rendered by VGStudio MAX users.

1.3 About this Manual

VGStudio MAX has been designed to be as intuitive as possible, but as it is a sophisticated program, you might need help from time to time. In this case, you should refer to this manual which includes a comprehensive table of contents and an index to help you find the information you need.

This manual assumes that you are familiar with the Unix or Windows operating systems. If you need help with features specific to either system, please refer to the documentation supplied with your computer.

1.4 Conventions Used in this Manual

This manual uses the following conventions to identify information:

- Whenever you must execute a command by clicking the mouse, the command will be displayed in **bold** text (for example, click **OK** to continue).
- Menu items and buttons also appear in **bold** text for easy identification (for example, the **File** menu or the **Save** button).
- You will find the following icons throughout the manual. The icons indicate which mouse button you should press to execute the appropriate action.

Press left mouse button 

Press middle mouse button 

Press right mouse button 

- Throughout the manual, you will find **Reminder** icons. They indicate important facts and exceptions.

- Chapter cross references are displayed in *italics* (for example, *Chapter 1 Introduction to VGStudio MAX 1.0).*
- This manual combines Windows and Unix instructions. In most cases, they overlap, but in those instances when there are differences (most often with key commands), the manual will list both commands.

1.5 Where to Get Additional Help

Check the table of contents or the index whenever you need to locate information on a particular function. If you cannot find the information, there are other ways to get help. Please also refer to *Chapter 2.5 Registering VGStudio MAX 1.0.*

- **Installation & Information Card—**Provides latest information on the current VGStudio MAX 1.0 release and information on the installation procedure for your operating system.

- **Volume Graphics Web Site—**The Internet is a quick way to get answers to your questions. You can use the Volume Graphics web site at www.volumegraphics.com as a technical support resource.

- **E-Mail—** Send an e-mail to Volume Graphics at vgstudio@volumegraphics.com

- **Volume Graphics Technical Support**—If none of the resources mentioned above provides the answer, you can contact the Volume Graphics technical support by sending an e-mail to vgstudio@volumegraphics.com or one of our sales representatives. Please be at your computer and have your registration number available when you call.

- **Volume Graphics Sales**—Our friendly and knowledgeable sales personnel can answer basic questions about product capabilities and give information on other Volume Graphics products which may fit your needs. You may contact our sales department by sending an e-mail to info@volumegrapics.com or one of our sales representatives.

1.6 Feedback

We are very interested in your comments on VGStudio MAX. Many of VGStudio MAX's changes and improvements over the years were based upon user requests and input. If you have comments or feature requests, please send them to us via the World Wide Web:

http://www.volumegraphics.com

e-mail: vgstudio@volumegraphics.com

You may also send a letter or fax to the following address / fax number:

Volume Graphics GmbH
VGStudio MAX Product Manager
Wieblinger Weg 92a
D-69123 Heidelberg
Germany
Tel: +49 / 6221 / 73920 60
Fax: +49 / 6221 / 73920 88

2 Installation

This chapter gives general information on installation requirements and on the installation itself. Each section provides the users with instructions for both Windows and Unix operating systems. Find the section that is appropriate for your operating system.

This chapter covers the following topics:

- System requirements
- Installation instructions
- Registering VGStudio MAX

2.1 System Requirements

This section lists the minimum system requirements for Windows and Unix users. Refer to the section that is appropriate for you. Also, see the section on VGStudio MAX and memory usage in the *Appendix*.

Windows

Microsoft Windows™ 9x, Windows NT 4.0 or Windows 2000 operating system

Pentium III or higher or equivalent CPU

128 MB RAM (256 MB or more recommended)

Super VGA display (17" or larger recommended) with 800x600 resolution and 256 colors (1280x1024 at High Color recommended)

CD-ROM drive

Unix

Linux 2.0 (other Unix OS on request) operating system

128 MB available RAM (256 MB or more recommended)

Super VGA display (17" or larger recommended) with 800x600 resolution and 256 colors (1280x1024 at High Color recommended)

CD-ROM drive

2.2 VGStudio MAX 1.0 on Multiprocessor Hardware

Almost all features included in VGStudio MAX 1.0 are implemented multithreaded so that VGStudio MAX 1.0 takes full advantage of modern processor technologies. Especially on multi-processor (SMP) hardware, VGStudio MAX 1.0 delivers an almost linear speedup proportional to the number of processors in use. VGStudio MAX 1.0 utilizes the full memory bandwidth of today's and upcoming system designs to provide its users with an optimal performance.

By default VGStudio MAX 1.0 utilizes all processors available in a system. The user may limit the number of processors used by VGStudio MAX 1.0 by applying the environment variable PROCESSORS with the appropriate number of processors.

Adding environment variables on a Windows NT 4.0 / 2000 System

Step 1: Choose **Settings** in the Program Manager **Start** menu.

Step 2: Choose **Control Panel** from the **Settings** menu.

Step 3: Double-click the **System** icon to display **System Properties**.

Step 4: On the **Environment** index card, click any existing variable name in the list you want to add the variable to.

Step 5: Type in the name of the new variable in the **Variable** box.

Step 6: Type in the value in the **Value** box.

Step 7: Click **Set**.

Notes:

If you are not an administrator, you may add variables only to the **User Variables** list. Windows NT will save changes in the registry so that they will be available automatically the next time you start your computer. Changes will not affect programs that are running, and will only be effective once you have restarted your computer.

Adding environment variables on a Unix system

Notes:

Ask your system administrator for help if you are not familiar with modifying system or environment variables. To modify your PROCESSORS variable, type in one of the following commands depending on what shell you use and where you have installed the software. Include the corresponding line into your .cshrc or your .bashrc file if you do not want to modify your environment variables every time you log into your system.

Examples for utilization of 2 processors.

For tcsh users type:

setenv PROCESSORS 2

For bash users type:

export PROCESSORS=2

2.3 Installation Instructions

Please refer to the installation information within the VGStudio MAX 1.0 CD booklet for up-to-date and detailed information on the installation procedure for your operating system.

Reminder: The VGStudio MAX 1.0 software ast to be installed by a user with **Administrator rights**. The installation without Administrator rights will result in an incomplete installation.

2.4 VGStudio MAX 1.0 License

The VGStudio MAX 1.0 **Node Locked License update** window will pop up when you start VGStudio MAX 1.0 for the first time or when no valid license was found on your system. Enter your name or the name of your company and the license key which is included in your VGStudio MAX 1.0 software package and click **OK**. You may also ask the Volume Graphics support for a trial license at vgstudio@volumegraphics.com. To do so press the **Create registration form button**, fill in the required information and send the registration form to Volume Graphics.

If you started VGStudio MAX 1.0 for the first time and you got no license you can click **Demo** for running VGStudio MAX 1.0 in demo mode. The application then runs ten minutes and you will not be able to save. Clicking **Exit** will exit the application.

When you chose **License update** the **Demo** button will be named **Cancel**. Clicking **Cancel** (please refer to *Chapter 4.3.8 Help Menu - License update)* closes just closes the window.

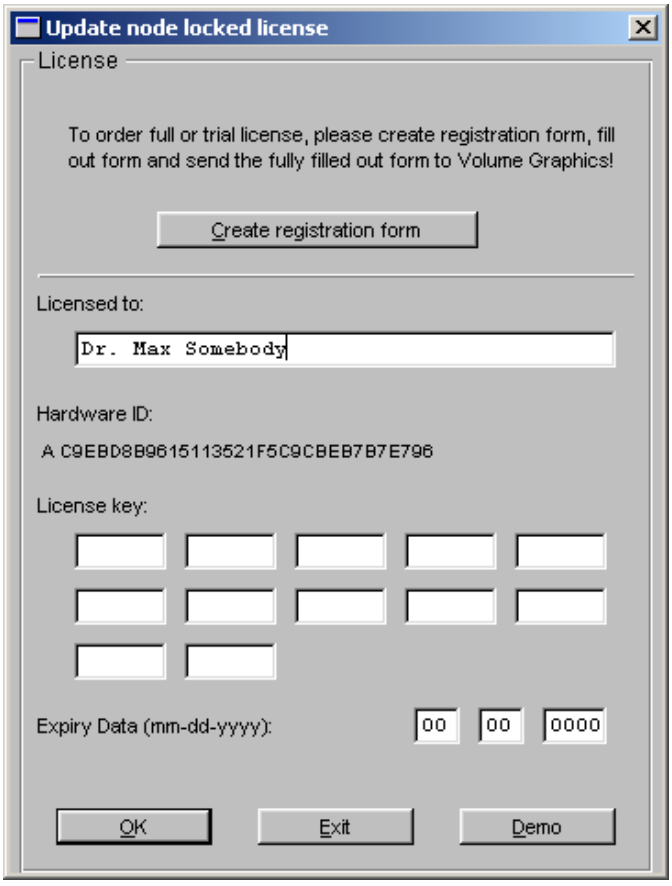


Fig. 3 The License update window where you enter your name and license key.

Reminder: The Node Locked License update dialog may not be used to enter a **Floating License Code.** Please refer to the **Installation & Information Card** delivered with your VGStudio MAX 1.0 software package in case that you purchased a **Floating License** of VGStudio MAX 1.0

2.5 Registering VGStudio MAX 1.0

To be eligible for technical support, as well as receive information on bug-fix updates and feature upgrades, you must register your copy of VGStudio MAX. To register press the **Create registration form** button in the License dialog (please refer to *Chapter 4.3.8 Help Menu - License update)*, fill in the required information and send the registration form to Volume Graphics either by fax, mail, or e-mail. If you change your address after registering, you may call or e-mail us so we can update your record, or send us a standard post office change of address notice. See *Chapter 1.6 Feedback* for more information on how to contact Volume Graphics directly.

3 Getting Started

This chapter explains how to get started using VGStudio by introducing some basic program concepts. It covers the following topics:

- Launching the program
- First steps with VGStudio MAX
- Exiting VGStudio MAX
- Image quality versus speed

3.1 Launching the Program

To launch VGStudio MAX 1.0 for Windows open the **Start** menu. Select the option **Programs** / **Volume Graphics** / **VGStudio MAX 1.0.** You may also **double-click** on a vgi-File e.g. in your Windows Explorer to start VGStudio MAX 1.0. You may drag a vgi file on the VGStudio MAX icon to start VGStudio MAX with the appropriate file loaded automatically.

To launch VGStudio MAX 1.0 for Linux/Unix enter the command **vgstudiomax** at the command prompt. You may add a vgi file as command line option to start VGStudio MAX with the appropriate file loaded automatically.

C:\>vgstudiomax [vgi-file]

Example: C:\>vgstudiomax demo.vgi

Reminder: When starting the program for the first time you have to enter your name and the license key. For more information on the installation procedure, see *Chapter 2 Installation.*

After having launched the program, the VGStudio MAX application will appear on your screen with its startup screen. The startup screen will disappear after a few seconds or upon pressing a key on your keyboard or a mouse button. The VGStudio MAX interface consists of seven main elements:

- Title bar
- Menu bar
- Icon bar
- Slice windows
- 3D window
- Tool box
- Status bar

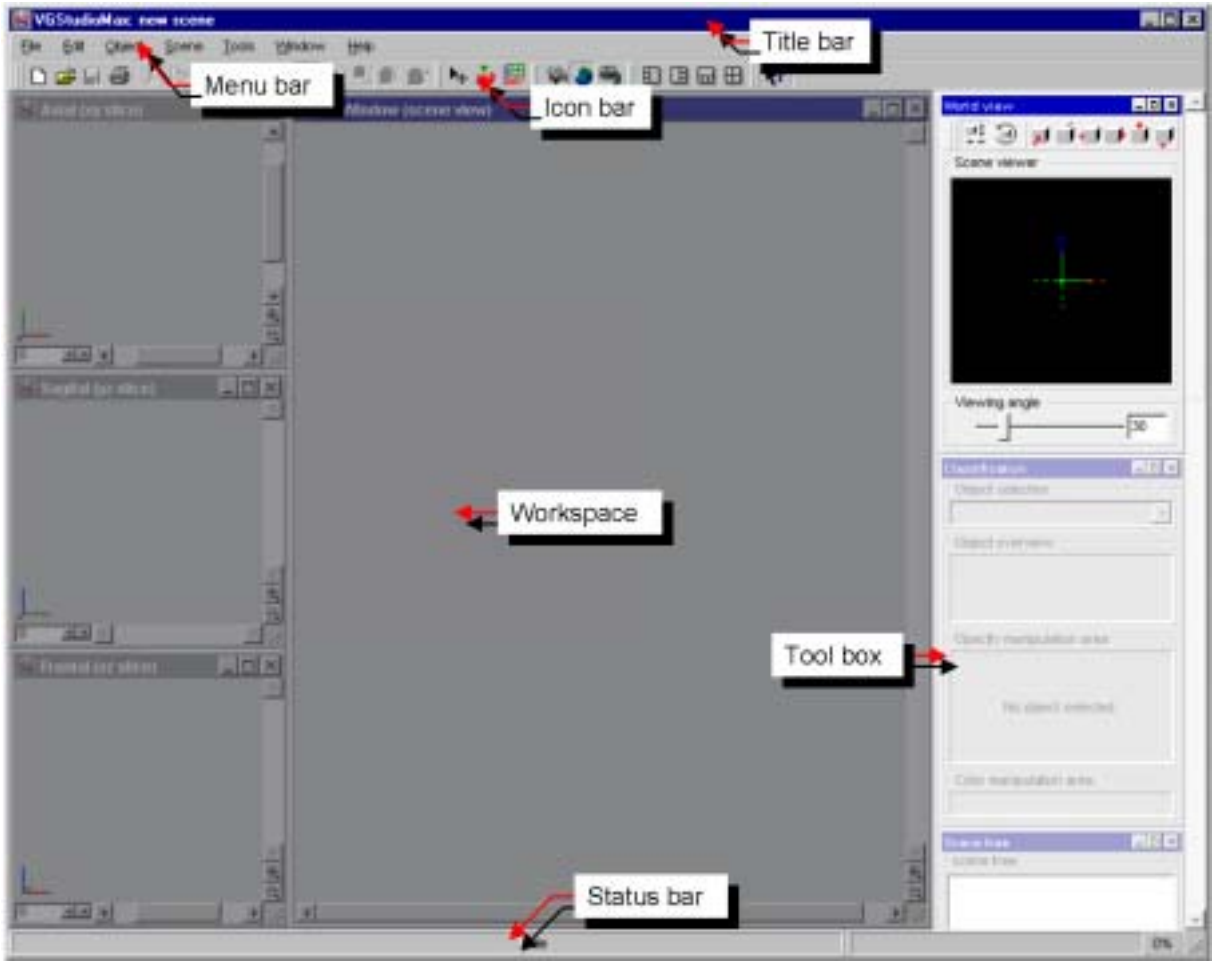


Fig. 4 The VGStudio MAX interface after startup.

All the functions included in VGStudio MAX are accessed either by selecting options in the main menu, by clicking buttons in the icon bar, by using the tools in the toolbox, or via context menus which you open by clicking into an element with the right mouse button.

3.1.1 Keyboard Usage

Most VGStudio MAX functions that are accessed via the menu may also be activated by using keyboard shortcuts. If keyboard shortcuts exist, they are displayed next to the entries in the pull-down menus. This can be seen in the following image where the **Edit** menu is shown as an example.

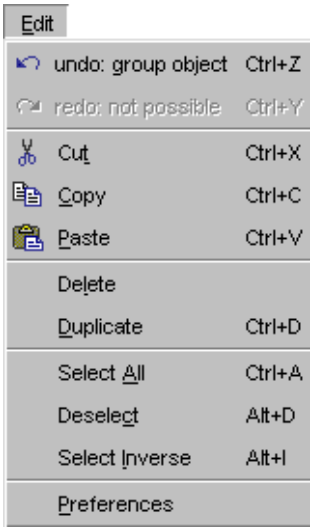


Fig. 5 The keyboard shortcuts are displayed next to the menu entries.

List of Keyboard Shortcuts

Command	**Keyboard Shortcut**
File Menu	
New	Ctrl + N
Open	Ctrl + O
Save	Ctrl + S
Save As	F12
Quit	Alt + F4
Object Menu	
Move	Shift + Ctrl + M
Rotate	Shift + Ctrl + R
Scale	Shift + Ctrl + S
Clipbox	Shift + Ctrl + B
Clipplane	Shift + Ctrl + C
Group	Ctrl + G
Ungroup	Ctrl + U
Edit Menu	
Undo	Ctrl + Z
Redo	Ctrl + Y
Cut	Ctrl + X
Copy	Ctrl + C
Paste	Ctrl + V
Delete	***Del***
Duplicate	Ctrl + D
Select All	Ctrl + A
Deselect	Alt + D
Select Inverse	Alt + I

3.1.2 Mouse Usage

VGStudio MAX is designed to work with a mouse with either two or three buttons. If you are using a two-button mouse, the third (middle) mouse button is emulated by simultaneously pressing the **Alt** key on your keyboard and the left mouse button. In conjunction with certain window managers, the **Alt + left mouse button** combination is already in use. A second alternative to emulate the middle mouse button when using a two-button mouse is to use the combination **Shift + Ctrl + left mouse button**.

Throughout the manual, you will find the following icons. The icons indicate which mouse button you should press to perform the appropriate action.

Press left mouse button	Press middle mouse button	Press right mouse button
		

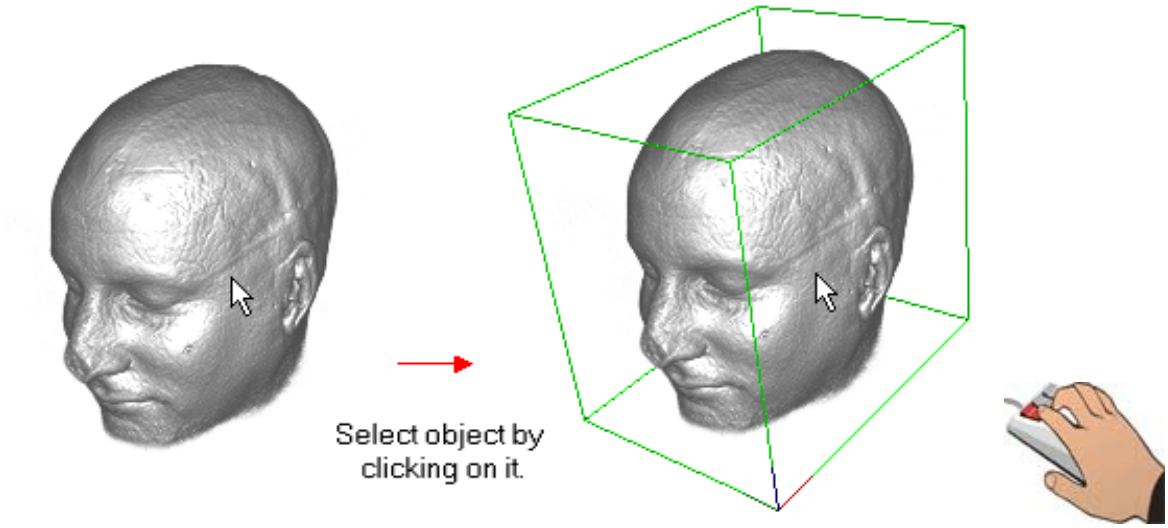


Fig. 6 When clicking an object with the left mouse button you select or activate it. This is indicated by a bounding box around the object.

By clicking an object with the left mouse button, you select or activate an object. You may also select several objects at once by clicking into a window with the left mouse button and then dragging a frame over the objects while the left mouse button is pressed or by using the shortcut **Ctrl + A** (when using this shortcut, **all** objects currently displayed in the scene will be selected). You may deselect one or several objects by clicking outside the bounding box of any object. The box around any object will disappear.

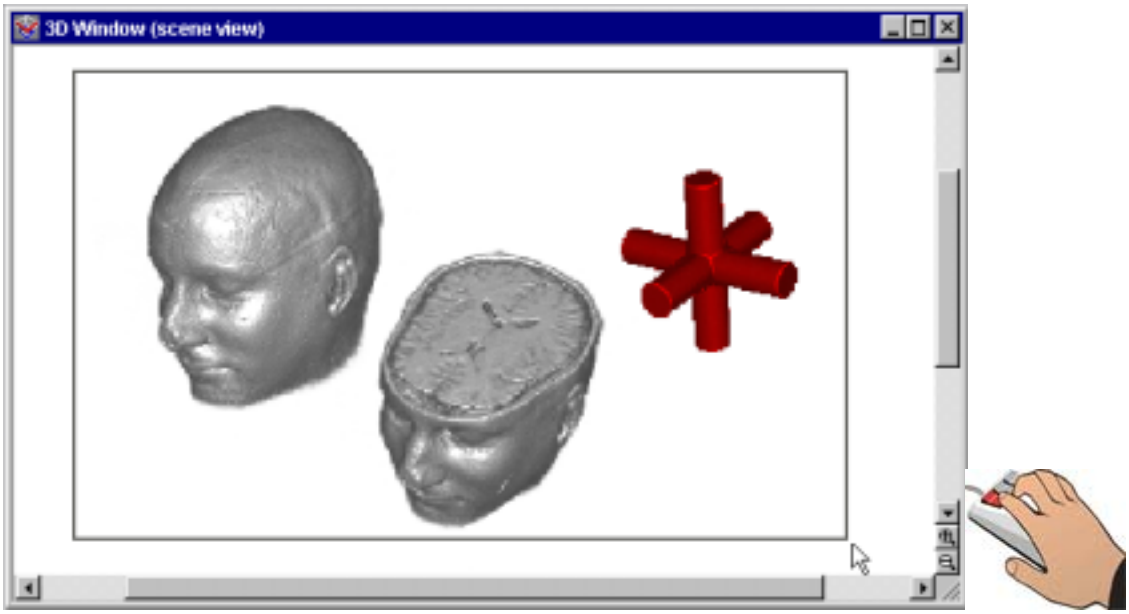


Fig. 7 Select several objects by dragging a frame over the objects while the left mouse button is pressed.

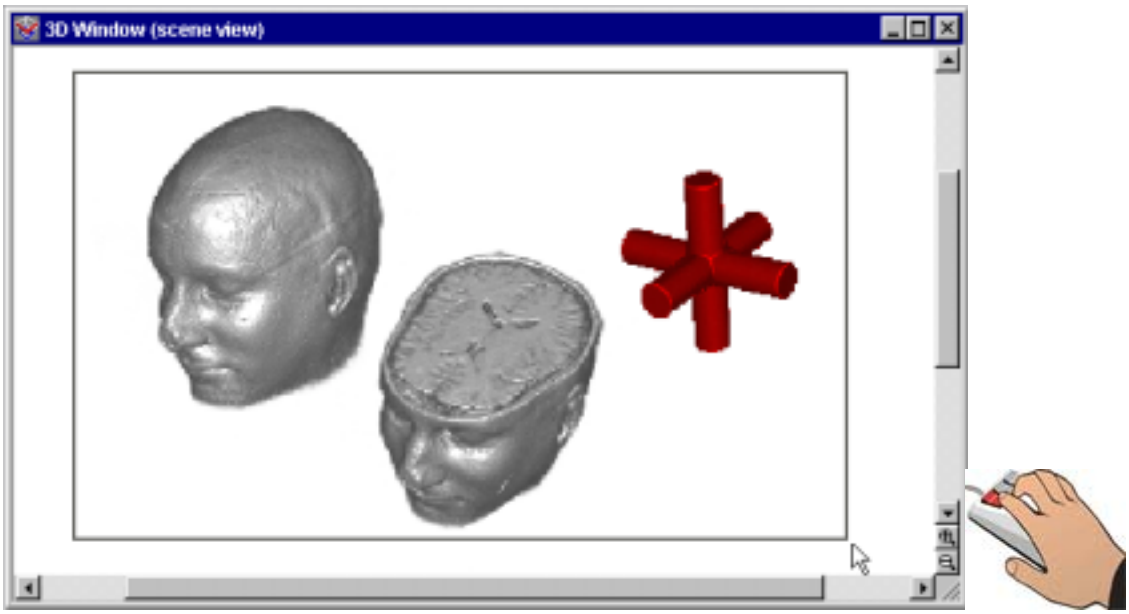


Fig. 8 Select several objects by dragging a frame over the objects while the left mouse button is pressed.

To select more than one object (but not **all** objects of the scene), keep the **Ctrl** key pressed while clicking the objects to be selected. A bounding box will appear around the selected, active objects. To deselect an object, press the **Ctrl** key and click the selected object. The bounding box will then disappear.

For different actions such as positioning, rotating, clipping, or scaling, the bounding boxes around the objects will be displayed in different colors (see table below). These bounding boxes also include **active areas**. The mouse cursor has to be moved into an active area before an action

can be applied to the object. In positioning, rotation, and clipplane mode, the whole bounding box is the active area. In clipbox mode (see figure below) or scale mode, squared handles on each side of the bounding box indicate the active areas.

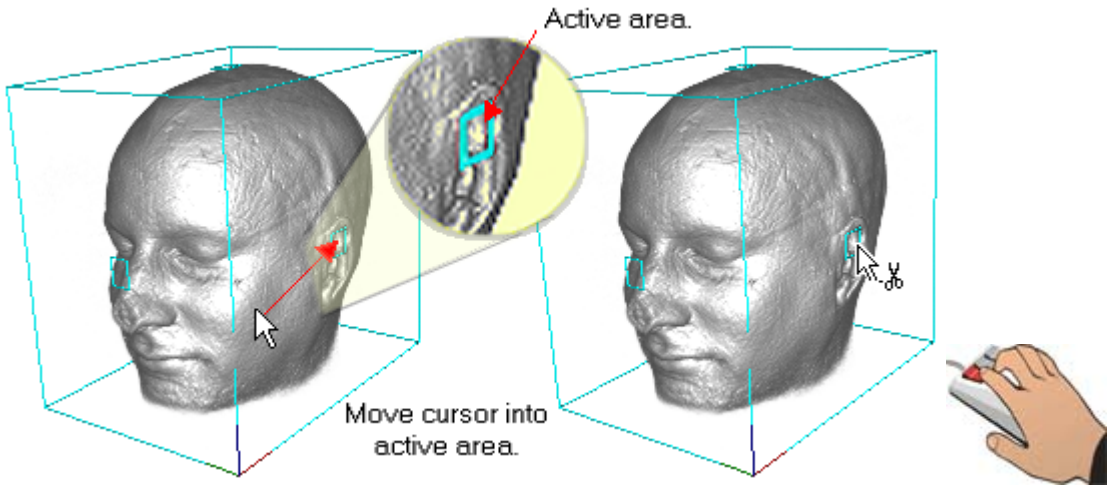


Fig. 9 Move the cursor into the active area to perform an action.

The mouse cursor will change as soon as the mouse is moved into an active area, which indicates that an action can now be performed. The following table shows the colors of the bounding boxes and the shape of the cursor when a certain mode is selected.

Action	**Color of bounding box**	**Default cursor**	**Cursor on active area**
Positioning	green		
Rotate	red		
Clipbox / Clipplane	cyan		
Scale	blue		

VGStudio MAX 1.0 Magellan® / SPACE MOUSE support

VGStudio MAX 1.0 is designed to work with the LogiCad Inc./GmbH Magellan® / SPACE MOUSE. To use VGStudio MAX 1.0 in combination with a LogiCad Spacemouse start the Space Mouse driver before starting VGStudio MAX 1.0.

The Space Mouse may be used to steer the six degrees of freedom of the currently selected ob-

Fig. 10 The Space Mouse

ject. The Magellan® / SPACE MOUSE allows you to control "flying objects" spatially without strain.

Information on the LogiCad Inc./GmbH Magellan® / SPACE MOUSE can be found under the internet address http://www.spacemouse.com.

3.2 First Steps with VGStudio MAX

This section will explain your first steps when using VGStudio MAX and will guide you through the most important steps of the program. A data set of a human jaw which was scanned with a CT scanner is used to show some of the basic functions of VGStudio MAX. This chapter will not go into detail, i.e. describe all the options and alternatives available. Each tool introduced in this chapter will be described in more detail in the following chapters.

Reminder: Some of the settings discussed here will only be valid for CT data!

Start the VGStudio MAX application. An empty scene will be displayed, i.e. the slice windows and the 3D window will be empty. Select the **Open** command in the **File** menu**.** In the **Open info file** dialog select the file **jaw.vgi** within the subdirectory "medical" by clicking it and pressing **Open** or by simply double-clicking the file. The file extension .vgi stands for **V**olume **G**raphics **I**nfo file. The data is loaded into VGStudio MAX and images will appear in the four windows of the workspace as shown below.

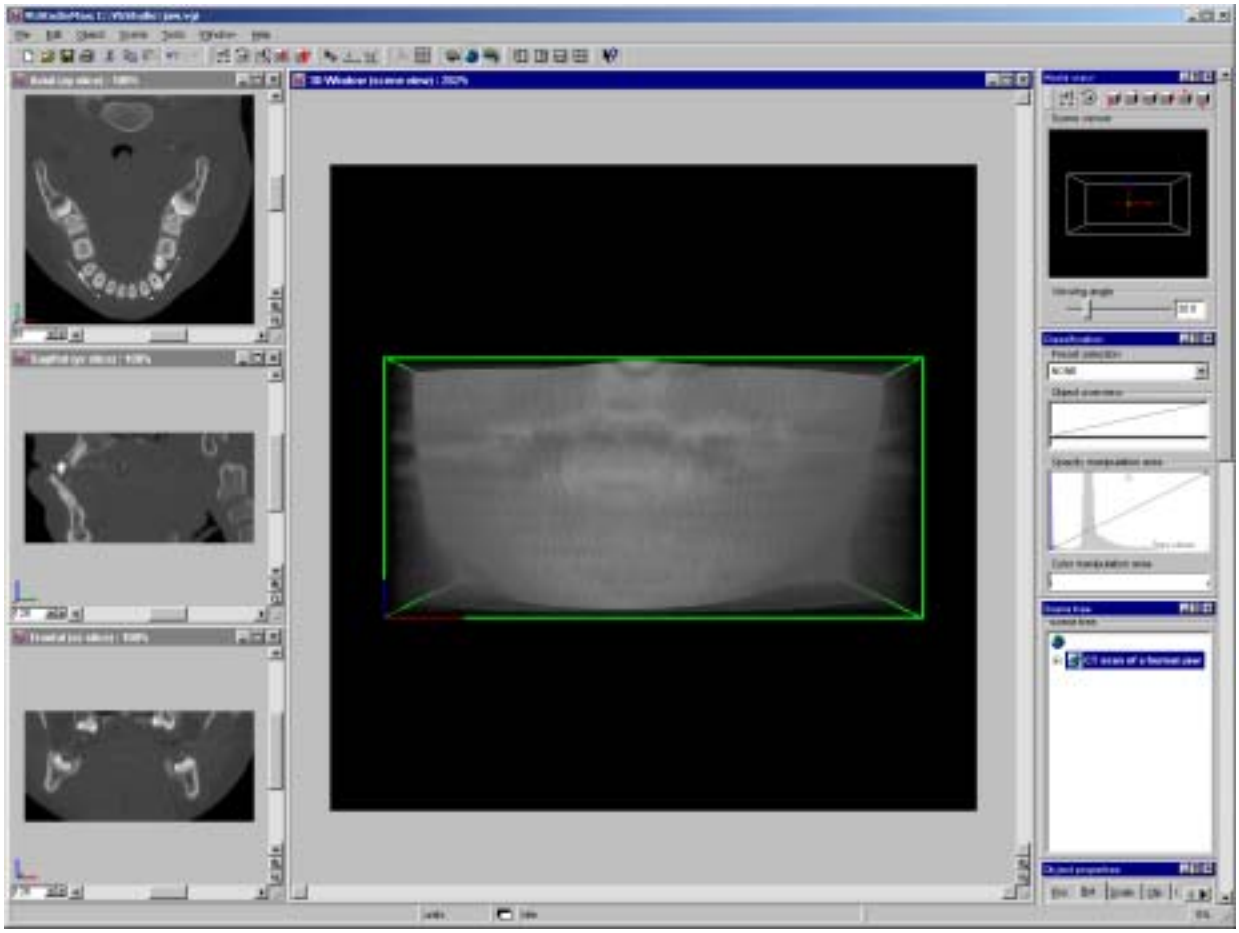


Fig. 11 The VGStudio MAX screen after a file has been loaded. Here, the Move mode is activated, which is indicated by the green bounding box.

The jaw data set is loaded into the scene. Around the jaw, a green bounding box will appear. The green box indicates that the object is the currently selected object and that the **Move** mode is activated. An action can be applied to the selected object only. **Click** with the left mouse button into the 3D view window outside the green bounding box to deselect the object. The bounding box will disappear. Click the jaw again to select the object. The green bounding box will reappear. Now move the object by clicking into the green bounding box with the left mouse button and dragging the mouse while the left mouse button is pressed.

To activate the **Rotate** mode, press the **Rotate** icon in the icon bar.

The bounding box around the jaw will appear now in red color, which indicates that the **Rotate** mode is active. Rotate the jaw by clicking into the red bounding box with the left mouse button and dragging the mouse while the left mouse button is pressed. The jaw can be rotated in any direction.

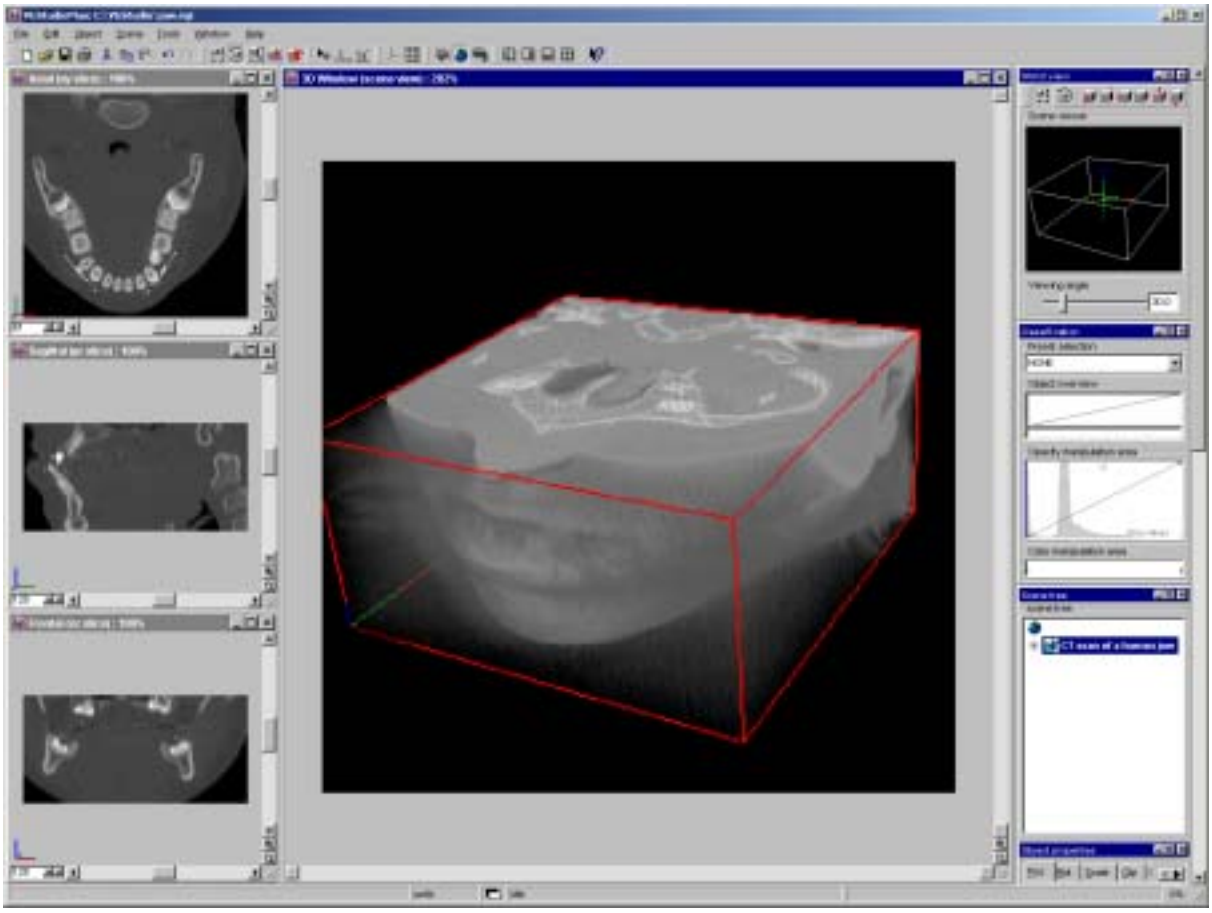


Fig. 12 The red bounding box indicates that the Rotate mode is active. Rotate the image by clicking into the bounding box and dragging the mouse while the left mouse button is pressed.

One of the most powerful tools of volume graphics is the possibility to map any gray value of the original data to any arbitrary opacity. This functionality is handled by the **Classification** tool.

In the main part of the **Classification** tool you find the **Opacity manipulation area**. It shows a function which maps any gray value (abscissa) to any opacity value (ordinate). It also shows a histogram of the frequency of occurrence of the different gray values in the background. The gray values are applied to the abscissa of the plot, the opacity values are applied to the ordinate. The line running from the lower left corner to the upper right corner is the default opacity function running from dark transparent voxels to bright opaque voxels. An arbitrary function may be applied to the data by inserting new handles to the function and moving these handles.

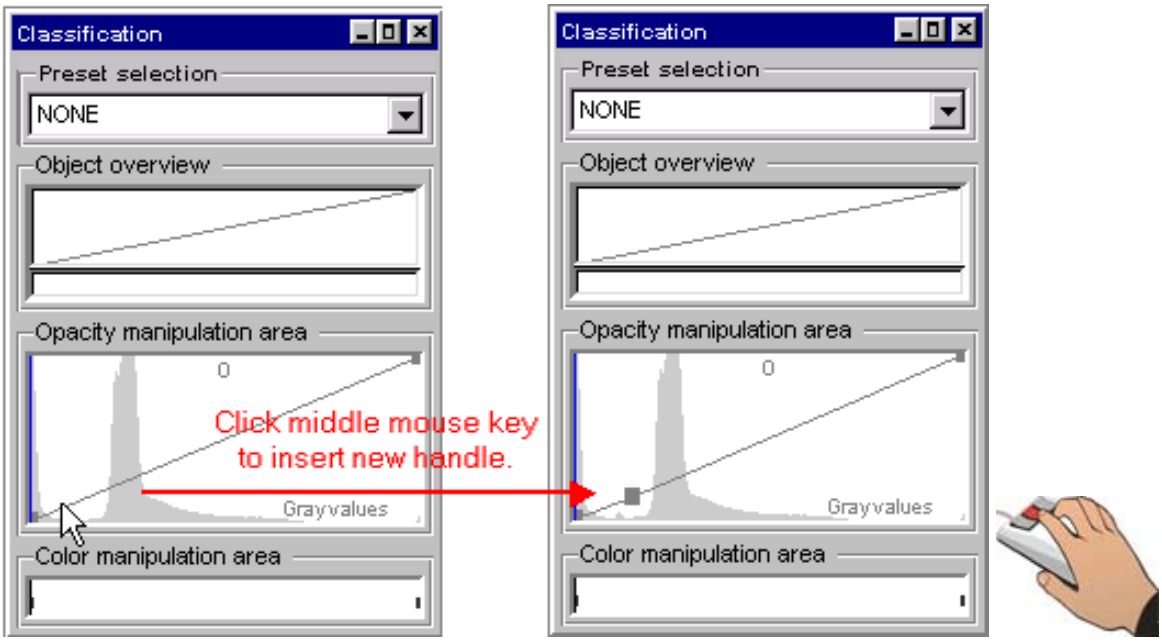


Fig. 13 To insert a new handle or to remove an existing handle in the Opacity manipulation area, click the desired position with the middle mouse button.

To manipulate the opacity function place the mouse into the **Classification** tool's **Opacity manipulation area** as shown above. Click the middle mouse button (or the left mouse button while the **Alt** key is pressed) to insert a new handle or remove an existing handle on the opacity function's line. Click the new handle with the left mouse button and drag it down to zero opacity. The opacity function should now look like the following example:

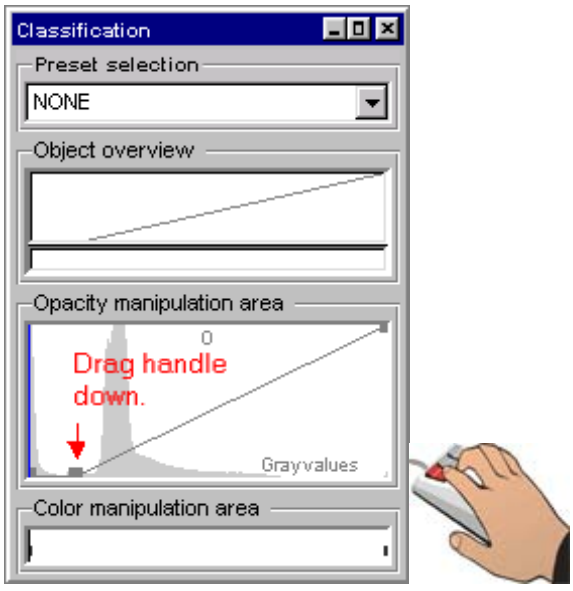


Fig. 14 The opacity function after a new handle has been inserted.

The resulting 3D image will appear much clearer since all the noise included in the lowest (the left side) gray values is now set to zero opacity and is therefore invisible. The 3D image is rendered even faster since most of the transparent data is removed. Se also *Chapter 3.3 Image Quality versus Rendering Speed.*

For another step grab the new opacity handle by clicking it with the left mouse button and drag it to the right while the left mouse button is pressed. Keep the handle on the base line, zero opacity, as shown in the following example. Drag it to the right-hand side of the gray peak displayed in the histogram of the **Opacity manipulation area.**

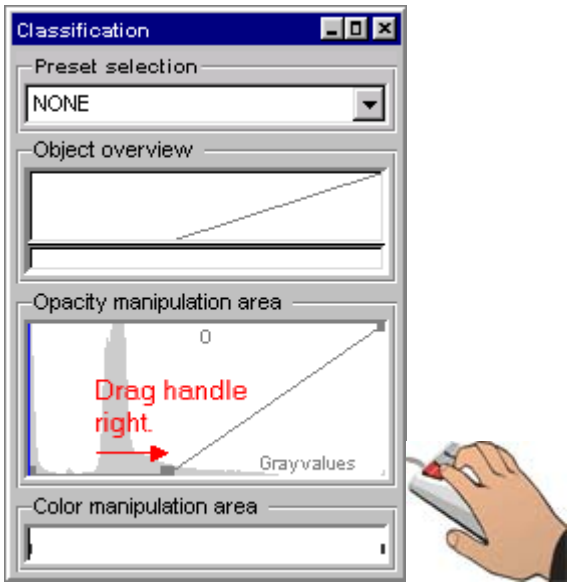


Fig. 15 Drag the new handle to the right to make soft tissue invisible in the 3D image.

The resulting 3D image should look like it is shown in the following figure. Only the bone structure, the teeth, and the braces are visible, the noise/air and the soft tissue are invisible.

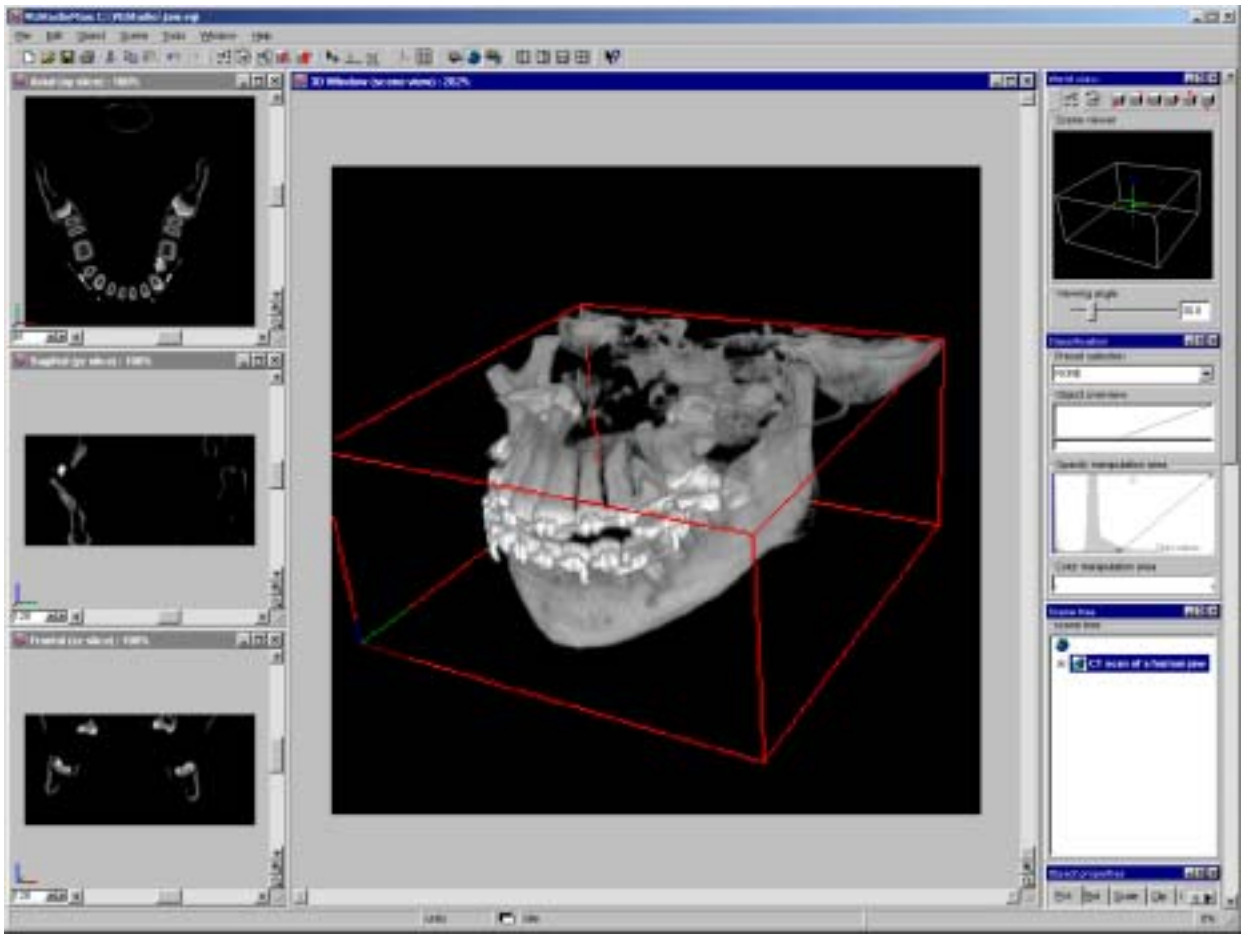


Fig. 16 The 3D image after noise/air and soft tissue have been removed. Only the bone structures, the teeth and metal parts are now visible.

The reason for this is explained in the following picture.

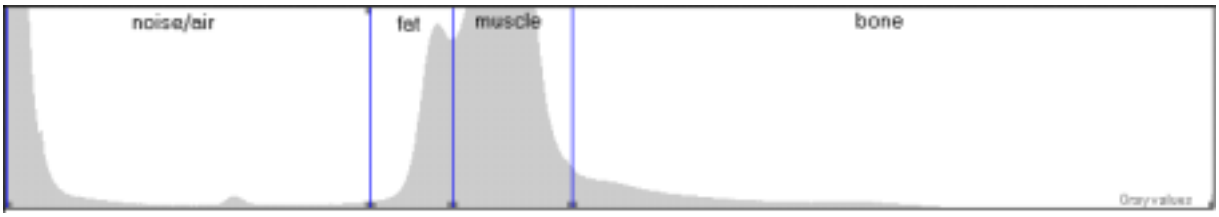


Fig. 17 From left to right, the gray values of the different structures are displayed, i.e. noise/air, fat, muscle, and bone structures.

Noise and air will appear on the left-hand side of the **Opacity manipulation area**. The next tissues which appear towards brighter gray values are fat and muscles. The brightest tissue is the bone structure, teeth and metal braces which appear on the right-hand side of the **Opacity manipulation area**. If all the gray values of tissues such as air/noise, fat and muscle are set to zero opacity, only the bone structure, teeth, and metal will remain visible.

To enhance the 3D perception of the image activate the **Shadow light source**.

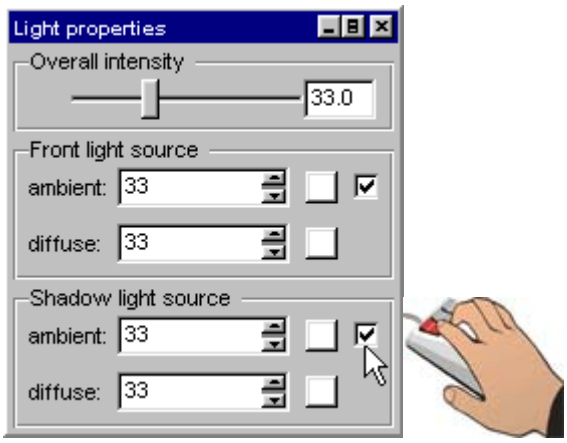


Fig. 18 The Light properties dialog.

To activate the shadow light source click the checkbox in the **Shadow light source** section of the **Light properties** dialog.

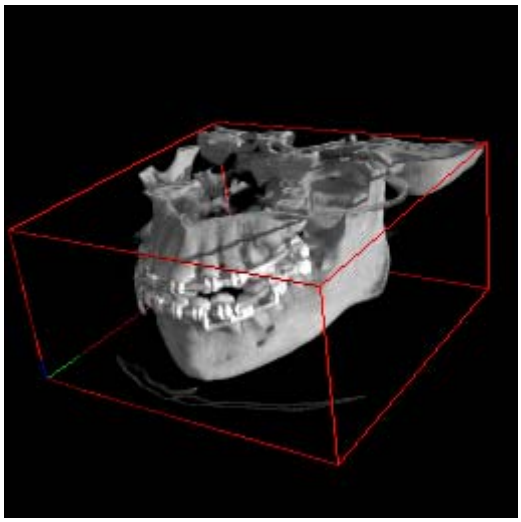


Fig. 19 The 3D image after having activated the Shadow light source.

The jaw will now appear with realistic shadowing.

Another very powerful function of the **Classification** tool is the gray value segmentation. To demonstrate this feature we will first reset the **Classification** tool. To do so click into the **Object** overview section with the right mouse button and click **Delete all segments** as shown in the following figure.

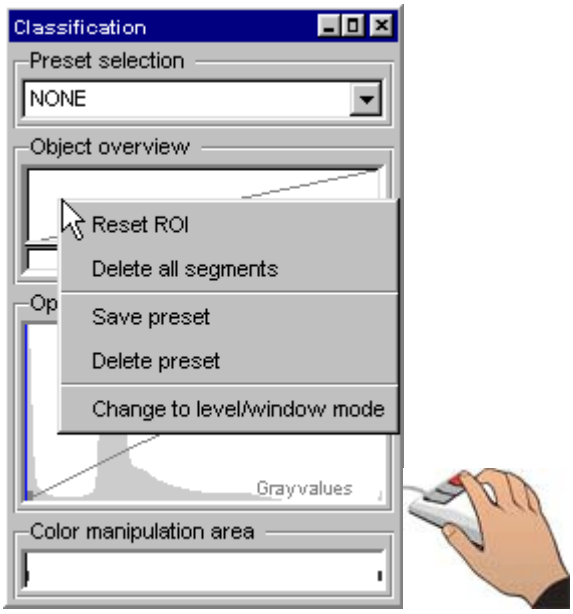


Fig. 20 Click Delete all segments to reset the Classification tool to its default values.

Then move the mouse cursor to the right border of the **Opacity manipulation** area.

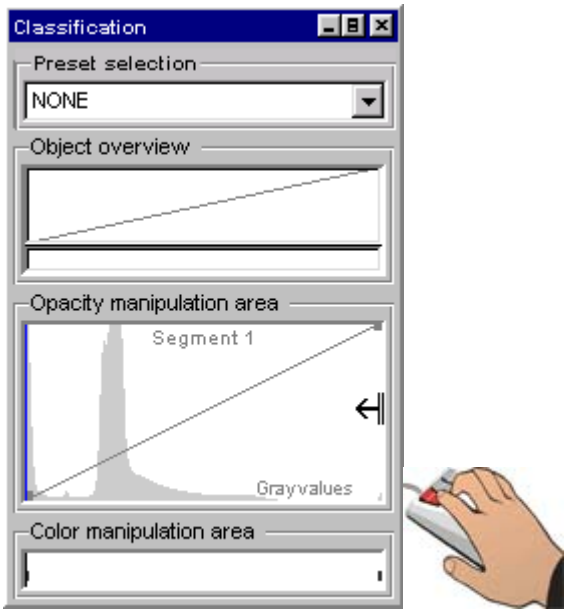


Fig. 21 For gray value segmentation, move the cursor to the right side of the Opacity manipulation area and drag the blue line.

The shape of the cursor will change as shown in the figure above. Drag the blue line which appears on the left-hand side of the **Opacity manipulation area** while keeping the left mouse button pressed. The gray values to the left and right of the blue line will be displayed while dragging the line. Drag the line to a gray value between 1300 and 1400. You can always move the line by dragging it to the left or right while keeping the left mouse button pressed.

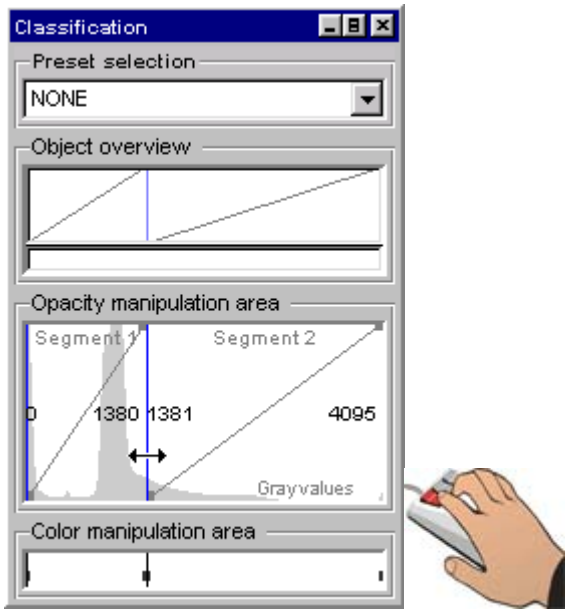


Fig. 22 The blue line marks the border between two gray value segments.

The blue line will mark the border between two gray value segments. Two segments have been created. The left segment includes the noise/air, fat, and muscle gray values, the right segment includes the bone structure and metal objects. To reduce the noise, add a new handle in the left segment as you did before by using the middle mouse button. The classification tool should now look like the following figure.

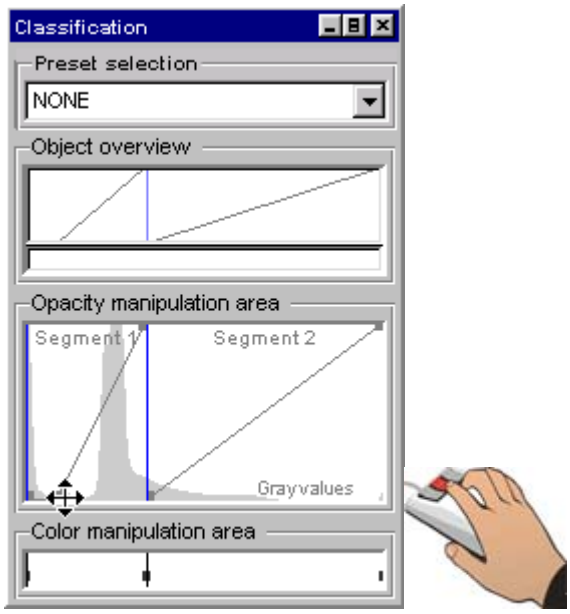


Fig. 23 Reduce the noise by inserting a new handle and dragging it down to zero position.

Click with the right mouse button into the left segment's section of the **Color manipulation area**. The following menu will pop up.

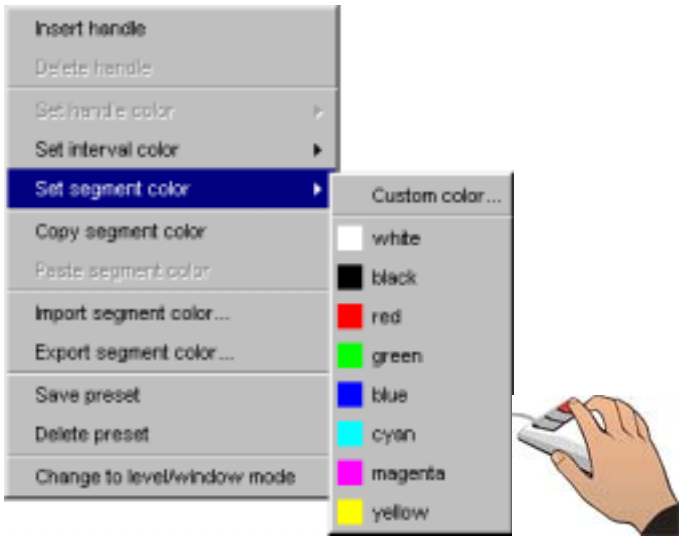


Fig. 24 Select a color for the different segments.

Click **Set segment color** and select a color for the left segment, the soft tissue, by clicking one of the default colors or using the **Custom color** option to select a user-defined color. After you have done so, the **Classification** tool will look as follows.

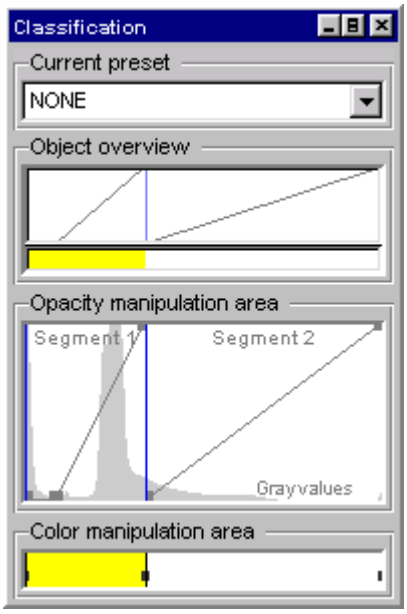


Fig. 25 The Classification tool after you have selected a color for the segments.

The jaw in the 3D image will then look like in the figure below. Soft tissue is displayed in yellow, the bone tissue in white.

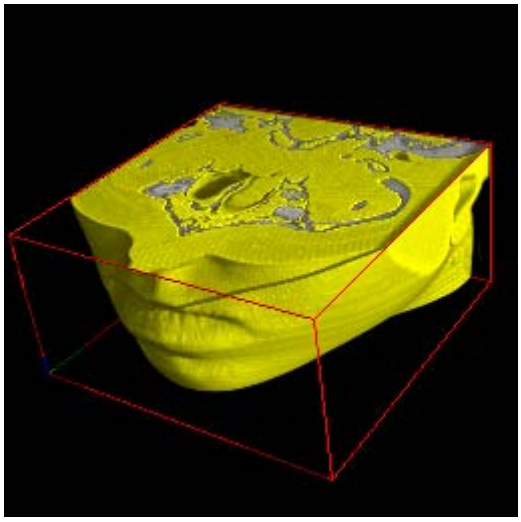


Fig. 26 The 3D image after a color has been assigned to one of the segments.

The gray value segmentation allows to set up independent gray value ranges where opacity and color can be customized without affecting other segments. A single segment may, for example, be extracted (see *Chapter 4.6.1 Classification Tool*), disabled, or enabled by clicking with the right mouse button into segment 1 shown in the **Opacity manipulation area**. A context menu will then open where you may, for example, select **Disable segment** to disable segment 1.

The next functions explained here are the **Clipbox** and **Clipplane** functions. Rotate the jaw into a position as shown in the following figure.

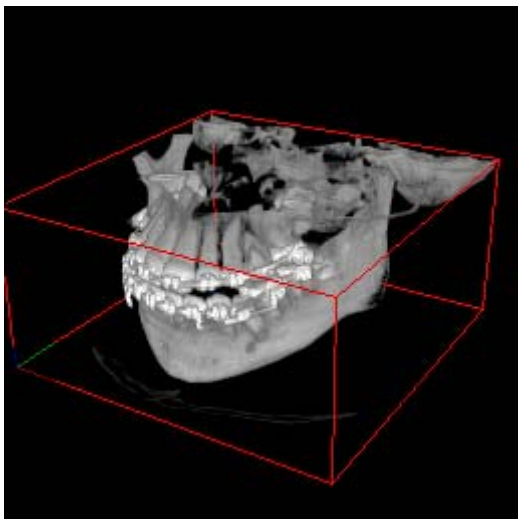


Fig. 27 The 3D image in Rotate mode indicated by the red frame.

Click the **Clipbox** icon in the icon bar.

The **Clipbox** mode is characterized by the cyan bounding box with squared handles, i.e. active areas on each side of the selected object or group of objects. When moving the cursor into the active area, a scissors will appear next to the cursor, as it is shown in the figures below. Clip the object by clicking the active area on one side of the bounding box and dragging the mouse inward while keeping the left mouse button pressed. Please refer also to *Chapter 4.6.7 Object Properties*.

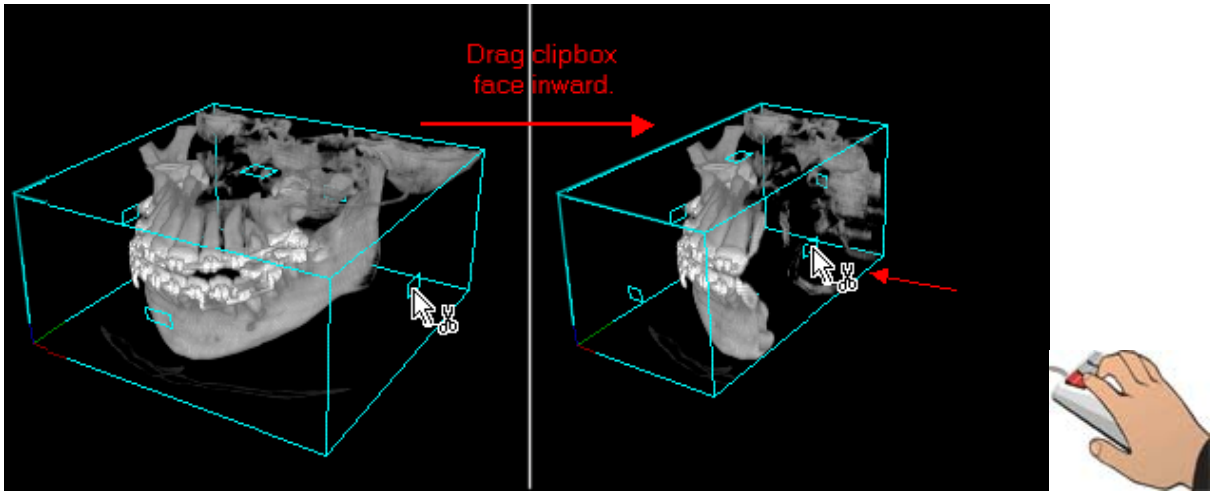


Fig. 28 The 3D window in Clipbox mode indicated by the cyan bounding box and the scissors displayed next to the cursor when moving it into an active area.

Remove the clipping by dragging the handles outward or by clicking the **Undo** button.

Most features included in VGStudio MAX 1.0 can be undone! After you have removed the clipping, the 3D image should look like the following image.

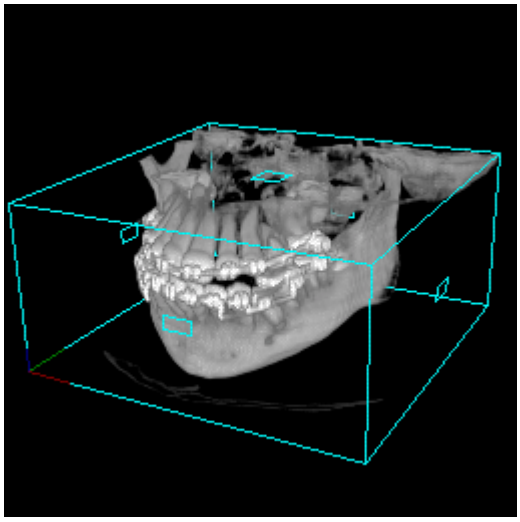


Fig. 29 The 3D view in Clipbox mode after the previous clipping has been undone.

Click the **Clipplane** icon to activate the **Clipplane** mode.

The **Clipplane** mode is characterized by the cyan bounding box with a normal vector on one side of the currently selected object. When moving the cursor into the bounding box, a scissors will appear next to the cursor. The object may be clipped along an arbitrary clipplane by dragging the mouse up and down while the **middle mouse button** (or the **Alt** key and the left mouse button) is pressed. Press the middle mouse button while positioning the mouse inside the active area and drag the mouse down to move the clipplane inward. Drag the mouse inside the active area while keeping the left mouse button pressed to rotate the clipplane in any arbitrary direction.

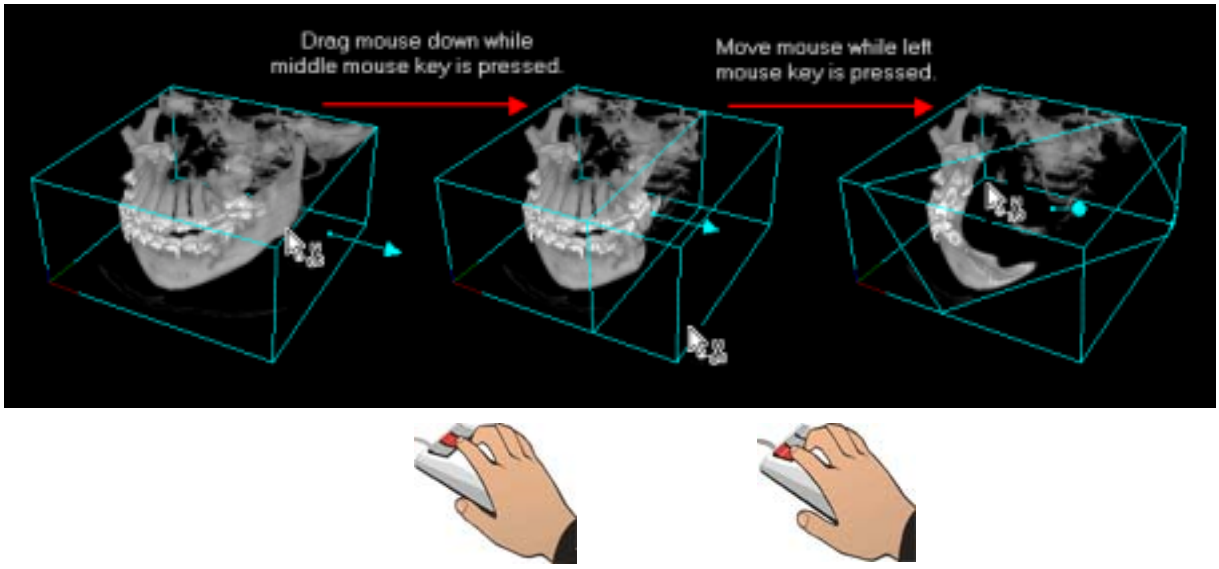


Fig. 30 Move the object along an arbitrary clipplane by dragging the mouse up or down while the middle mouse button is pressed. By dragging the mouse inside the active area while the left mouse button is pressed, the clipplane will be rotated in any arbitrary direction.

You may save your current work at any time by using the **Save** or **Save as** option in the **File** menu. As an example, use the **Save as** option and name the scene **jaw1** (the original file will then not be overwritten). The file extension .vgi (**V**olume **G**raphics **I**nfo file) will be added automatically and therefore has not to be added by you. To reload the current scene, you may use the **Open** option in the **File** menu.

A single image such as the rendered 3D image or one of the slice images may be saved by selecting the appropriate image window and using the **Save image** option in the **File** menu.

3.2.1 Scenes, Scene- & Object-Coordinate-System and Units

All objects loaded into VGStudio MAX will be placed into "**the Scene**". The scene is the virtual space displayed in VGStudio MAX' 3D window. By default, the orientation of the scene coordinate axes will be oriented as shown in the following figure.

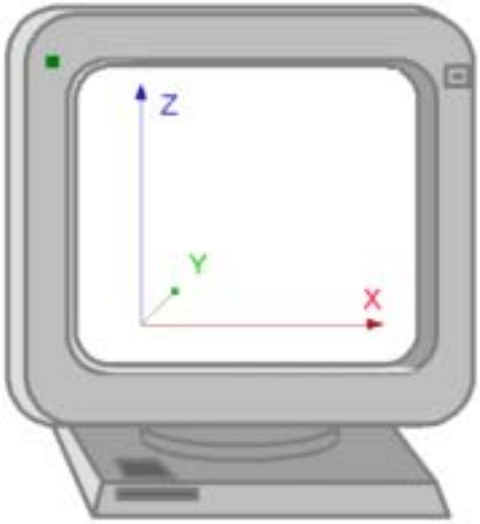


Fig. 31 The VGStudio MAX scene coordinate system.

The coordinate system used by VGStudio MAX is right-handed, with the coordinate origin in the lower left corner. The coordinate origin is on the left side of a body (x), at the front (y), and at the feet (z). By default, the positive x-direction in the scene runs from left to right. The positive y-direction in the scene runs from the front to the back of the screen plane. The positive z-direction in the scene runs from the bottom upwards. However, these orientations represent the default settings. The whole scene may be rotated or moved with help of the **World view** tool. All axes or planes orthogonal to the axes in VGStudio MAX have a consistent color coding. The x-axis and planes orthogonal to the x-axis are displayed in red, the y-axis and planes orthogonal to the y-axis in green, and the z-axis and planes orthogonal to the z-axis in blue. For easy identification, all sections in the windows of the tool box related to the coordinate axes are also marked according to this color scheme.

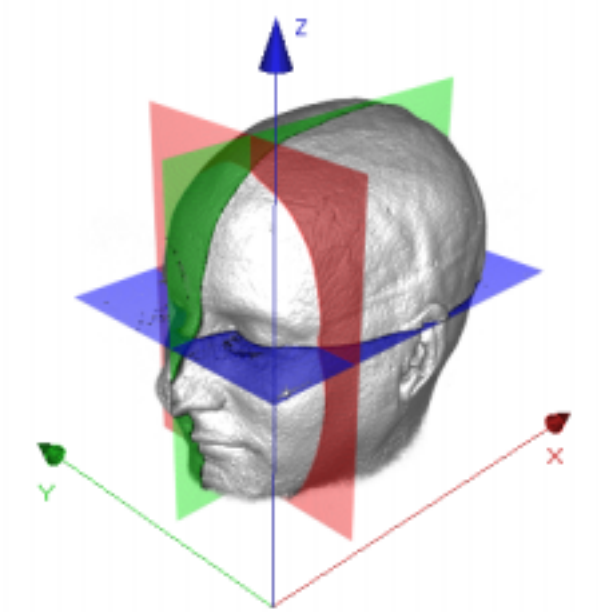


Fig. 32 Color coding of axes and orthogonal planes.

An object loaded into a scene will be placed in the scene's origin (0,0,0) with its center, not with its origin. Each object loaded into the scene has its own inherent coordinate system. The origin of a voxel objects coordinate system is located at the voxel at position (0,0,0) as shown in Fig. 33. An object may be moved or rotated arbitrarily within the scene as shown in the following example:

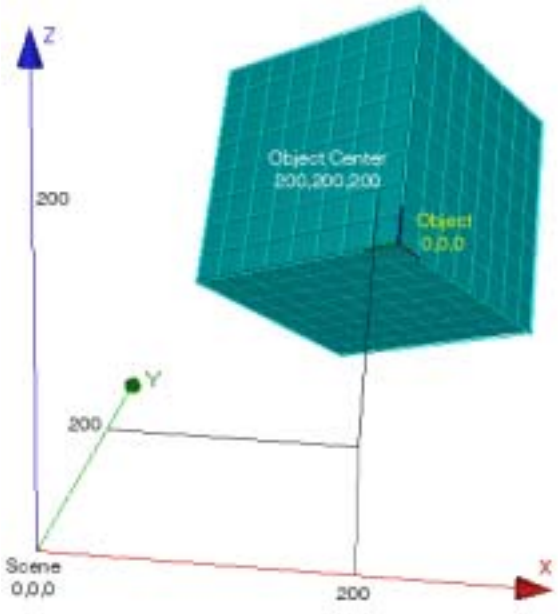


Fig. 33 An arbitrarily rotated object is moved to scene position 200,200,200.

This means that the object coordinate system of an object may differ from the scene coordinate system. Several tools within VGStudio MAX provide information in object coordinates, e.g. the Clip section in the object properties tool showing the depth of the clipping plane within the ob-

ject, while other tools display scene coordinates like the Position section in the object properties tool showing the absolute position of the object within the scene.

Each object loaded into VGStudio MAX has an inherent resolution, this means for voxel objects that a voxel has a defined x-, y- and z-resolution. This resolution as well as the measurement unit are normally applied during the import process to each object. By this VGStudio MAX supports the processing of an arbitrary number of objects with different inherent voxel resolutions. The correct relative scaling of the objects is handled by VGStudio MAX.

Reminder: VGStudio MAX does sopport only a limited dynamic in object scaling for objects loaded at the same time. Loading an object with a voxel resolution of several µm and another object with a voxel resolution of several m may result in enormous memory consumption or even to fatal errors!

The measure unit used for measurement and positioning tasks within VGStudio MAX is defined application wide. The current measurement unit applied can be seen in the VGStudio MAX status bar. The application wide unit is defined normally through the unit applied to the objects loaded into VGStudio MAX. The word "unit" is displayed in the status bar if no unit is applied. All numbers displayed representing measurement and positioning numbers are displayed in virtual "voxel" units in that case.

3.2.2 Voxel and Polygon Objects

VGStudio MAX is able to handle and render objects or data sets in voxel and polygonal representation. In traditional 3D graphics (polygon graphics), objects are represented as mathematical models. Surfaces are subdivided into many small triangles or polygons, which are assigned colors, textures, and levels of transparency or opacity.

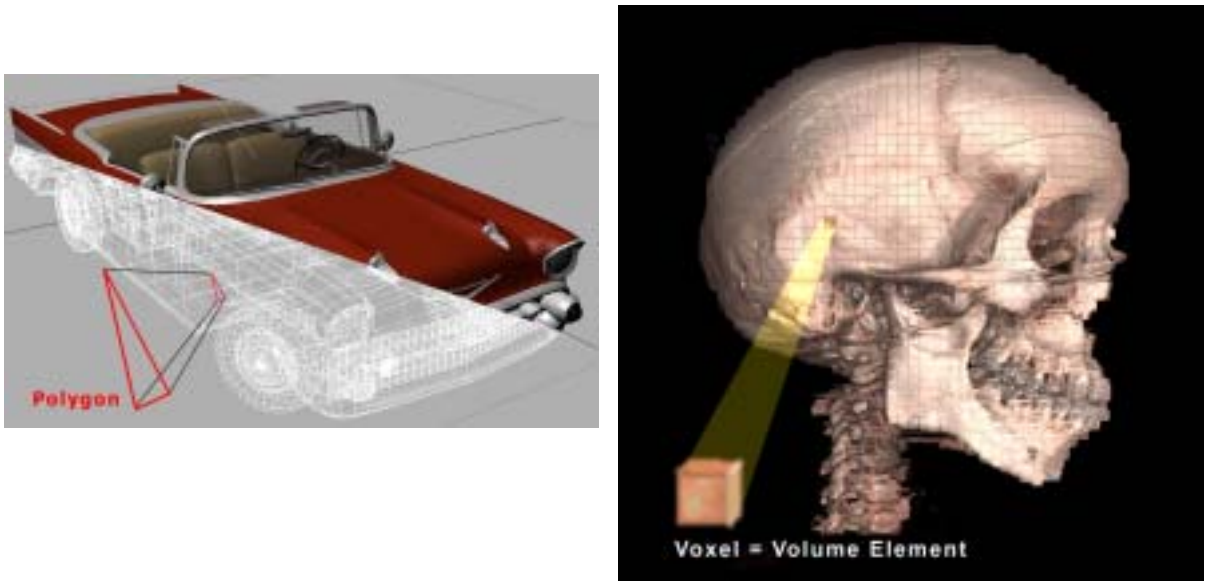


Fig. 34 Objects in polygonal representation (left) and voxel representation (right).

Volume graphics is a sub-specialty of 3D computer graphics. It deals with the discrete representation and visualization of objects represented as sampled data in three or more dimensions. A volume/voxel data set is a three-dimensional array of voxels. The term *voxel* is used to characterize a volume element; it is a generalization of the notion of *pixel* that stands for a picture element. A volume data set usually contains values that have been obtained by some type of 3D scanning or sampling device or by a simulation process. Typical sampling devices are x-ray, CAT, MNR, PET, SPECT, and Confocal Laser microscopy. Each voxel consists of a position and a value. The voxel position is a three-tuple that specifies a position within the three-dimensional voxel array. The origin of the volume data set is considered to be the center of the first voxel (i.e., the voxel with coordinates (0,0,0)). The first coordinate of the voxel position represents the column, the second coordinate represents the row, and the third coordinate represents the image (or slice).

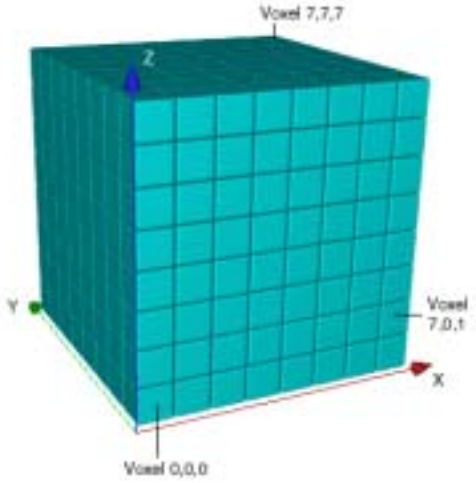


Fig. 35 A schematic Voxel data set.

Columns, rows, and images are numbered starting from 0. The voxel in the 8th column, 1st row, and 2nd image would then have the position (7,0,1).

3.2.3 Data Sets, Sections and Segments

A typical voxel data set includes several millions voxels with different gray values within a specific gray value range. We will use a data set of a MRI scan of a human head (Fig. 36).

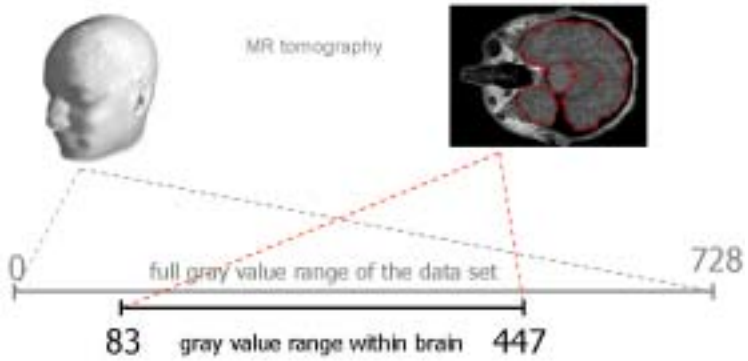


Fig. 36 Data ranges within a voxel data set.

The gray values within the MRI scan range from 0 to 728. Different tissues within the data set appear with different gray values within the data set. However we can not always separate a certain tissue or structure within the data set by just specifying a gray value range. E.g. the gray value within the brain in our example range from 83 to 447 but other tissues within the data set e.g. parts of the muscles and skin have gray values within the same gray value range. This means it is not possible to get a visualization of the brain tissue only by defining a simple gray value range, in other words by a gray value classification. For these cases VGStudio MAX 1.0 includes powerful segmentation tools allowing manual or semi automated definition of structures within the data set according their morphological properties. In our MRI data set example VGStudio MAX' segmentation where used to classify the brain tissue by creating a 3D selection of all Voxels belonging to the brain. The result of such a morphological classification is called a Section. The MRI data set in our MRI example will now include two sections: section (1) which includes all voxels representing the brain and section (0) including all the remaining voxels. The tissue within the brain can further be classified into the white and the gray brain mass.

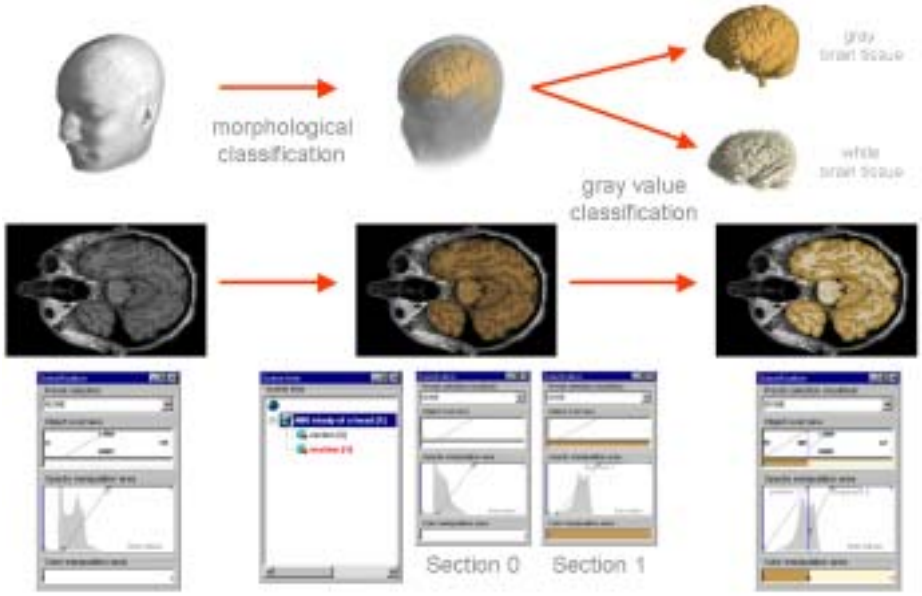


Fig. 37 MRI data set with brain section and brain tissue gray value classification.

In this case the two tissues can easily be separated by a gray value classification since these two tissues appear clearly within two separate gray value ranges and there are no other tissues within this section of the data set. (see Fig. 37). This leads us to the principle data hierarchy supported by VGStudio MAX 1.0: VGStudio MAX 1.0 allows to handle an arbitrary number of data sets at the same time. A data set can be divided into an arbitrary number of sections (morphological classification). Each section can be divided into several segments (gray value classification) (see Fig. 38).

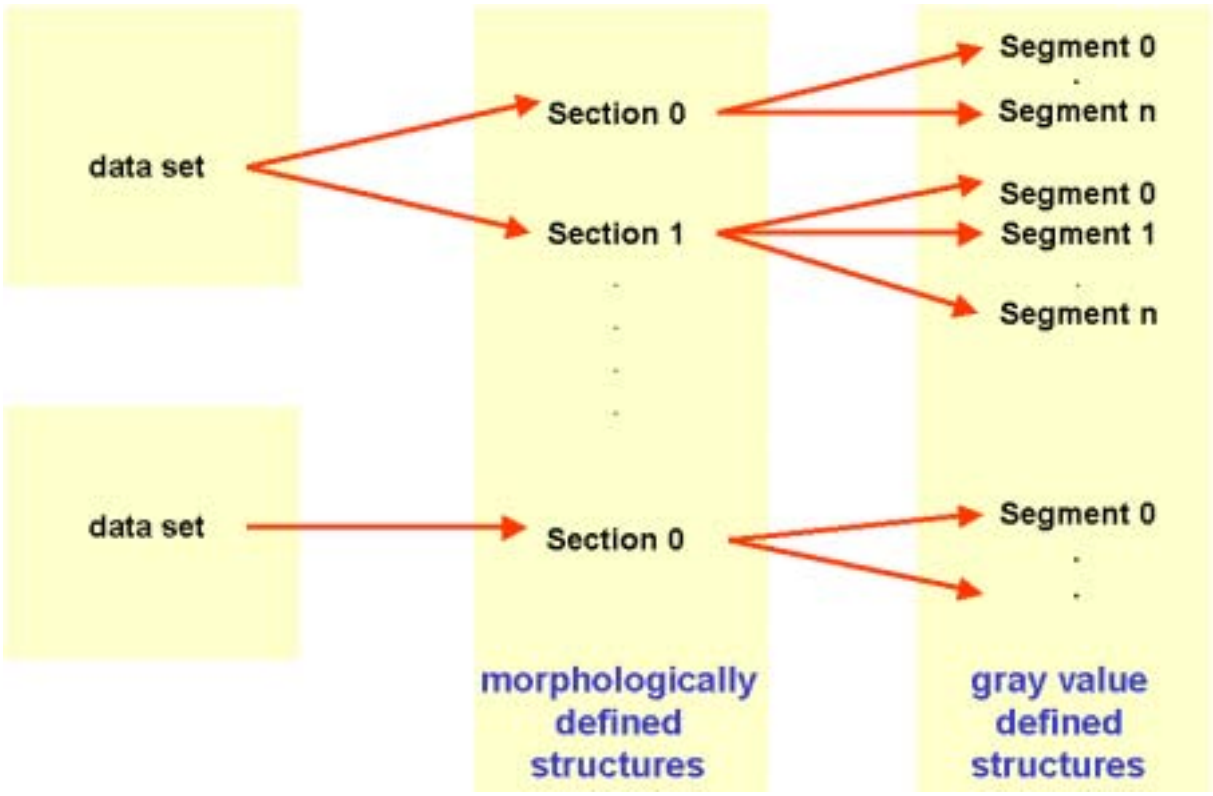


Fig. 38 Data hierarchy.

Sections are created and manipulated by the Segmentation tool (for more information on the **Segmentation tool**, please refer to *Chapter 4.6.10 Segmentation*) as well as the Scene tree tool (for more information on the **Scene Tree tool**, please refer to *Chapter4.6.2 Scene Tree*) which allows to select, delete and merge sections. Segments are created and handled by the Classification tool (for more information on the **Classification tool**, please refer to *Chapter 4.6.1* Classification Tool).

3.2.4 The Illumination Model

VGStudio MAX supports an illumination of the scene by two light sources with parallel light. You may adjust the light settings in the **Light properties** dialog (for more information on the **Light properties** tool, please refer to *Chapter 4.6.4*

Light Properties).

The **Front light source** is positioned in 0°, i.e. in the eye of the observer, the **Shadow light source** is positioned in 45°, to the right of the observer. The light sources are located at fixed positions relative to the observer.

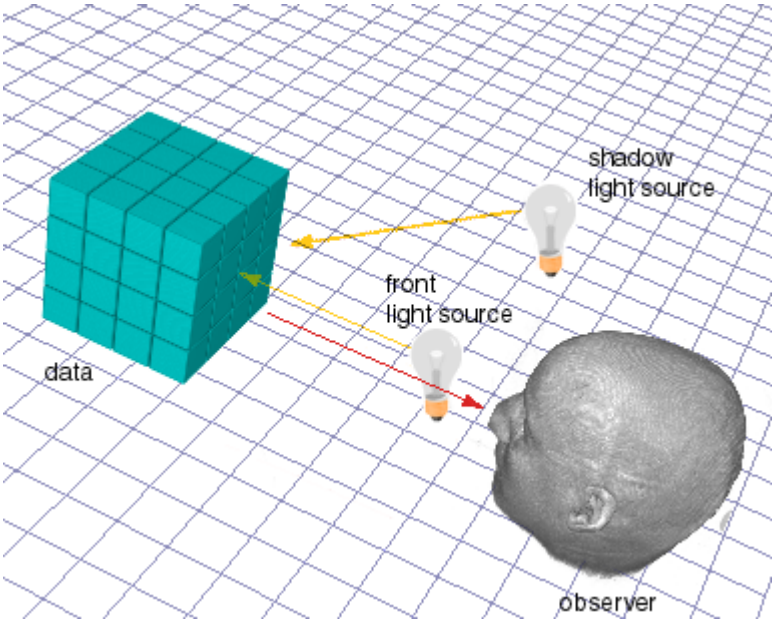


Fig. 39 Usage of the light sources in VGStudio MAX will enhance the 3D perception of an image.

Activating the shadow light source will considerably enhance the 3D perception of an image.

3.2.5 VGStudio MAX Clipboard

VGStudio MAX has its own clipboard and does **NOT** use the standard clipboards of your operating system since these clipboards are not capable to handle the different data used by VGStudio MAX. Due to this you will not be able to use the cut, copy, and paste commands to copy data or images into other applications or from other applications into VGStudio MAX. Use the **Save Image** command to export rendered 3D images or slice images in standard image files.

3.2.6 Exiting VGStudio MAX

To exit VGStudio MAX, click **File** in the menu bar and select **Quit**. If there are any unsaved scenes, VGStudio MAX will ask you whether you want to save them before exiting. You may also exit VGStudio MAX by clicking the **Close Window** button in the upper right corner of the window.

3.3 Image Quality versus Rendering Speed

With every decision you make in VGStudio MAX, you make a trade-off between rendering speed and image quality. As a rule of thumb, the higher the quality of the rendered images, the slower the rendering speed. Additional lights or many semitransparent structures in the image will increase the rendering time.

As you go through the scene creation process, you will probably want to keep the rendering quality low in order to increase the rendering speed.

When you are satisfied with your scene, you may increase the rendering quality to see what the scene looks like in its final form.

Here are some hints on how to adjust parameters in order to achieve optimal settings for performance or quality.

Optimal settings for performance:

- Use the Scatter HQ algorithm,
- use small result image sizes, e.g. 256x256,
- use only front light and disable shadow light source,
- use oversampling factor of 1.0,
- deactivate color rendering,
- use opaque data structures and avoid transparent data.

Optimal settings for image quality:

- Use the Scatter HQ or Scatter + Gradients algorithms,
- use large result image sizes,
- use oversampling factor of 3.0 or more,
- activate color rendering.

4 VGStudio MAX Interface & Tools

This chapter will guide you through the various functions of VGStudio MAX. Before you actually start working with the program, you should familiarize yourself with the various parts of the interface. In this chapter, the following parts of the interface will be explained in detail:

- Menu bar
- Tool bar
- Tool box
- Slice windows
- 3D window
- Status bar

4.1 Basic Concepts of the VGStudio MAX User Interface

4.1.1 2D slices and 3D images

In the past, working with volume or voxel data meant working with stacks of 2D image slices. Radiologists got tenths of images from a CT scanner and viewed them slice by slice along the scan axis to get a 3D impression of the data. Thanks to the upcoming computer technology, radiologists now have the possibility do use MPR (Multi Planar Reconstruction) image slices, which means that they can view image stacks not only along the scan axis but also along all three axes of a voxel data set. VGStudio MAX overcomes the limitations of simple 2D image viewing. It provides full 3D visualization and analysis functionality. In addition, VGStudio MAX supports the MPR technology. The VGStudio MAX user interface includes a 3D view window as well as the 2D image viewing windows with the three orthogonal cross sections axial, frontal, and sagittal.

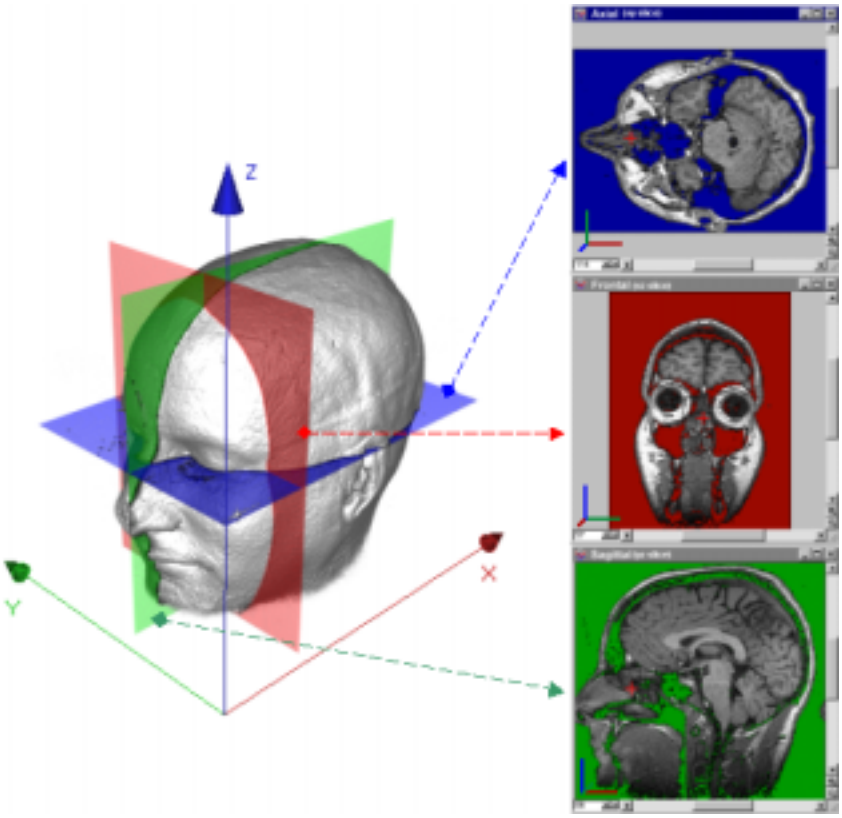


Fig. 40 In addition to the 3D view window, VGStudio MAX also displays 2D image viewing windows with the three orthogonal cross sections axial, frontal, and sagittal.

4.1.2 VGStudio MAX Color Coding

The x-, y-, and z-axes and the planes orthogonal to these axes are coded by a color scheme throughout the whole VGStudio MAX user interface. The x-axis and image planes orthogonal to the x-axis are displayed in red, the y-axis and image planes orthogonal to the y-axis in green, and the z-axis and image planes orthogonal to the z-axis in blue. In the three slice windows, a small colored tripod is displayed in the lower left corner, which shows the orientation of the respective image in the 3D data set. Labels in tools as well as scene axes or grids are displayed in the same colors.

The bounding box of an object includes a colored tripod at voxel position (0,0,0). The axes are colored in the same scheme, i.e. the x-axis is red, the y-axis is green, and the z-axis is blue.

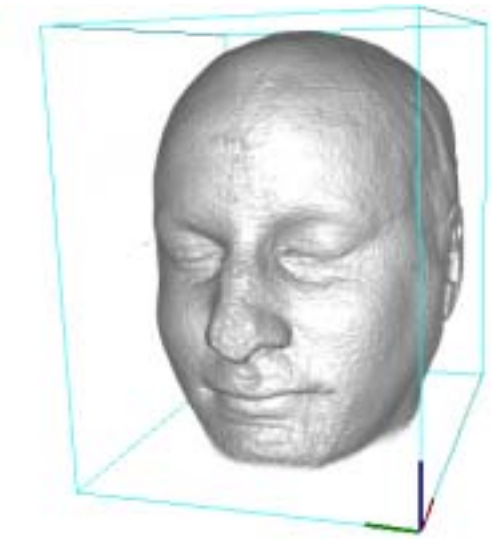


Fig. 41 A tripod colored according to the VGStudio MAX color scheme is displayed at voxel position (0,0,0).

4.1.3 Tool tips

A tool tip will pop up and display the function of an element of the VGStudio MAX user interface when the mouse pointer is placed on an element, e.g. buttons or tools.

Fig. 42 Tool tips will pop up when the mouse pointer rests on an icon.

4.2 Title Bar Elements

Title bar

In the title bar, "VGStudio MAX" and the filename of the current scene are displayed.

Control icon

In the left corner of the title bar you find the **Control** icon, which is used to access the **Control** menu (see following section). Double-clicking the **Control** icon will close VGStudio MAX.

Control menu

You open the **Control** menu by clicking the **Control** icon with the left mouse button. You can use the **Control** menu to position the main window or to exit VGStudio MAX.

Window buttons

The window buttons can be found in the right corner of the title bar. You can use the buttons to position the main window or to exit VGStudio MAX.

4.3 Menu Bar

The **Menu** bar displays VGStudio MAX's menu titles. Each menu lists a group of entries, and with each entry, a specific action is performed.

Menus or menu items that are not available are disabled.

Using the menus

1. You open a menu by clicking it, or by pressing <**Alt**> plus the letter that is underlined in the menu's title. For example, to open the **File** menu, you press <**Alt**> + <**F**>.

2. Once you have opened a menu, you choose a menu item by clicking it, by pressing the underlined letter, or by using the cursor keys to highlight it and then pressing <**Enter**>. Menu items that appear in gray are currently not available.

In the following sections, you will find a description of each of these menus in the order in which they appear in the menu bar.

4.3.1 File Menu

Click **File** to open a pulldown menu containing the following entries:

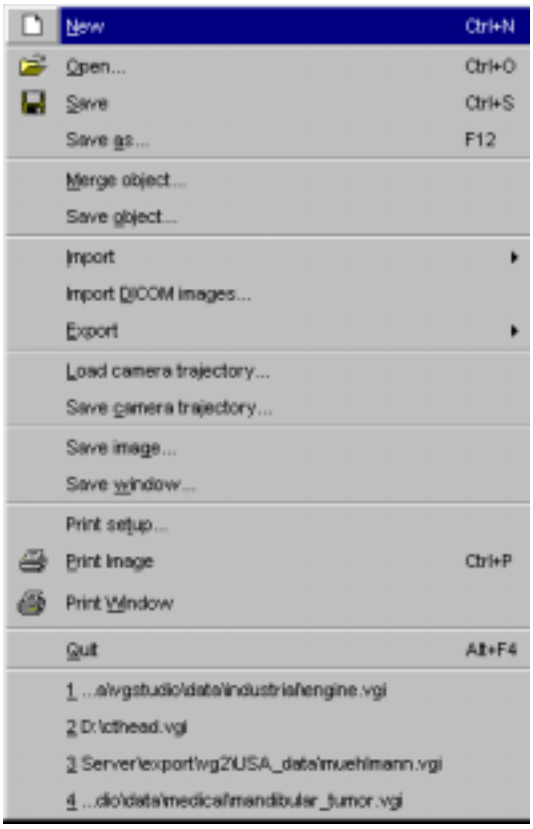


Fig. 43 The File menu

- **New**—Select this command to create a new scene. Note that selecting this entry will close the scene you are currently working on. After you have created a scene, you can save it by using the **Save** command. The scene can be accessed again using the **Open** command. Both commands are described below. You may also use the keyboard shortcut **Ctrl+N** to create a new scene.

- **Open**—Select this command to open an existing scene. You may load Volume Graphics Info files (.vgi extension) as well as old info files (.info extension) by selecting the desired file and clicking **Open** or by simply double-clicking the file in the **Open info file** window. You may also use the keyboard shortcut **Ctrl+O** to open an existing scene.

- **Save—**Select this command to save your work. You should save your work frequently throughout the scene creation process. Saving a scene with **Save** or **Save as** will generate a Volume Graphics Info file (.vgi extension). The *.vgi file includes data-relevant information such as the file name and path, data type, file type, file size, and data mapping as well as scene-relevant information such as light settings, rendering algorithm, or background color. You may also use the keyboard shortcut **Ctrl+S** to save a scene.

- **Save As—**Select this command to save the current scene under a different name. You could use this, for example, to save the current scene to a different drive or to save the changes under a different name, thereby keeping the original scene intact. You may also use the **F12** key on your keyboard to save a scene under a different name.

- **Merge Object—**Select this command to load additional objects into the active scene. To merge objects, select a *.vgi file and click **Open**. If the *.vgi file includes more than one object, a dialog box will open where you may select one or several of the included objects that are to be loaded into the active scene. The scene properties of the active scene, e.g. background color, scene resolution or illumination, will remain unchanged.

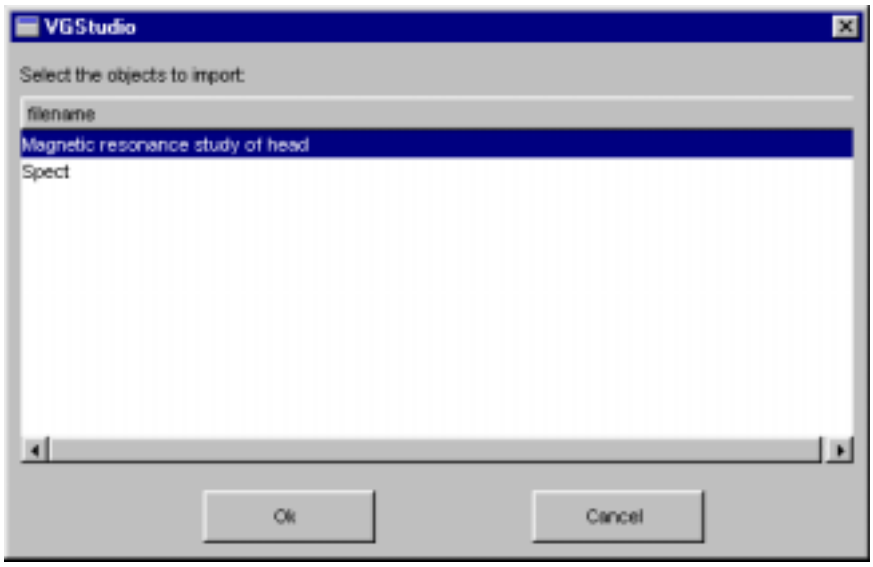


Fig. 44 Select the objects to be imported and click OK.

- **Save Object—**Select this command to save the currently selected object only. The object will be saved in its default settings; no scene-relevant settings such as position, rotation, or clipping will be saved with the object. Only the object's voxel resolution will be saved. Use the **Save** or **Save As** command to save an object with all scene parameters.

- **Import**—Select this command to import objects and data of different data types into VGStudio MAX. VGStudio MAX supports image stacks of TIFF, JPEG, BMP, PPM, DICOM, and RAW Images as well as RAW data volumes (un-/signed 8, 16, 32 bit Integer, 32 bit Floating Point and 32 bit RGBA), HDF volumes, Analyze volumes, and DICOM data. Polygonal data can be imported in OFF file format. For more information on how to import images, please refer to *Chapter 5.1 Importing Data.*

- **Import DICOM images**—Select this command to import DICOM volume data or image files into VGStudio. Use the file dialog to select one or several data files. For more information on how to import images, please refer to *Chapter 5.1.6 Importing DICOM Data.*

- **Export**—Select this command to export the currently selected object. For more information on how to import images, please refer to *Chapter 5.2 Exporting Data.*

- **Load camera trajectory**—Select this command to load a previously saved camera trajectory. For more information on camera trajectories, please refer to *Chapter 4.6.14 Keyframer*. The file format for camera trajectories is *.trj.

- **Save camera trajectory**—Select this command to save the current camera trajectory.

- **Save Image—**Select this command to save a rendered image or a slice image to a file. Supported file formats are TIFF, JPEG, BMP, or PPM. The rendered 3D image or one of the three slice images may be saved. To save an image, select one of the four windows in the workspace by clicking into the image (**View** window, **3D Scene** view, **Camera** view or one of the three slice windows) and then selecting **Save Image** in the **File** menu.

Reminder: The size, width, and height in pixels of a saved image is independent of the applied zoom factor in the 3D or slice windows.

The size of a saved slice image is the original size of the cross section of the volume data set. When saving a slice image, only the cross section of the current volume data set will be saved. No bounding box cross sections or instruments will be saved in the image.

The size of a saved 3D image is the size (width and height) which is adjusted in the **Render properties** tool. When saving a 3D image, the full scene as shown in the 3D window will be saved, including all instruments, active bounding boxes, coordinate axes, or grids. To remove the bounding box of an object use the **Deselect** option in the **Edit** menu.

- **Save Window—**Select this command to save a rendered image or a slice image with all information displayed in a window, e.g. measurement tools to a file. For more information refer to **Save Image**.

- **Print Setup**—Select this command to access the standard print options dialog box.

- **Print Image**—Select this command to print the image within the active window. You may select one of the three slice windows or the 3D window as the active window by clicking the title bar or into one of the windows. You may also use the keyboard shortcut **Ctrl+P** to print the active window.

Reminder: The **Print** option will scale the printed image so that it fits best to the page.

When printing a slice image, only the cross section of the current volume data set will be printed. No bounding box cross sections or instruments will be printed.

When printing a 3D image, the full scene as it is shown in the 3D window will be printed, including all instruments, active bounding boxes, coordinate axes, or grids. To remove the bounding box of an object use the **Deselect** option in the **Edit** menu.

- **Print Window**—Select this command to print the active window with all information displayed in a window, e.g. measurement ttols.. For more information refer to **Print Image**.

- **Quit**—Select this command to exit VGStudio MAX. Note that if there is an open scene that you have not yet saved, VGStudio MAX will ask you whether you want to save your changes prior to exiting. You may also use the keyboard shortcut **Alt+F4** to exit VGStudio MAX.

- List of the last four edited scenes.

4.3.2 Edit Menu

Click **Edit** to open a pulldown menu containing the following entries:

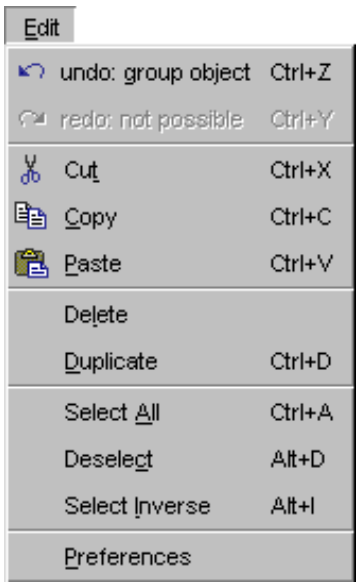


Fig. 45 The Edit menu.

- **Undo**—Select this command to undo your previous action. This menu item changes depending on the action you last performed. For instance, if you have pasted an object into your scene, the text reads **undo: paste object** and the object will be removed from the scene when you select this command. You may also use the keyboard shortcut **Ctrl+Z** to undo your last command. You may undo the last 100 actions and commands. Only one exception will destroy the undo history.

Reminder: The undo history will be **destroyed** in a few cases, e.g. when modifying a data set by segmentation or when deleting an object. You have to select the undo command **immediately** after having modified or deleted the object.

- **Redo**—Select this command to redo your previous **Undo** action. This menu item changes depending on the **Undo** action you last performed. For instance, if you have undone the pasting of an object, the text reads **redo: paste object** and the object will be pasted into the scene again when you select this command. You may also use the keyboard shortcut **Ctrl+Y** to redo your last **Undo** command.

- **Cut**—Select this command to cut objects within a scene in VGStudio MAX. The cut objects will remain in the VGStudio MAX clipboard. When you cut objects, you cut all related information such as opacity and color along with whatever you cut. Note that VGStudio MAX objects cannot be pasted into another program. You may also use the keyboard shortcut **Ctrl+X** to cut objects.

- **Copy**—Select this command to copy selected objects into the VGStudio MAX clipboard. When you copy objects, you copy all related information such as opacity and color along with whatever you copy. Note that VGStudio MAX objects cannot be copied into another program. You may also use the keyboard shortcut **Ctrl+C** to copy objects.

- **Paste**—Select this command to paste previously copied or cut objects into a scene. You may also use the keyboard shortcut **Ctrl+V** to paste objects.

- **Delete**—Select this command to delete any selected object in the scene. Note that you can undo this action by using the **Undo** command explained above. You must, however, undo your action **immediately** after having deleted the object. You may also use the **Del** key to delete an object.

- **Duplicate**—The **Duplicate** option is the fastest possibility to generate and use a copy of an object. You may also use the keyboard shortcut **Ctrl+D** to duplicate objects. In contrast to the **Copy** and **Paste** command the duplicate command does not use the clipboard. The copied object will be placed directly into the scene where it can be used immediately. When duplicating an object, VGStudio MAX places the object directly above the original object. The relative position will be used as default offset. If the new object is moved, its offset to the original object is used as offset for every new duplication process. This procedure is called smart duplicate.

Reminder: The offset adjusted during a smart duplicate will be set to its default value (zero) as soon as the duplicated object is deselected or another object is selected.

- **Select All**—Select this command to select all objects in the scene. You may also use the keyboard shortcut **Ctrl+A** to select all objects.

- **Deselect**—Select this command to deselect all selected objects in the scene. You may also use the keyboard shortcut **Alt+D** to deselect all objects.

- **Select Inverse**—Select this command to invert the active objects in the scene. You may also use the keyboard shortcut **Alt+I** to generate an inverse selection.

- **Preferences**—Select this command to access the **Preferences** dialog box where you can set VGStudio MAX preferences. For more information on this dialog please refer to *Chapter 4.3.3 Setting Preferences*.

4.3.3 Setting Preferences

Numerous program settings are stored in the preferences file (vgstudio.cfg), located in the VGStudio MAX application folder. The settings stored in this file include general appearance options, directory information, tool options, and options such as time periods for auto-saving the scenes you are currently working on. In the **Preferences** dialog, you may adjust the settings for

Directory information, other **Options** such as auto-saving, measurement and scene wide used **Units** and **Tuning** parameters. Preference settings are saved each time you exit VGStudio MAX.

To open the **Preferences** dialog box select **Preferences** in the **Edit** menu. Then choose the desired preference index card by clicking it.

The index card **Directories** is used to set up where VGStudio MAX should look up or save different kinds of files. Enter the appropriate path or click the **Browse** button to select a directory in the **Find Directory** dialog box.

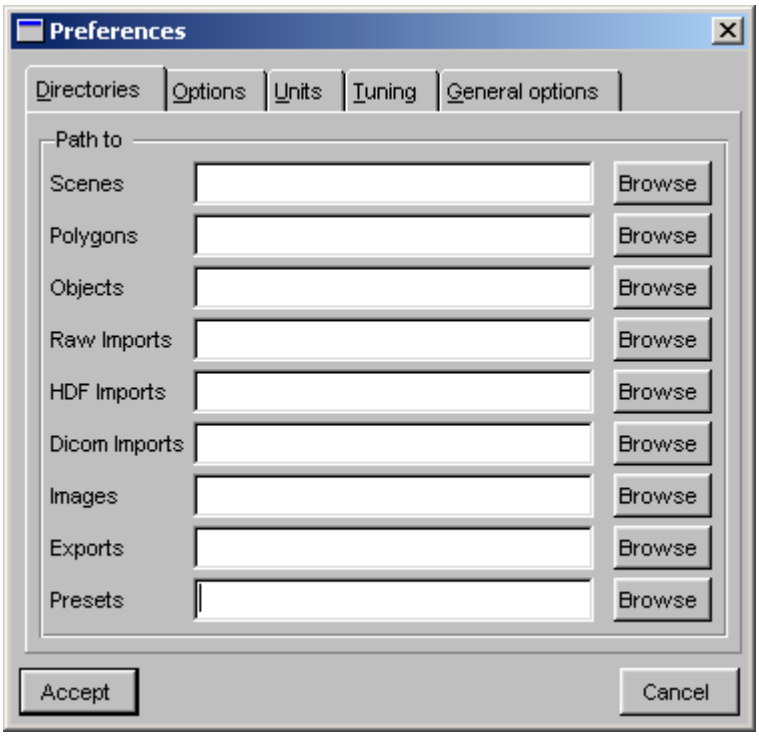


Fig. 46 The Preferences dialog box with the Directories index card selected.

The **Scenes** path is the default directory where the **Open** file dialog looks up scene files saved as Volume Graphics Info files (.vgi).

The **Polygons** path is the default directory where the **Import - Polygon** file dialog looks up polygonal data files (.off).

The **Objects** path is the default directory where the **Merge object** file dialog looks up Volume Graphics Info files (.vgi).

The **Raw Imports** path is the default directory where the **Import - Raw volume** import wizard looks up raw data files.

The **HDF Imports** path is the default directory where the **Import - HDF volume** file dialog looks up Hierarchical Data Format files (.hdf).

The **Dicom Imports** path is the default directory where the **Import - DICOM image series** file dialog looks up Dicom and Papyrus files.

The **Images** path is the default directory where the **Save image** file dialog saves image files.

The **Export** path is the default directory where the **Export** file dialog saves volumes.

The index card **Options** is used to apply several parameters to VGStudio MAX.

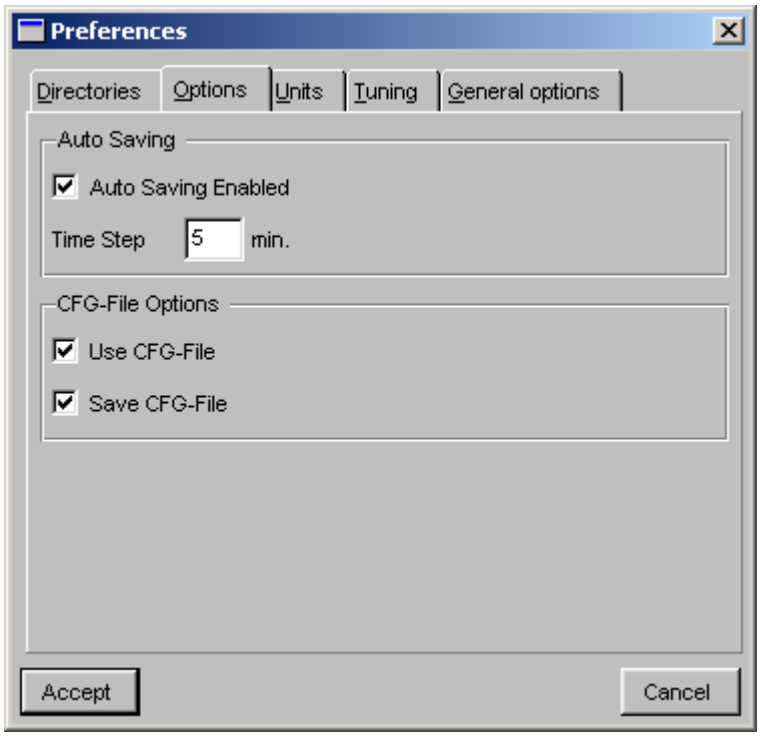


Fig. 47 The index card Options in the Preferences dialog box.

Auto Saving – Click the **Auto Saving Enabled** checkbox and enter the **Time Step** in minutes, i.e. the regular interval when VGStudio MAX should auto-save the scene you are currently working on. A file named #last.vgi will then be saved. You may use this file to restore your work after e.g. a system crash by loading it using the **Open** command in the **File** menu.

CFG-File Options – If the checkbox **Use CFG-File** is activated VGStudio MAX will load the application settings from the vgstudio.cfg file in your VGStudio MAX application folder at every startup. If the option **Use CFG-File** is disabled, VGStudio MAX will start with its default settings. If the checkbox **Save CFG-File** is activated VGStudio MAX will save the application settings to the vgstudio.cfg file in your VGStudio MAX application folder every time you exit VGStudio MAX. If **Save CFG-File** is disabled VGStudio MAX will not save any new application settings and will use the last vgstudio.cfg configuration file at every startup.

The index card **Units** is used to apply units settings to the current scene.

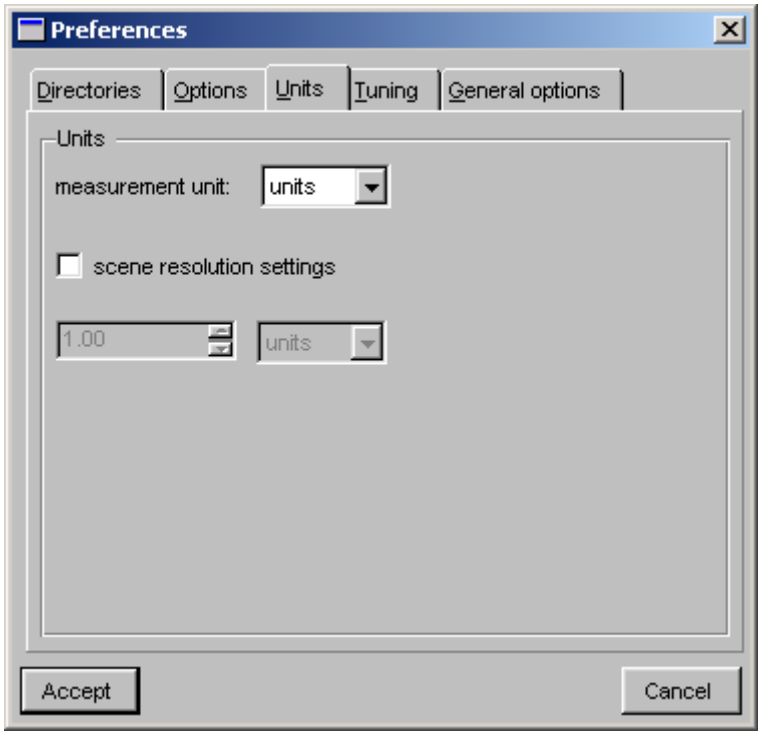


Fig. 48 The index card Units in the Preferences dialog box.

Measurement Units are the units in which distances, surfaces areas, volumes and cursor positions are displayed. You can choose every metric unit from nanometers to kilometers, inch and units, where units are arbitrary units. All measurement results are displayed in "virtual" voxel units if there was no unit applied to the actual scene. The word unit is displayed in the VGStudio MAX 1.0 status bar in that case.

If check box **Scene Resolution Settings** is activated, then resampling of scene during the rendering process will be changed according to the resolution factor applied by the user. Changing this setting may cause changes in the appearance of the rendered images and the behavior of the scene illumination. As default the Scene resolution is optimized automatically by VGStudio MAX 1.0 according to the data loaded so that no user interaction is required.

Reminder: **Scene Resolution Settings** should only be manipulated by the advanced user since it may cause very large memory and computation time consumption.

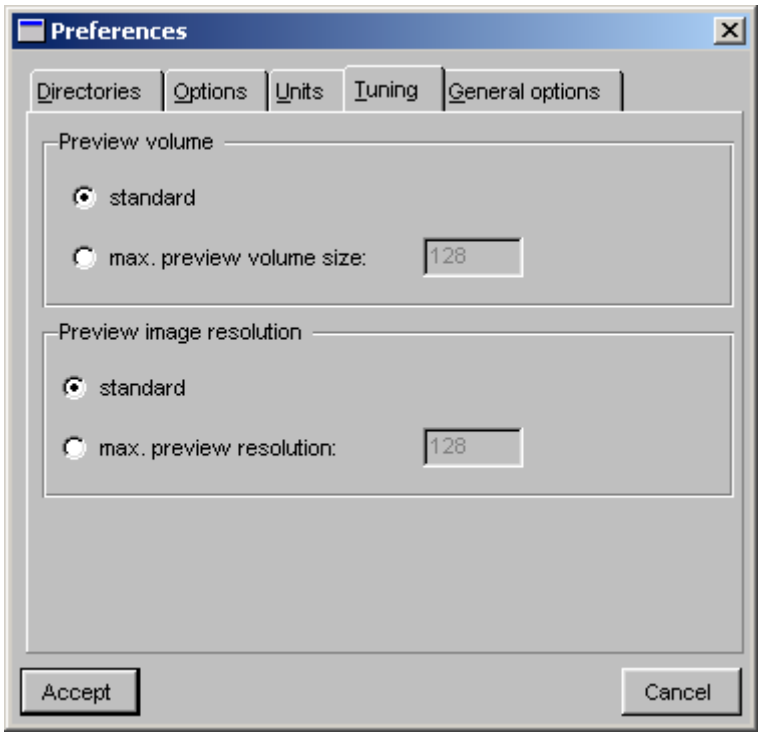


Fig. 49 The index card Tuning in the Preferences dialog box.

The **Tuning** index card is used to adjust interactivity to the computing power of your computer.

If you are changing the data, which will change the rendering. The standard **maximum preview volume** size is half the size of the original volume in every direction, i.e. an eighth of the original volume. The preview volume is used, if you, for example, change the opacity level. Before space leaping, other precomputing steps and rendering will be done on the whole volume, this steps will be done for the preview volume. If you want interactivity, you may adjust the maximum preview volume size. So, if you have a volume of size 512^3 voxels and the maximum preview volume size is 128, the preview volume will be 128^3. Being 64 times smaller, the preview volume will be rendered a lot faster (about the same factor). On the other hand, the image may change a lot for the finally rendered volume, if the size difference is to great, since you are practically rendering only every forth voxel in every direction in the example given above. Try to find settings, that are a trade off of your computing power and the preview quality.

The standard **maximum preview resolution** is half the render resolution you specify in the render tool. Choosing a specific maximum preview resolution will lead to a nearly constant render frame rate regardless the specified render resolution, because the render time per volume is mainly resolution dependent.

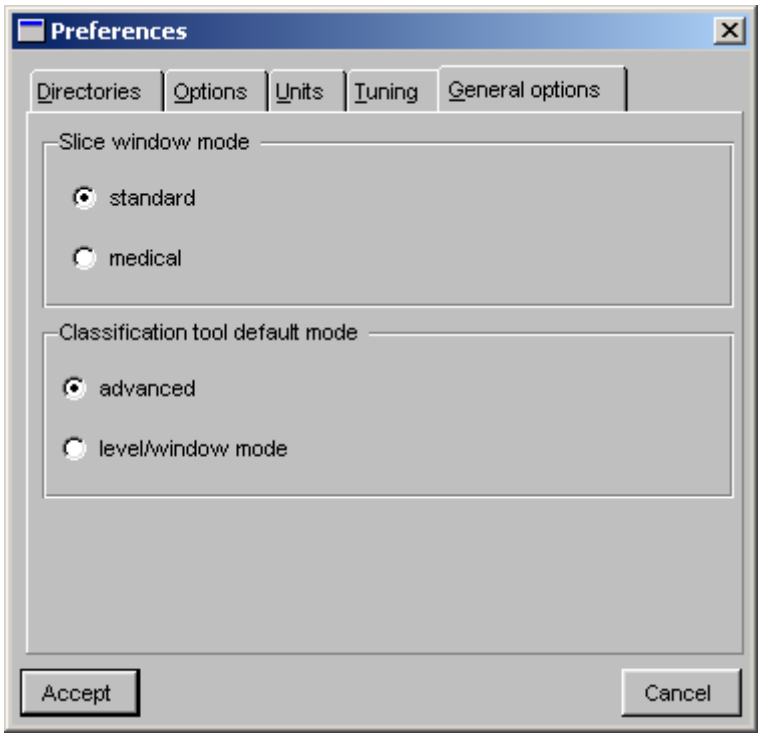


Fig. 50 The index card General options in the preferences dialog box.

In the **General options** index card of the preferences dialog you can change the orientation of the coordinate system in the slice windows. The standard orientation for the xy slice is that of a standard right handed coordinate system, where the x-axis shows to the right and the y-axis upwards. In the medical slice window mode, the y-axis shows downwards, the x-axis shows to the right. This is the medical convention for the orientation of axial projections.

In the Classification tool default mode, you can choose, in which mode the classification tool will appear. See *Chapter 4.6.1 Classification Tool* for further information about level/window and advanced mode.

Reminder: To restore all preferences to their default settings open the VGStudio MAX application folder and rename or delete the VGStudio MAX 1.0 configuration file (vgstudio.cfg). New default preferences files will be created the next time you start VGStudio MAX.

4.3.4 Object Menu

Click **Object** to open a pulldown menu containing the following entries:

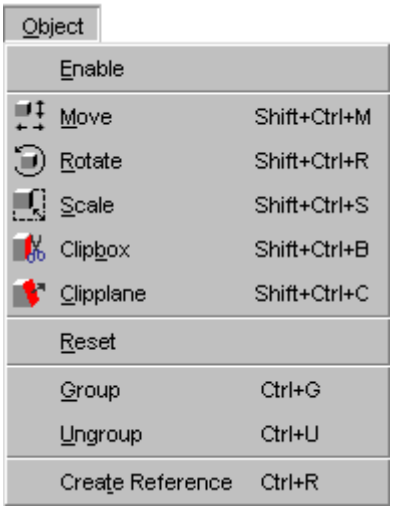


Fig. 51 The Object menu.

- **Disable**—Select this command to disable an object or object group. A disabled object will not be displayed in the scene. No action can be applied to a disabled object; you first have to enable it again. To do so, select the object in the **Scene tree** tool by clicking it and then selecting the **Enable** option in the **Object** menu. The **Enable** and **Disable** menu options will toggle in the object menu, i.e. will only be visible one at a time.

- **Enable**—Select this command to enable a previously disabled object or object group. To enable an object, select a disabled object in the **Scene tree** tool by clicking it and then selecting the **Enable** option in the **Object** menu. The **Enable** and **Disable** menu options will toggle in the object menu, i.e. will only be visible one at a time.

- **Move**—Select this command to move the selected object or object group. The **Move** mode is characterized by the green bounding box around the selected object or group of objects. When moving the cursor into the bounding box, it will take the shape of one vertical and one horizontal arrow (see the table in *Chapter 3.1.2 Mouse Usage*). The object may be moved in the image plane by clicking into the bounding box and dragging the mouse while the left mouse button is pressed. The object may be moved forwards or backwards (and thus will be enlarged or reduced) by clicking into the bounding box and dragging the mouse while the middle mouse button (or the **Alt** key and the left mouse button) is pressed. The whole bounding box may be used as active area to apply the appropriate action. For more information on the **Move** mode, please refer to *Chapter 4.6.7 Object Properties*.

- **Rotate**—Select this command to rotate the selected object or object group. The **Rotate** mode is characterized by the red bounding box around the selected object or group of objects. When moving the cursor into the bounding box, it will take the shape of one vertical and one horizontal circular arrow (see the table in *Chapter 3.1.2 Mouse Usage*). The object may be rotated around the x- or y-axes of the image plane by clicking into the bounding box and dragging the mouse while the left mouse button is pressed. The object may be rotated around

the viewing direction by clicking into the bounding box and dragging the mouse while the middle mouse button (or the **Alt** key and the left mouse button) is pressed. The whole bounding box may be used as active area to apply the appropriate action. For more information on the **Rotate** mode, see also *Chapter 4.6.7 Object Properties*.

- **Scale** —Select this command to scale the selected object or object group. The **Scale** mode is characterized by the dark blue bounding box with squared handles, i.e. active areas on each side of the selected object or group of objects. A rectangular shape will appear next to the cursor when moving it into the active area (see the table in *Chapter 3.1.2 Mouse Usage*). The object may be scaled along the x-, y-, or z-axes by clicking the handle, i.e. the active area on one side of the bounding box and dragging the mouse while the left mouse button is pressed. Isotropic scaling may be performed by clicking into the bounding box and moving the mouse up or down while the middle mouse button (or the **Alt** key and the left mouse button) is pressed. When several objects are selected, only isotropic scaling is supported. Group the objects first if you need to perform unisotropic scaling for several objects at a time. For more information on the **Scale** mode, see also *Chapter 4.6.7 Object Properties*.

- **Clipbox** —Select this command to box clip the selected object or object group along the axes of its bounding box. The **Clipbox** mode is characterized by the cyan bounding box with squared handles, i.e. active areas on each side of the selected object or group of objects. When moving the cursor into the active area, a scissors will appear next to the cursor (see the table in *Chapter 3.1.2 Mouse Usage*). The object may be clipped by clicking one of the handles of the bounding box and dragging the mouse along the desired clip direction while the left mouse button is pressed. Group the objects first if you want to clip several objects at a time. For more information on the **Clipbox** mode, see also *Chapter 4.6.7 Object Properties*.

- **Clipplane** —Select this command to clip the selected object or object group by an arbitrary clipplane. The **Clipplane** mode is characterized by the cyan bounding box with a normal vector on one side of the currently selected object. When moving the cursor into the bounding box, a scissors will appear next to the cursor (see the table in *Chapter 3.1.2 Mouse Usage*). The object may be clipped along an arbitrary clipplane by moving the mouse up and down while the middle mouse button (or the **Alt** key and the left mouse button) is pressed. To rotate the clipplane around the origin of the clipplane's normal vector click into the clipplane and drag the mouse while the left mouse button is pressed. The origin of the clipplane's normal vector may be moved to any arbitrary position on the clipplane by clicking the clipplane's normal vector origin with the left mouse button and dragging the mouse while the left mouse button is pressed. The clipplane will be disabled if several objects are selected. Group the objects first if you want to clip several objects with one clipplane at a time. For more information on the **Clipplane** mode, see also *Chapter 4.6.7 Object Properties*.

- **Reset** —Select this command to reset actions of all categories applied to the selected object such as translation, rotation, clipping, and scaling to their default values. Reset single categories of actions in the **Object properties** tool. For more information see also *Chapter 4.6.7 Object Properties*.

- **Group** —Select this command to combine the current selection of objects or groups to a single group. A group of objects can be handled like a single object. The **Group** command remains disabled until more than one object is selected. Several objects can be selected by dragging a frame over the objects in the 3D view window, by clicking the objects with the

left mouse button while the **Ctrl** key is pressed or by clicking the object's name in the **Scene tree** tool with the left mouse button while pressing the **Ctrl** or the **Shift** key. The bounding boxes of each selected object will be visible when several objects have been selected. After grouping, a single bounding box around all the selected objects will be displayed. You may also use the keyboard shortcut **Ctrl+G** to group the objects. For more information see also *Chapter 4.6.7 Object Properties*.

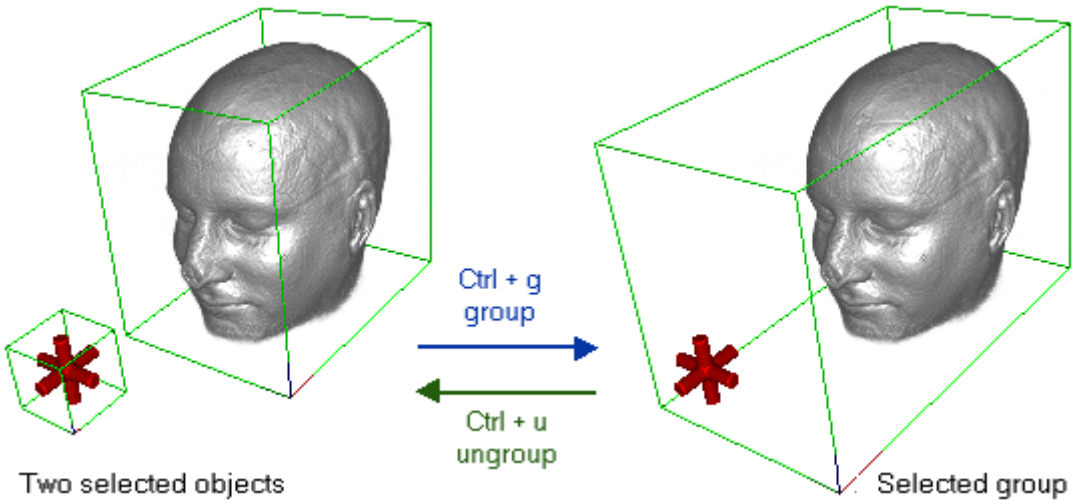


Fig. 52 Use the keyboard shortcut Ctrl + G to group two or more objects. After having grouped the objects, a single bounding box will be displayed around the selected objects. Press Ctrl + U to ungroup the objects again.

- **Ungroup** —Select this command to ungroup an object group previously created with the **Group** command. The **Ungroup** command remains disabled until an object group is selected. You may also use the keyboard shortcut **Ctrl+U** to ungroup objects. For more information see also *Chapter 4.6.7 Object Properties*.

Reminder: The clipping of an object group will be reset as soon as you ungroup the object group.

- **Create reference** —Select this command to create a reference of an object. A reference is a copy of an object which uses the same classification tool settings (color and opacity settings) as the original object. Due to this special property, a reference needs hardly any additional system memory. Therefore, a reference is a memory-saving possibility to copy objects. You may also use the keyboard shortcut **Ctrl+R** to create a reference. In the **Scene tree** tool, a small arrow will appear in the symbol displayed on the left-hand side of the scene name and next to the scene name, the text **reference: #** will appear. Applying the **Create reference** command to a polygon object will result in a "normal" copy of the object. Creating a reference includes a smart placement functionality. An example: select an object and click **Create reference** in the **Object** menu or press **Ctrl+R**. The new referenced object will appear as the currently selected object. Move the reference to a new position in the scene. Select **Create**

Reference in the **Object** menu or press **Ctrl+R** once again**.** The second referenced object will appear in the same relative position as in the first reference.

Reminder: The new offsets of the smart create reference procedure will be reset to their default values as soon as you deselect the object.

4.3.5 Scene Menu

Click **Scene** to open a pulldown menu containing the following entries:

Fig. 53 The scene menu.

- **Camera mode / World view mode**—Select this command to switch between **Camera mode** and **World view mode**. These options are toggles, i.e. only visible one at a time depending on the mode you are currently working in. If you are working in **World view mode** (indicated in the 3D view window with the text **scene view**), you may switch to **Camera mode** and vice versa.

- **Axis**—Select this command to activate or deactivate the axes within a scene. A small check mark in front of the menu item indicates that the axes are activated. The axes can be customized within the **Grid, Axes & Instrument properties** dialog which you open by clicking **Properties** in the **Scene** menu (see below).

- **Grid**—Select this command to activate or deactivate the grid within a scene. A small check mark in front of the menu item indicates that the grid is activated. The grid can be customized within the **Grid, Axes & Instrument properties** dialog which you open by clicking **Properties** in the **Scene** menu (see below).

- **Instrument**—Select this command to activate or deactivate the 3D cursor within a scene. A small check mark in front of the menu item indicates that the instrument is activated. You can move the cursor around in the three slice windows. The cursor position and the appropriate gray or color values are displayed in the status line of the VGStudio MAX user interface. The instrument can be customized within the **Grid, Axes & Instrument properties** dialog

which you open by clicking **Properties** in the **Scene** menu (see below).

- **Distance**—Select this command to activate or deactivate the 3D distance measurement tool. A small check mark in front of the menu item indicates that the distance tool is activated. You can move both ends of the distance tool around independently in the three slice windows. The distance will be displayed in scene units in each slice window somewhere in the middle of the distance. The distance tool also will be used to obtain density profiles of your voxel objects (see *Chapter 4.5.4 Profile Window* for more information about profiles).

- **Angle**—Select this command to activate or deactivate the 3D angle measurement tool. A small check in front of the menu item indicates, that the angle tool is activated. The angle tool consists out of three handles, which define an angle. Each handle can be placed in any of the three slice windows. The size of the angle will be displayed in each slice window near the angle tool.

- **Keyframer**—Select this command to activate the keyframer. The keyframer can be used to create aninamtions, which can be stored frame by frame in one of the supported image formats. For further information see *Chapter 4.6.14 Keyframer*.

- **Properties** —Select this command to open the **Grid, Axes & Instrument properties** dialog where you may adjust the display of the grid, axes, and instrument.

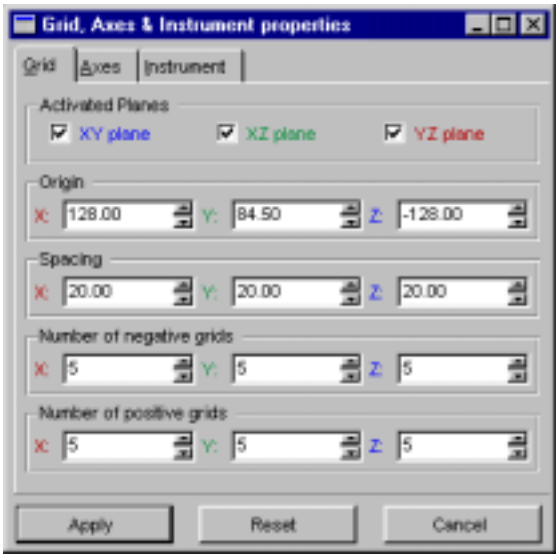


Fig. 54 The Grid, Axes & Instrument properties dialog where you may adjust the display of the grid, axes and instrument. Here, the index card Grid is displayed.

Every single grid plane may be enabled or disabled by clicking the checkbox in front of it. The grids' origins can be defined in scene coordinates. The spacing of a single grid cell can be adjusted independently for every direction. The number of grid cells in positive and negative direction can also be adjusted separately for each axis. Click **Apply** to accept the new settings. To reset the values to their default, simply click **Reset**. If you want to quit the dialog without accept-

ing the new settings, click **Cancel**.

Fig. 55 The Axes index card in the Grid, Axes & Instrument properties dialog.

Every single coordinate axis can be enabled or disabled by clicking the checkbox in front of it. The coordinate system's origin can be defined in scene coordinates. The length of each axis in positive and negative direction can be adjusted separately for each axis. Click **Apply** to accept the new settings. To reset the values to their default, simply click **Reset**. If you want to quit the dialog without accepting the new settings, click **Cancel**.

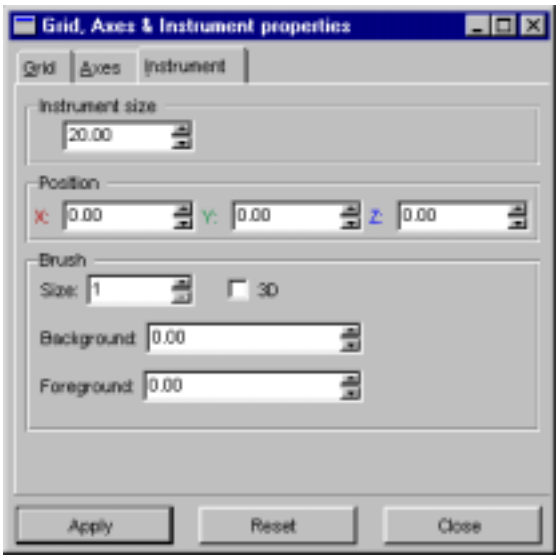


Fig. 56 The Instrument index card in the Grid, Axes & Instrument properties dialog.

Use the dialog shown in Fig. 56 to adjust the instrument position in scene coordinates. The size of the instrument can also be adjusted. With the instrument you can draw into the current voxel object. The parameters for drawing will be set in the Brush box. Size defines the size of the

brush in voxels. You can choose the shape of the Brush with the check box **3D**: if it is checked, the brush will be a cube of the chosen size otherwise the brush will only be a 2D square. **Background** and **Foreground** fields allow to enter the appropriate color in gray values. For more information on drawing, please refer to *Chapter 4.4.3 Measurement Utilities*. Click **Apply** to accept the new settings. To reset the values to their default, simply click **Reset**. If you want to quit the dialog without accepting the new settings, click **Cancel**.

All labels related to axes or planes orthogonal to the appropriate axis are colored according to the VGStudio MAX color scheme, i.e. all labels related to the x-axis are displayed in red, all labels related to the y-axis in green, and all labels related to the z-axis in blue.

- **Background color** —Select this command to choose a background color for the current scene. Select one of the default colors from the menu shown in the figure below.

Fig. 57 Select a color for handles, intervals, and segments.

You may also select **Custom color** to activate a color selection tool shown in *Fig. 58*.

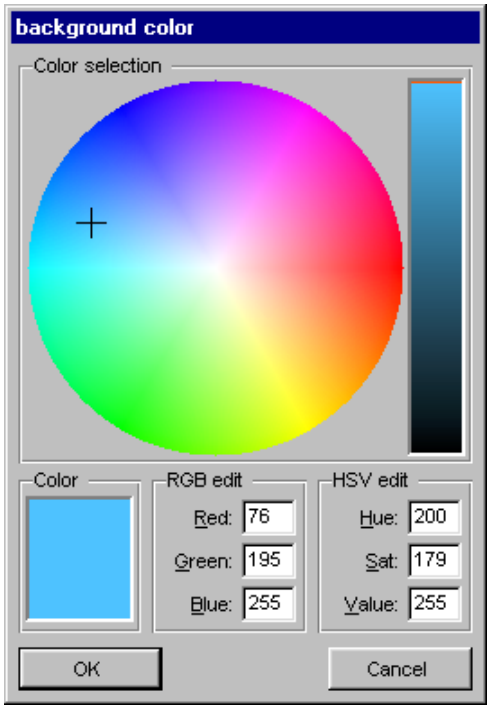


Fig. 58 In the background color window you may define a background color for the active scene.

4.3.6 Tools Menu

Click **Tool** to open a pulldown menu containing the following entries:

Fig. 59 The Tools menu.

Use the **Tools** menu to activate or deactivate the various tools of VGStudio MAX. A check mark in front of each entry indicates that a tool is activated.

- **Classification**—Select this command to activate or deactivate the **Classification** tool. For more information on the **Classification** tool please refer to *Chapter 4.6.1*.

- **Render properties**—Select this command to activate or deactivate the **Render properties** tool. For more information on the **Render properties** tool, please refer to *Chapter 4.6.3*.

- **Stereo properties**—Select this command to activate or deactivate the **Stereo properties** tool. For more information on the **Stereo properties** tool, please refer to *Chapter 4.6.5*.

- **Scene tree**—Select this command to activate or deactivate the **Scene tree** tool. For more information on the **Scene tree** tool, please refer to *Chapter 4.6.2*.

- **Light properties**—Select this command to activate or deactivate the **Light properties** tool. For more information on the **Light properties** tool, please refer to *Chapter 4.6.4*.

- **World view**—Select this command to activate or deactivate the **World view** tool. For more information on the **World view** tool, please refer to *Chapter 4.6.8*.

- **Camera view**—Select this command to activate or deactivate the **Camera view** tool. For more information on the **Camera view** tool, please refer to *Chapter 4.6.9*.

- **Polygon properties**—Select this command to activate or deactivate the **Polygon properties** tool. For more information on the **Polygon properties** tool, please refer to *Chapter 4.6.6*.

- **Object properties**—Select this command to activate or deactivate the **Object properties** tool. For more information on the **Object properties** tool, please refer to *Chapter 4.6.7*.

- **Registration**—Select this command to activate or deactivate the **Registration** tool. For more information on the **Registration** tool, please refer to *Chapter 4.6.12*.

- **Keyframer**—Select this command to activate or deactivate the **Keyframer** tool. For more information on the **Keyframer** tool, please refer to *Chapter 4.6.14*.

- **Filter operations**—Select this command to activate or deactivate the **Filter** tool. For more information on the **Filter** tool, please refer to *Chapter 4.6.11*.

- **Polygon Extract**—Select this command to activate or deactivate the **Polygon extraction** tool. For more information on the **Polygon extraction** tool, please refer to *Chapter 4.6.13*.

- **Segmentation**—Select this command to activate or deactivate the **Segmentation** tool. For more information on the **Segmentation** tool, please refer to *Chapter 4.6.10*.

4.3.7 Window Menu

Click **Window** to open a pulldown menu containing the following entries:

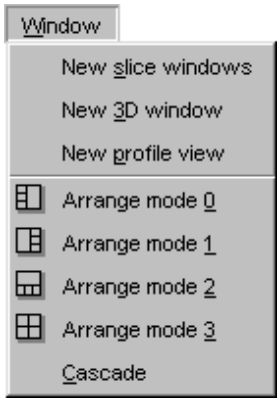


Fig. 60 The Window menu.

- **New slice windows**—Select this command to open the three slice windows within VGStudio MAX's workspace. The menu entry remains disabled as long a these windows are open in the workspace.

- **New 3D window**—Select this command to open the 3D window within VGStudio MAX's workspace. The menu entry remains disabled as long a this window is open in the workspace.

- **New Profile window**—Select this command to open the profile window within the VGStudio MAX's workspace. The menu entry remains disabled as long as this window is open in the workspace.

- **Arrange modes** and **Cascade**—Click one of the **Arrange modes** 0 to 3 to choose a predefined layout for the windows within the workspace. VGStudio MAX uses a Multiple Document Interface (MDI). The 3D window and the three slice windows may also be arranged arbitrarily within the workspace by clicking into the title bar of the corresponding window with the left mouse button and dragging the window to the desired position. The arbitrarily arranged windows may be rearranged by one of the **Arrange modes** or by the **Cascade** option.

4.3.8 Help Menu

Click **Help** to open a pulldown menu containing the following entries:

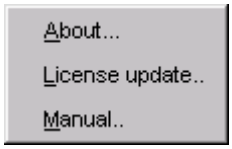


Fig. 61 The Help menu.

- **About**—Select this command to open a window with information on your VGStudio MAX release.

Fig. 62 In this window, you will find information on your VGStudio MAX release.

- **License update**—Select this command to open VGStudio MAX's N**ode Locked License update** window. The license key shown as wildcards, if a valid license is in use, the current license date will be shown, too. If you running the application in demo mode, the license key fields will be empty. Here you can enter your license key, if you purchased a new license. Click **Cancel** or the **Escape** key to leave license dialog, click **OK** or **Enter** if entered a new license key.

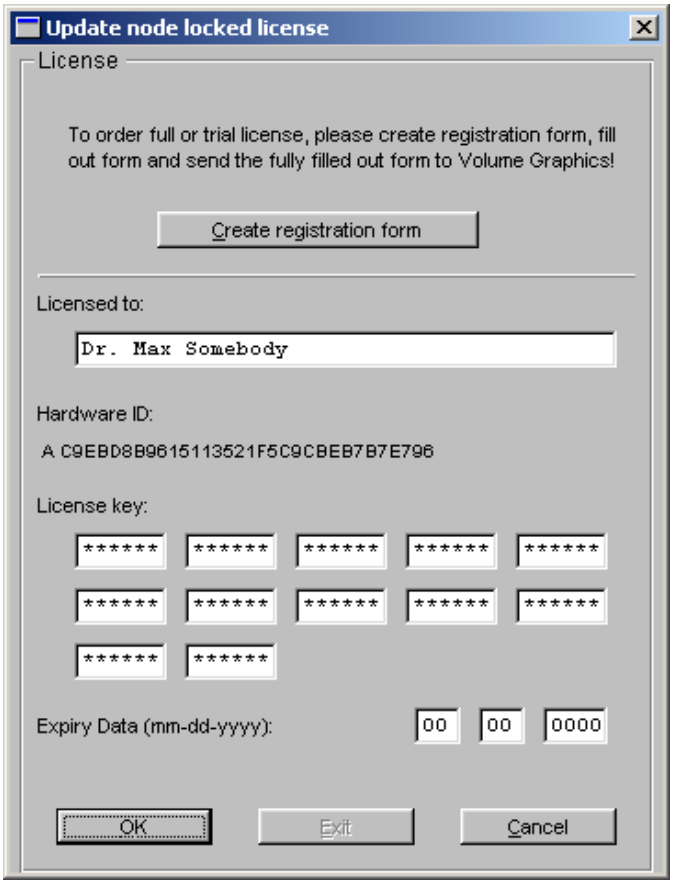


Fig. 63 VGStudio MAX's License update window.

- **Manual**—Select this command to open VGStudio's **Manual**. Please keep in mind that the Adobe Acrobat Reader has to be installed on your computer to be able to open up the manual.

4.4 Icon Bar

Fig. 64 The VGStudio MAX icon bar.

The tools in the icon bar provide quick access to many common VGStudio MAX functions. When placing the cursor on an icon, a tooltip will appear which shows the function of the icon. The tools are divided into five main categories:

Standard icon section 

Object manipulation section 

Measurement section 

Scene utilities section 

View selection section 

Window layout tools section 

What's this section 

4.4.1 Standard Icon Section

New

New—Click this icon to create a new scene. Note that selecting this command will close the scene you are currently working on. After you have created a scene, you can save it by using the **Save** command. The scene can be accessed again using the **Open** command. Both commands are described below. You may also use the keyboard shortcut **Ctrl+N** to create a new scene.

Open

Open—Click this icon to open an existing scene. You may load Volume Graphics Info files (.vgi extension) as well as old info files (.info extension) by selecting the desired file and clicking **Open** or by simply double-clicking the file in the **Open info file** dialog. You may also use the keyboard shortcut **Ctrl+O** to open an existing scene.

Save

Save—Click this icon to save your work. You should save your work frequently throughout the scene creation process. Saving a scene will generate a Volume Graphics Info file (.vgi extension). The *.vgi file includes data-relevant information such as the file name and path, data type, file type, file size, and data mapping as well as scene-relevant information such as light settings, rendering algorithm, or background color. You may also use the keyboard shortcut **Ctrl+S** to save a scene.

Print

Print—Click this icon to print the active window. You may select either one of the three slice windows or the 3D window as the active window by clicking the title bar or into one of the windows. You may also use the keyboard shortcut **Ctrl+P** to print the active window.

Cut

Cut—Click this icon to cut objects within a scene in VGStudio MAX. The cut objects will remain in the VGStudio MAX clipboard. When you cut objects, you cut all related information such as opacity and color along with whatever you cut. Note that VGStudio MAX objects cannot be pasted into another program. You may also use the keyboard shortcut **Ctrl+X** to cut objects.

Copy

Copy—Click this icon to copy selected objects into the VGStudio MAX clipboard. When you copy objects, you copy all related information such as opacity and color along with whatever you copy. Note that VGStudio MAX objects cannot be copied into another program. You may also

use the keyboard shortcut **Ctrl+C** to copy objects.

Paste

Paste—Click this icon to paste previously copied or cut objects into a scene. You may also use the keyboard shortcut **Ctrl+V** to paste objects.

Undo

Undo—Click this icon to undo your previous action. This menu item changes depending on the action you last performed. For instance, if you have pasted an object into your scene, the text reads **undo: paste object** and the object will be removed from the scene when you select this command. You may undo the last 100 actions and commands. Only one exception will destroy the undo history. You may also use the keyboard shortcut **Ctrl+Z** to undo your last command.

Reminder: The undo history will be **destroyed** in case of deleting an object. You have to select the undo command **immediately** after the delete command to undo a delete process.

Redo

Redo—Click this icon to redo your previous **Undo** action. This menu item changes depending on the last **Undo** action. For instance, if you have undone the pasting of an object, the text reads **redo: paste object** and the object will be pasted into the scene again when you select this command. You may also use the keyboard shortcut **Ctrl+Y** to redo your last **Undo** command.

4.4.2 Object Manipulation Section

VGStudio MAX provides five object manipulation modes: translation, rotation, scaling, clipbox, and clipplane. All five modes allow interactive object manipulation. The mode can be selected by clicking the icons in the icon bar after you have selected an object.

Object manipulation can also be applied by using the **Object properties** tool which allows the user to type in exact translation, rotation, clipping, and scaling values. For more information on the **Object properties** tool, please refer to *Chapter 4.6.7*.

Object Selection and Deselection

Before any object manipulation can be applied, you have to select an object or a group of objects. A bounding box around an object will indicate that the object is selected. This means that the object is the active object to which actions may be applied. When loading an object into VGStudio MAX, the object will automatically be the active object, indicated by a green bounding box around the object. You may deselect an object by selecting another object, by clicking into the scene outside an object's bounding box, or by clicking **Deselect** in the **Edit** menu (alternatively, you may also use the keyboard shortcut **Alt+D**).

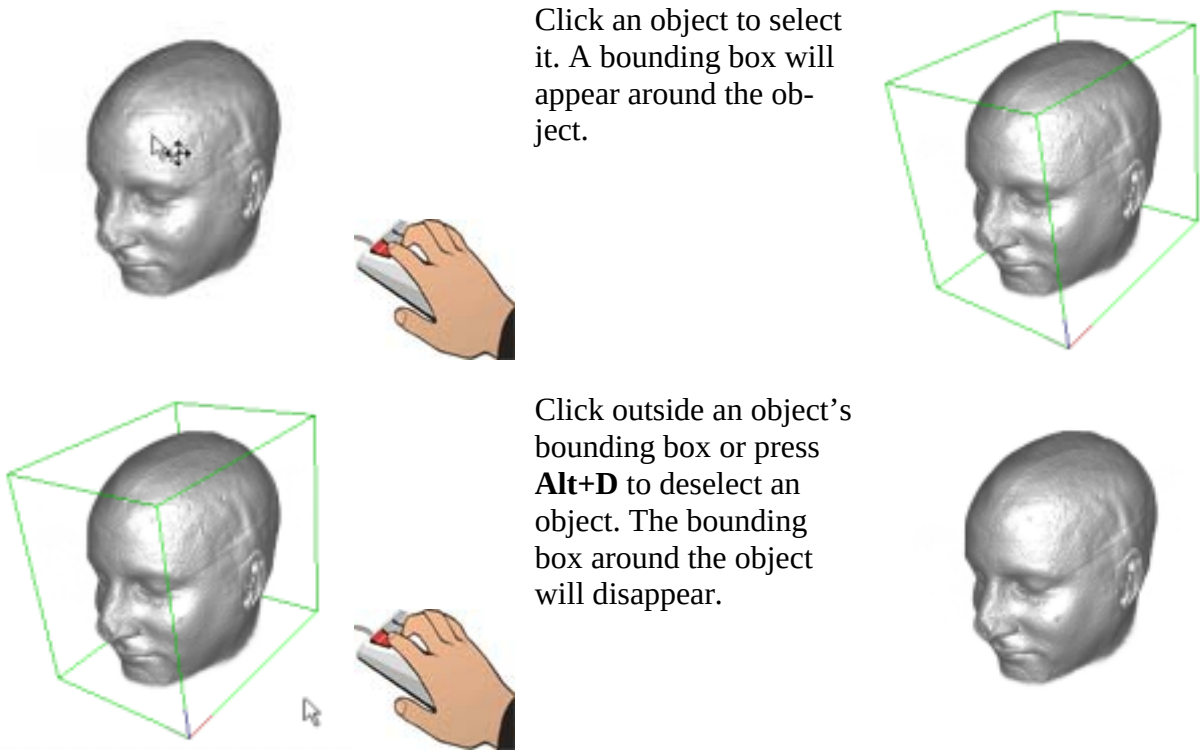


Fig. 65 Select or deselect an object. A bounding box around the object indicates that an object is selected.

Move

Click this icon to move the selected object or object group. The **Move** mode is characterized by the green bounding box around the selected object or group of objects. When moving the cursor into the bounding box, it will take the shape of one vertical and one horizontal arrow (see the table in *Chapter 3.1.2 Mouse Usage*). The object may be moved in the image plane by clicking into the bounding box and dragging the mouse while the left mouse button is pressed. The whole bounding box may be used as active area to apply the appropriate action. The object may be moved forwards or backwards (and thus will be enlarged or reduced) by clicking into the bounding box and dragging the mouse while the middle mouse button (or the **Alt** key and the left mouse button) is pressed. The whole bounding box may be used as active area to apply the appropriate action. Using the **Shift** modifier in **Move** mode allows you to move the object along either the vertical or horizontal direction of the 3D window image plane. For more information on the **Move** mode, please refer to *Chapter 4.6.7 Object Properties*.

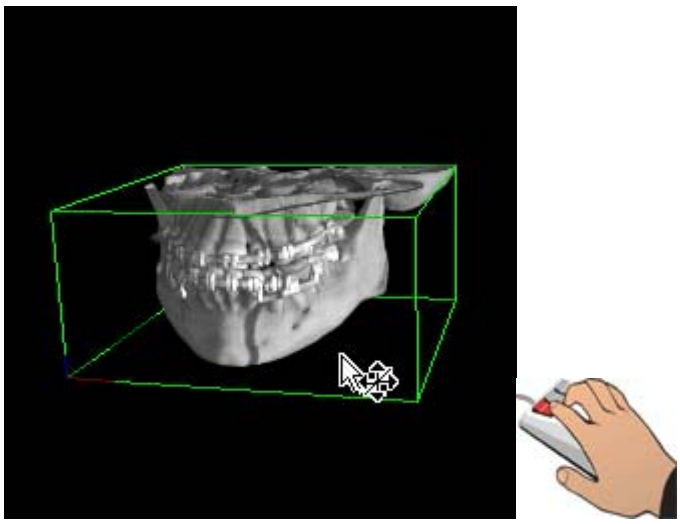


Fig. 66 The 3D window in Move mode indicated by the green bounding box and the tripod displayed next to the cursor when moving it into an active area..

Rotation

Click this icon to rotate the selected object or object group. The **Rotate** mode is characterized by the red bounding box around the selected object or group of objects. When moving the cursor into the bounding box, it will take the shape of one vertical and one horizontal circular arrow (see the table in *Chapter 3.1.2 Mouse Usage*). The object may be rotated around the x- or y-axes of the image plane by clicking into the bounding box and dragging the mouse while the left mouse button is pressed. The object may be rotated around the viewing direction by clicking into the bounding box and dragging the mouse while the middle mouse button (or the **Alt** key and the left mouse button) is pressed. The whole bounding box may be used as active area to apply the appropriate action. Using the **Shift** modifier in **Rotate** mode allows you to rotate the object either around the vertical or horizontal axes of the 3D window image plane. For more information on the **Rotate** mode, please refer to *Chapter 4.6.7 Object Properties*.

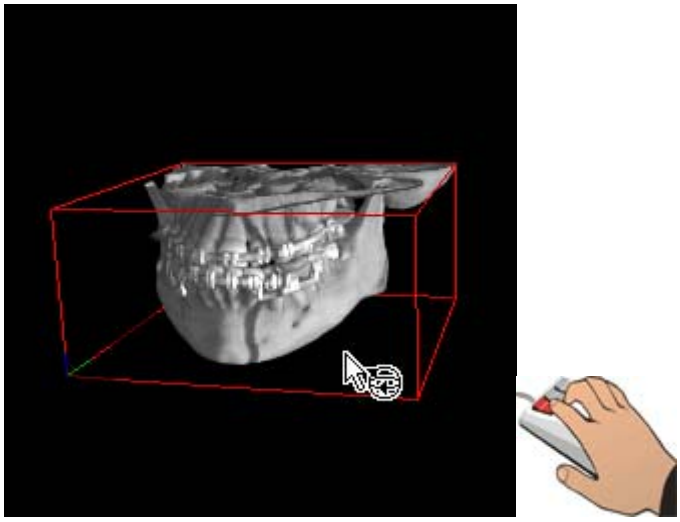


Fig. 67 The 3D window in Rotate mode indicated by the red bounding box and the ball with arrows displayed next to the cursor when moving it into an active area..

Scaling

Click this icon to scale the selected object or object group. The **Scale** mode is characterized by the dark blue bounding box with squared handles, i.e. active areas on each side of the selected object or group of objects. A rectangular shape will appear next to the cursor when moving it into the active area (see the table in *Chapter 3.1.2 Mouse Usage*). The object may be scaled along its x-, y-, or z-axes by clicking the handle, i.e. the active area, of one side of the bounding box and dragging the mouse while the left mouse button is pressed. Isotropic scaling may be performed by clicking into the bounding box and moving the mouse up or down while the middle mouse button (or the **Alt** key and the left mouse button) is pressed. When several objects are selected, only isotropic scaling is supported. Group the objects first if you need to perform unisotropic scaling for several objects at a time. For more information on the **Scale** mode, please refer to *Chapter 4.6.7 Object Properties*.

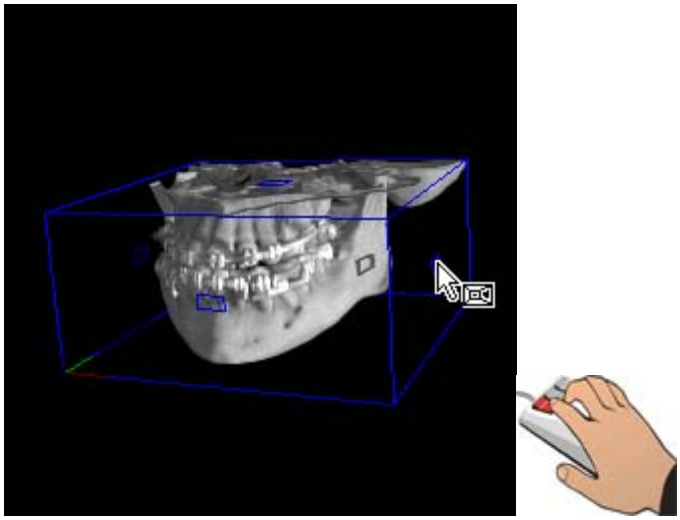


Fig. 68 The 3D window in Scale mode indicated by the blue bounding box and the perspective box displayed next to the cursor when moving it into an active area..

Clipbox

Click this icon to box clip the selected object or object group along the axes of its bounding box. The **Clipbox** mode is characterized by the cyan bounding box with squared handles, i.e. active areas on each side of the selected object or group of objects. When moving the cursor into the active area, a scissors will appear next to the cursor (see the table in *Chapter 3.1.2 Mouse Usage*). The object may be clipped by clicking one of the handles of the bounding box and dragging the mouse along the desired clip direction while the left mouse button is pressed. The box clipping will be disabled if several objects where selected. Group the objects first if you want to clip several objects at a time. For more information on the **Clipbox** mode, please refer to *Chapter 4.6.7 Object Properties*.

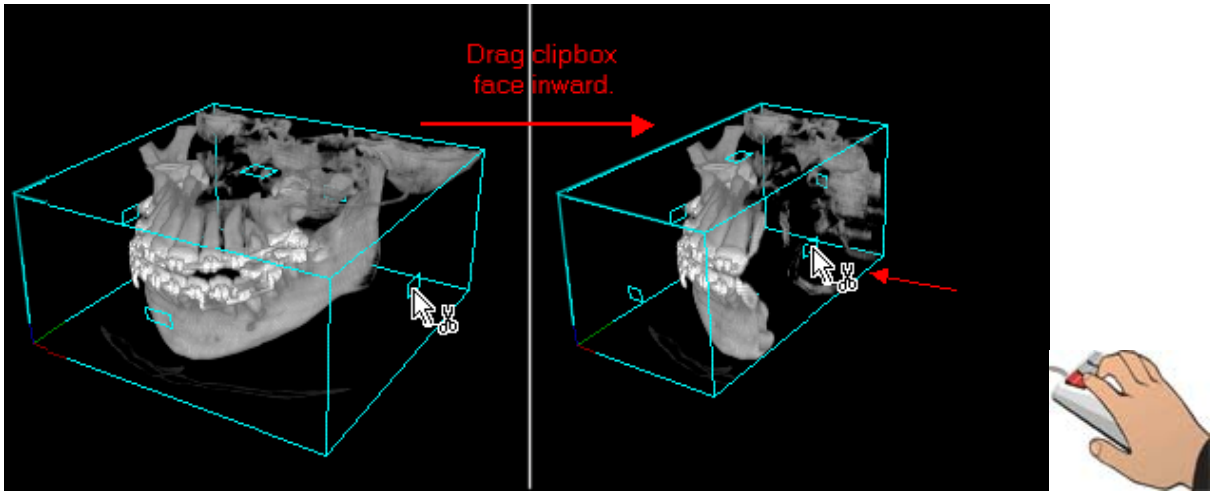


Fig. 69 The 3D window in Clipbox mode indicated by the cyan bounding box and the scissors displayed next to the cursor when moving it into an active area.

Clipplane

Click this icon to clip the selected object or object group by an arbitrary clipplane. The **Clipplane** mode is characterized by the cyan bounding box with a normal vector on one side of the active object. When moving the cursor into the bounding box, a scissors will appear next to the cursor (see the table in *Chapter 3.1.2 Mouse Usage*). The object may be clipped along an arbitrary clipplane by moving the mouse up and down while the middle mouse button (or the **Alt** key and the left mouse button) is pressed. To rotate the clipplane around the origin of the clipplane's

normal vector click into the clipplane and drag the mouse while the left mouse button is pressed. The origin of the clipplane's normal vector may be moved to any arbitrary position on the clipplane by clicking the clipplane's normal vector origin with the left mouse button and dragging the mouse while the left mouse button is pressed. The clipplane will be disabled if several objects are selected. Group the objects first if you want to clip several objects with one clipplane at a time. For more information on the **Clipplane** mode, please refer to *Chapter 4.6.7 Object Properties*.

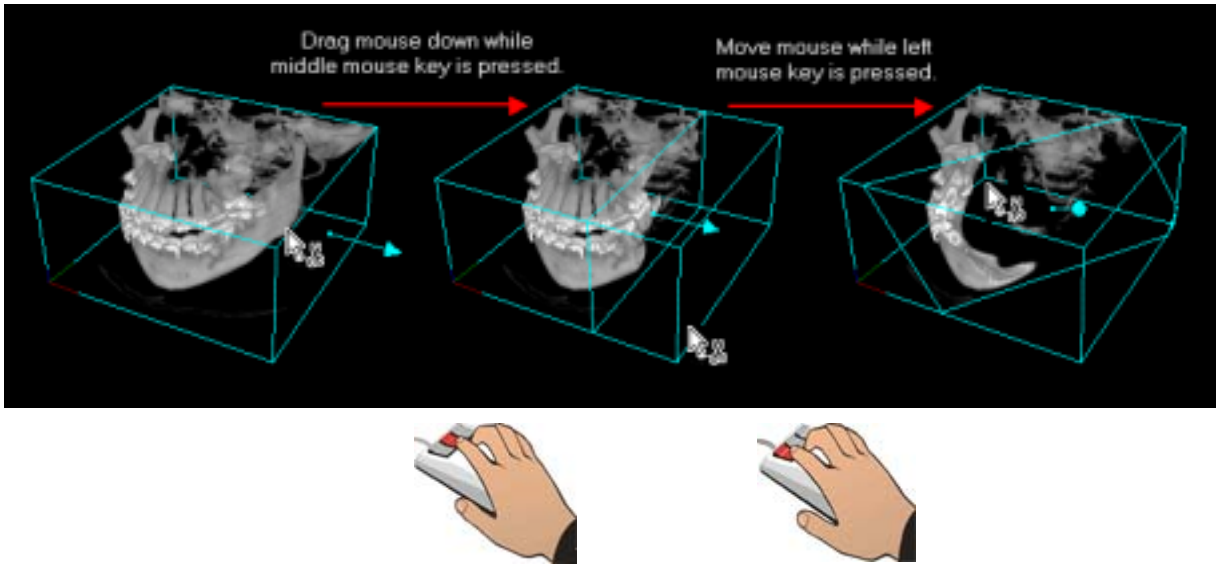


Fig. 70 Clip the object along an arbitrary clipplane by dragging the mouse up or down while the middle mouse button is pressed. By dragging the mouse inside the active area while the left mouse button is pressed, the clipplane will be rotated in any arbitrary direction.

4.4.3 Measurement Utilities

Three different utilities may be activated for data analysis and better evaluation.

Activate the utilities by clicking one of the three icons in the icon bar. You may only activate one utility at the same time

or by using **3D Instrument**, **Distance** or **Angle** options in the **Scene** menu.

3D Instrument

Click this icon to activate or deactivate the 3D instrument in the scene. A small cross will appear in each slice window as well as in the 3D Window. The 3D instrument can be positioned anywhere in the scene or an object within the three slice windows.

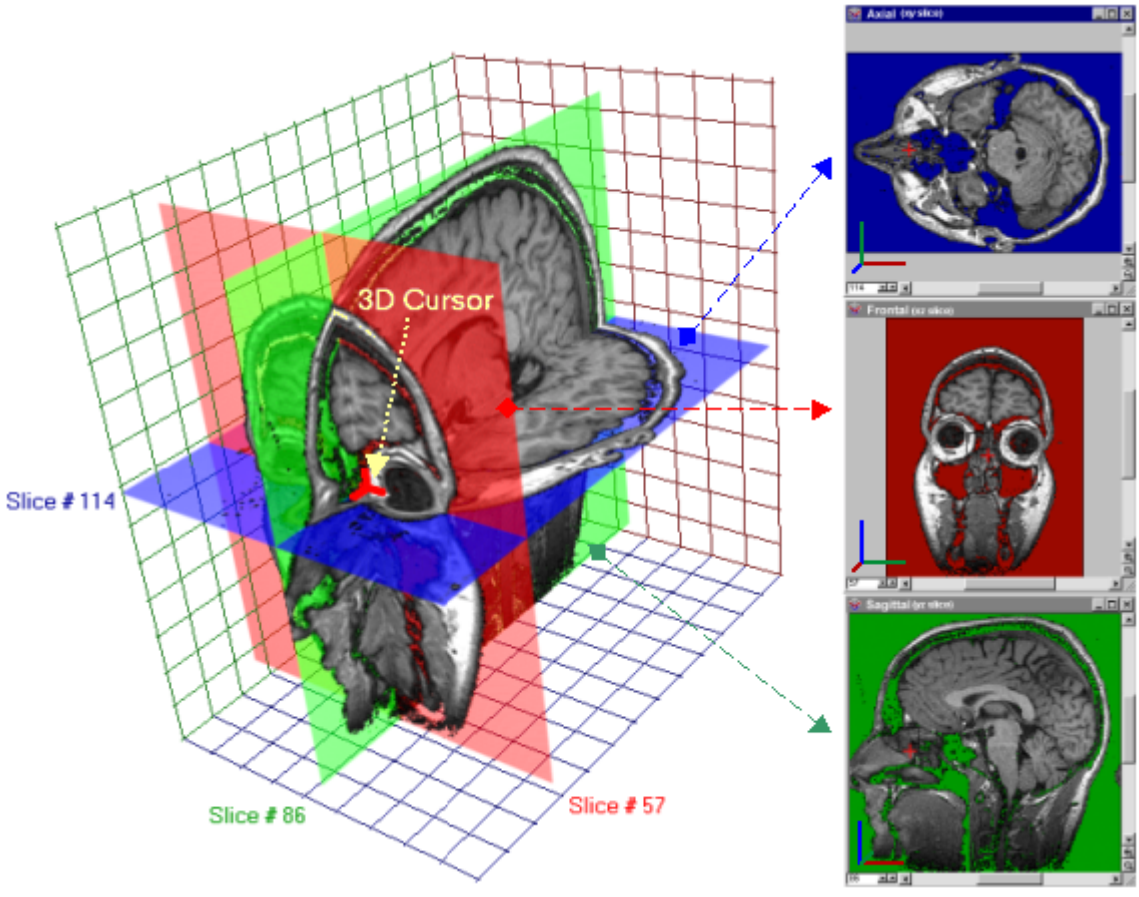


Fig. 71 The 3D instrument can be used to steer the three slice windows.

After activated the 3D instrument information about the instruments position and the data at this position will be displayed in the very left section of the status bar. The position is displayed in voxel coordinates of the current object (in peaked brackets) and in object coordinates in scene units. The gray value at the 3D cursors position is also displayed. In the second section of the status bar the current scene unit, e.g. µm, mm, cm, m are displayed.

The cursor can be moved in two ways:

- You can **click** near the center of the cursor, which will focus the slice windows to the slice where the cursor is located and you can drag the cursor to any place in the slice.

- Or you can **click** in any slice not near the cursor's center, which will set the cursor to that position. You can drag the cursor to any place in that slice until you release the left button.

When moving the cursor in the slice windows, the three cross sections through the volume data will be displayed with the 3D instrument in the center of the three sections. You may use the 3D instrument to scroll through the volume data set in the slice windows in two directions simultaneously by clicking it with the left mouse button and then dragging the mouse while the left mouse button is pressed.

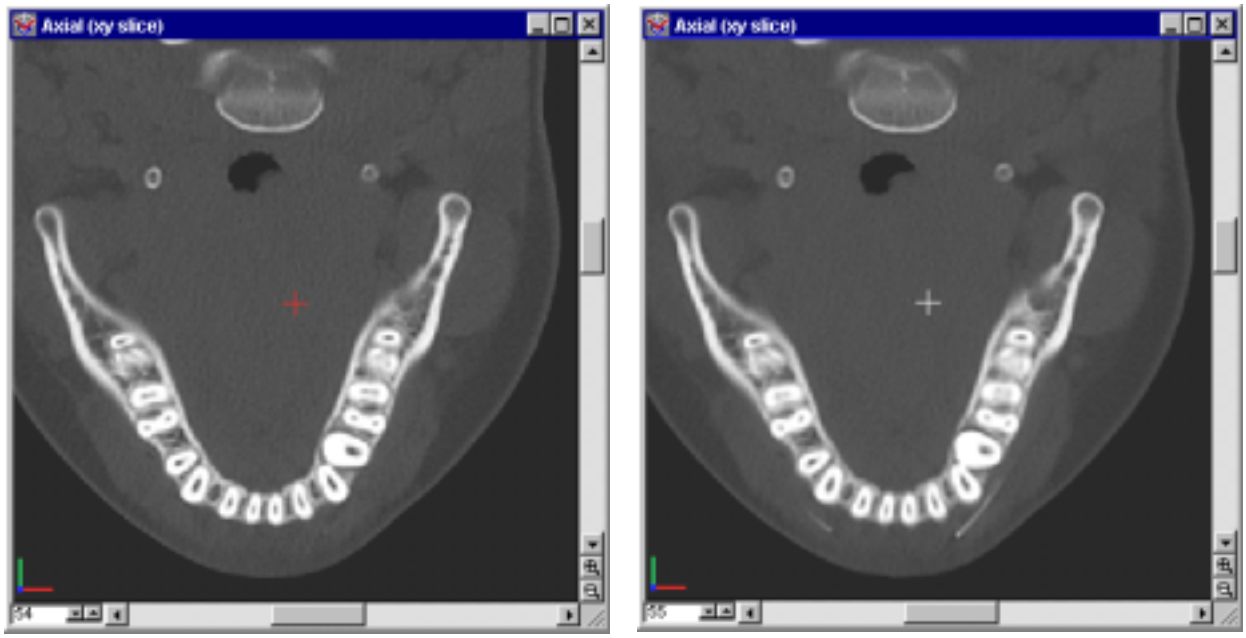


Fig. 72 The 3D instrument will be displayed in red when the cursor is located in the currently selected slice.

In a slice image, the cursor will appear in red when the cursor is located in the slice that is currently selected. It will appear in white as soon as the displayed slice is another one than the one in which the cursor is positioned at the moment. In the example shown in Fig. 72, the cursor is located in slice # 54 and the cursor in the left image slice # 54 is displayed in red. In the right image, slice # 55 is shown and the cursor is displayed in white.

If the cursor is placed outside the selected voxel data set or if the active object is a polygon object, only a red bounding box will appear in the slice windows (see figure below).

Fig. 73 A red bounding box will be displayed when the cursor is placed outside the selected voxel data set.

Drawing with the 3D Instrument

With the instrument you can draw, too. You have a palette of two colors, which will be displayed in the status bar. If you want to draw, just press the **Shift key** and **left-click** into a slice window to draw with the foreground color or press the **Shift key** and **middle-click** into a slice window to draw with the background color. Drawing also places the instrument to the position, where you draw. Drawing outside an object is not possible and will only place the instrument. When the **Shift key** is pressed and the cursor is over an activated slice window, the cursor will have the shape of a brush, indicating, that you are in the drawing mode.

You can choose the back- and foreground colors in two ways:

- By pressing the **Ctrl key** and press the corresponding mouse button (**Left button** for foreground and **Middle button** for background) at the location in the slice from where you want to peek the color. The cursor will become a pipette as long as you hold the **Ctrl key**. The newly taken drawing colors will be updated in the status bar immediately.

- Or by selecting the properties dialog in the scene menu and choosing the instruments section. Here you not only can change back- and foreground color, but the size and the shape (square or cube) of the brush. Please see *Chapter 4.3.5 Scene Menu* for further details.

Distance Measurement Tool

Click on this Icon to activate the distance measurement tool in the scene. Two short delimiting lines connected by a green line will appear in each slice window as well in the 3D window. If the delimiting lines are in the slice displayed in a slice window, they will be red, white otherwise.

Near the center of the green line will appear a marking which shows the distance. The distance between the two points will be shown in scene units (for setting units see *Chapter 4.3.3 Setting Preferences*). The distance will be shown in the first field of the status bar, too.

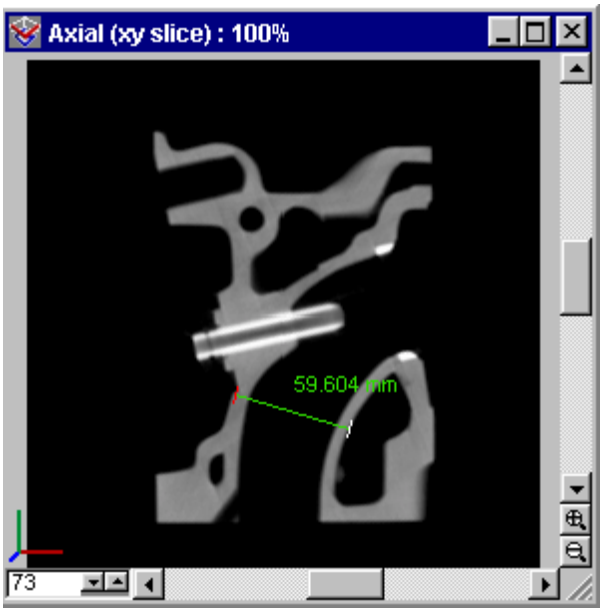


Fig. 74 A distance delimiter will be red when it is the slice, which is displayed and white if not.

You can change measure distances in two ways:

- By clicking on one of the two delimiting lines in any slice and dragging it to another position. If the delimiting line is not in the slice displayed, the slice window will “jump” to the slice. The delimiting line will appear in red color in case that the slice displayed is the slice where the delimiting line is located.

- Or by clicking anywhere in a slice window, specifying the first point of the line and dragging the second point of the line until the line fits your choice. The line defined that way will “snap” to the two most significant edges between the two points (for further details see *Chapter 4.5.4 Profile Window*).

Angle Measurement Tool

Click on this icon to activate the **Angle Measurement Tool**.

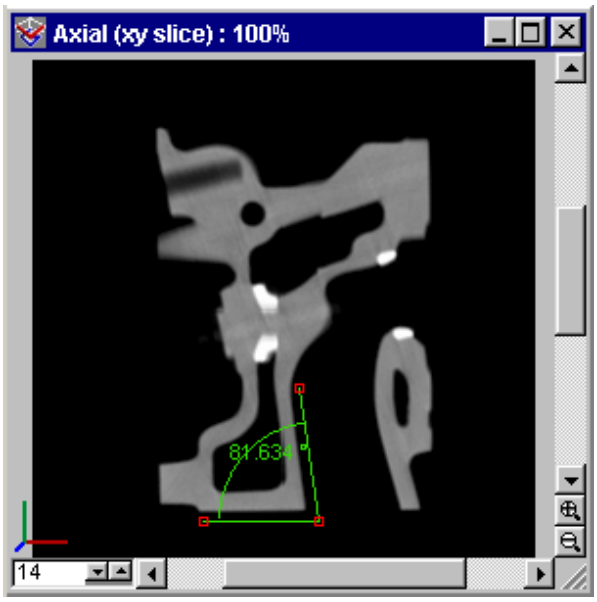


Fig. 75 The three points defining the angle will be displayed as red squares in the slice window if they are in the current slice, white otherwise.

The angle measurement tool consists out of two line segments, an arc and three points, defined by the centers of squares, which lie at the ends of the line segments. If a point does not lie in the displayed slice the square will be displayed white, if it does lie in the displayed slice it will be red. A label at the arc shows the value of the angle between the to line segments. The value of the angle is also displayed in the first field of the status bar.

You can manipulate the angle by left-clicking on one of the points and dragging them to any position. If the square defining the point is white, the slice window will jump to the slice where the square lies and you will move it there. If you left-click anywhere in a slice window the angle measurement tool will be placed to that position with an default angle of about 50°.

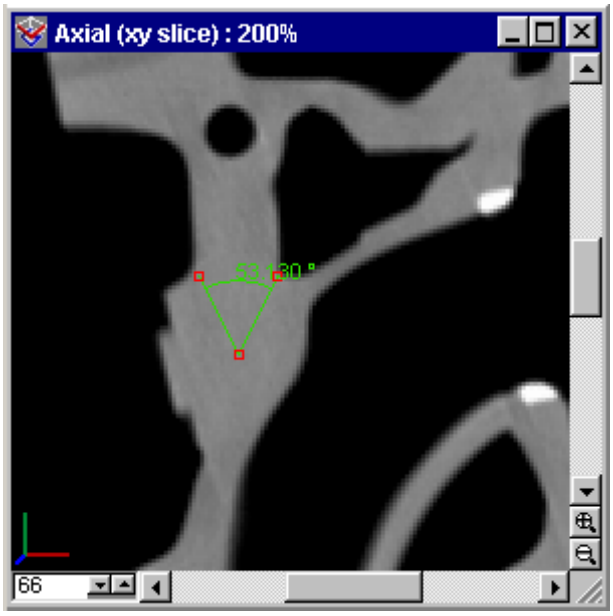


Fig. 76 Clicking into a slice window with activated angle measurement tool will set the tool to that position with an angle of about 50°.

4.4.4 Scene Utilities

Two different utilities may be activated for better orientation in the scene.

Activate the utilities by clicking one of the two icons in the icon bar

or by using the **Axis** and **Grid** options in the **Scene** menu.

Scene Axes

Click this icon to activate the scene coordinate axes. The display of the axes can be customized in the **Properties** dialog which you open via the **Scene** menu.

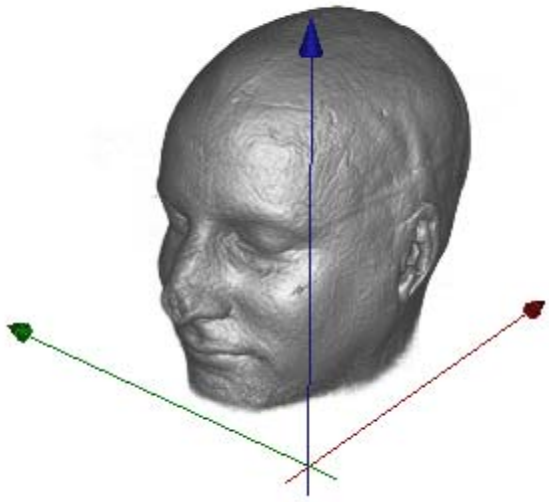


Fig. 77 The coordinate axes are displayed.

Scene Grid

Click this icon to activate a grid in the scene. The display of the grid can be customized in the **Properties** dialog in the **Scene** menu.

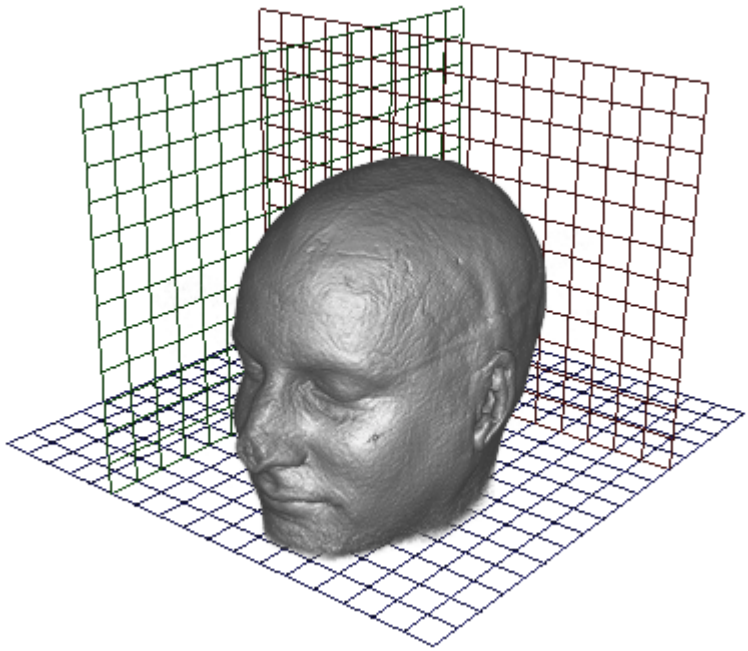


Fig. 78 The grid is activated in the scene.

4.4.5 View Selection

The **3D view** window supports three different viewing modes (for more information on the **3D view**, please refer to *Chapter 4.5.2*). Click the **View selection** buttons to activate the appropriate mode.

Camera View

Use this button to activate the **Camera** mode. For more information on the **Camera** mode, please refer to *Chapter 4.6.9*.

World View

Use this button to activate the **World View** mode. For more information on the **World view** mode, please refer to *Chapter 4.6.8*.

Keyframer

Use this button to activate the **Keyframer** mode. For more Information on the **Keyframer**, please refer to *Chapter 4.6.14*.

4.4.6 Window Layout Section

Click one of these icons to select a predefined layout for the windows within the workspace. VGStudio MAX uses a Multiple Document Interface (MDI). The 3D window, the profile view window and the three slice windows may also be arranged arbitrarily within the workspace by

clicking into the title bar of the window and dragging the window to the desired position. The arbitrarily arranged windows may be rearranged by clicking one of the window layout buttons.

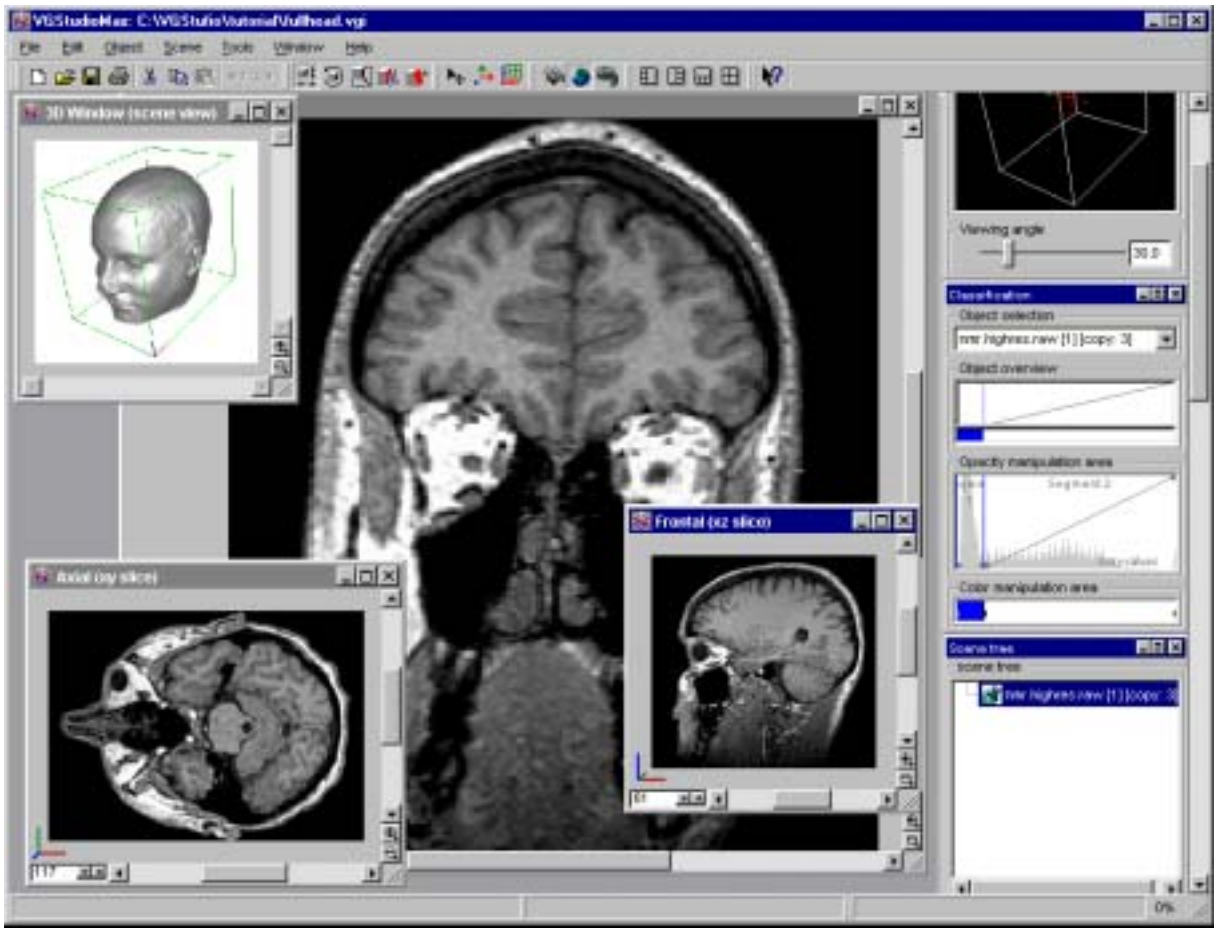


Fig. 79 The VGStudio MAX interface with arbitrarily arranged windows.

You may also arrange the windows by using the options of the **Window** menu (see *Chapter 4.3.7*).

4.4.7 “What‘s this” Section

Click this icon to change into “What’s this” mode. A question mark will then be displayed next to the cursor. If you need help or information on a certain function simply click into a window or on a component of the user interface; a popup window containing online help topics about the selected component will then appear. There you will find short information on the functions and

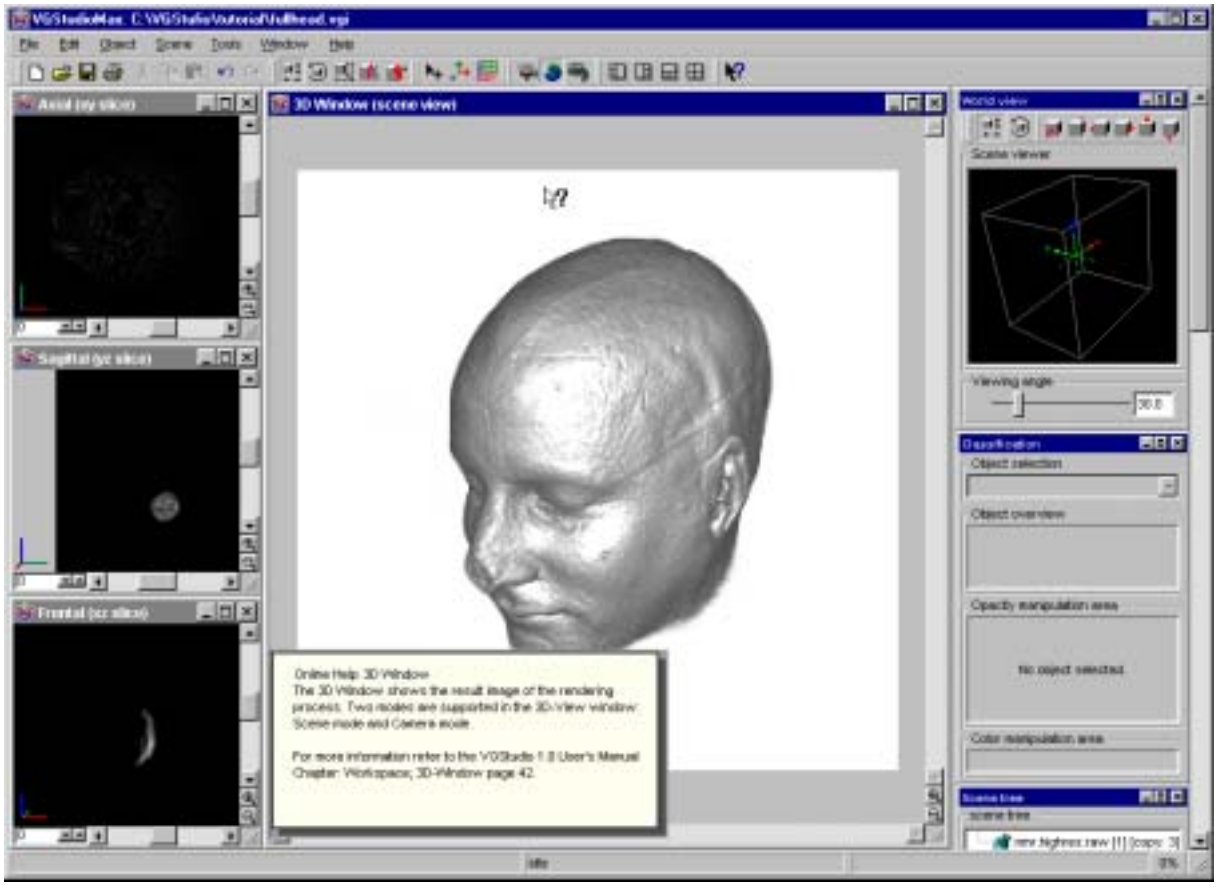


Fig. 80 VGStudio MAX’s online help.

also on where to find the information in the User’s Manual.

4.5 The Workspace

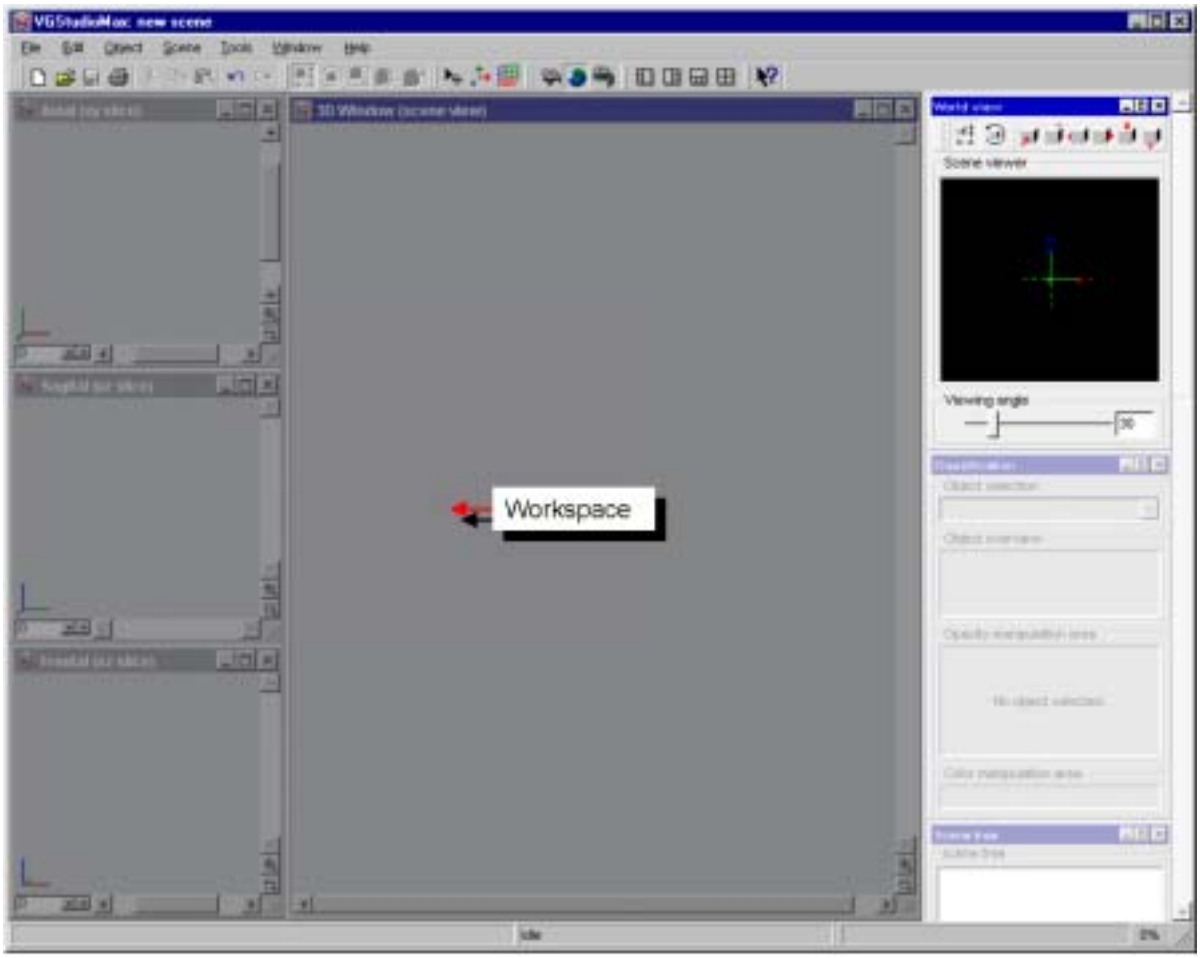


Fig. 81 Default layout screen after VGStudio MAX has been started.

The VGStudio MAX workspace includes four elements, i.e. the 3D window and the three slice windows. The 3D window, the slice windows and the profile window may be activated or deactivated by simply clicking into the title bar or into the windows. The three slice windows form one entity which means that they can only be opened or closed all together and not separately. To close either the 3D window, the profile window or the slice windows, click the **Close** button in the upper right corner of the window. To activate a disabled window again use the **Window** menu and select **New slice windows**, **New profile view** or **New 3D window**. For more information on how to work with the windows, see also *Chapter 4.3.7 Window Menu*.

The layout of the windows in the workspace can also be adjusted arbitrarily by simply clicking into the title bar with the left mouse button and dragging the window to the desired position. Each window can be positioned or enlarged independently from the other windows.

You may use the **Window** menu or the window icons to enlarge, minimize, or close a window.

Use the **Minimize** button to minimize a window within the workspace.

Use the **Maximize** button to maximize a window within the workspace.

4.5.1 Slice Windows and Multiplanar Reformatting

The slice windows provide the VGStudio MAX user with full Multi Planar Reformatting (MPR) functionality for voxel data sets. In the slice windows, three perpendicularly oriented cross sections (axial, sagittal, and frontal) of the currently selected object are displayed. The projection of the origin is always displayed in the lower left corner of the window. The coordinate system used in the slice images is always the object coordinate system of the currently selected object. Axial slices are perpendicular to the z-axis, frontal slices are perpendicular to the y-axis, and sagittal slices are perpendicular to the x-axis.

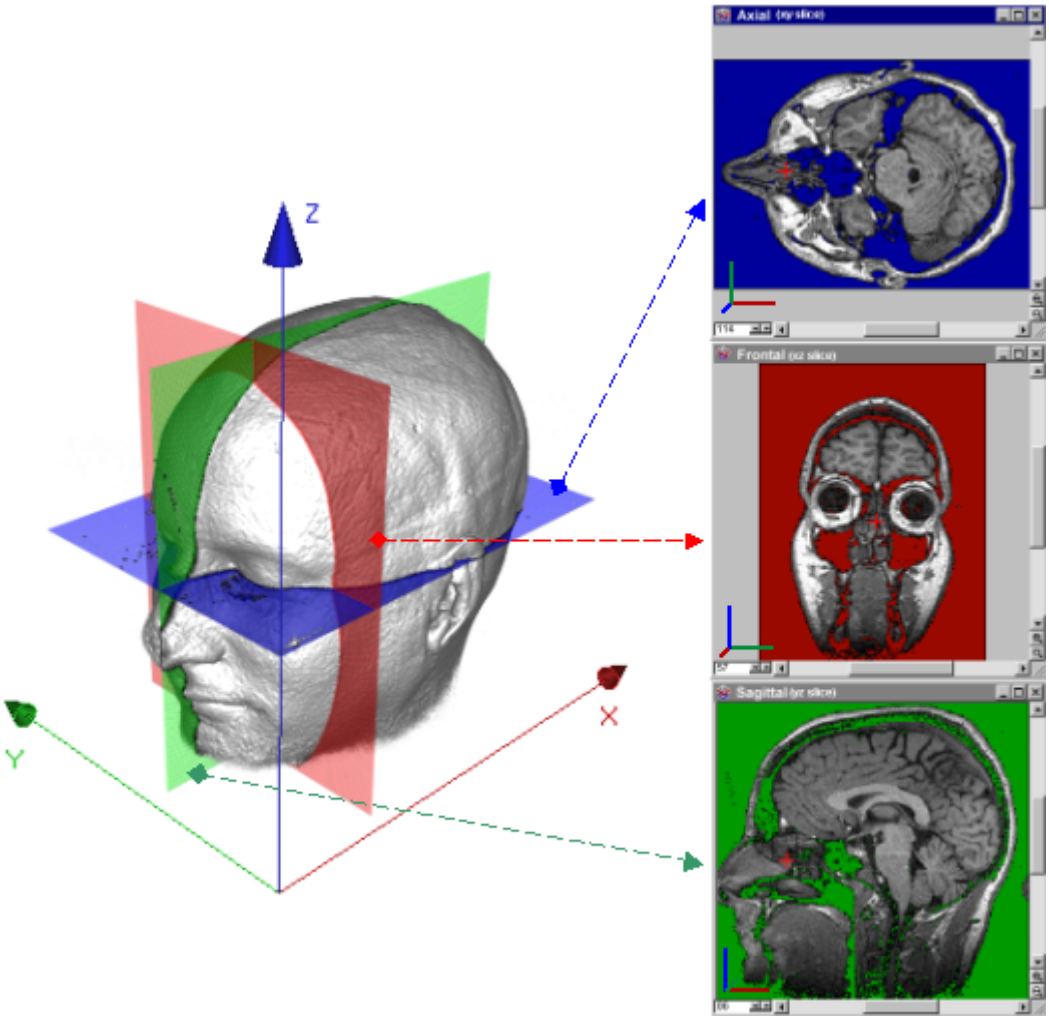


Fig. 82 In the three slice windows of VGStudio MAX, the cross sections axial, frontal, and sagittal are displayed.

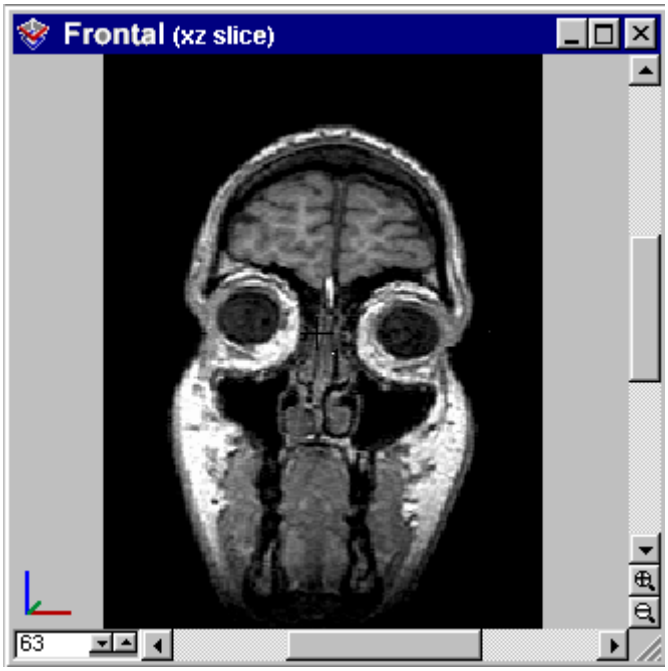
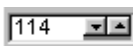


Fig. 83 VGStudio MAX's frontal view window.

In the title bar of the slice windows, the orientation (i.e. axial, sagittal, or frontal) and the image planes (i.e. the xy, yz, and xz planes) are displayed. In the left corner of the title bar you find the **Control** icon, which you use to access the **Control** menu. Double-clicking this icon will close all three slice windows. You can use the **Control** menu to maximize or minimize the slice windows or to close them. The window buttons can be found in the right corner of the title bar. These buttons can also be used to maximize, minimize, or close the slice windows.

In each slice window you will also find two scrollbars to pan large images as well as two **zoom** buttons and one slice selection box. In the lower left corner of each slice window a small tripod colored in the VGStudio MAX color scheme will be displayed, which shows the orientation of the corresponding slice in the object coordinate system.

Use the slice selection box in the lower left corner of the slice windows to scroll through the image stack by clicking the up and down arrows or to select a specific slice by typing in the slice number and then clicking into another window. The selected slice will then be displayed.



Use the **zoom in** and **zoom out** buttons in the lower right corner of the slice windows to zoom in on an image (i.e. enlarge the image) or to zoom out (i.e. reduce the image). The images will then be enlarged or reduced by a preset zoom factor.

When clicking into a slice window with the right mouse button, a context menu will be opened.

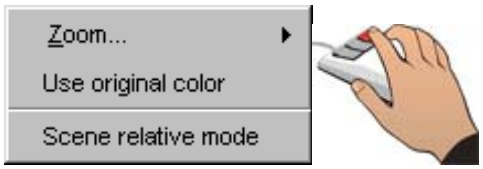


Fig. 84 A context menu will be opened when clicking into one of the slice windows with the right mouse button.

- **Zoom**—Select this command to open the **Zoom** menu.

Fig. 85 The Zoom menu of the slice images.

  The slice window may be zoomed in (enlarged) or zoomed out (reduced). These functions may also be applied by using the zoom buttons in the lower right corner of the slice windows. The images will then be enlarged or reduced by a preset zoom factor. The **Fit to scene** option will zoom the slice window so that all objects included in the scene may be seen. The **Fit to object** option allows to zoom the active object so that it is displayed with maximum zoom factor. The **Actual Pixels** option applies a zoom factor so that one pixel in the image of the slice window will be one pixel on your screen.

- **Use original color**—Select this command to display the slice images in its original color, brightness, and contrast settings.

- **Use classification color**—Select this command to apply the color, brightness, and contrast settings of the classification tool to the slice images.

- **Object relative mode**— Select this command to switch the three orthogonal slice windows into Object relative mode. The object will be sliced along the axes of the object coordinate system. The originally scanned slice data will be displayed in this case.

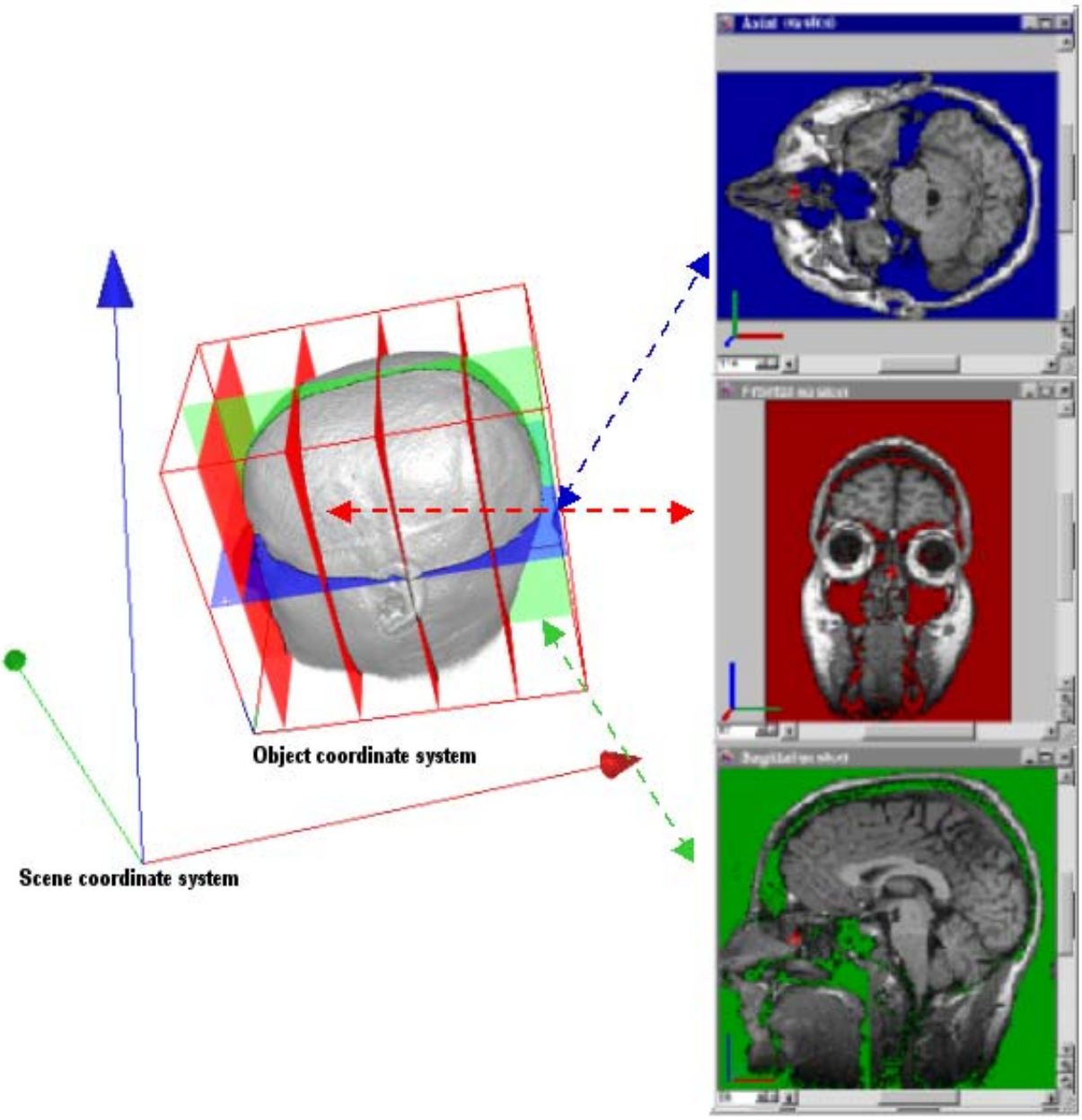


Fig. 86 MRI scan sliced in object relative.

- **Scene relative mode**—Select this command to switch the three orthogonal slice windows into Scene relative mode. The object will be sliced along the axes of the scene coordinate system. This mode allows the user to slice the object along any arbitrary axis. To define the slicing orientation rotate the object against the scene coordinate system. Select the rotate

mode in the 3D window and rotate the object against the scene coordinate system. The scene coordinate system can be seen when activating the Axis in the 3D window.

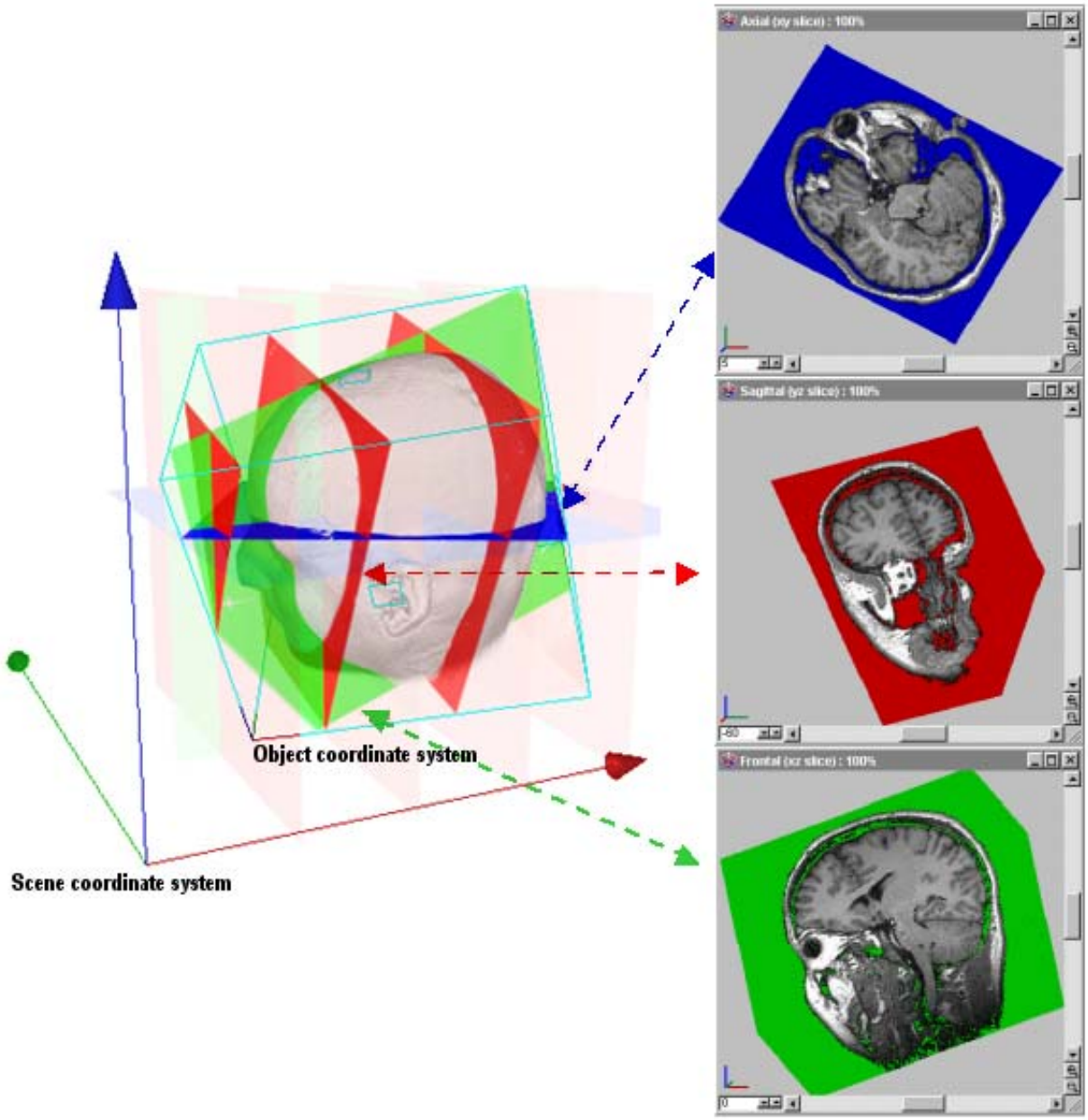


Fig. 87 MRI scan sliced in scene relative mode.

Cross Sections Displayed in the Slice Images

If several objects are loaded into the scene, only one of the objects will be displayed as slice images. All other objects or groups of objects will appear as a cross section through their bounding box if the box is crossed by the slice plane of the currently selected object. Only the bounding boxes will be displayed in the slice windows if several objects, a group of objects, or a polygon object are selected.

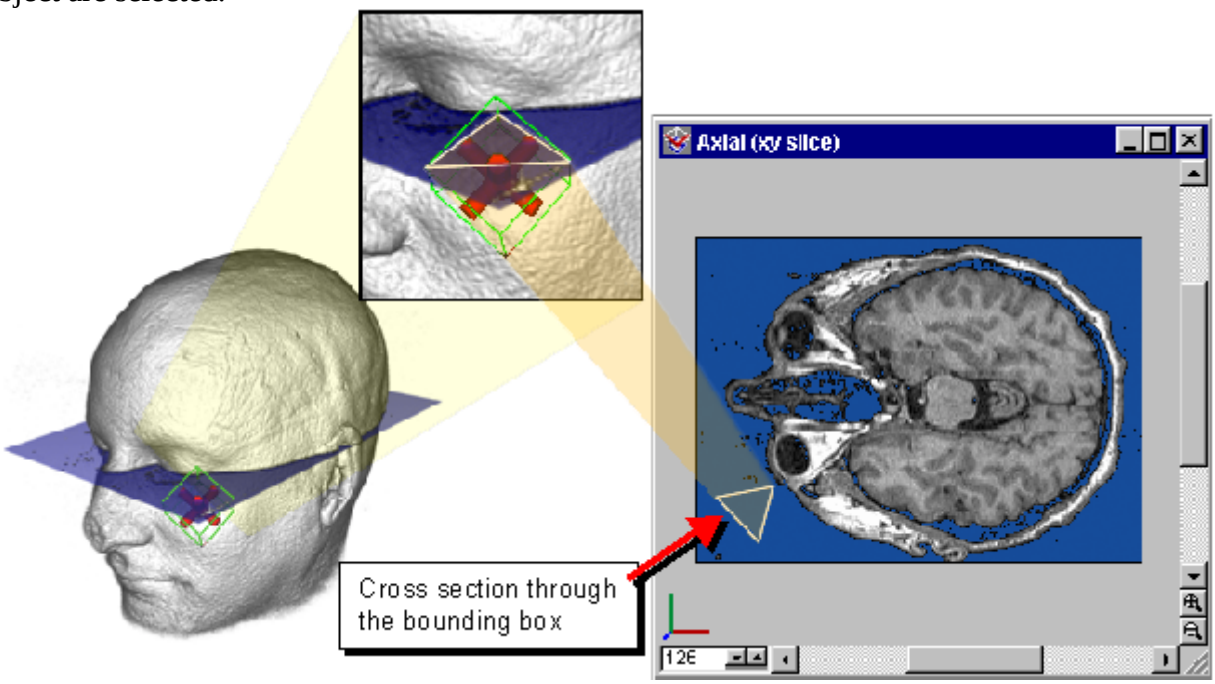


Fig. 88 If several objects are loaded into the scene, one of the objects will be displayed as a slice image; for the other objects, only the bounding boxes will be shown.

If a slice outside the active volume data set is chosen, only a red bounding box will be displayed in the slice windows to display the currently selected object.

Fig. 89 A red bounding box will be displayed if a slice outside the current volume data set is chosen.

The object that was selected last will remain visible in the slice windows when it is deselected until a new object is selected. This feature helps the user to navigate in **Camera** mode with no bounding box visible (for more information on the **Camera** mode please refer to *Chapter 4.6.9 Camera View*).

4.5.2 3D Window

The **3D window** shows the result image of the rendering process. Two modes are supported in the 3D window: **Scene view** (i.e. **World View** mode) and **Camera view** (i.e. **Camera** mode).

In the title bar of the 3D window the currently selected mode (**World view** mode or **Camera view** mode) is displayed. In the left corner of the title bar you find the **Control** icon, which you use to access the **Control** menu. Double-clicking this icon will close the 3D window. You can use the **Control** menu to maximize or minimize the 3D window or to close it. The window buttons can be found in the right corner of the title bar. These buttons can also be used to maximize, minimize, or close the 3D window.

In the 3D window you will also find two scrollbars to pan large images as well as two **zoom** buttons.

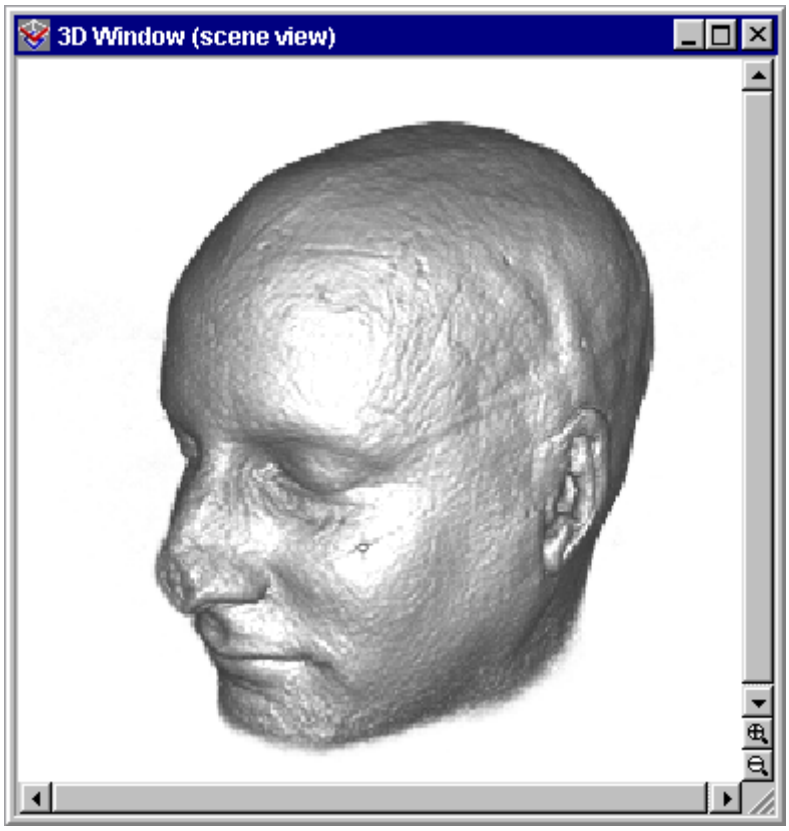


Fig. 90 The 3D window in scene view mode.

When clicking into the 3D window with the right mouse button, a context menu will be opened.

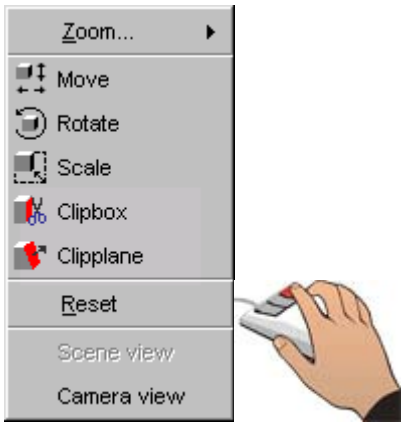


Fig. 91 The context menu in the 3D window.

Use the **Zoom** option to open the **Zoom** menu.

Fig. 92 The Zoom menu of the 3D window.

The 3D window may be zoomed in (i.e. enlarged) or zoomed out (i.e. reduced). These functions may also be applied by using the zoom buttons in the lower right corner of the 3D window. The image will then be enlarged or reduced by a preset zoom factor.

The **Fit to Window** option allows to zoom the active object so that it is displayed with maximum zoom factor. The **Actual Pixels** option applies a zoom factor so that one pixel in the 3D image of the 3D window will be one pixel on your screen.

In the following, the other options of the 3D view context menu will be explained.

- **Move**— Select this command to move the selected object or object group. The **Move** mode is characterized by the green bounding box around the selected object or group of objects. When moving the cursor into the bounding box, it will take the shape of one vertical and one horizontal arrow (see the table in *Chapter 3.1.2 Mouse Usage*). The object may be moved in the image plane by clicking into the bounding box and dragging the mouse while the left mouse button is pressed. The object may be moved forwards or backwards (and thus will be enlarged or reduced) by clicking into the bounding box and dragging the mouse while the middle mouse button (or the **Alt** key and the left mouse button) is pressed. The whole bounding box may be used as active area to apply the appropriate action. Using the Shift modifier in **Move** mode allows you to pan the object along either the vertical or horizontal direction of the 3D window image plane. For more information on the **Move** mode, please refer to *Chapter 4.6.7 Object Properties*.

- **Rotate**— Select this command to rotate the selected object or object group. The **Rotate** mode is characterized by the red bounding box around the selected object or group of objects. When moving the cursor into the bounding box, it will take the shape of one vertical and one horizontal circular arrow (see the table in *Chapter 3.1.2 Mouse Usage*). The object may be rotated around the x- or y-axes of the image plane by clicking into the bounding box and dragging the mouse while the left mouse button is pressed. The object may be rotated around the viewing direction by clicking into the bounding box and dragging the mouse while the middle mouse button (or the **Alt** key and the left mouse button) is pressed. The whole bounding box may be used as active area to apply the appropriate action. Using the Shift modifier in **Rotate** mode allows you to rotate the object in either around the vertical or horizontal axes of the 3D window image plane. For more information on the **Rotate** mode, please refer to *Chapter 4.6.7 Object Properties*.

- **Scale** — Select this command to scale the selected object or object group. The **Scale** mode is characterized by the dark blue bounding box with squared handles, i.e. active areas on each side of the selected object or group of objects. A rectangular shape will appear next to the cursor when moving it into the active area (see the table in *Chapter 3.1.2 Mouse Usage*). The object may be scaled along the x-, y-, or z-axes by clicking the handle, i.e. the active area on one side of the bounding box and dragging the mouse while the left mouse button is pressed. Isotropic scaling may be performed by clicking into the bounding box and moving the mouse up or down while the middle mouse button (or the **Alt** key and the left mouse button) is pressed. When several objects are selected, only isotropic scaling is supported. Group the objects first if you need to perform unisotropic scaling for several objects at a time. For more information on the **Scale** mode, please refer to *Chapter 4.6.7 Object Properties*.

- **Clipbox** — Select this command to box clip the selected object or object group along the axes of its bounding box. The **Clipbox** mode is characterized by the cyan bounding box with squared handles, i.e. active areas on each side of the selected object or group of objects. When moving the cursor into the active area, a scissors will appear next to the cursor (see the table in *Chapter 3.1.2 Mouse Usage*). The object may be clipped by clicking one of the handles of the bounding box and dragging the mouse along the desired clip direction while the left mouse button is pressed. Group the objects first if you want to clip several objects at a time. For more information on the **Clipbox** mode, please refer to *Chapter 4.6.7 Object Properties*.

- **Clipplane** — Select this command to clip the selected object or object group by an arbitrary clipplane. The **Clipplane** mode is characterized by the cyan bounding box with a normal vector on one side of the active object. When moving the cursor into the bounding box, a scissors will appear next to the cursor (see the table in *Chapter 3.1.2 Mouse Usage*). The object may be clipped along an arbitrary clipplane by moving the mouse up and down while the middle mouse button (or the **Alt** key and the left mouse button) is pressed. To rotate the clipplane around the origin of the clipplane's normal vector click into the clipplane and drag the mouse while the left mouse button is pressed. The origin of the clipplane's normal vector may be moved to any arbitrary position on the clipplane by clicking the clipplane's normal vector origin with the left mouse button and dragging the mouse while the left mouse button is pressed. The clipplane will be disabled if several objects are selected. Group the objects first if you want to clip several objects with one clipplane at a time. For more information on the **Clipbox** mode, please refer to *Chapter 4.6.7 Object Properties*.

- **Reset** —Select this command to reset actions of all categories applied to the selected object such as translation, rotation, clipping, and scaling to their default values. Reset single categories of actions in the **Object properties** tool. For more information see also *Chapter 4.6.7 Object Properties*.

- **Camera mode / World view mode**—Select this command to switch between **Camera mode** and **World view mode**. These options are toggles, i.e. only visible one at a time depending on the mode you are currently working in. If you are working in **World view mode** (indicated in the 3D view window with the text **scene view**), you may switch to **Camera mode** and vice versa.

4.5.3 World and Camera View

VGStudio MAX provides two different modes to view your data: **World view** mode and **Camera view** mode.

By default, VGStudio MAX will start in world view mode. You may switch between **World view** mode and **Camera view** mode by clicking the icons in the icon bar or by using the **Camera view** or **World view** option in the **Scene** menu.

In **World view** mode you can view your data from “outside”. By using the **World view** tool you may rotate and move the whole scene or change the viewing angle without affecting the scene itself. For more information see *Chapter 4.6.8.*

In **Camera view** mode you can view your data from “inside”. This means that you can place a camera into the scene and adjust all camera parameters such as camera position, look-at point, up vector, and viewing angle. For more information see *Chapter 4.6.9.*

VGStudio MAX users will be able to perform an arbitrary data walkthrough when activating the **Camera view** mode. A camera may be placed into any position within the scene or even within a data set. The viewing direction and viewing angle may also be chosen arbitrarily.

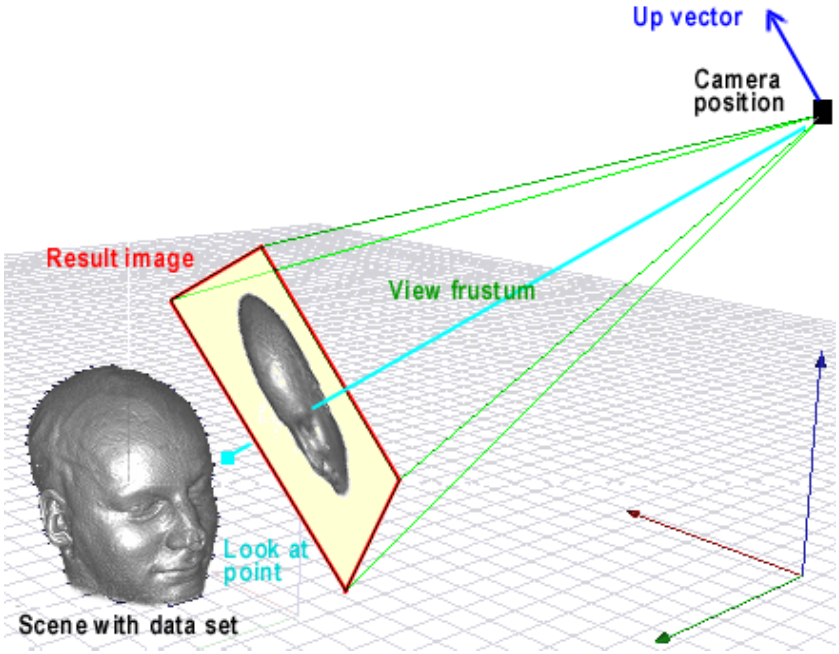


Fig. 93 The Camera view mode allows you to view your data from inside. You may adjust all camera parameters shown here according to your needs.

The camera symbol will appear in all slice images after having activated the **Camera view** mode. The camera symbol looks as follows:

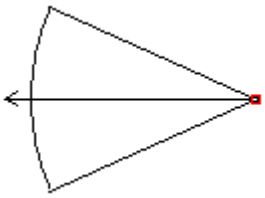


Fig. 94 The camera symbol as it is displayed in the slice images.

Several handles are included in the camera symbol. The **Camera position** handle is marked with a small circle. The **Look-at point** is marked by the tip of the viewing vector. The two front edges of the **View frustum** are the viewing angle handles.

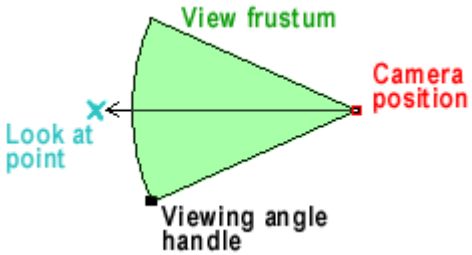


Fig. 95 All camera parameters may be changed by dragging the handles.

Each handle may be manipulated by using the mouse. To do so, click the camera handle in one of the slice images with the left mouse button and then drag the handle while the left mouse but-

ton is pressed to change the camera position. By using two slice images the user will gain full 3D control over the camera position. Grab one of the viewing angle handles and drag the **View frustum** so that it becomes wider or more narrow. This will change the viewing angle of your camera. The changes of the camera position will become visible in all images, i.e. all slice images and the 3D window simultaneously.

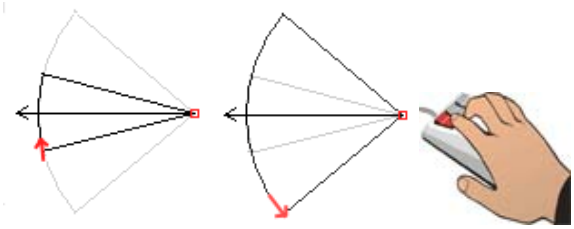


Fig. 96 Reduce or enlarge the view frustum by dragging the handles.

The up vector (the up direction defined in scene coordinates) of your camera may also be adjusted by clicking with the middle mouse button (or with the left mouse button while holding the **Alt** key pressed) into a slice window and dragging the mouse up or down while the middle mouse button is pressed. This will rotate the rendered image around the viewing vector.

Reminder: The option to adjust the up vector with the middle mouse key **may not be used** when the Keyframer is activated. The middle mouse key will add or remove Keyframe handes when the Keyframer is activated. For detailed information about the Keyframer please refer to *Chapter 4.6.14 Keyframer*.

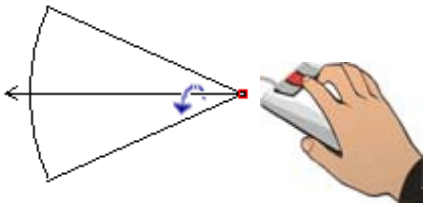


Fig. 97 Rotate the image around the viewing vector.

The length of the viewing vector is of no importance.

While moving the camera the slice images will show the three cross sections through the volume data with the appropriate handle either in camera position or the look-at handle as the center of the three sections. The active handle which marks the center of the slice sections will be displayed in red. The following image shows the slice images with the camera tool activated. The look-at handle is the active handle and the slices show the sections with the look-at handle as center.

All camera parameters described here may be adjusted exactly by typing in numerical values in the **Camera view** tool. For more information on this tool, please refer to *Chapter 4.6.9 Camera View.*

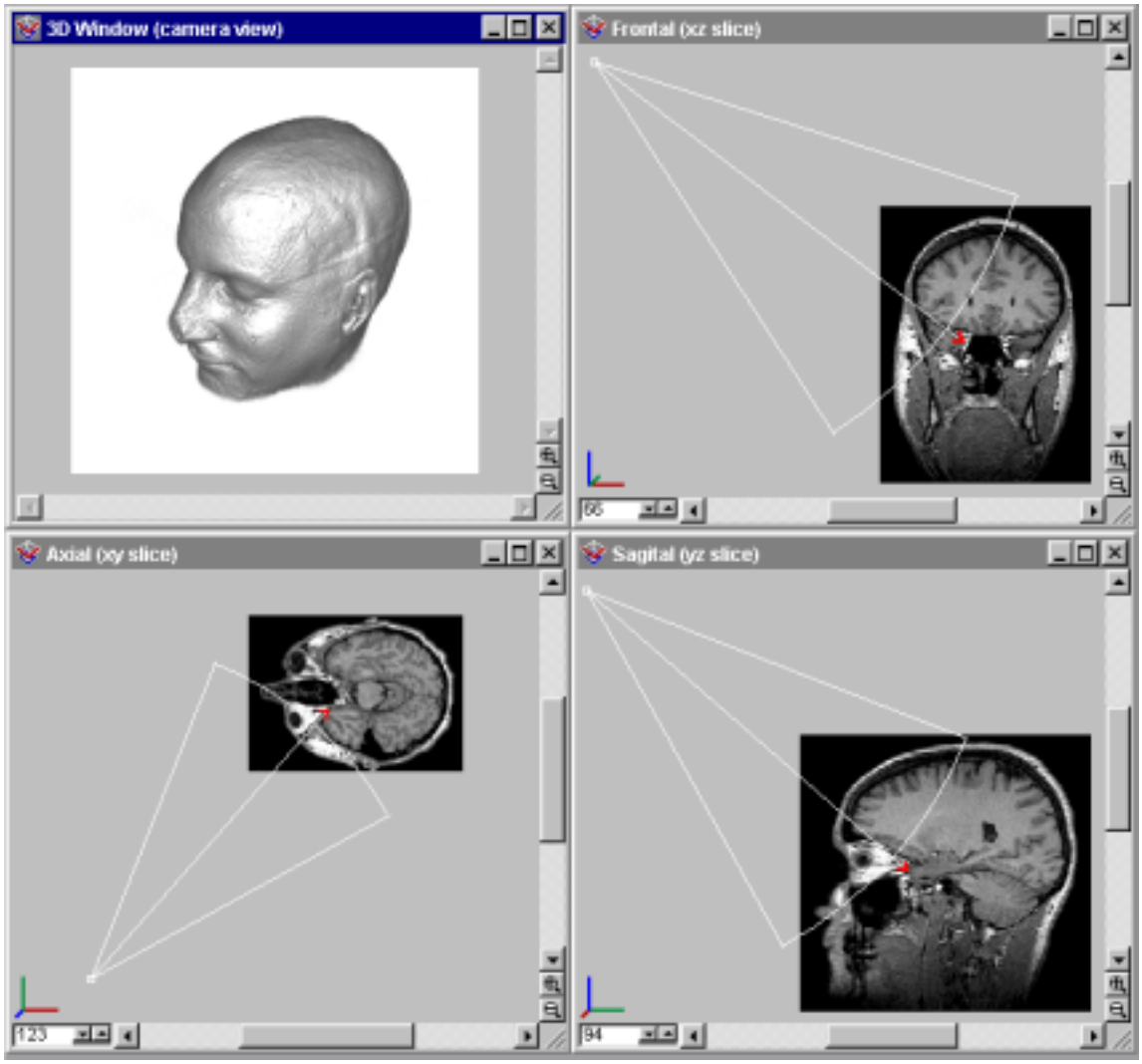


Fig. 98 The 3D window and the slice images while the Camera view mode is selected.

Reminder: The camera and look-at position are defined in scene coordinates while most of the other tools are displayed in object coordinates! Also, the color coding in the slice tools may not correspond to the color coding of the camera tool in case of a rotated object.

4.5.4 Profile Window

In the **Profile Window** you can see the data profile along the line defined by the **Distance Measurement Tool** (see *Chapter 4.4.3 Measurement Utilities*) if it is activated. The Profile Window is active only in conjunction with the **Distance Measurement Tool** . If the **Distance Measurement Tool** is not activated the Profile Window will just show an empty rectangle. If **Distance Measurement Tool** is activated the Profile Window shows the profile of the volume object as a function gray value or opacity against scene units.

You can choose between two profile modes: the opacity profile and the gray value profile. The gray value profile is activated if you choose *Use original color* in any slice window, the opacity profile is activated by choosing *Use classification color* in any slice window. Please refer to *Chapter 4.5.1 Slice Windows and Multiplanar Reformatting*.

In the title bar of the profile window the currently horizontal and vertical zoom values are displayed (see description below). In the left corner of the title bar you find the **Control** icon, which you use to access the **Control** menu. Double-clicking this icon will close the Profile Window. You can use the **Control** menu to maximize or minimize the Profile Window or to close it. The window buttons can be found in the right corner of the title bar. These buttons can also be used to maximize, minimize, or close the profile window.

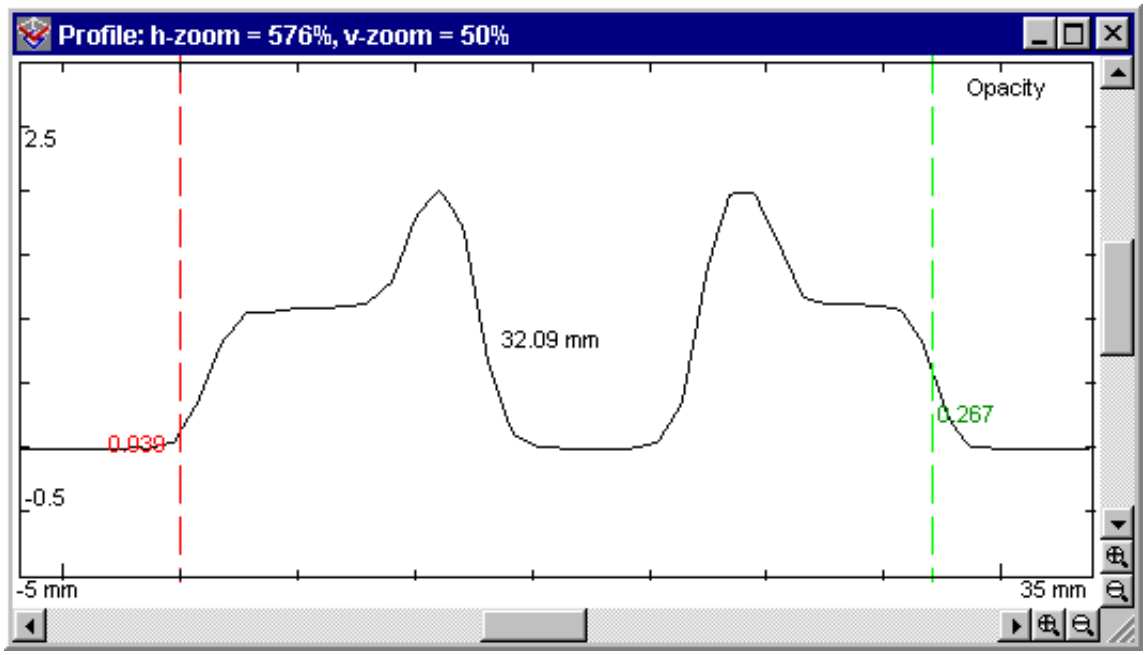


Fig. 99 The profile window showing a profile of classification color data .

In the profile window you will also find two scroll bars and for each scroll bar two zoom buttons. The vertical scroll bar scrolls the values (either gray values or classification values) and the corresponding zoom buttons zoom the range of values displayed. The horizontal scroll bar selects the region of the line, where the profile will be displayed. The corresponding zoom buttons select the range of the region.

The **Distance Measurement Tool** will be displayed by a vertical red dashed line for the first point of the distance and a vertical green dashed line for the second point of the distance. In the

middle between both lines, the distance in the chosen units will be displayed. Where each line cuts the profile the value of the profile will be displayed. You can left click on each line and drag it to an anrbitrary position, except, that you cannot drag a line above or beyond the other line. You can replace the distance by left clicking anywhere into the profile window where no line lies, to define the start point of the line. Now you can drag the second point to any place left of the starting point until the left mouse button is released. Once the button is released, the two points will "snap" to the two most significant points within the two starting points (for "snapping" see below).

When clicking into the profile window with the right mouse button, a context menu will be opened.

Use the **Zoom** option to open the **Zoom** menu.

Choosing **In** or **Out** will zoom both value range and distance range, **Value in** or **Value out** will zoom value range and **Distance in** or **Distance out** will zoom distance range.

The other menu items of the context menu will be described in the following.

Fig. 100 The context menu in the profile window.

- **Focus on line**— Select this command to adjust region and zoom to the start and end point of the **Distance Measurement Tool** in that way, that the profile within the two points is fully visible and the distance (i.e. the two points), too.

- **Snap line**— Select this command to let the two points of the **Distance Measurement Tool** snap at the two most significant edges between the two points, where an edge is defined as an inflection point of the profile. The most significant edges are those where of all inflection points the first derivative has the highest absolute value. After "snapping" a **Focus on line** action as described above will be performed.

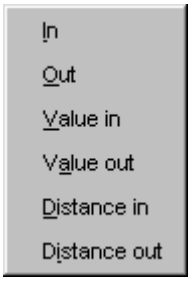


Fig. 101 The Zoom menu of the profile window.

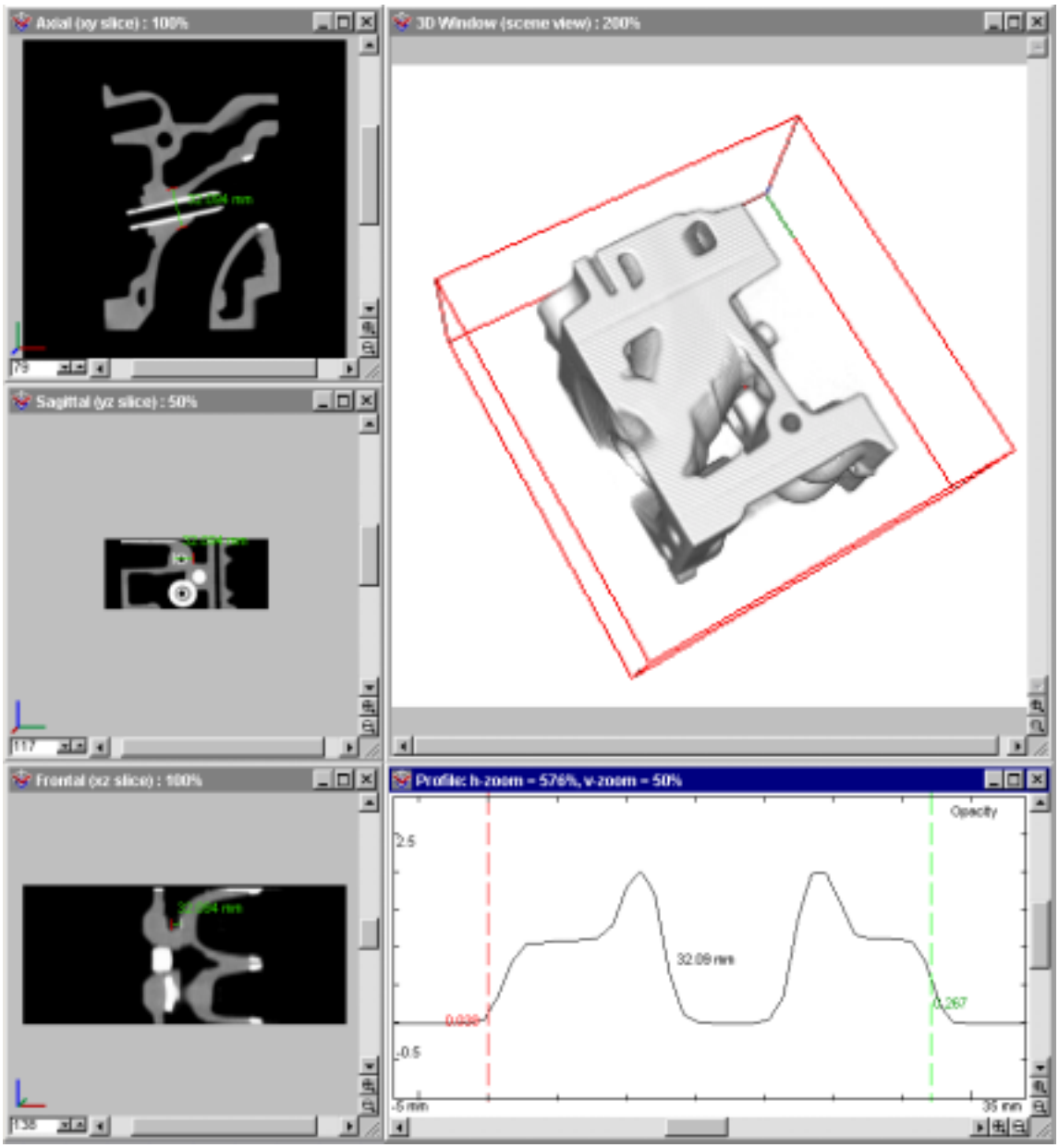


Fig. 102 The workspace with slice windows, 3D window and profile window. Distance measurement tool is activated.

Since the Profile Window is deeply connected with the **Distant Measurement Tool**, each change of one of the points either in a Slice Window or in the Profile Window will effect the other window. Especially when you make a new line in a Slice Window by pointing anywhere in the Slice Window (assuming **Distance Measurement Tool** is activated) and dragging the second point to any position, you can always see the profile of that line. Releasing the left button will immediately be followed by "snapping" the line and a focus on that line as described at **Snap line** above. Also changing the line in the Profile Window as described above will be shown directly in the Slice Windows.

4.6 Tool Box

The tool box is located on the right-hand side of the VGStudio MAX user interface. The activated tools will all be located in the tool box. You may scroll through the tool box by means of the scroll bar located on the right-hand side of the tool box.

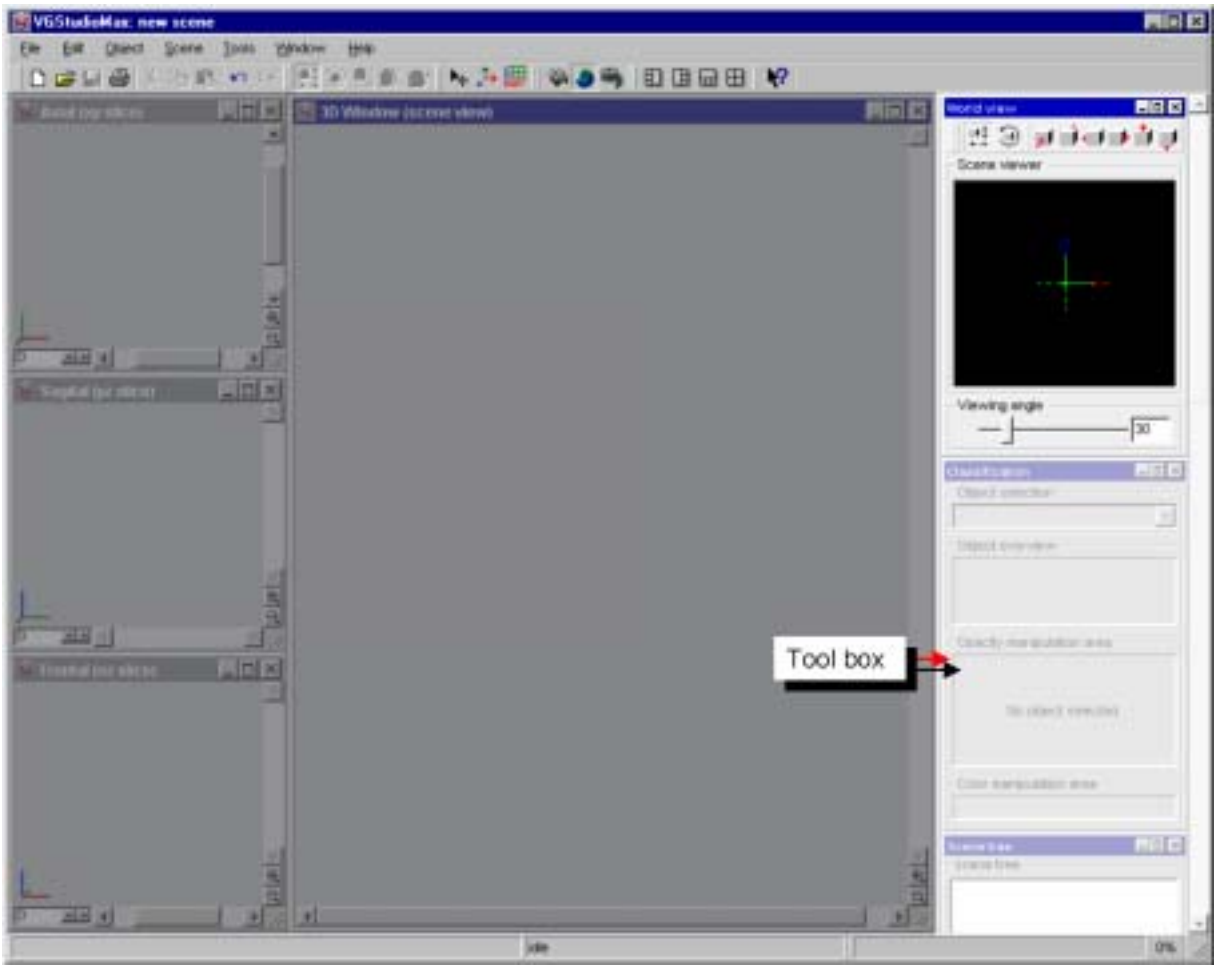


Fig. 103 The tool box of VGStudio MAX.

Tools can be enabled or disabled. To do so click the corresponding menu item in the **Tools** menu. A check mark next to the entries will show that the tool is enabled. A tool which was just enabled will appear at the bottom end of the tool box.

You may also arrange the tools in an arbitrary vertical order within the tool box by clicking into their title bar with the left mouse button and then dragging them to the desired position within the tool box while the left mouse button is pressed.

Tools can also be dragged out of the toolbox by clicking into their title bar with the left mouse button and then dragging them to the desired position outside the tool box. The tools are then “floating” tools which are independent of the main application window. Tools dragged out of the

tool box will stay on top all the time. Inside the tool box, the tools have a fixed size. If you need to enlarge or reduce the windows, e.g. for better handling, you first have to drag them out of the tool box. Most tools can be resized when they are located outside the tool box by clicking into the frame of the corresponding window and then dragging the mouse until the desired size is reached. When placing the tool back into the tool box, it will be reduced or enlarged to its default size. The tool will be resized to the size defined by the user once it is dragged out of the tool box again.

When you deactivate all tools, the tool box will shrink so that the whole window can be used as workspace. Activate a tool to expand the toolbox again.

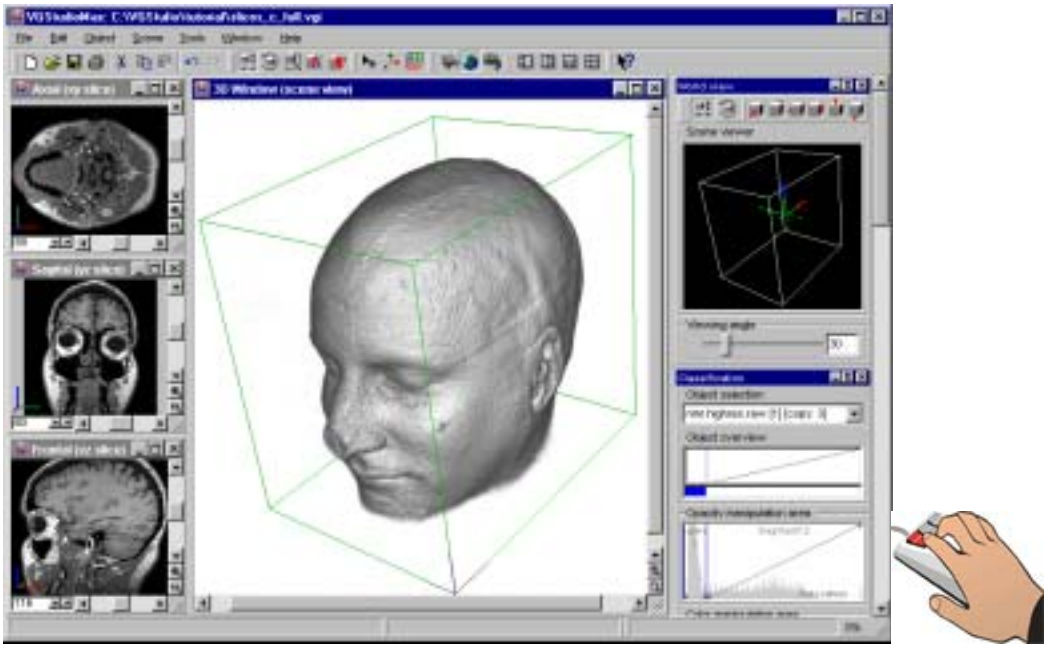


Fig. 104 The Classification tool is now inside the tool box. Click into the title bar of the tool and drag it out of the tool box while the left mouse button is pressed. You may then adjust the size of the tool.

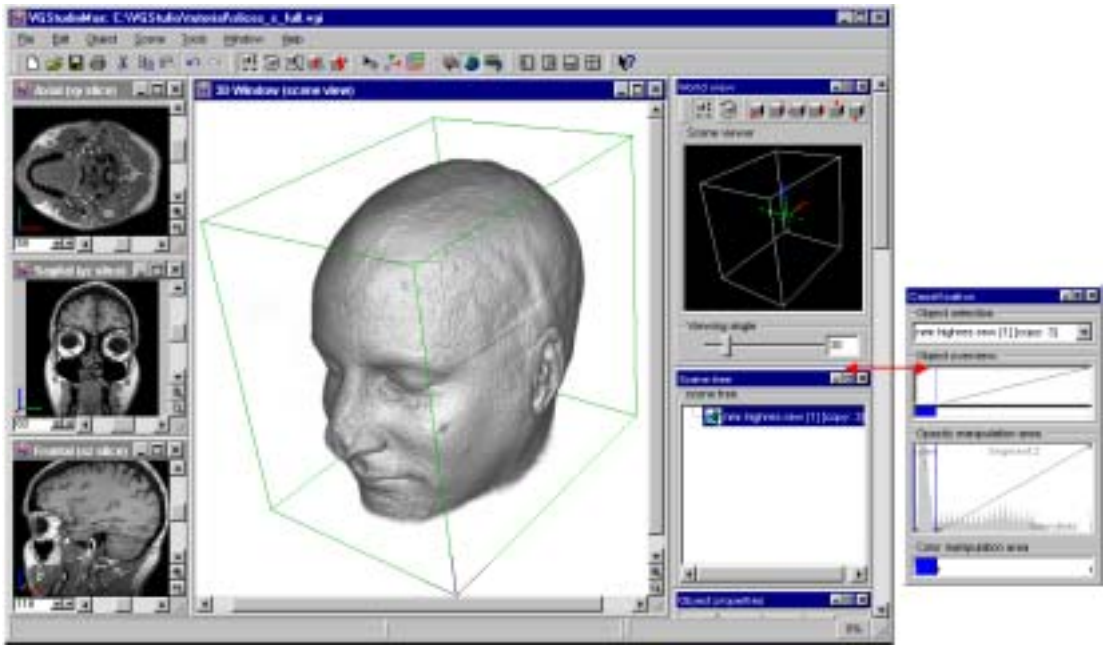


Fig. 105 The Classification tool is dragged out of the tool box where you may adjust its size to your needs.

You may use the **Close** button to close a tool. Use the **Tools** menu to enable a tool again by clicking it. A check mark will then appear next to the menu item. For further information on the **Tools** menu, see also *Chapter 4.3.6.*

Use the **minimize** button to minimize the tool. If you press the **minimize** button in a floating tool, the tool will be placed back into the tool box as a minimized tool and will appear at the end of the tool box.

When you click the **maximize** button of a tool, it will be taken out of the tool box and will become a floating tool. If you press the **maximize** button in a floating tool, the tool will be placed back into the tool box as the last tool in the box.

4.6.1 Classification Tool

The **Classification** tool is one of the most important and most powerful tools of VGStudio MAX 1.0. The main purpose of the **Classification** tool is used to apply user-defined transfer functions to the data for both opacity and color. The opacity transfer function can be adjusted in the graph which is shown in the **Opacity manipulation area**.

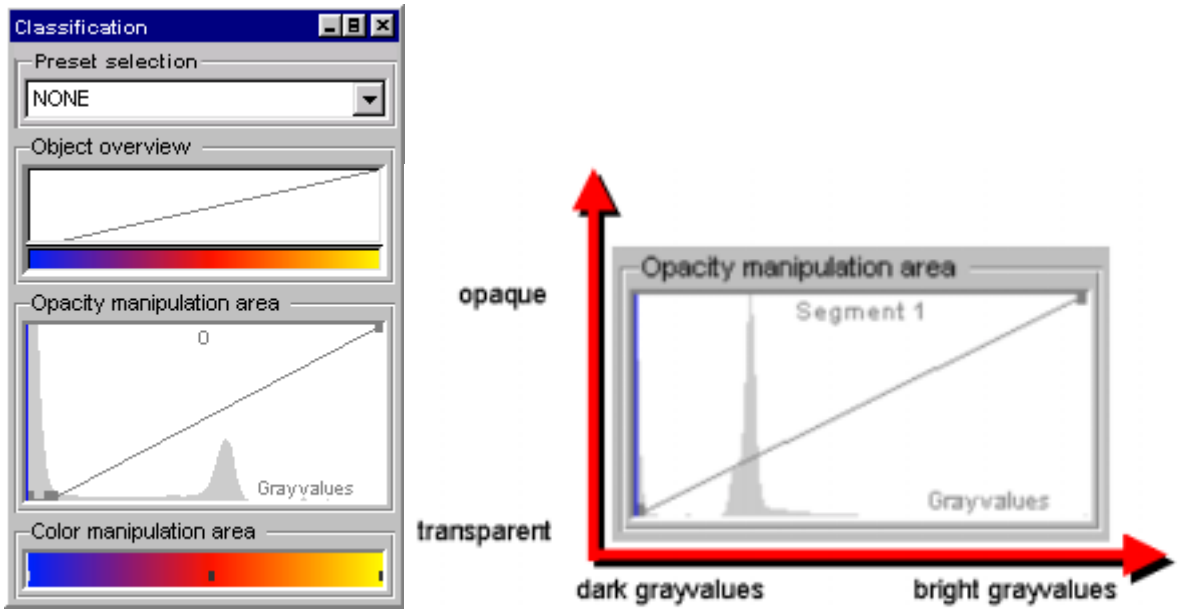


Fig. 106 The Opacity manipulation area of the Classification tool.

The default transfer function maps the darkest gray values to transparent and the brightest gray values to totally opaque. The default color mapping is set to white. The default mappings may be manipulated arbitrarily. Thus, the **Classification** tool allows the user to apply any transparency level or color to any gray value within the data set. The examples below show what the images will look like when you change the opacity values.

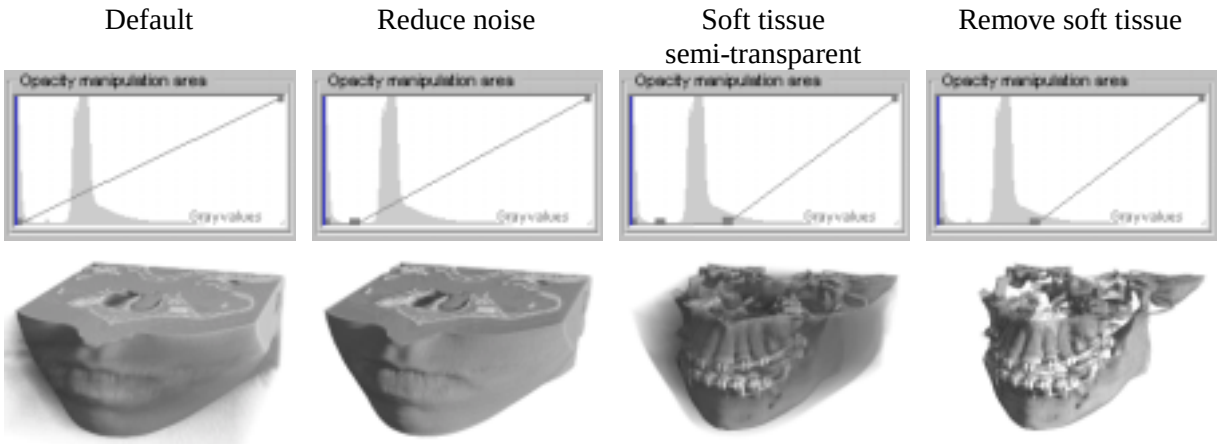


Fig. 107 When changing the opacity values, the images will look like shown here.

Reminder: Exceptions occur in case of RGBA color data, e.g. colored TIF, JPEG, BMP, or PPM images or RAW RGBA data. No color mapping will be possible for color data. The color intensity is used as “gray value” in the classification tool for color data.

The classification tool can be used in two different modes: **Level/Window mode** and **Advance mode**. Level/Window mode provides an easy to use interface which allows to apply a simple opacity ramp with a defined width and center. Window-leveling is mostly used and well known in the medical community. Advanced mode allows the user to apply arbitrary opacity functions which can not be generated by using a simple ramp. Both modes are described in this chapter.

The **Classification** tool consists of several elements:

- Preset selection

In **Advanced mode**:

- Object overview
- Opacity manipulation area
- Color manipulation area

In **Level/Window mode**:

- Level – Window area
- Opacity manipulation area

Preset selection

The **Preset selection** contains a set of predefined Window-Level/Opacity and color settings. Clicking the Preset selection will show several predefined settings. Clicking one of these presets changes the Window and Level settings or the opacity function in the classification tool to the preset values. You may apply the various presets to see which works best for displaying the volume.

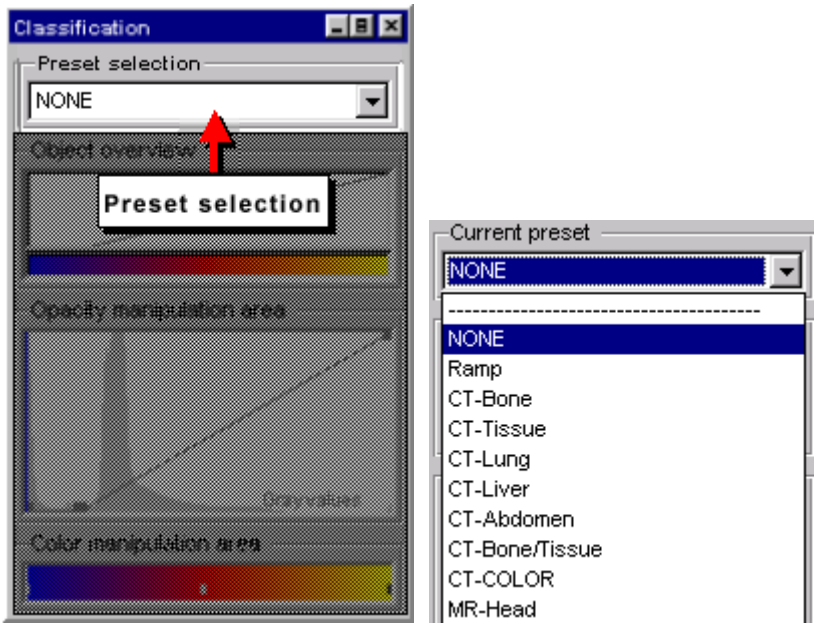


Fig. 108 Select a classification tool preset from the pull down list.

The following presets for medical users are included as default and therefore may not be removed from the preset list: Ramp, Inverse Ramp, CT-Bone, CT-Tissue, CT-Lung, CT-Liver, CT-Abdomen, CT-Bone/Tissue, CT-Color and MR-Head.

You may add your own or overwrite existing settings in the preset list by saving the current settings defined in the classification tool. Press the right mouse key within the classification tool to bring up the context menu. Select the **Save preset** option to save the current settings.

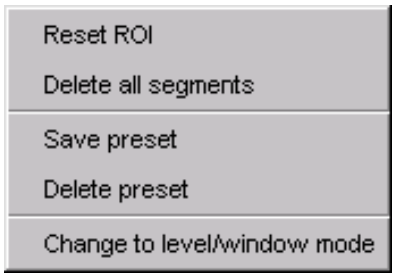


Fig. 109 The context menu with the Save/Delete preset options..

A dialog will come up to where you have to either select an existing preset to overwrite or to enter an name to create a new preset.

Fig. 110 The Save preset dialog..

A Preset will be applied relative to the existing data range of your data. This means that the color and opacity/window – level settings for a certain gray value may vary in case that the data range (minimum to maximum gray value in your data) changes. You may save absolute Presets to prevent this behavior. Activate the **Absolute Preset** check box in case that the Presets should be applied according to absolute gray values.

You may delete a preset from the preset list. To do so press the right mouse key within the classification tool to bring up the context menu. Select the **Delete preset** option to delete the selected preset. Keep in mind that default Presets can not be deleted.

Object overview *(Advanced mode)*

The **Object overview** section of the **Classification** tool is divided into two parts, i.e. the opacity area which shows the grayscale to opacity mapping function and the color area which shows the color mapping.

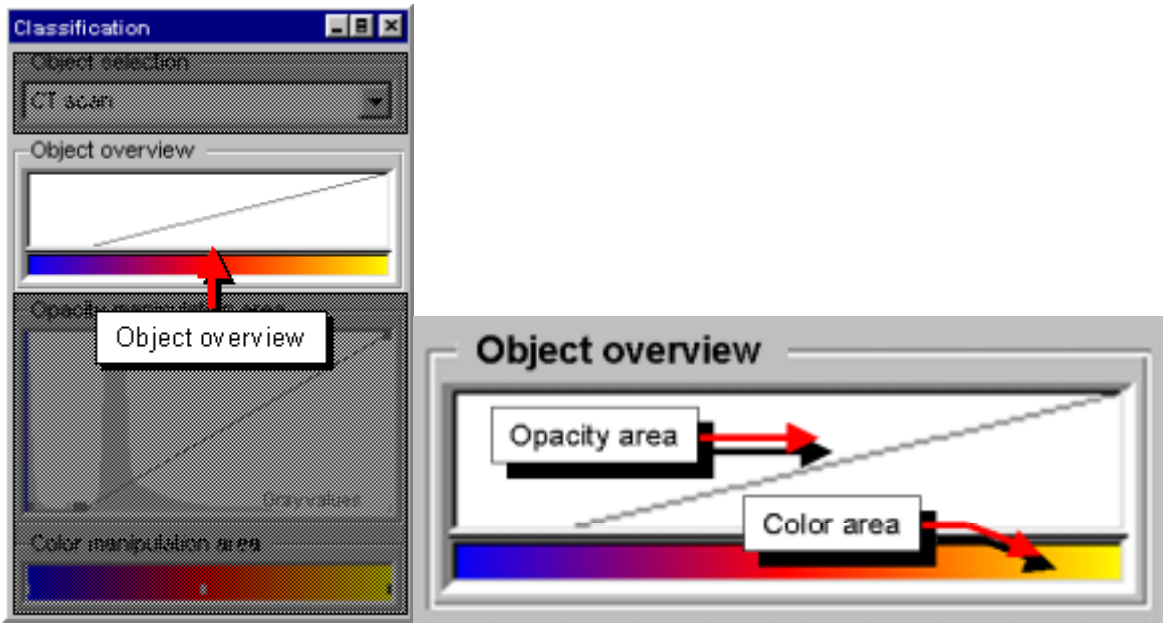


Fig. 111 The Object overview section is divided into two parts, i.e. the opacity area and the color area.

As the name says, the **Object overview** section provides the user with an overview of the entire grayscale and opacity range as well as the color settings of the selected object. To display the grayscale and opacity range of the active object, click with the left mouse button into the opacity area of the **Object overview** section. The values will disappear as soon as you release the mouse button.

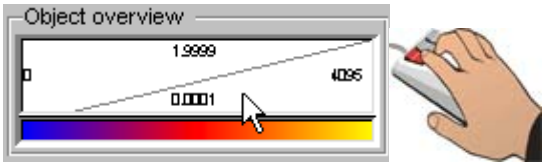


Fig. 112 When clicking into the opacity area of the Object overview section, the grayscale and opacity values of the active object will be displayed.

The **Object overview** section may also be used to define a Region of Interest (ROI) within the opacity area. The ROI will be displayed enlarged in the **Opacity manipulation area** of the classification tool.

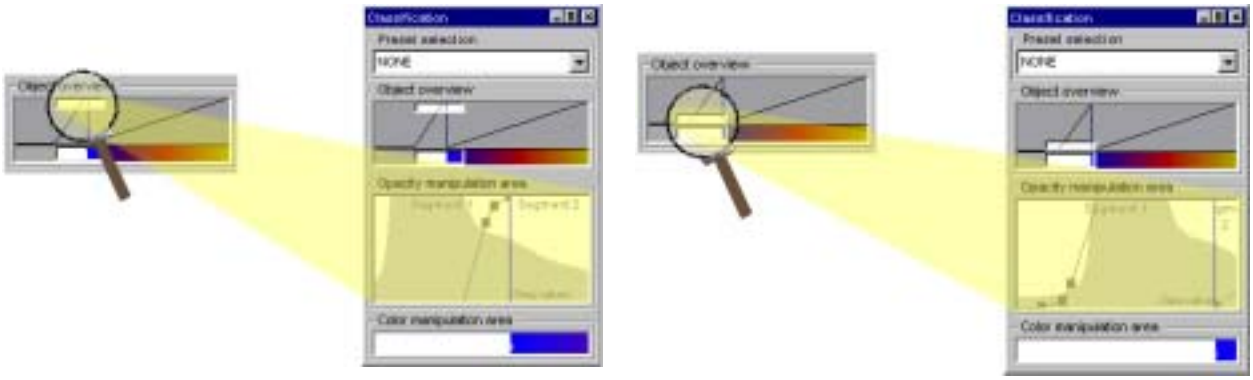


Fig. 113 Define regions of interest in the Object overview section of the Classification tool.

By default, the ROI covers the whole opacity area. The background of the opacity area will be white.

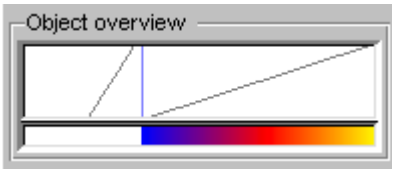


Fig. 114 The ROI covers the entire opacity area.

When defining a ROI the background of the opacity area will be gray while the ROI has a white background.

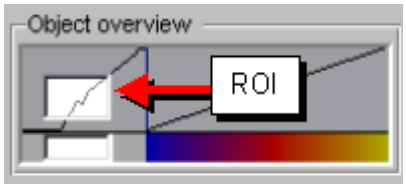


Fig. 115 Once you have defined a ROI, the opacity area will be displayed in gray and the ROI in white.

The ROI may also be set for a single segment by clicking with the left mouse button into the appropriate segment of the color area in the **Object overview** section.

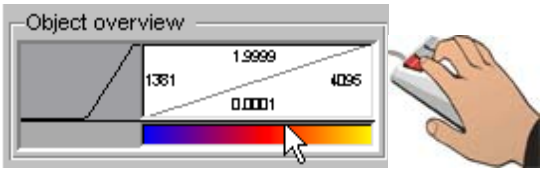


Fig. 116 Set a ROI for a single segment only.

Arbitrary ROIs may be defined by moving the mouse cursor to one of the four borders of the opacity area. The mouse cursor will change as shown in the images below which indicates that the manipulation of the ROI is possible. When the mouse cursor changes click the left mouse button and drag the ROI border in the desired direction. The appropriate border value will be displayed while changing the ROI.

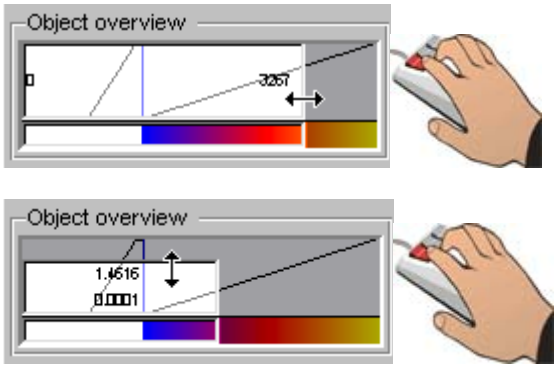


Fig. 117 Change a ROI by dragging the ROI's borders to the desired position.

A ROI may be moved in the opacity area like a magnifier. Click with the left mouse button into the ROI and drag the ROI around while keeping the left mouse button pressed. The appropriate border values will be displayed while moving the ROI.

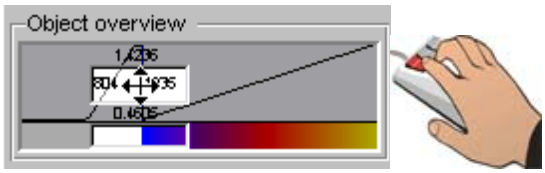


Fig. 118 Drag the ROI around in the opacity area.

Click with the right mouse button into the **Object overview** area to open a context menu containing the entries shown in the following figure.

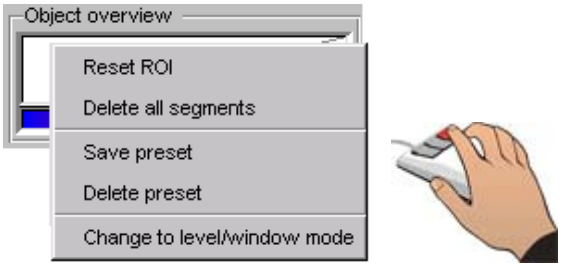


Fig. 119 The context menu which opens upon clicking into the opacity area with the right mouse button.

The menu option **Reset ROI** will reset all ROI settings.

The menu option **Delete all segments** allows you to reset all segment, opacity, and color settings to default values which means that all segments will be removed. The default opacity ramp is applied and the color is set to white. The **Save/Delete preset** options may be used to save or delete Window-Level/Opacity and color presets from the Preset selection list. See *Preset selection within this chapter*.

Opacity manipulation area *(Advanced mode)*

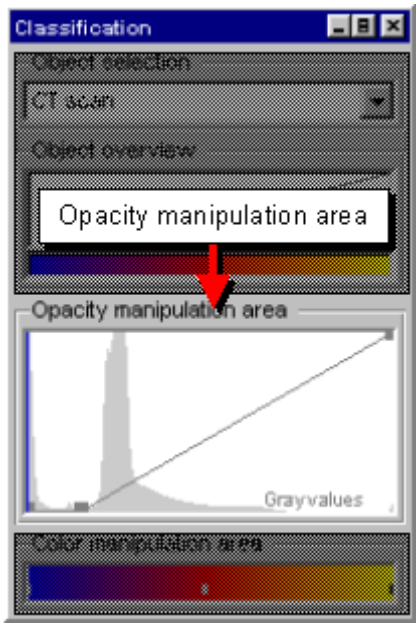


Fig. 120 The Opacity manipulation area.

The **Opacity manipulation area** contains the following elements:

- Histogram
- Opacity function
- Opacity handles
- Segment borders
- Segment names

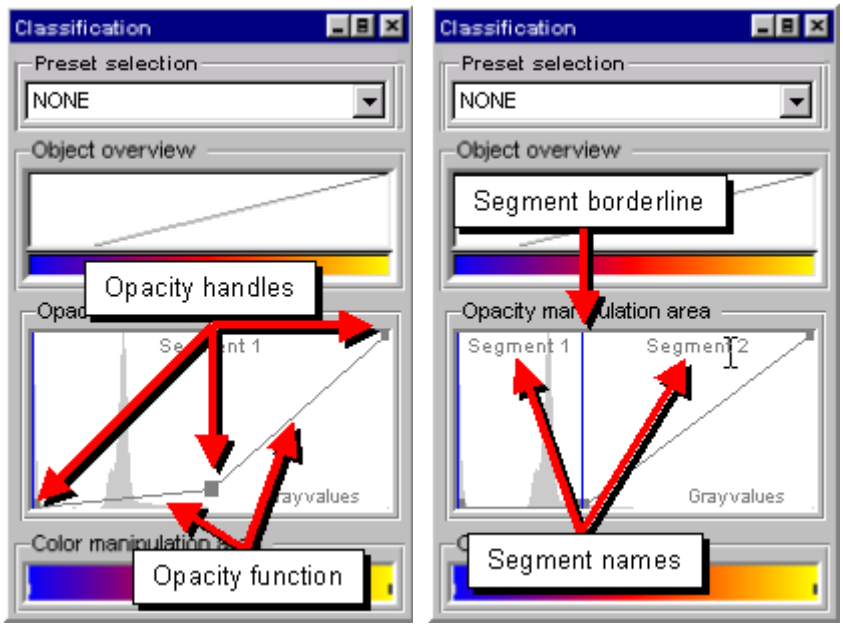


Fig. 121 The different elements of the Opacity manipulation area.

The gray value histogram of the active data set is displayed in the background of the opacity manipulation area. You may zoom in or zoom out on the histogram or disable the histogram by clicking with the right mouse button into the **Opacity manipulation area** and then clicking **Histogram** in the context menu. Another menu will then open where you may select the appropriate function (**Disable/Enable histogram**, **Zoom in**, **Zoom out**, or **Zoom reset**).

The default opacity mapping function will look like shown in the following figure. The opacity function looks like a linear ramp from the opacity handle at the lowest, darkest gray value with zero opacity to the opacity handle at the brightest gray value with maximum opacity.

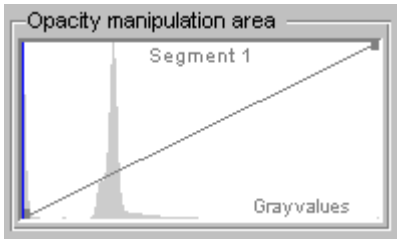


Fig. 122 The default opacity mapping function.

The opacity function may be adjusted to any arbitrary shape. New opacity handles may be inserted by clicking the desired position with the middle mouse button (or with the left mouse button while keeping the **Alt** key pressed). You may also insert a new handle by using the context menu which you open by clicking into the **Opacity manipulation area** with the right mouse button. Click the desired position with the right mouse button and then select **Insert handle** in the context menu.

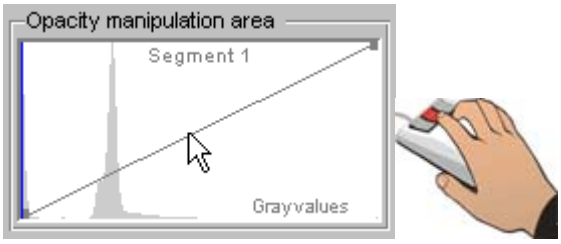


Fig. 123 Insert a new handle by clicking the desired position with the middle mouse button.

The handle may be moved by clicking it with the left mouse button and then dragging it to the desired position while keeping the left mouse button pressed. Opacity handles may be removed by clicking them with the middle mouse button (or with the left mouse button while keeping the **Alt** key pressed). You may also remove a handle by using the context menu which you open by clicking into the **Opacity manipulation area** with the right mouse button. Click the handle you wish to remove with the right mouse button and then select **Remove handle** in the context menu. Please note that the two outer handles can neither be moved nor removed.

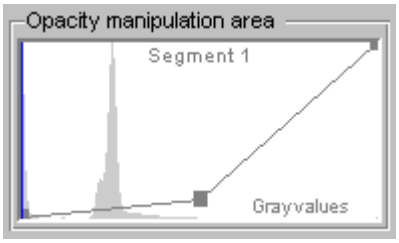


Fig. 124 The new handle is displayed.

Any element of the opacity function, i.e. opacity handles or line segments, may be moved within the opacity manipulation area by clicking the element and dragging it around while the left mouse button is pressed. The cursor's shape will change when moving it on a handle or the opacity function line to indicate that the appropriate element may be moved. The cursor's shape also indicates into which direction the element may be moved (generally in horizontal and vertical direction, which is indicated by one vertical and one horizontal arrow). Please note that the two outer handles may only be moved in vertical direction.

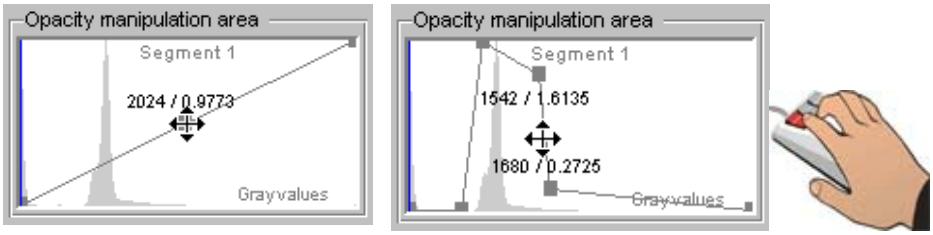


Fig. 125 You may drag the line and the handles to new positions with the left mouse button pressed.

VGStudio allows the user to generate the maximum number of one opacity handle per gray value. This provides a maximum degree of freedom when applying an arbitrary opacity mapping.

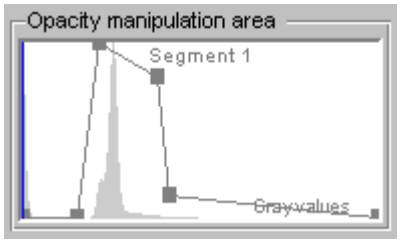


Fig. 126 The Opacity manipulation with four new handles.

VGStudio MAX 1.0 provides the user with a powerful tool to separate structures within a volume data set by their gray value range. This process is called gray value segmentation. A segment is defined by a gray value range within a data set. A segment may include a range from one single gray value up to the full gray value range of the volume data set.

To define a gray value segment, place the cursor on the borders of the **Opacity manipulation area** so that the cursor's shape changes as shown in the following figure.

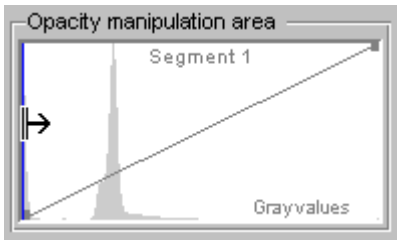


Fig. 127 To define a segment, drag the line to the desired position.

Keep the left mouse button pressed and drag the line to the desired position in the **Opacity manipulation area**. The segment ranges will be displayed while dragging the line.

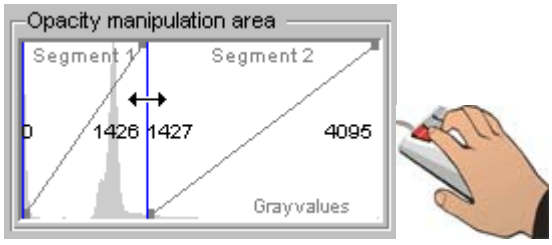


Fig. 128 While dragging the line, the segment ranges will be displayed.

A new segment may be generated by dragging either the left or the right border of the **Opacity manipulation area** or the blue segment border line. When placing the cursor on one of the segment border lines, it will assume different shapes. Each shape indicates the action that can be applied when clicking the line with the left mouse button and then dragging the line (see Fig. 129 for the different shapes the cursor may assume).

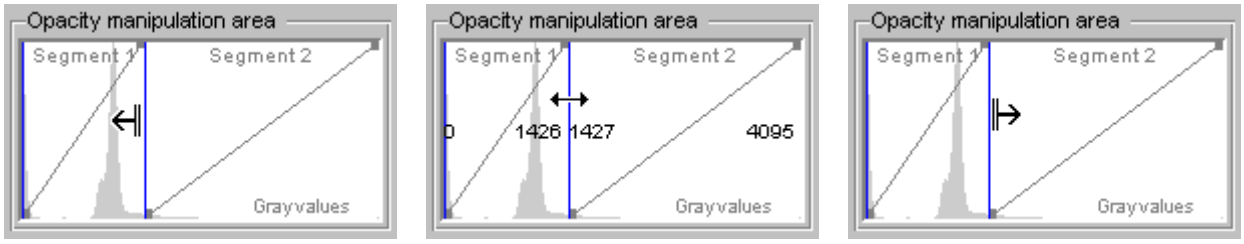


Fig. 129 The cursor shown in the left image indicates that you may generate a new segment to the left of the current segment's border. The middle image indicates that the segment border may be moved to the left or right. The right image indicates that you may generate a new segment to the right of the current segment's border.

VGStudio allows the user to generate the maximum number of one segment per gray value. This provides a maximum degree of freedom when applying arbitrary opacity and color values.

The segment names displayed in the **Opacity manipulation area** may be changed. To do so, simply click the name with the left mouse button and type in the new name.

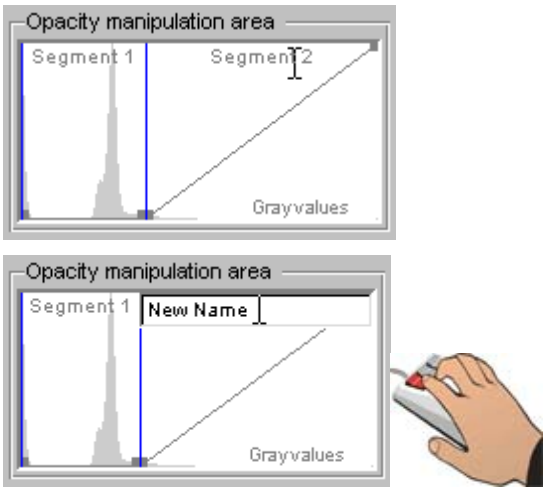


Fig. 130 Change the segment name in the Opacity manipulation area by clicking the name with the left mouse button and then typing in the new name.

Press the right mouse button within the **Opacity manipulation area** to the context menu. Features such as **Copy opacity curve**, **Paste opacity curve**, **Cut segment**, and **Delete segment** may be disabled; this depends on the position you click with the right mouse button within the **Opacity manipulation area**. In the context menu of the **Opacity manipulation area** you will find the following functions:

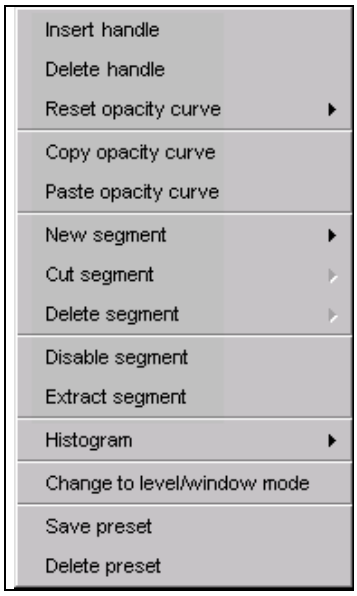
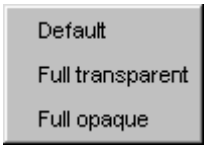


Fig. 131 The context menu of the Opacity manipulation area.

- **Insert handle**—Select this command to generate a new opacity handle in the **Opacity manipulation area**. The handle will be inserted at the position you click with the right mouse button.

- **Delete handle**—Select this command to remove an opacity handle from the **Opacity manipulation area**. Click the handle to be removed with the right mouse button and then select **Delete handle** in the menu.

- **Reset opacity curve**—Select this command to open the following menu:



  - **Default**—Select this command to apply the default opacity function to the appropriate segment.

  - **Full transparent**—Select this command to set the opacity to totally transparent.

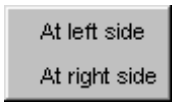
  - **Full opaque**—Select this command to set the opacity to totally opaque.

- **Copy opacity curve**—Select this command to copy the current segment's opacity curve into the clipboard. Use **Paste opacity curve** to paste the copied opacity settings to another object or segment.

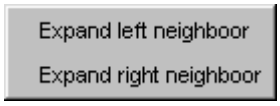
- **Paste opacity curve**—Select this command to paste a previously copied opacity curve to another object or segment.

- **New segment**—Select this command to generate a new segment. Use the following menu to decide on which side of the current segment the new segment is to be generated, i.e. either on

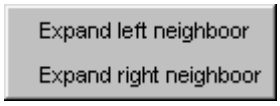
the left-hand side or the right-hand side.



- **Cut segment**—Select this command to cut the current segment. Use the following menu to decide which segment should be expanded when cutting the current segment.



- **Delete segment**—Select this command to delete the current segment. Use the following menu to decide which segment should be expanded when deleting the current segment.



- **Disable/Enable**—Select this command to disable a segment. In the **Opacity manipulation area**, a disabled segment will be shown with a gray background; the text *disabled* will be displayed in brackets beneath the segment name. In the 3D and the slice windows, the segment will no longer be visible. The same effect may be achieved by mapping the opacity curve to totally transparent. A disabled segment's opacity or color mapping may be manipulated, but the results of such a manipulation can only be observed in the 3D and the slice windows when the segment is enabled again.

- **Extract**—Select this command to extract a segment from the original volume object. VGStudio's **Extract** function allows the user to separate parts of a volume data set which are defined by a segment, i.e. by a gray value range. The extract process will generate a new independent object in the scene. The new object may be manipulated independently from the original object.

Extract Example

Since it is a very powerful and useful feature of VGStudio MAX 1.0, the **Extract** function will be explained here by means of an example. We will use a CT scan of a human jaw.

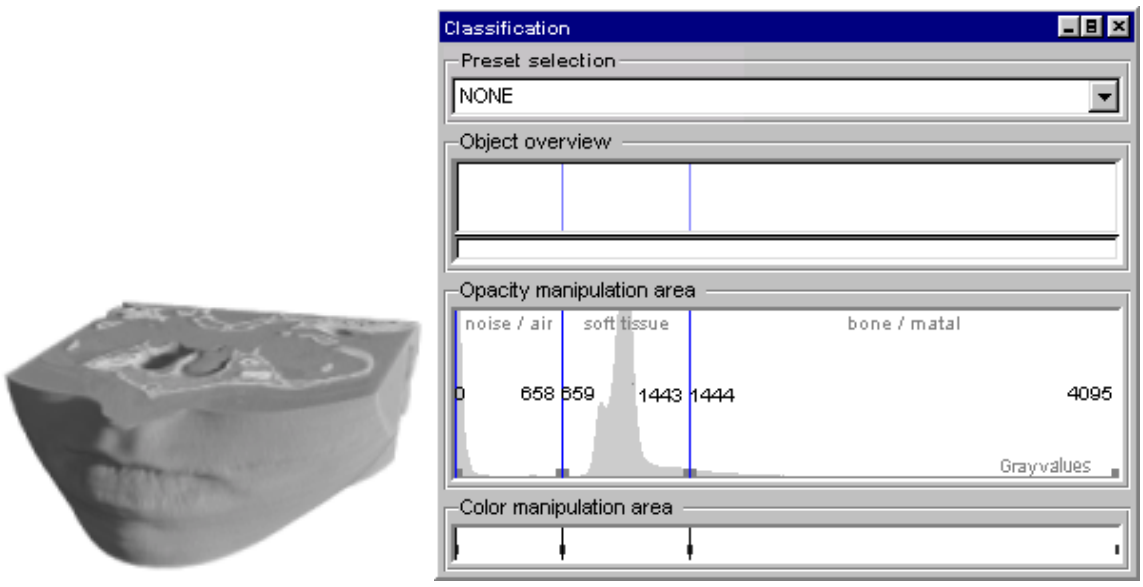


Fig. 132 The CT scan of a human jaw and the Classification tool with three gray value segments defined.

The classification tool above shows three gray value segments within the CT data set. Segment 1 includes the gray value range from 0 to 658. It represents the noise and air within the CT data set. Segment 2 ranges from 659 to 1443 and represents the soft tissue. Segment 3 includes the brightest gray values from 1444 to 4095. It represents the bone structures and the metal of the braces in the CT data set. As we can see in Chapter *4.6.1 Classification Tool*, the opacity and color mapping of the three segments can be handled independently of each other. However, the geometric settings such as position, rotation, scaling, and clipping of one of the segments cannot be handled independently from the rest of the CT scan. The **Extract** function is an easy-to-use and powerful tool to generate images as shown below in Fig. 136 where the soft tissue is removed from half of the jaw.

In the example shown here we need to clip the soft tissue only. In order to clip only one segment the segment has to be extracted.

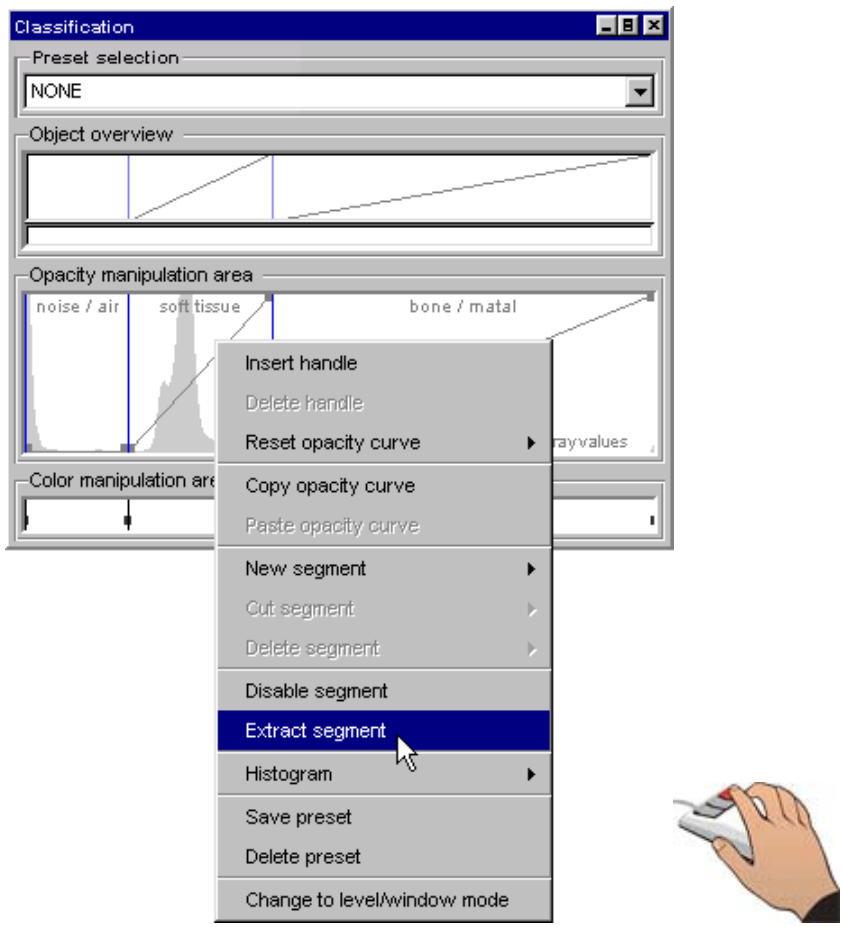


Fig. 133 To extract a segment, click into the segment with the right mouse button and select Extract segment from the context menu.

In the **Opacity manipulation area**, click into Segment 2 (named “soft tissue”) with the right mouse button. Select **Extract segment** in the context menu. After the extraction process, only the extracted soft tissue segment with a gray value range from 659 to 1443 will be shown in the **Classification** tool.

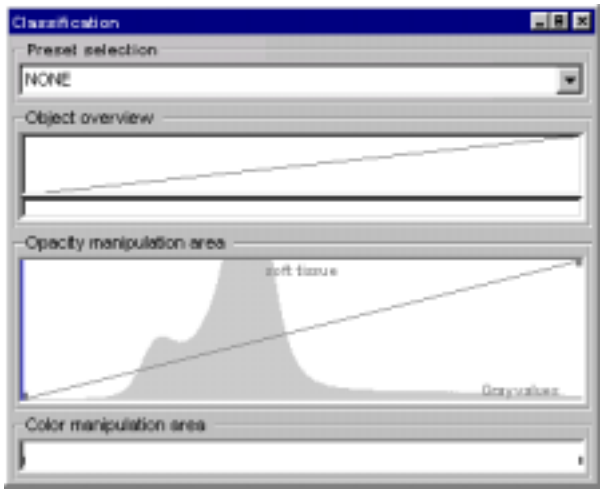


Fig. 134 After the extraction process, only the soft tissue segment will be shown.

In the **Scene tree** the new object will be displayed with the following name: “soft tissue [extracted of CT scan of a human jaw: 1]”.

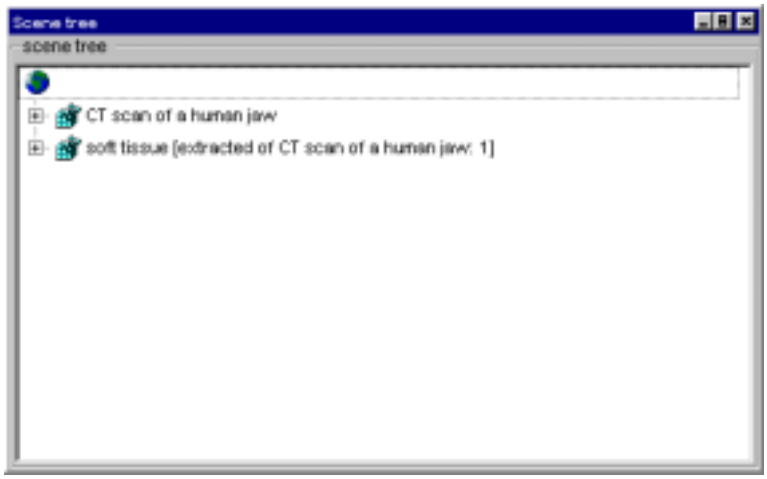


Fig. 135 In the Scene tree, the newly created object will be displayed.

The newly created object only includes the soft tissue and may now be manipulated independently from all other objects in the scene like any other object. It may be positioned, rotated, scaled, or clipped; the opacity and color mapping may also be changed. In our example, the soft tissue object was clipped half by means of the clipbox mode, so that half of the bone structure can be seen. Please note that you have to enable both the CT scan of the jaw and the extracted soft tissue; otherwise the bone structure will not be visible when clipping the object.

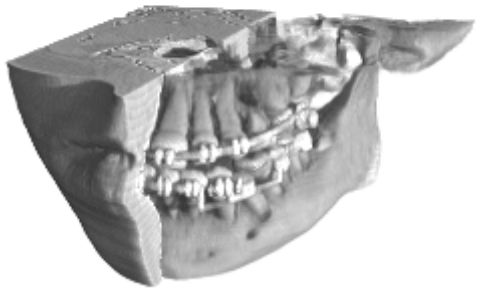


Fig. 136 The CT scan of a human jaw after the soft tissue has been removed from half of the jaw.

The extracted segment in the original volume data object will not be destroyed. The extracted segment will only be disabled in the original object.

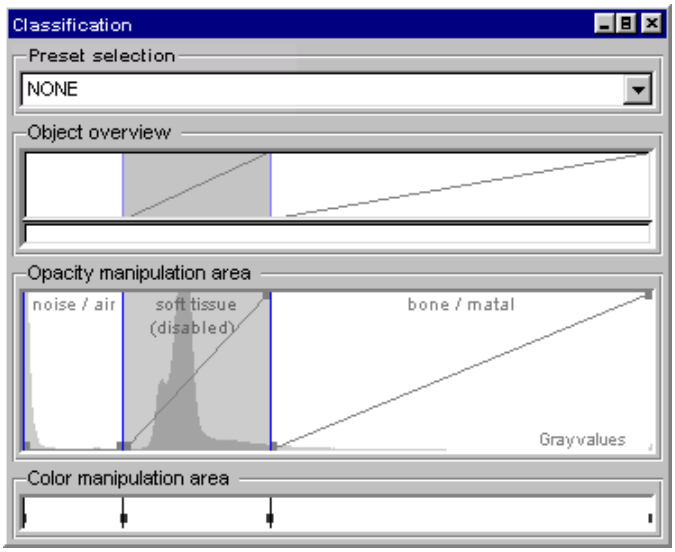


Fig. 137 The soft tissue segment will be disabled after the extraction process.

The extracted and disabled segment may be enabled again by using the **Enable segment** option in the context menu of the **Opacity manipulation area**. This allows the VGStudio user to extract a segment several times to apply different clippings or opacities as shown in the following example.

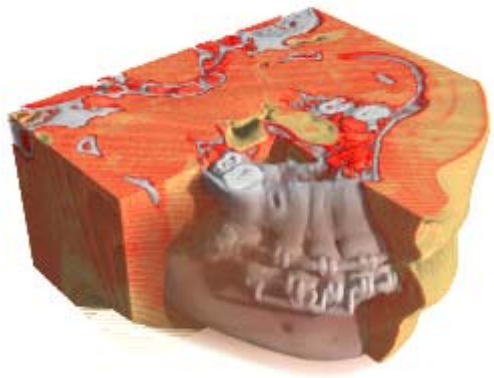


Fig. 138 Different clippings or opacities may be applied to an object.

Data extracted from an object may be saved to disk as a separate data file. If data from an extracted segment is saved with the **Export raw** option of the **File** menu, only the gray value range of the extracted segment will be saved. All other voxels with gray values below the data range of the extracted segment will be mapped to the minimum value of the appropriate data representation, all values above the data range will be mapped to the maximum value of the appropriate data representation.

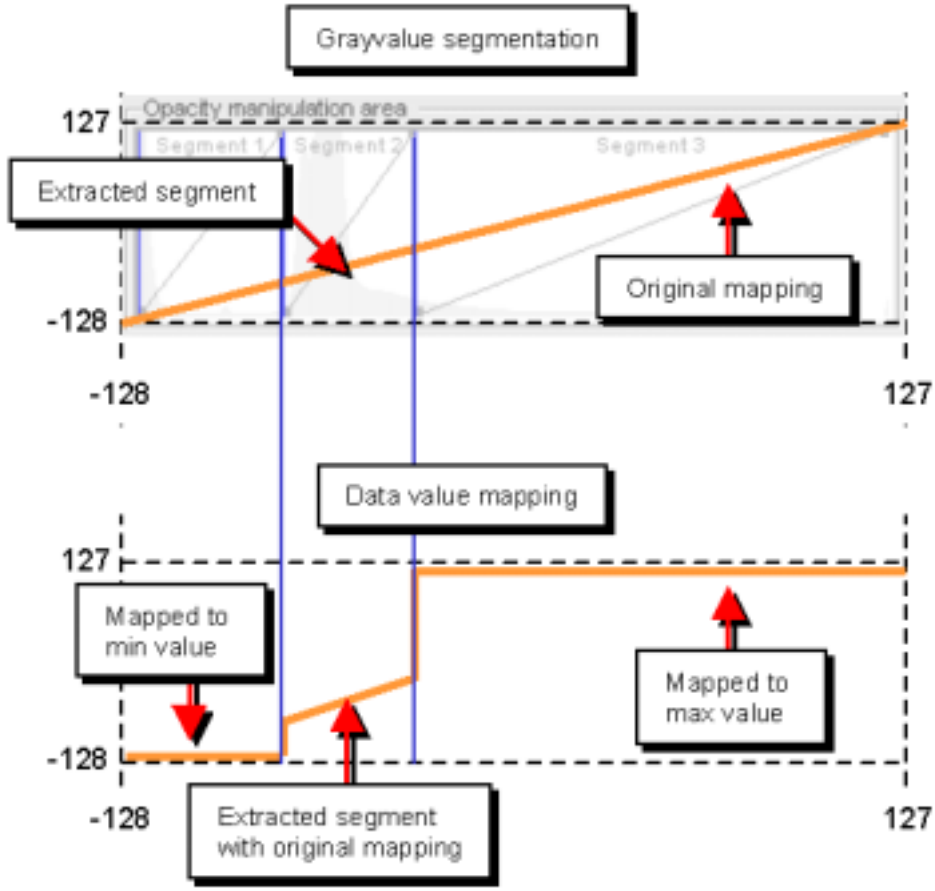


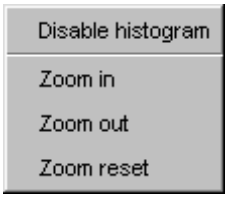
Fig. 139 After the extraction process, only the gray values within the extracted segments will remain.

In the example shown here a segment was extracted out of a signed 8 bit integer data set (data range –128 to 127). The voxels with gray values below the extracted segments data range will be mapped to –128 while the voxels with values above the extracted segments data range will be mapped to 127. Only the gray values within the extracted segments data range will remain.

In most cases, the size of the bounding box of an extracted object will differ from the size of the original object. The new bounding box will be cropped so that the extracted object will fit exactly into the bounding box.

In the following you will find a description of the remaining context menu entries of the **Opacity manipulation area**.

- **Histogram**—Select this command to open the histogram menu.



- **Disable histogram**—Select this command to disable the histogram within the **Opacity manipulation area**.
- **Zoom in**—Select this command to zoom in the histogram within the **Opacity manipulation area**.
- **Zoom out**—Select this command to zoom out the histogram within the **Opacity manipulation area**.
- **Zoom reset**—Select this command to reset the zoom factor of the histogram within the **Opacity manipulation area** to its default value.

- **Change to Level/Window mode** —Select this command to switch the classification tool into Level/Window mode.
- **Save/Delete preset** —Select this command to save or delete Window-Level/Opacity and color presets from the Preset selection list. See *Preset selection within this chapter*.

Level-Window area (Level/Window mode)

The user may apply a value for Center (also known as Level value) and Width (also known as Window value) of a ramp in Level-Window mode. To adjust the values, simply type in the appropriate values or use the up and down arrows to either increase or reduce the Center or Width value. The resulting opacity ramp can be seen immediately in the Opacity manipulation area.

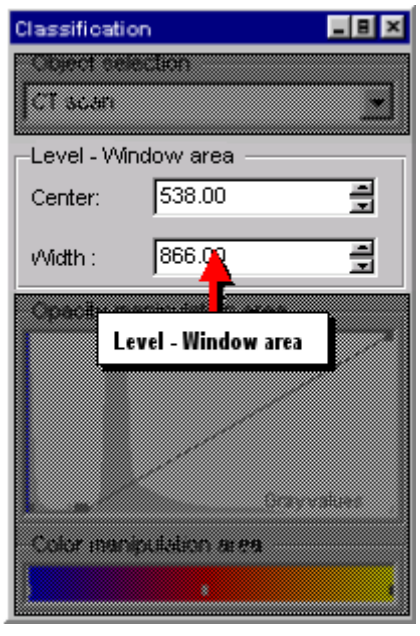


Fig. 140 The Opacity manipulation area.

Opacity manipulation area *(Level/Window mode)*

The opacity manipulation area can be used as an convenient tool to adjust the Level and Window values. Left-click into the opacity manipulation area and keep the left mouse button pressed

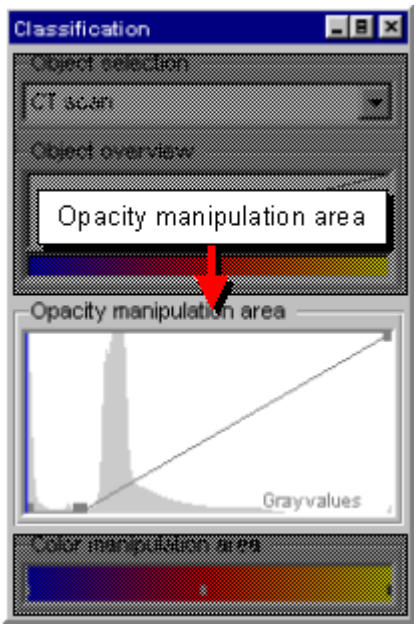


Fig. 141 The Opacity manipulation area.

while moving the cursor up and down will change the Center value while moving the cursor in the left and right direction will change the Width value.

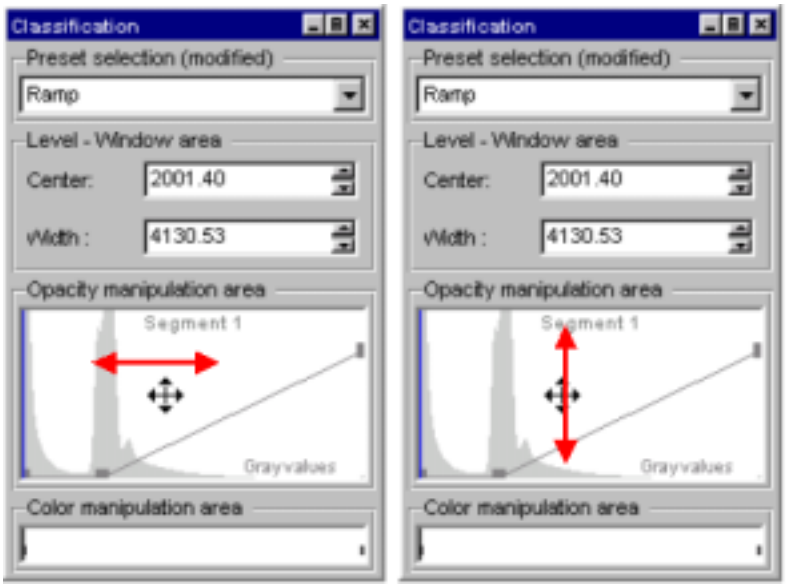


Fig. 142 Moving the cursor horizontal changes the Width value while moving the cursor vertical changes the Center value .

Color manipulation area

The **Color manipulation are**a is used to apply and modify the color mapping of an object. The default color of a voxel object is white.

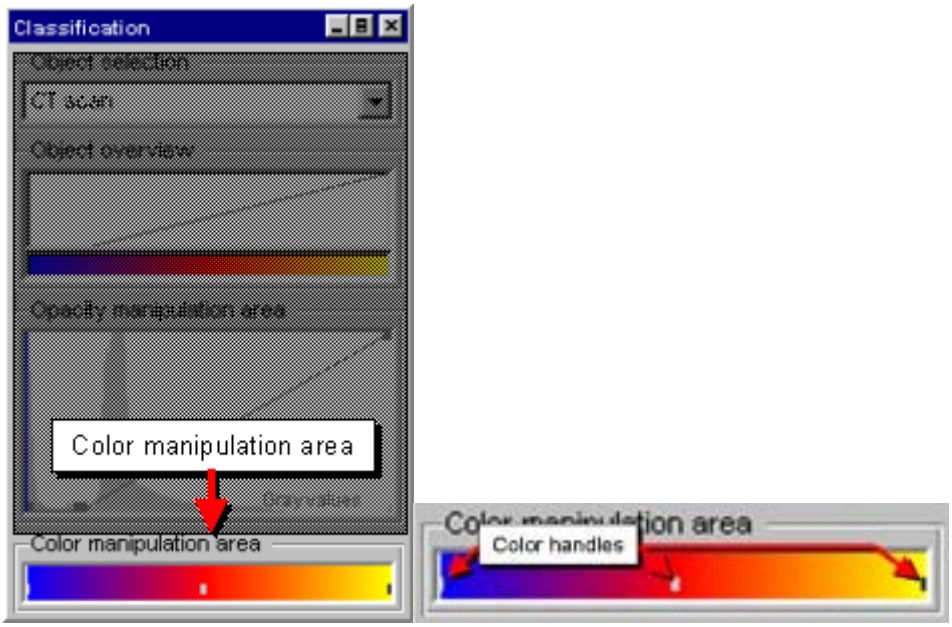


Fig. 143 The Color manipulation area of the Classification tool.

Reminder: No color mapping will be possible for RGBA color data.

A color may be applied to a color handle, an interval between two handles, or a whole segment. The appropriate element will be marked in the **Color manipulation area**.

To apply a color to a handle, interval, or segment double click the appropriate element with the left mouse button or open the context menu by clicking the element with the right mouse button.

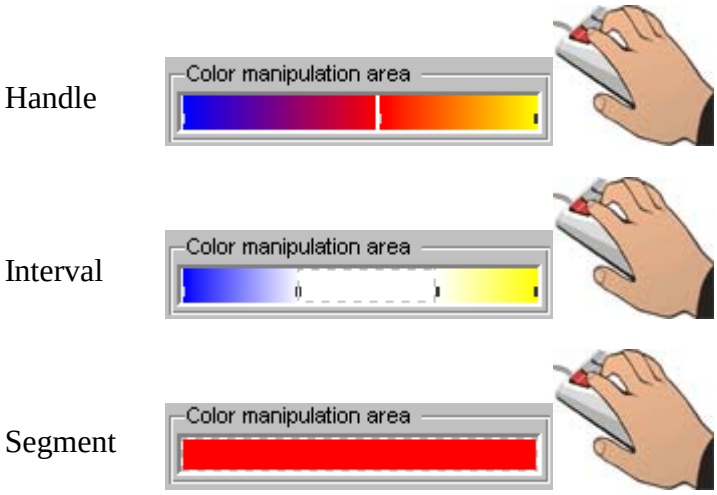


Fig. 144 Different colors may be applied to handles, intervals, and segments.

The two handles at an interval or segment border will receive the identical color when applying a color to an interval or a segment. Colors between two handles will be interpolated. This allows the VGStudio user to easily define color transitions. To create a sharp color transition either create gray value segments or insert two color handles with the appropriate color and place the handles directly side by side.

A single color handle or an interval not adjoined to a segment border may be moved. The mouse cursor will change to a two sided arrow as soon as your cursor is placed on a movable element of the color mapping area. Click a single color handle with the left mouse button or click into the appropriate interval and drag the mouse to the left or right to move the color mapping. The gray values of the appropriate color handles will be displayed while moving the color handles or intervals.

The color mapping will be shifted during the creation process of new gray value segments. Color mapping will only be applied to a segment. Color mappings will not be interpolated across segment borders. You may apply a color to each color handle on both sides of a segment border.

Fig. 145 Color handles or intervals that are not adjoined to a segment border may be moved by clicking them and then dragging the mouse while the left mouse button is pressed.

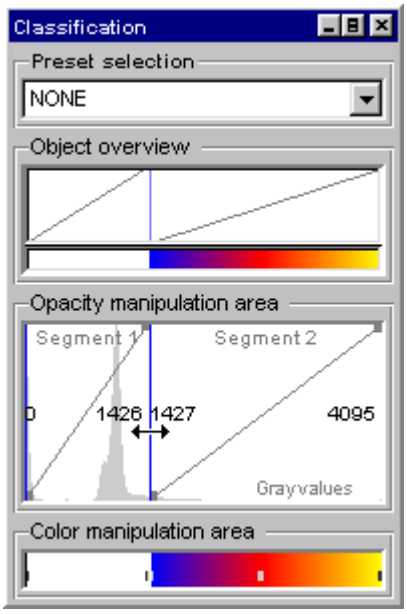


Fig. 146 A color is applied to segment 2.

VGStudio allows the user to insert the maximum number of one color handle per gray value. This provides a maximum degree of freedom by applying an arbitrary color mapping.

Press the right mouse button within the color manipulation area to open the context menu. Features such as **Copy, Paste segment color**, **Set segment color**, **Set interval color**, or **Set handle color** may be disabled; this depends on the position you click with the right mouse button within the **Color manipulation area**.

Fig. 147 The context menu of the Color manipulation area.

- **Insert handle**—Select this command to generate a new color handle in the **Color manipulation area**.

- **Delete handle**—Select this command to remove a color handle in the **Color manipulation area**.

- **Set handle color**—Select this command to apply a color to a single color handle in the **Color manipulation area**. Use the following menu to choose a color or to open the color selection tool to define a custom color.

Fig. 148 Select a color for handles, intervals, and segments.

- **Set interval color**—Select this command to apply a color to an interval between two color handles in the **Color manipulation area**.

- **Set segment color**—Select this command to apply a color to a whole segment in the **Color manipulation area**.

- **Copy segment color**—Select this command to copy the current segment's color mapping to the clipboard. Use **Paste segment color** to apply the copied color mapping to another object or segment.

- **Paste segment color**—Select this command to apply a previously copied segment color mapping to the currently selected object or segment.

- **Import segment color**—Select this command to import a previously saved segment color map file.

- **Export segment color**—Select this command to save the color mapping of the currently selected segment to a human readable colormap file on your disk.

- **Save/Delete preset** —Select this command to save or delete Window-Level/Opacity and color presets from the Preset selection list. See *Preset selection within this chapter*.

- **Change to Level/Window mode** —Select this command to switch the classification tool into Level/Window mode.

4.6.2 Scene Tree

The **Scene tree** shows an overview of all objects included in the scene. It also shows the sections of an object, the object type and the hierarchical organization of objects in groups of objects. The hierarchy within the scene tree tool is organized as follows: The highest hierarchy level within the **Scene tree** tool is the Scene object itself. The next level contains voxel- and polygon-

objects and groups of these objects . A voxel-object contains on or several sections . Sections are the last hierarchy level within the **Scene tree** tool. The **Scene tree** may be used to select one or several objects in the scene or a section of an object. Select a single object in the scene tree by clicking it with the left mouse button. Use the **Shift** or **Ctrl** modifier to select several objects. Keep the **Ctrl** key pressed and select several objects in the **Scene tree** by clicking the objects with the left mouse button. Keep the **Shift** key pressed and click a second object in the scene tree, e.g. the last object in the row. Then all objects in between the two selected objects will be selected, too.

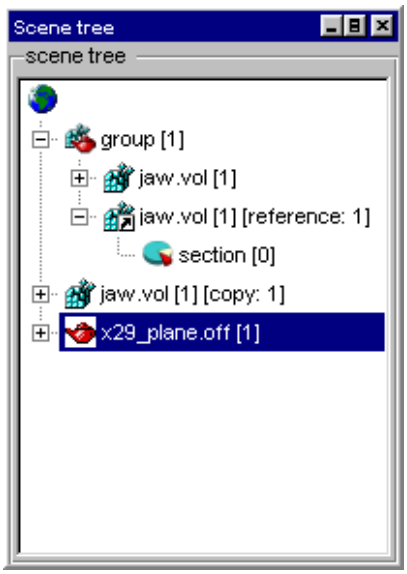


Fig. 149 The Scene tree shows objects are included in the scene.

Overview of the symbols used in the **Scene tree** tool:

Object type	Enabled	Disabled
Scene Object		
Voxel objects		
Polygon objects		
Reference of a voxel object		
Group of objects		
Section of an Object		

The selection of an object in the scene tree will be indicated with a blue bar highlighting its entry in the **Scene tree** tool. The selected object/objects can now be manipulated by the different

VGStudio MAX 1.0 features, e.g. move rotate or clip the object. The selection of a section within a voxel object will automatically result in the selection of the superior voxel object at the same time. The red color of a section entry in the **Scene tree** tool will indicate the current se-

lected section. The current selected sections color and opacity mapping can be manipulated in the classification tool.

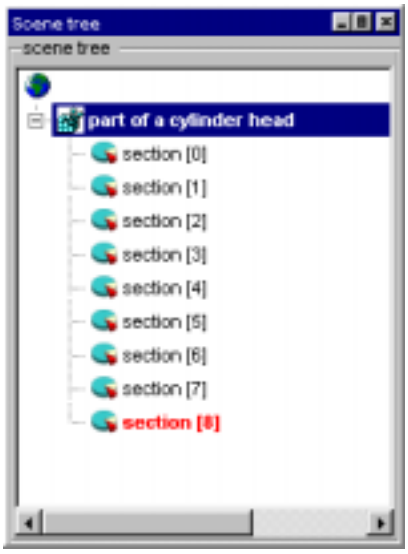


Fig. 150 The Scene tree shows an object with section (8) selected.

You may change the name of an object, a section or an object group. Simply double click the object with the left mouse button and then type in the new name.

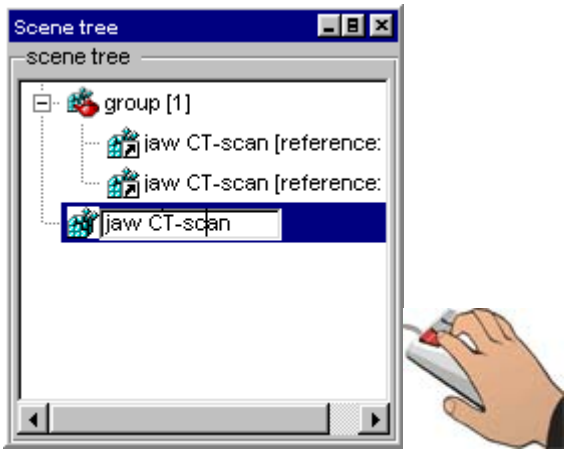


Fig. 151 The name of the object may be changed by double-clicking it and then typing in the new name.

Objects within the **Scene tree** tool are sorted in alphabetic order. Changing the name of an object within the **Scene tree** tool will change its position in the **Scene tree** tool display order.

Clicking into the **Scene tree** tool or on an object within the **Scene tree** tool with the right mouse button will bring up the context menu for the chosen object.

Context menu for the **Scene tree** tool and toplevel Objects:

- **Disable**—Select this command to disable an object or object group. A disabled object will no longer be displayed in the scene. No action can be applied to a disabled object. You first have to enable it again. To do so, click the object in the **Scene tree** window with the left mouse button, then click with the right mouse button into the **Scene tree** window to open the context menu and select the **Enable** option. The **Enable** and **Disable** options will toggle in the context menu, i.e. will only be visible one at a time.

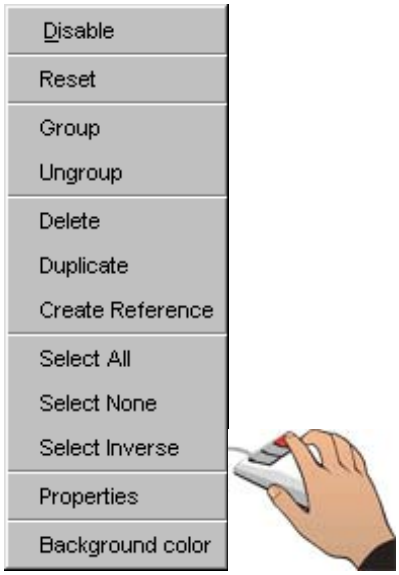


Fig. 152 The context menu of a top level object.

- **Enable**—Select this command to enable a previously disabled object or object group. To do so, select a disabled object in the **Scene Tree** window by clicking it with the left mouse button, then click with the right mouse button into the **Scene tree** window to open the context menu and select the **Enable** option. The **Enable** and **Disable** options will toggle in the context menu, i.e. will only be visible one at a time.

- **Reset** —Select this command to reset actions of all categories applied to the selected object such as translation, rotation, clipping, and scaling to the default values. Reset single categories of actions in the **Object properties** tool . See also *Chapter 4.6.7 Object Properties*.

- **Group** —Select this command to combine the current selection of objects or groups to a single group. A group of objects can be handled like a single object. The **Group** command remains disabled until more than one object is selected. Several objects can be selected by dragging a frame over the objects in the 3D view window, by clicking the objects with the left mouse button while the **Ctrl** key is pressed or by clicking the object's name with the left mouse button while the **Ctrl** key or **Shift** key is pressed in the scene tree tool. The bounding box of each selected object will be visible when several objects have been selected. After grouping the objects, a single bounding box around all the selected objects will be visible.

You may also use the keyboard shortcut **Ctrl+G** to group objects. See also *Chapter 4.6.7 Object Properties*.

- **Ungroup** —Select this command to ungroup an object group previously created with the **Group** command. The **Ungroup** command remains disabled until an object group is selected. You may also use the keyboard shortcut **Ctrl+U** to ungroup objects. See also *Chapter 4.6.7 Object Properties.*

Reminder: The clipping of an object group will be reset as soon as you ungroup the object group.

- **Delete**—Select this command to delete any selected object in the scene. Note that you can undo a deletion process by selecting the **Undo** command defined earlier. Remember that you have to select the **Undo** command immediately after having deleted the object. You may also use the **Del** key to delete an object.

- **Duplicate**— The **Duplicate** option is the fastest possibility to generate and use a copy of an object. You may also use the keyboard shortcut **Ctrl+D** to duplicate objects. The copied object will be placed directly into the scene where it can be used immediately. When duplicating an object, VGStudio MAX places the object directly above the original object. The relative position will be used as default offset. If the new object is moved, its offset to the original object is used as offset for every new duplication process. This procedure is called smart duplicate.

Reminder: The offset adjusted during a smart duplicate will be set to its default value (zero) as soon as the duplicated object is deselected or another object is selected.

- **Create Reference** — Select this command to create a reference of an object. A reference is a copy of an object which uses the same classification tool settings (color and opacity settings) as the original object. Due to this special property, a reference needs hardly any additional system memory. Therefore, a reference is a memory-saving possibility to copy objects. You may also use the keyboard shortcut **Ctrl+R** to create a reference. In the **Scene tree** tool, a small arrow will appear in the symbol displayed on the left-hand side of the scene name and after the scene name, the text **[reference: #]** will appear. Applying the **Create Reference** command to a polygon object will result in a “normal” copy of the object. Creating a reference includes a smart placement functionality. An example: select an object and click **Create Reference** in the context menu or press **Ctrl+R**. The new referenced object will appear as the currently selected object. Move the reference to a new position in the scene. Select **Create Reference** in the context menu or press **Ctrl+R** once again**.** The second referenced object will appear in the same relative position as in the first reference.

Reminder: The new offsets of the smart create reference procedure will be reset to its default values as soon as you deselect the object.

- **Select All**—Select this command to select all objects in the scene. You may also use the keyboard shortcut **Ctrl+A** to select all objects.

- **Deselect**—Select this command to deselect all selected objects in the scene. You may also use the keyboard shortcut **Alt+D** to deselect all objects.

- **Select Inverse**—Select this command to invert the active objects in the scene. You may also use the keyboard shortcut **Alt+I** to generate an inverse selection.

- **Properties**—Select this command to open the object properties dialog. The dialog provides you with two index cards: **General analysis** and **Structural analysis**. General analysis shows basic information about the volume object, such as data type, size, mean value of the voxel values and derivation of the voxel values. Structural analyisis. The volume of the voxel object will be displayed as well.

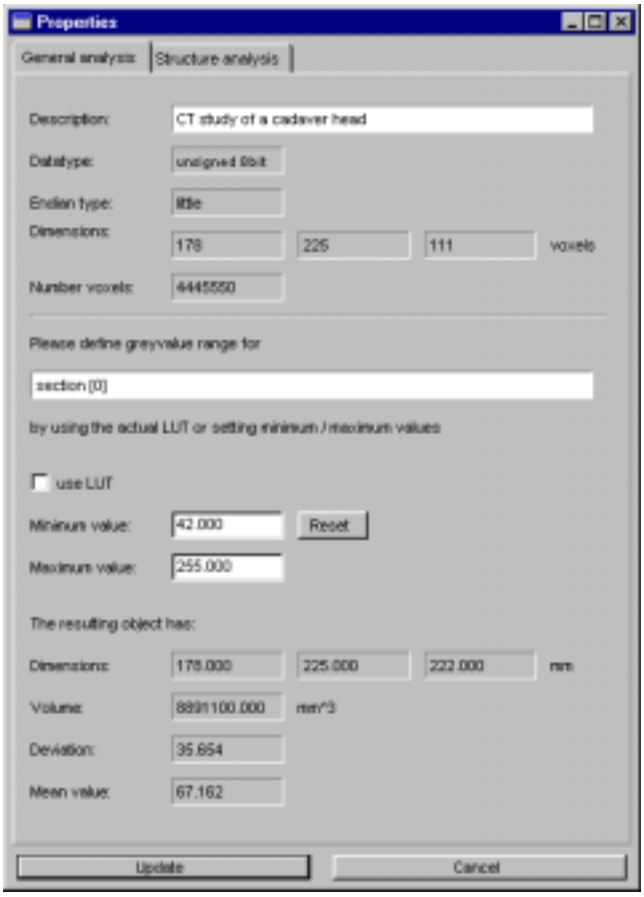


Fig. 153 The Properties dialog.

- **Background color**—Select this command to choose a background color for the current scene. Select a color within the color selection tool. See also section Background color in *Chapter 4.3.5 Scene Menu.*

Context menu for sections:

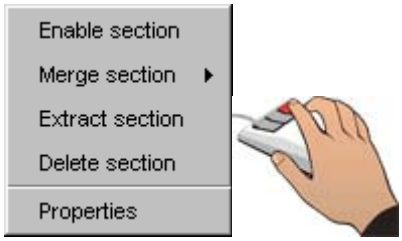


Fig. 154 The context menu of a section.

- **Enable/Disable section**—Select this command to disable an section of an object. A disabled section will no longer be displayed in the scene. No action can be applied to a disabled section. You first have to enable it again. To do so, click the section in the **Scene tree** window with the right mouse button to open the context menu and select the **Enable** option. The **Enable** and **Disable** options will toggle in the context menu, i.e. will only be visible one at a time.

- **Merge section**—Select this command to merge two section. Select the section to merge to the current selected section from the pull-down menu.

- **Extract**—Select this command to extract a section from the original volume object. VGStudio MAX' **Extract** function allows the user to separate parts of a volume data set which are defined by a section. The extract process will generate a new independent object in the scene. The new object containing only the current section may be manipulated independently from the original object and e.g. can be saved as separate data set to a file.

- **Delete section**—Select this command to delete any selected object in the scene. Note that you can undo a deletion process by selecting the **Undo** command defined earlier. Remember that you have to select the **Undo** command immediately after having deleted the object. You may also use the **Del** key to delete an object.

- **Properties**—Select this command to open the object properties dialog. The dialog provides you with two index cards: **General analysis** and **Structural analysis**. General analysis shows basic information about the volume object, such as data type, size, mean value of the voxel values and derivation of the voxel values. Structural analyisis

4.6.3 Renderer Properties

The **Renderer properties** tools allows you to control the rendering-relevant settings of VGStudio MAX 1.0. The rendering algorithm may be selected as well as the resolution of the resulting image and the image rendering quality.

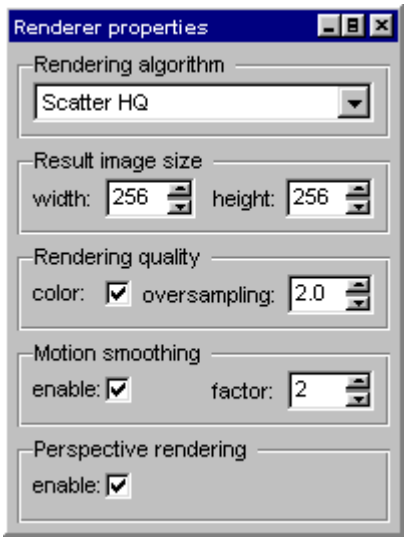


Fig. 155 The Render properties dialog.

Rendering algorithms

In VGStudio MAX 1.0 you may choose between six different rendering algorithms. Use the **Rendering algorithm** section to select one of the following algorithms:

- **Scatter –** This algorithm is a volume rendering algorithm which is suited best for the visualization of transparent structures only, e.g. in computational fluid dynamics.

- **Scatter HQ –** This algorithm is a volume rendering algorithm. It is the "all-rounder" of VGStudio MAX' visualization algorithms. It is well suited for the visualization of faint gray-value differences within the voxel data as well as to visualize surface structure details.

- **Scatter + gradients –** This algorithm is a volume rendering algorithm which emphasizes the local gradients within the voxel data. Therefore it is suited best to visualize objects with a clearly defined surface structure.

- **Maximum projection (MIP) –** The Maximum intensity projection casts rays, one for each pixel in the rendering, into the data set. For each ray, the maximum voxel intensity encountered along the ray is determined. This maximum intensity becomes the value of the pixel associated with the ray.

- **Sum along ray –** The Sum along ray algorithms casts rays, one for each pixel in the rendering, into the data set. For each ray, the voxel opacities are summed along the ray. This opacity sum becomes the value of the pixel associated with the ray.

- **X-ray –** The X-ray algorithms casts rays, one for each pixel in the rendering, into the data set. For each ray, the absorption of each voxel is calculated proportional to its opacities and integrated along the ray. This integrated absorption value becomes the value of the pixel associated with the ray.

The Renderer Properties, are tightly coupled with the Light Properties (refer to *Chapter 4.6.4* Light Properties). The appearance and quality of the rendered images are especially a result of the render algorithm and the light settings. There are two extreme examples rendered of one data set shown in Fig. 156.

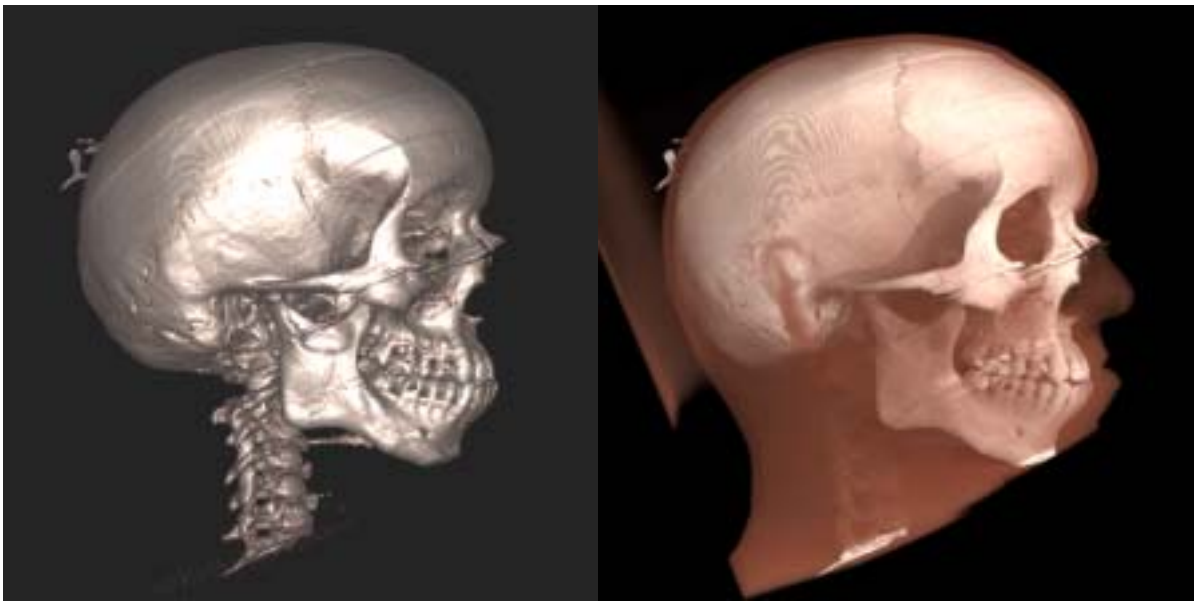


Fig. 156 Images rendered emphasizing surfaces (left) and transparent structures (right).

The left image emphasizes the surface structures of the object. It was rendered by the **Scatter + Gradients** algorithm with an oversampling of 3.0 and only the **Front light source** activated. The ambient part of the **Front light source** was set to a very low value while the diffuse part was set to a high value The right image emphasizes the transparent tissue and was rendered by the Scatter HQ algorithm with an oversampling of 3.0 and the **Front** and **Shadow light source** activated. This time the ambient parts of the light sources were set to high values while the diffuse parts were set to low values.

The following examples show one data set rendered by the six different rendering algorithms.

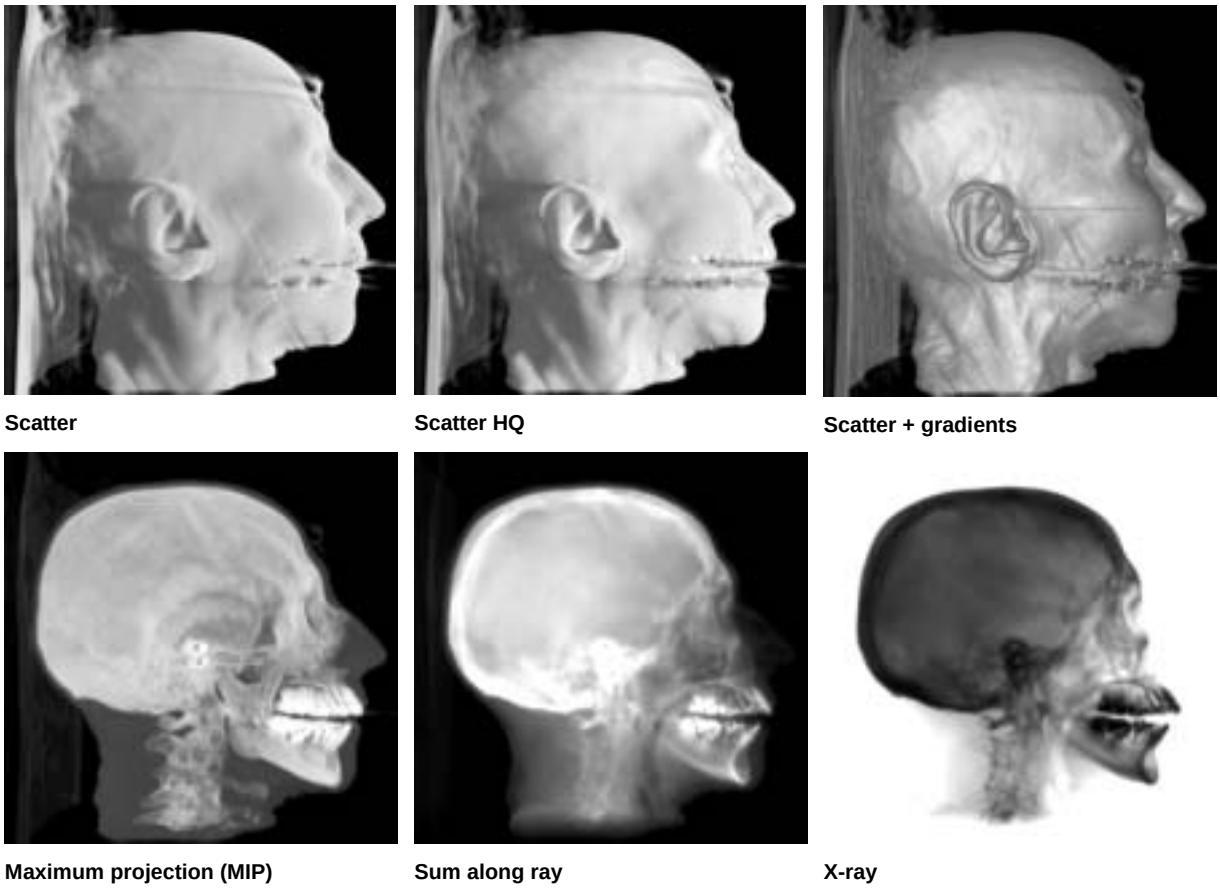


Fig. 157 One image is shown in the six rendering algorithms available in VGStudio MAX.

Result image size

Use the **Result image size** in the **Render properties** dialog to set the size in which the image should be rendered by VGStudio MAX. In addition, the image on the screen may be enlarged or reduced by applying a zoom factor to the **3D View** window. Set the image size by simply typing in the desired values or by using the up and down arrows to either enlarge or reduce the width or height of the image.

Rendering quality

Images may be rendered in true color or in monochrome. Rendering in monochrome will increase the rendering speed by a factor of two.

Oversampling allows to adjust the resampling step width during the rendering process. Higher values normally lead to higher image quality. Images may appear darker with higher oversampling factors due to higher light absorption during the rendering process.

To adjust the values, simply type in the appropriate values or use the up and down arrows to either increase or reduce the oversampling value.

Motion smoothing

Motion smoothing allows to apply and adjust a reduction factor by which the image size is reduced in x- and y- direction while manipulating a scene. Higher reduction factors will lead to more smooth interaction. This is a helpful function especially on computers with a lower performance. Type in the appropriate value or use the arrows or the scroll function to enlarge or reduce the motion smoothing value.

Additional settings can be done in the Tuning Dialog in (see *Chapter 4.3.3 Setting Preferences* for further details).

Perspective rendering

This switch allows to disable/enable perspective rendering.

4.6.4 Light Properties

VGStudio MAX supports the illumination of the scene by two light sources with parallel light. You may adjust the light settings in the **Light properties** dialog.

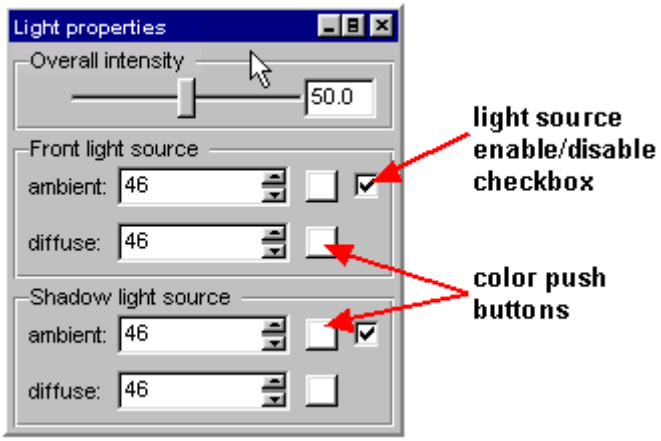


Fig. 158 The Light properties dialog.

The **Overall intensity** determines the total brightness of the scene's illumination. To adjust this value, simply drag the slider to the left or the right or type in the desired value and press **Enter**.

The **Front light source** is positioned in 0°, i.e. in the eye of the observer, the **Shadow light source** is positioned in 45°, to the right of the observer. The light sources are located at fixed positions relative to the observer.

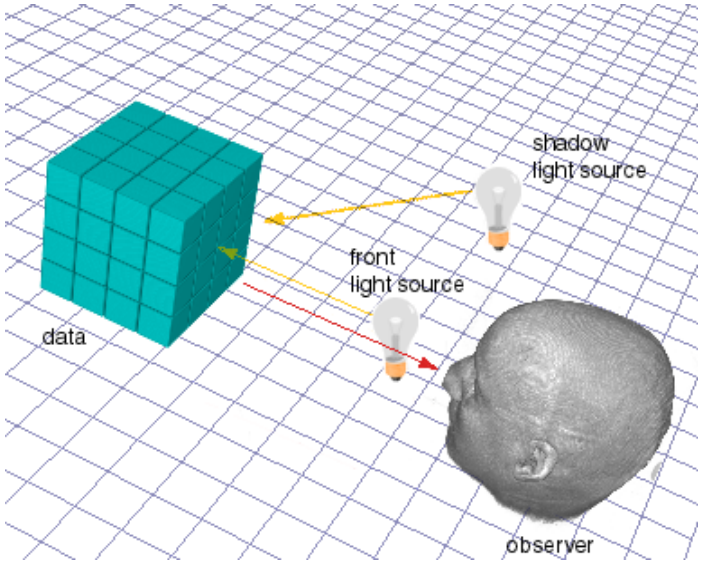


Fig. 159 The front light source and the shadow light source are located at fixed positions relative to the observer.

The two light sources **Front light** and **Shadow light** consist of two parts each, i.e. an **Ambient** part and a **Diffuse** part. Each part's intensity can be adjusted independently by typing in the desired values or using the up and down arrows. The diffuse part of the light sources provide a

shading of the data which emphasizes structures (gradients) within the data while the ambient light parts provide an illumination which is independent of the orientation of structures (gradients) within the data.

Deactivating the shadow light source will result in an increased rendering speed (when working with the **Scatter** or **Scatter HQ** algorithms, the speed will be increased by a factor up to two).

Click the white/colored push buttons to apply a color to the appropriate light source.

Use the checkbox on the right-hand side to enable or disable the light sources.

4.6.5 Stereo Properties

VGStudio MAX supports several stereo image rendering modes.

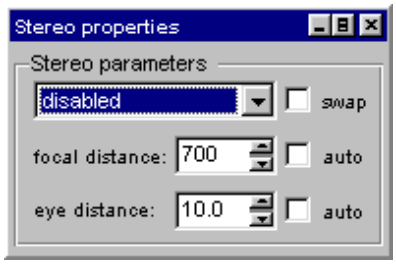


Fig. 160 The Stereo properties dialog.

Select one of the following rendering modes in the **Stereo parameters** listbox:

- **Red-green** (red on right eye)
- **Red-blue** (red on right eye)
- **Interlaced v**(ertical) (e.g. for autostereoscopic 3D displays)

  VGStudio MAX 1.0 supports the D4D display. The D4D is a flat autostereoscopic 3D display, a new type of computer output device for true 3D visual representation of data or other three-dimensional information. Information on the D4D can be found on http://kastor.inf.tu-dresden.de/D4D/

- **Interlaced h**(orizontal) (e.g. for HMD devices)

Select a stereo mode in the listbox to activate stereo rendering. Use the **Swap** checkbox to swap between left and right images. By changing the **Focal distance** and **Eye distance** values you may adjust the stereo projection parameters. Simply type in the appropriate value or use the up and down arrows to increase or reduce the values.

If the upper **Auto** checkbox is activated, the focal distance will be set to the distance between observer and currently selected object. If no object is selected the focal distance will not be updated automatically.

If the lower **Auto** checkbox is activated, a default relation of 30:1 between focal distance and eye distance will be applied.

While a stereo mode is activated images will be saved as stereo images when the **Save Image** option in the **File** menu is selected.

4.6.6 Polygon Properties

Select a polygon object in the scene and use the **Polygon properties** tool to adjust the polygon rendering mode for the selected object.

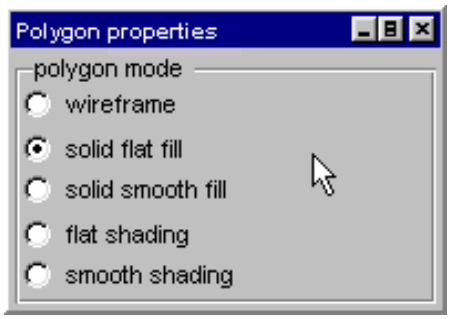


Fig. 161 The Polygon properties dialog.

Choose between a shading mode or wireframe mode. If no polygon object is selected, the **Polygon properties** tool will be disabled.

4.6.7 Object Properties

The **Object properties** tool provides four index cards for the different kinds of actions which may be applied to an object (i.e. translation, rotation, scaling, and clipping).

Each index card allows you to reset the properties to their default values by simply pressing the **Reset** button.

The entered values may be applied by pressing the **Apply** button. The appropriate action will also be applied when moving the mouse cursor away from the **Object properties** tool into the 3D window.

Position/Translation

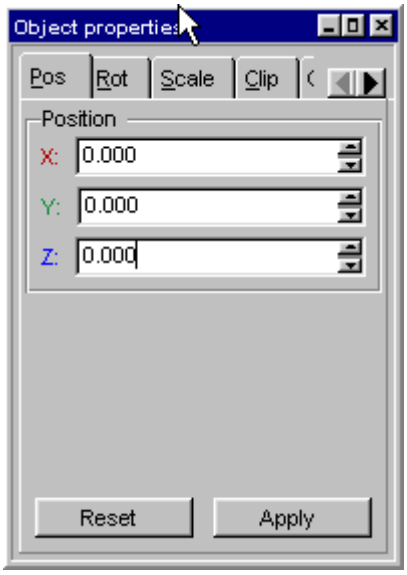


Fig. 162 The Object properties dialog with the index card Position selected.

When the **Pos** index card (i.e. the position/translation index card) is selected, the bounding box of the selected object will be displayed in green, the color of the **Position/Translation** mode.

All positions in the **Position** index card refer to scene coordinates. On the position/translation index card, the current position of an object is displayed in scene coordinates.

The position/translation dialog allows you to type in the exact position values in x, y and z coordinates. You may also use the up and down arrows to increase or reduce the values.

Press the **Reset** button to move the currently selected object back to the scene's origin.

Press the **Apply** button to accept the new values entered in the position dialog.

Rotation

When the **Rotate** index card is selected the bounding box of the selected object will be displayed in red, the color of the **Rotate** mode.

The index card **Rotate** provides the VGStudio MAX user with two different interfaces to rotate the selected object in the scene, i.e. the **Standard** dialog and the **Advanced** dialog. Use the **Standard/Advanced** toggle button to switch between the two modes.

The **Standard** dialog looks like the following image.

The **Standard** dialog provides you with an interface where you may enter **incremental** rotation

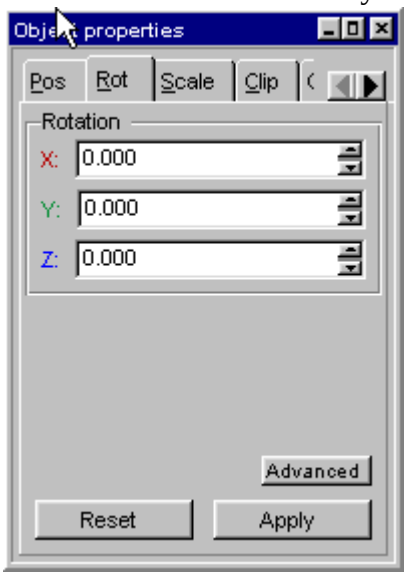


Fig. 163 The Standard dialog of the Rotate index card.

values for each axis. Type in the incremental rotation around the x, y, or z axis or use the up and down arrows to increase or reduce the rotation values.

The **Advanced** dialog looks like the following image.

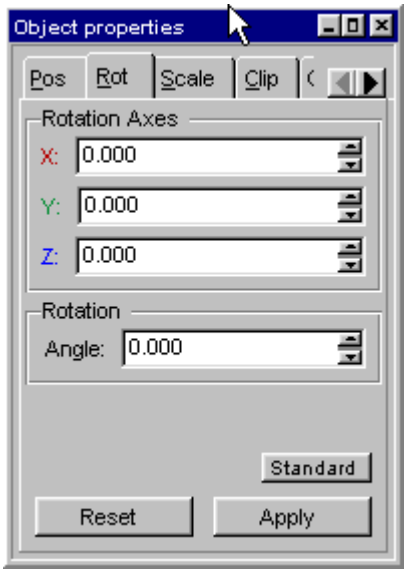


Fig. 164 The Advanced dialog of the Rotate index card.

The **Advanced** dialog provides you with an interface where you may enter **absolute** rotation values for the selected object. The absolute rotation is defined by a normalized vector in the 3D space and a rotation angle around this vector. Non-normalized vectors may also be entered. They will be normalized when the values are applied.

Type in the x, y, or z coordinates to define the vector around which you want to rotate the image or use the up and down arrows to increase or reduce the x, y, or z values.

Type in the absolute rotation angle around the axis defined by the x, y, or z value or use the up and down arrows to increase or reduce the rotation angle.

Press the **Reset** button to reset the orientation of the selected object to its original value.

Press the **Apply** button to activate the new values entered in the rotation dialog.

Scaling

When the **Scale** index card is selected the bounding box of the selected object will be displayed in dark blue, the color of the **Scale** mode.

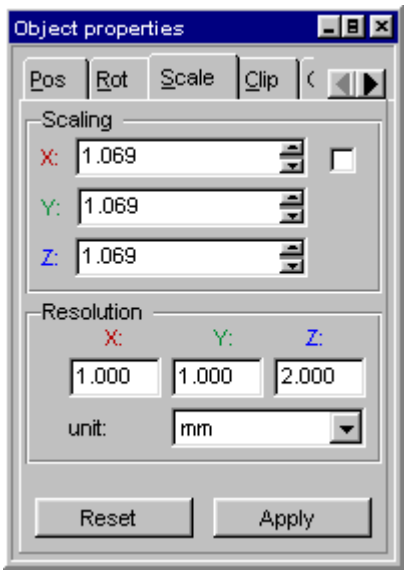


Fig. 165 The Scale index cad of the Object properties dialog.

When several objects are selected, the index card **Scale** will be disabled. If you wish to manipulate several objects together, you have to group the objects first. For more information on the grouping and ungrouping of objects, please refer to *Chapter 4.3.3 Setting Preferences.*

The index card **Scale** provides you with an interface which allows you to type in the scaling factors for the selected object. You may also use the up and down arrows to increase or reduce the values.

Use the checkbox on the right-hand side to lock the three values for isotropic scaling. The three values will then be changed simultaneously and cannot be changed independently of each other.

Use the **Reset** button to set the scaling values to the default values of 1.0.

On the index card **Scale** you may also enter the initial voxel resolution of the selected voxel object. The **Resolution** area will be disabled if an object group is selected.

You may also apply the unit, e.g. µm, mm, cm, m, of the applied resolution values in the **Resolution** area. Applying an measurement unit to an object leads to the automated process, if no object with a unit was loaded into the scene before, that this measurement unit will be also applied as measurement unit within the whole scene. You can see the current scene measurement unit displayed in the Status Bar, please refer to *Chapter 4.7 Status Bar*.

Press the **Reset** button to reset the scaling of the selected object. The index card **Scale** Reset leaves the resolution settings untouched.

Press the **Apply** button to activate the new scaling values entered in the rotation dialog.

Reminder: You should not scale objects down to factors less than 0.1! Please take into account that scaling **and** resolution will end up in an effective object scaling. Very low object scaling values will result in reduced image quality. Higher oversampling values may enhance the image quality again. In scenes that include objects with different scaling values you should scale up all objects so that the smallest object will have an effective scaling value of at least 1.0.

Clipping

When the **Clip** index card is selected the bounding box of the selected object will be displayed in cyan, the color of the **Clip** mode.

The index card **Clip** provides the VGStudio MAX user with two different interfaces to clip the selected object in the scene, i.e. the **Clipbox** dialog and the **Clipplane** dialog. Use the **Clipbox/Clipplane** toggle button to switch between the two modes.

All parameters in the **Clipbox** or **Clipplane** dialogs are in object voxel coordinates.

Clipbox — Select this command to box clip the selected object or object group along the axes of its bounding box. The **Clipbox** mode is characterized by the cyan bounding box with squared handles, i.e. active areas on each side of the selected object or group of objects (a small scissors will appear next to the cursor when you place it on one of the handles). The object may be clipped by typing in the position of each of the six clipplanes on the **Clip** index card. Use the two values for each coordinate axis to apply a clipplane to all sides of the selected object. Type in the values for the clipplane position or use the up and down arrows to increase or reduce the clipplane position values. Group the objects first if you want to clip several objects at a time.

Press the **Reset** button to remove the clipping of the selected object. Press the **Apply** button to activate the appropriate parameters.

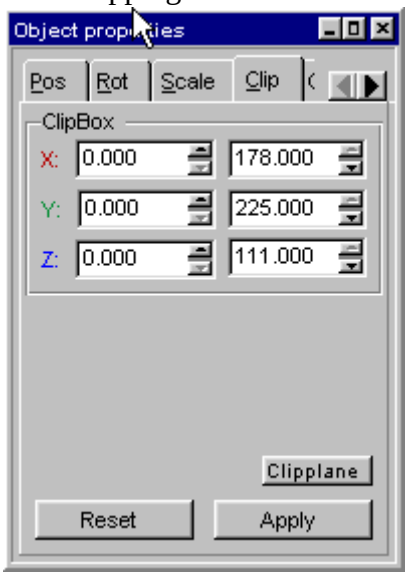


Fig. 166 The Clipbox index card of the Object properties dialog.

Clipplane — Select this command to clip the selected object or object group by an arbitrary clipplane. The **Clipplane** mode is characterized by the cyan bounding box with a normal vector on one side of the current object. The object may be clipped along an arbitrary clipplane by typing in the values for the arbitrary clipplanes in the **Clipplane** dialog of the **Clip** index card. The clipplane will be disabled if several objects are selected. Group the objects first if you want to clip several objects with one clipplane at a time.

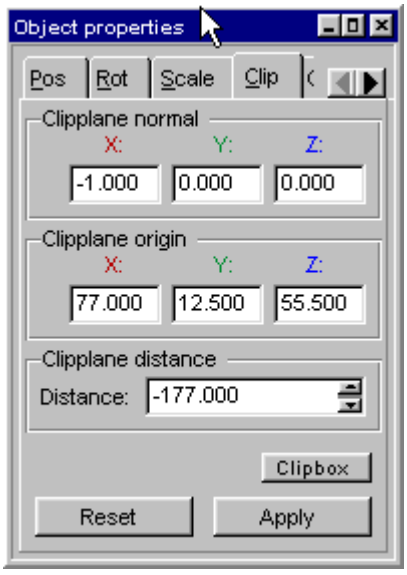


Fig. 167 The Clipplane index card of the Object properties dialog.

The arbitrary clipplane is defined by the **clipplane's normal** vector and the **distance** between the clipplane and the origin of the clipped object. The **clipplane's origin** may be placed to any arbitrary position in order to be able to rotate the clipplane around the specified point.

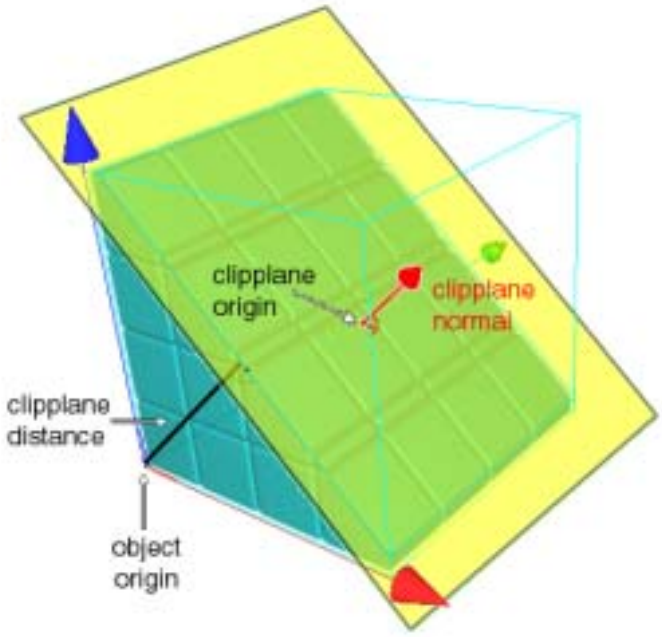


Fig. 168 The clipplane is defined by the clipplane's normal vector and the distance between the clipplane and the origin of the clipped object.

The clipping of an object group will be reset if the object group is ungrouped.

When several objects are selected, the **Clip** index card will be disabled. If you wish to manipulate several objects together, you have to group the objects first. For more information on the grouping and ungrouping of objects, please refer to *Chapter 4.3.3.*

Press the **Reset** button to remove any clipplane from the selected object. Press the **Apply** button to activate the new values.

Center

When the **Center** index card is selected the center of an object or say the origin of the object coordinate system can be applied in voxel coordinates. By default the origin of an object is at (Xmax/2, Ymax/2, Zmax/2). If several objects are selected, the default center will be the center of the bounding box containing all objects.

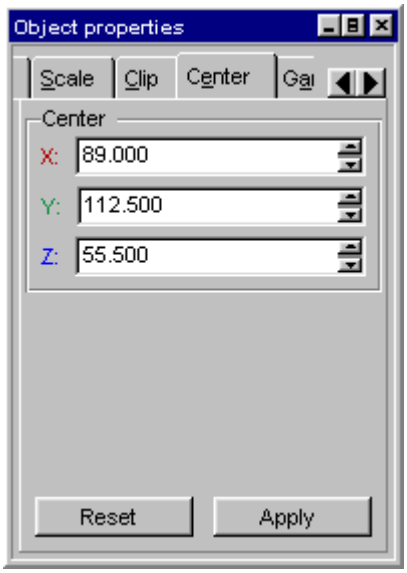


Fig. 169 The Center index card of the Object properties dialog.

You can enter any value for the center, that seems appropriate for you. Press the **Reset** button to reset values to the default center. Press the **Apply** button to activate the new values.

Reminder: Any rotation of an object will be around the center, so using a center which lies outside the object will rotate the object very differently from the default center.

Gantry

Several imaging devices, especially CT-scanners allow to acquire a data set with a gantry-tilt. This procedure will result in an sheered image stack.

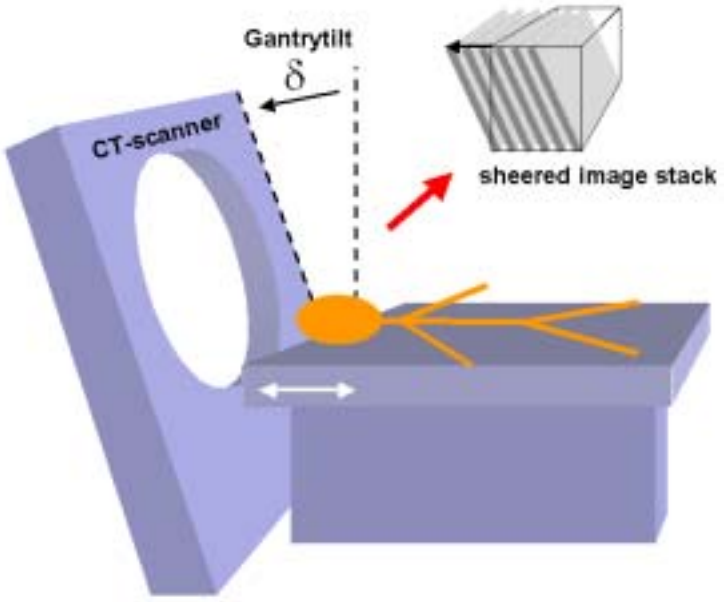


Fig. 170 The Gantry index card of the Object properties dialog.

Special visualization techniques are necessary for a proper visualization of such sheered image stack. VGStudio MAX 1.0 includes support for sheered data set. The user may apply any arbitrary gantry tilt when the **Gantry** index card is selected.

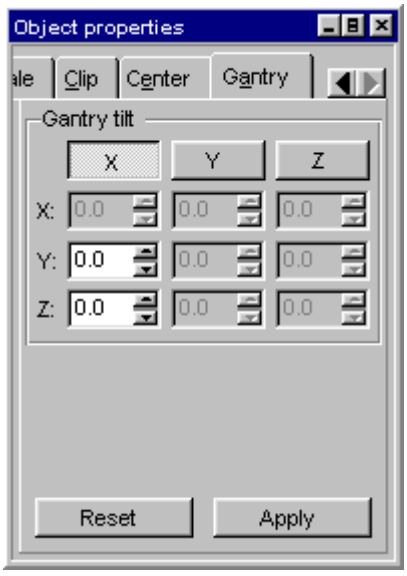


Fig. 171 The Gantry index card of the Object properties dialog.

VGStudio MAX 1.0 supports DICOM 3 image data including gantry tilt.

4.6.8 World View

The **World view** tool is used to steer your view on the scene. The position, rotation, and the viewing angle may be manipulated. In the **World view** tool an overview of the current scene is displayed in form of the bounding boxes of each object or group of objects.

You activate the **World view** tool by pressing the **World view** mode button in the icon bar or by clicking **World view mode** in the **Scene** Menu. All changes can be observed in the **3D view** window. Changes in the **World view** tool will not affect the scene itself.

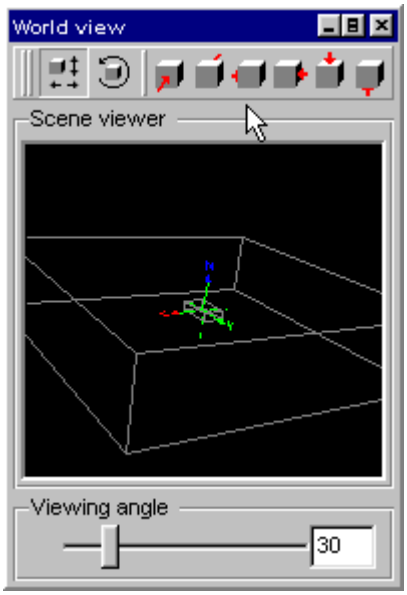


Fig. 172 The World view tool of VGStudio MAX.

Click the **Move** button to activate the **World view** tool's **Move** mode.

The **Move** mode is characterized by the green color of the scene coordinate system axes in the **World view** tool. The scene may be moved in the image plane by clicking into the **Scene viewer** area with the left mouse button and dragging the mouse while the left mouse button is pressed. The scene may be moved forwards or backwards by clicking into the **Scene viewer** area and dragging the mouse while the middle mouse button (or the **Alt** key and the left mouse button) is pressed.

Using the **Shift** modifier in **Move** mode allows you to move the scene in vertical or horizontal direction.

Click the **Rotation** button to activate the **World view** tool's **Rotate** mode.

The **Rotate** mode is characterized by the red color of the scene coordinate system axes in the **World view** tool. The scene may be rotated around the x-, or y-axes of the image plane in the **Scene viewer** window by clicking into the **Scene viewer** area with the left mouse button and dragging the mouse while the left mouse button is pressed. The scene may be rotated around the viewing direction by clicking into the Scene viewer area and moving the mouse while the middle mouse button (or the **Alt** key and the left mouse button) is pressed.

Using the **Shift** modifier in **Rotate** mode allows you to rotate the scene around the vertical or horizontal axes of the image plane.

Click one of the six **Default view** buttons to view the scene either from the front, back, left, right, top, or bottom.

The distance between the observer and the scene's center, which can be adjusted in **Move** mode, will remain unchanged when one of the **Default view** buttons is pressed.

Drag the **Viewing angle** slider to the left or right or type in the desired value to adjust the viewing angle.

By clicking into the **Scene viewer** window with the right mouse button you open the following context menu.

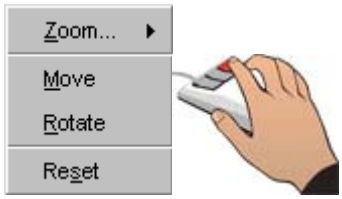


Fig. 173 The context menu of the Scene viewer area.

When clicking **Zoom** the following menu will be opened.

The **Scene viewer** window may be zoomed in or out. Click **Reset** to reset the zoom factor to its default value.

In the context menu, click **Move** or **Rotate** to access the **Move** or **Rotate** mode.

Select **Reset** to reset the **World view** settings to its default values.

For more detailed information on the **World view** mode, please refer to *Chapter 4.5.3 World and Camera View*.

4.6.9 Camera View

While the **Camera mode** is activated you may use the **Camera View** tool to adjust camera-relevant settings. The **Camera View** tool is activated by pressing the **Camera mode** button in the icon bar or by clicking **Camera mode** in the **Scene** Menu.

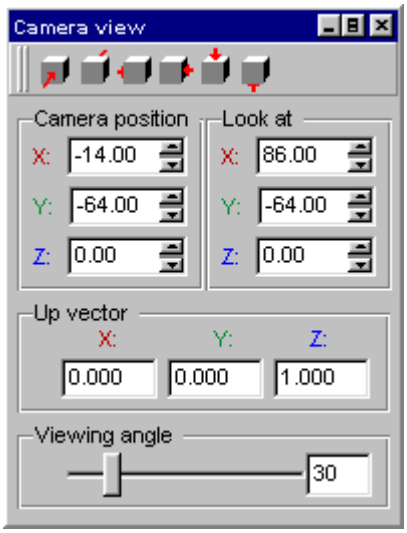


Fig. 174 The Camera view tool of VGStudio MAX.

You may either type in the exact values for the **Camera position** and for the **Look-at** point or use the up and down arrows to increase or reduce the x, y, and z position values.

Use the **Up vector** section to type in the exact value for the up vector relative to scene coordinates.

Reminder: The camera and look-at position are defined in scene coordinates while most other tools work in object coordinates! The color coding in the slice tools may not fit to the color coding of the camera tool in case of an rotated object.

Click one of the six **Default view** buttons to view the scene either from the front, back, left, right, top, or bottom.

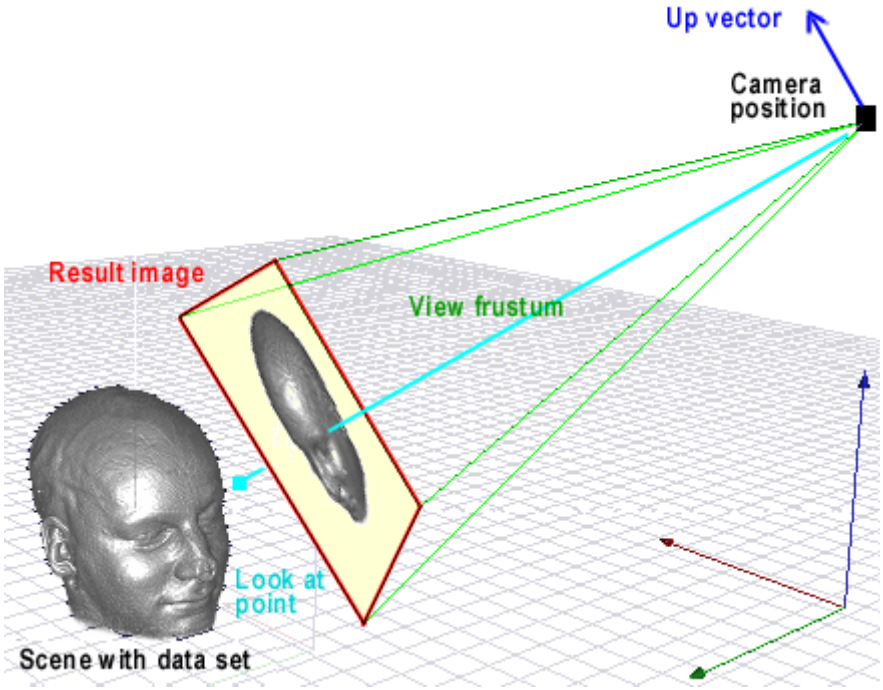


Fig. 175 The Camera view mode allows you to view your data from inside. You may adjust all camera parameters shown here according to your needs.

The distance between the observer and the scene's center, which can be adjusted in **Move** mode, will remain unchanged when one of the **Default view** buttons is pressed.

Drag the **Viewing angle** slider to the left or right or type in the desired value to adjust the viewing angle.

For more detailed information on the **Camera view** mode, please refer to *Chapter 4.5.3 World and Camera View.*

4.6.10 Segmentation

VGStudio MAX 1.0 includes a powerful set of segmentation functions. The process of segmentation can be informally described as the task of partitioning an volumetric data set into separate regions, e.g. representing different materials or tissue. In contrast to gray value classification, which can be performed within the classification tool, the segmentation tool provides capabilities to separate structures which can not be separated by a simple gray value classification but only on a morphological level. Examples can be seen in *Fig. 176*.

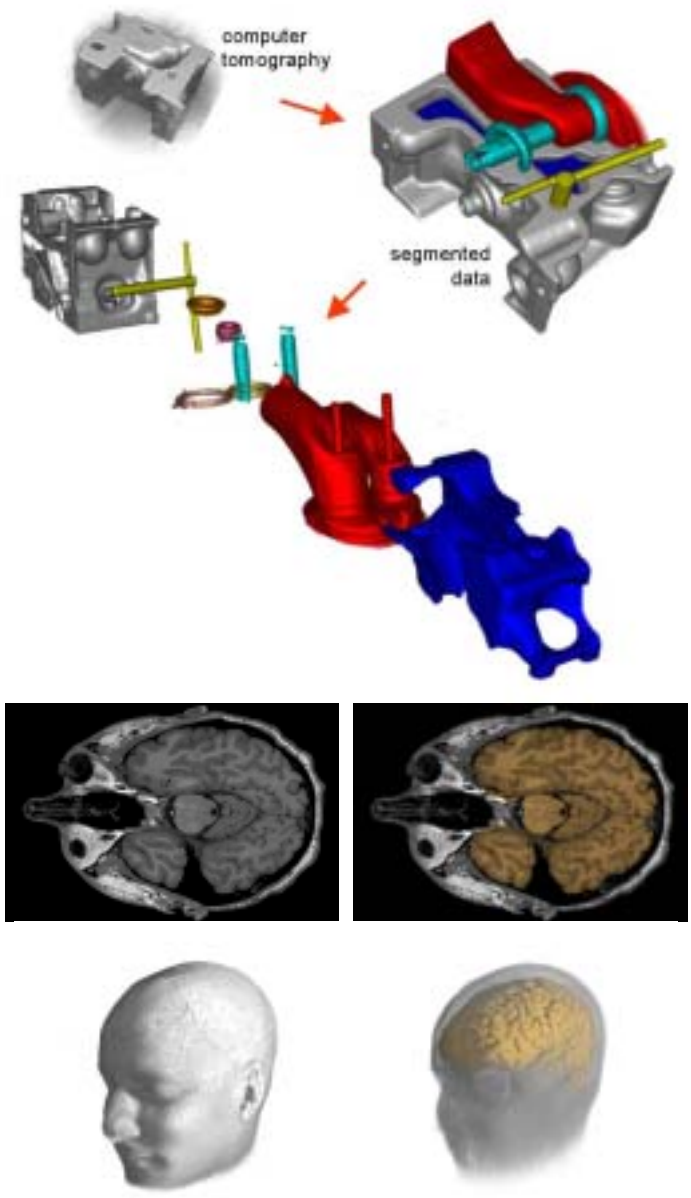


Fig. 176 Tomography of an engine and an MRI scan of a human head (2D and 3D). Original data and segmented data.

VGStudio MAX' segmentation capabilities are accessed by the segmentation tool. The segmentation tool includes

- the icon bar including 3D and 2D segmentation modes
- the magic wand options
- the 2D propagation mode section
- the morphological operations section
- and the button section

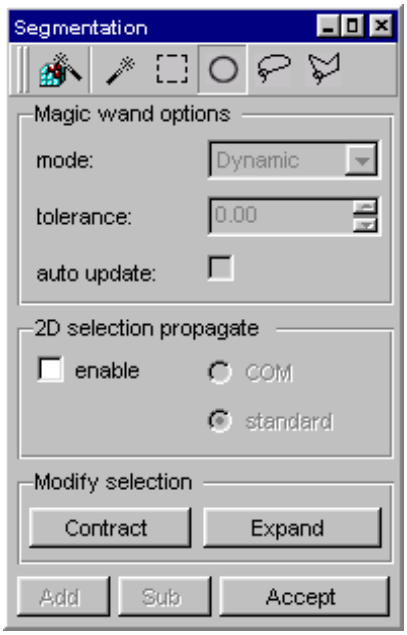


Fig. 177 The Segmentation tool of VGStudio MAX.

The different functions and elements are explained in the following chapter. We will first explain some vocabulary used and the principle concepts of VGStudio MAX' segmentation modes on the basis of an example.

Working selection and sections

Drawing an outline within the data will create a green colored **working selection**. A working selection may consist of an single area within one 2D slice image, it may be an area in 3D or even several 2D or 3D areas throughout the whole data set.

The result of a segmentation process within VGStudio MAX is called a **section** (*see also Chapter 3.2.3 Data Sets, Sections and Segments*). A working selection will become a section when the accept button is pressed within the segmentation tool. A section will be outlined in red color when the section is selected while a segmentation mode is activated.

Segmentation example

We use the lasso tool  within our example, however all the described features are also applicable with all other segmentation modes. We use the lasso tool to outline the brain tissue within the axial slice image of an MRI scan of a human head (*see Fig. 178*).

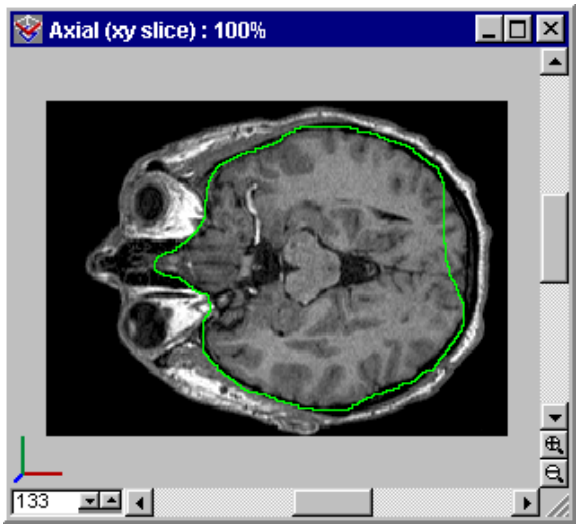


Fig. 178 A green line surrounds the selection.

The current so called **working selection** shows up in green color. If the selection process was not optimal the user may just start to draw a new selection. The existing selection will be destroyed when drawing a new one. A working selection may also be modified by adding or subtracting parts. This is possible by using the **Shift** or **Control** modifiers. In our example shown in *Fig. 178* we can see that the outline of the brain tissue was not optimal at the right side. Not all the brain tissue was selected. We can add parts to the current working selection by keeping the **Shift** key pressed while outlining an additional area within the data set. A little "+" symbol will show up as long as the Shift key remains pressed (*see* Fig. 179).

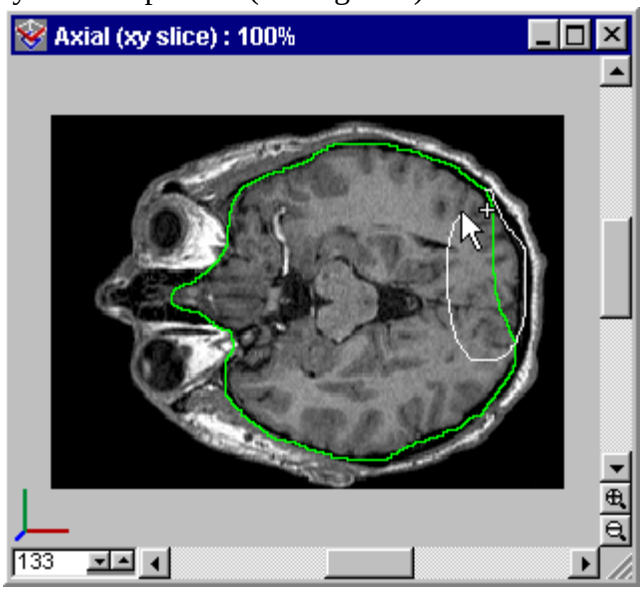


Fig. 179 Adding areas to the current selection.

In our example we surround the missing parts of the brain tissue with the lasso tool while the Shift key is pressed. The resulting working selection is the sum of the initial selection and the added selection.

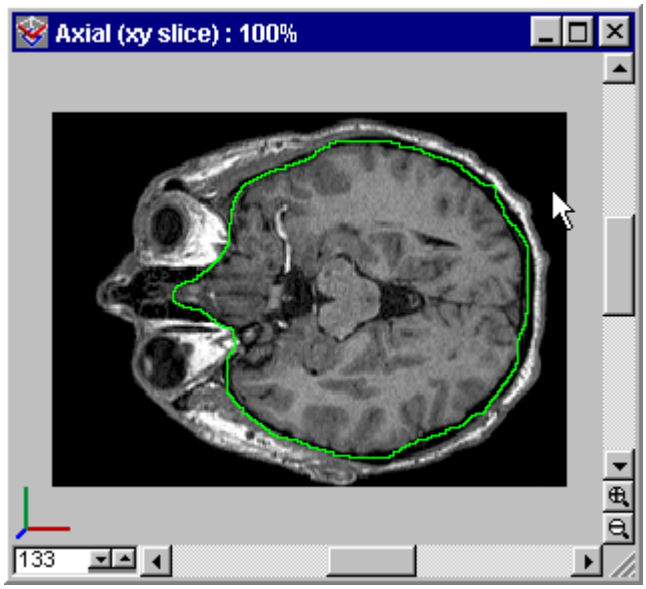


Fig. 180 Final selection.

The final selection can be seen in Fig. 180. In the same way we used the Shift modifier to add parts to the selection we can use the Ctrl modifier to subtract areas from the working selection. As an example we activate the marquee tool  to remove a rectangle area from the working selection.

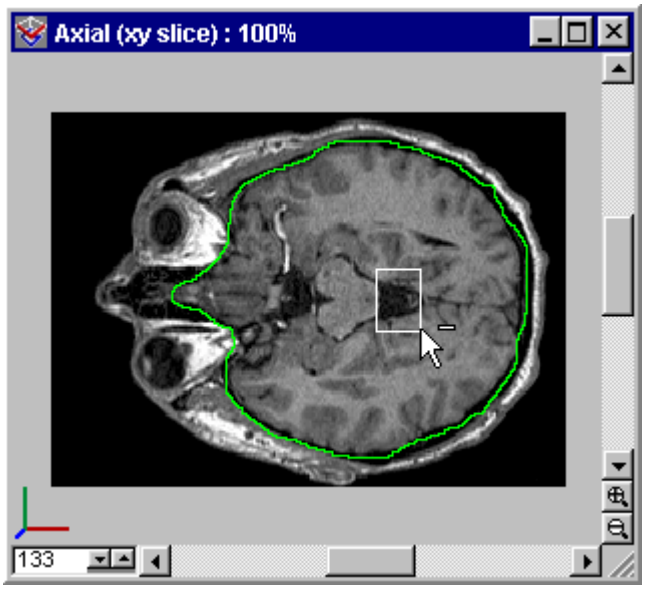


Fig. 181 Subtract a rectangle area from the selection.

We bring up a rectangle area within the working selection while the Ctrl key is pressed. A little "-" symbol appears to show up that we subtract this area from the current working selection. The result of this process can be seen in Fig. 182.

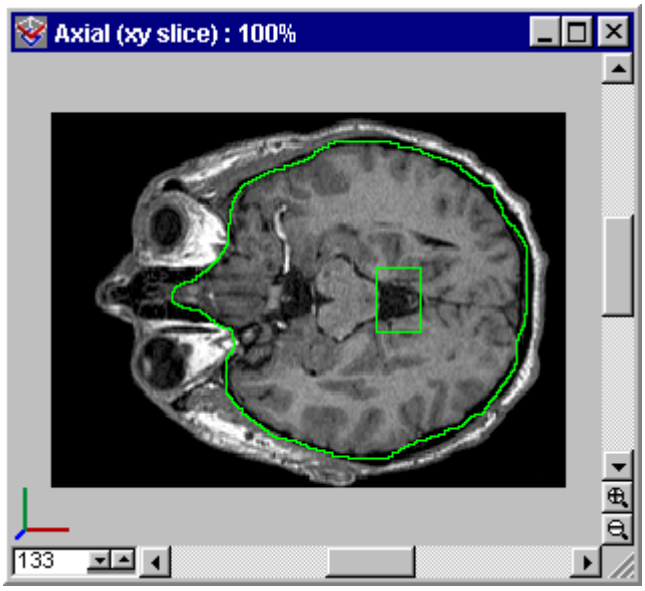


Fig. 182 The final selection.

This example shows that a working selection can be optimized by adding (Shift) or subtracting (Ctrl) areas by any of the segmentation modes. The different segmentation modes may be used in any combination to create a selection. The user may even create a working selection by the 3D Magic Wand and optimize the result slice by slice with the different 2D segmentation modes.

Our working selection will become a “true” section when the A**ccept** button in the segmentation tool is pressed. The green outline of the working selection will become a red outline of the current section (see Fig. 183).

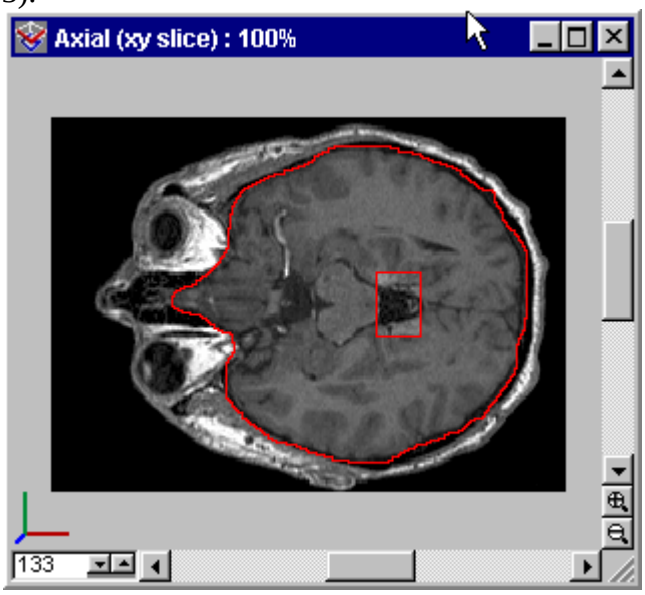


Fig. 183 The resulting section.

A section may also be modified. The user may simply draw a new working selection to add or subtract it from the red outlined section. In our example shown in *Fig. 184* the working section was added to the section by pressing the **Add** button within the segmentation tool.

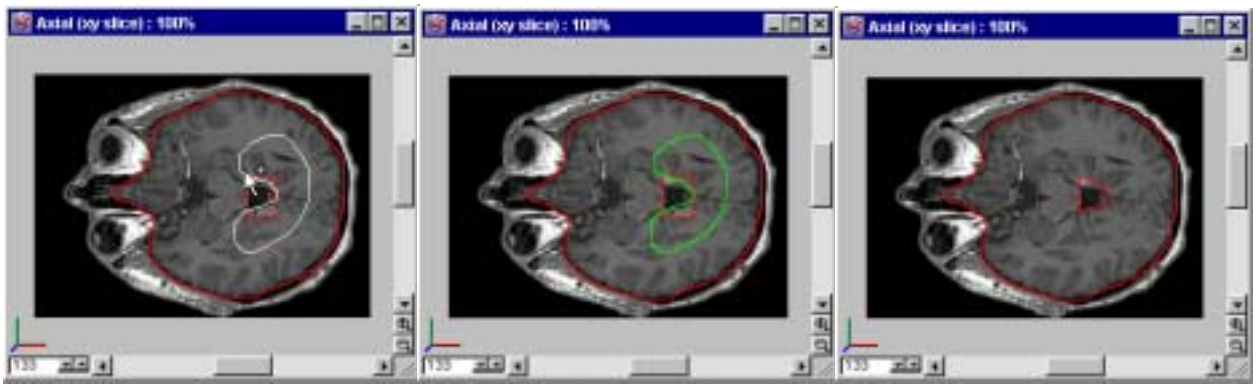


Fig. 184 Drawing a working selection within an existing section and adding it to the section.

In the presented example the resulting section includes data from a single slice image only since we created a selection within this single slice image using 2D segmentation modes. However the user may create section in the whole 3D data set by using 2D segmentation modes stepping through the data slice by slice or he may use the 3D Magic Wand to generate a 3D selection at once.

One important fact of VGStudio MAX' segmentation tools is that you have to decide in which slice window you want to work while creating a working selection. If you change the slice window, while segmenting data in another slice window, you will loose the working selection within all slices.

Reminder: You must not change the slice window, while segmenting data in another slice window. Changing the slice window will result in loosing the working selection within all slices.

You may change between the slice windows after accepting a working selection so that it becomes a section. A section will not be lost when changing the slice window and it may be modified in any of the three slice windows.

The segmentation tool icon bar

The icon bar allows activate/deactivate on of five segmentation modes. A segmentation mode remains active as long as the appropriate icon is pressed. Using several features of VGStudio MAX, e.g. activating measurement tool, will automatically deactivate the segmentation mode. The segmentation modes are: the 3D magic wand, 2D magic wand, marquee tool, ellipse tool, lasso tool and the polygon lasso tool.

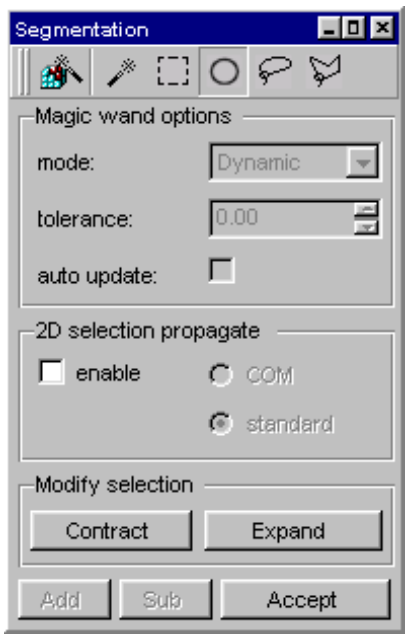


Fig. 185 The Segmentation tool of VGStudio MAX.

Unlike the other segmentation modes, the 3D  and 2D  **Magic Wand** tool works by selecting content rather than defining edges. The Magic wand tools use a so called region growing algorithm to create a selection. Region growing is an image processing technique that segments all voxels that are connected to a seed point and that are within a user defined **tolerance** of voxel values. The larger the tolerance value the more areas will be included into the selection. The tolerance as well as other parameters of the Magic Wand modes can be adjusted in the Magic Wand options section of the classification tool. There are two different modes available for the Magic Wand tools: the Dynamic and the **Static** mode. Using static region growing, adds all adjoining points of the current voxel to the selection, which are within the tolerance from the gray value of the voxel at the seed point position. Using **Dynamic** region growing adds all adjoining points of the current voxel to the selection, with voxel values that are within the tolerance in respect to the mean gray value of all voxels that are already in the selection. The dynamic mode is used as default since it is less susceptible to noise within the data. Another convenience mode is the **auto update** mode. Changing the tolerance value requires in addition that the seed point has to be set to start the region growing process. Changing the tolerance value will automatically start the region growing process with the seed point of the previous selection if the auto update checkbox is activated.

Creating a 3D Magic Wand Selection

To make a Magic Wand selection:

1 Activate the 3D Magic Wand mode

2 Apply a tolerance value

3 Move the cursor over one of the three slice windows.

4 Click the area you want to select.

5 Release the mouse button. A marquee surrounds the selection.

6 The selection can be optimized by choosing another tolerance value and restart with Step 3.

Creating a 2D Magic Wand Selection

To make a Magic Wand selection:

1 Activate the 2D Magic Wand mode

2 Apply a tolerance value

3 Move the cursor over one of the three slice windows.

4 Click the area you want to select.

5 Release the mouse button. A marquee surrounds the selection.

6 The selection can be optimized by choosing another tolerance value and restart with Step 3.

The marquee tool  let you select rectangular or square areas and the ellipse tool  let you select elliptic or circular areas. The lasso  and polygon lasso  tools let you draw both straight-edged and freehand segments of a selection border.

Creating a Marquee or a Ellipse Selection

To make a selection:

1 Click the marquee button  on the Tool palette for rectangular outlines and the  button for an elliptic outline. To create square or circular outline, click with the middle mouse button instead of the left one (if your mouse got no middle mouse button, click with the left mouse button and hold the Alt button simultaneously).

2 Place the mouse on the image at one of two places:

a. To create a rectangular selection, place the cursor at a corner of the area you want to select..

b. To create a circular or elliptical selection, place the cursor at the edge of the area you want to select.

3 Click and drag the mouse until the selection is the size you want. As the mouse moves, a line appears to indicate the border of the selection.

4 Release the mouse button. The selection border becomes a marquee.

Making a Lasso Selection

To make a lasso selection:

1 Click the lasso button  on the Segmentation Tool icon bar.

2 On the Tool Options palette, choose lasso as the Selection Type and set the options.

3 Move the cursor over the image.

4 Click the image at a point that you want to become the border of the selection.

5 Drag the cursor to create an outline of the area you want to select. IMPORTANT: Do not release the mouse while creating your selection.

6 When the line encloses the selection, release the mouse. The line becomes a marquee indicating the border of the selection.

Making a Polygon Lasso Selection

To make a polygon lasso selection:

1 Click the polygon lasso button on the Segmentation Tool icon bar.

2 Click the cursor on the point in the image where you want to begin the line. As the mouse moves, a straight line connects it to the starting point.

3 Click the image wherever you want to anchor the line and change its direction.

4 Click the middle mouse key to finish the polygon lasso selection.

The 2D selection propagate mode

VGStudio MAX' 2D segmentation tools can be used for the convenient segmentation of a 3D data set in conjunction with the 2D propagate mode. A 2D selection generated in a slice image can easily be propagated to any slice image by choosing another slice within the slice selection box in the lower left corner of the slice windows when the 2D selection propagate mode was activated within the segmentation tool.

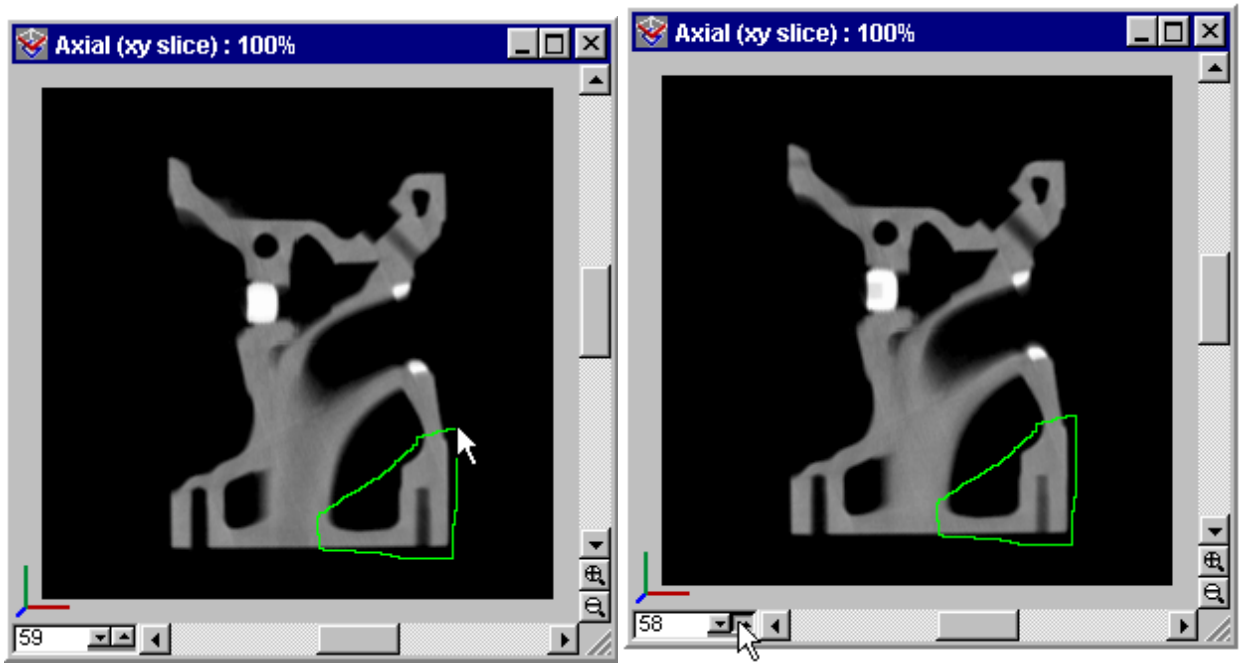


Fig. 186 A selection gerenated in slice no 59 (left) can be propagated to slice no 58(right).

The user may step through the volumetric data set slice by slice and segment the whole data set by propagating the 2D selections through the data set. The user may optimize the working selection while stepping from slice to slice. If there is already a working selection within a slice the propagate mode will not overwrite the existing selection. Therefore the best way to use the propagate mode is to step through the data set in one direction.

The propagate mode used in combination with the 2D Magic Wand will propagate the seed point not the selection itself. Starting from the same seed point coordinates with the same tolerance

value the 2D region growing will start within the next slice selected. There is an additional options when using the propagate mode in combination with the 2D Magic Wand mode. The **Center Of Mass** (COM) mode will calculate the new seed point coordinates as the "center of mass" of the current slice's working selection before propagating the seed point to the next slice. The default setting for propagating the 2D Magic Wand is the **standard** mode.

Modify selection / Morphological operators

VGStudio MAX includes the morphological operators **Contact** (Erosion) and **Expand** (Dilation). Pressing the Contract button within the segmentation tool will contract the current working selection about one voxel in each direction. Pressing the Expand button within the segmentation tool will expand the current working selection about one voxel in each direction. Depending on which type of segmentation mode (2D or 3D) is selected the contract or expand function will be applied to the 2D working selection within the current slice only or to the whole selection in the 3D data set. The corresponding text can also be seen on the text written on the corresponding button, e.g. Contract or Contract (3D).

Fig. 187 Original selection (middle), contracted selection (left) and expanded selection (right).

The slice window context menu in segmentation mode

Many of VGStudio MAX' segmentation capabilities can be accessed through the context menu of the slice windows.

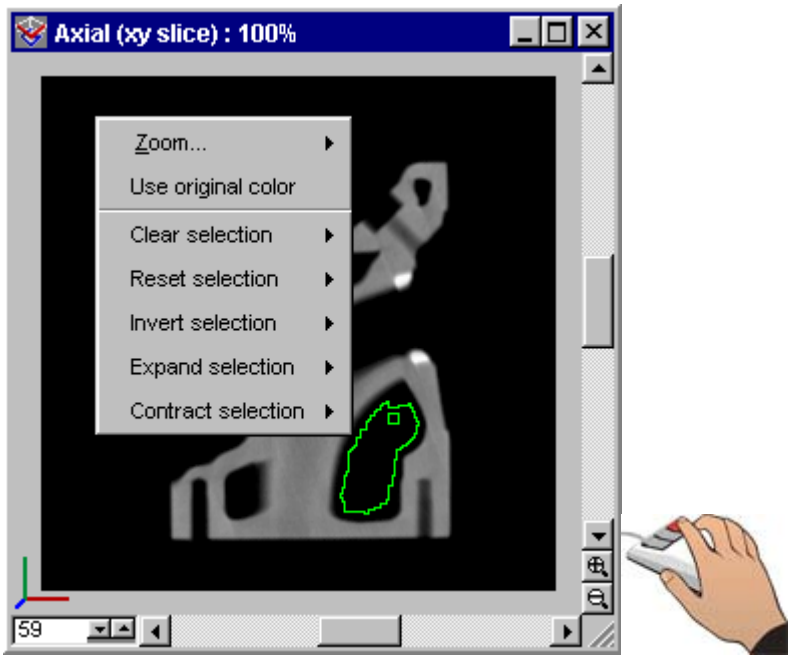


Fig. 188 Slice window context menu in segmentation mode.

The slice window context menu includes the following features when a segmentation mode is activated:

- **Clear selection –** This option will clear the current working selection within the current slice only or within all slices.
- **Reset selection –** This option will use the current section outline (red coloured outline) as working selection within the current slice only or within all slices.
- **Invert selection –** These option will invert the current working selection within the current slice only or within all slices.
- **Expand selection –** These option will expand the current working selection within the current slice only or within all slices.
- **Contract selection –** These option contract will invert the current working selection within the current slice only or within all slices.

Creating several sections

Each time the Accept button is pressed within the segmentation tool a new section will be created. A new section will appear within the scene tree tool when you expand the current data set with the “+” sign.

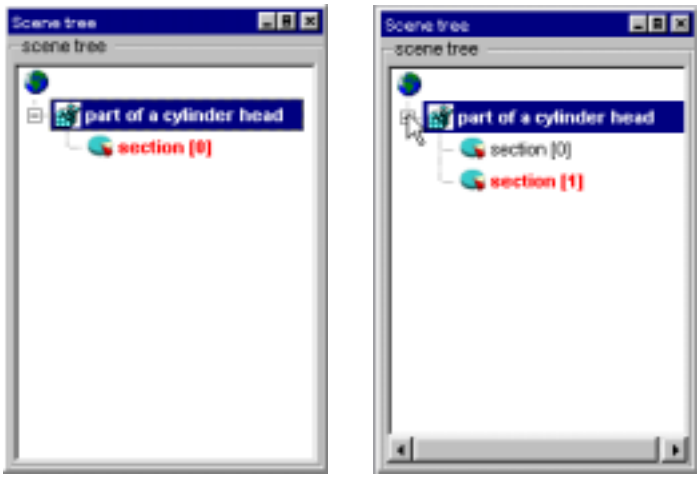


Fig. 189 Sceene tree entry of an unsegmented (left) and a segmented (right) data set..

Each volumetric data set includes a base section called section [0]. The first section generated by the segmentation tool will become section [1] within the scene tree. You may rename the sections within the scene tree by double click the section entry. The red colored section entry within the scene tree shows the current section under access.

To generate a new section, e.g. section [2] the user has to select the base section - section [0] – first. As long as any other section than the base section is selected the user may modify the current section.

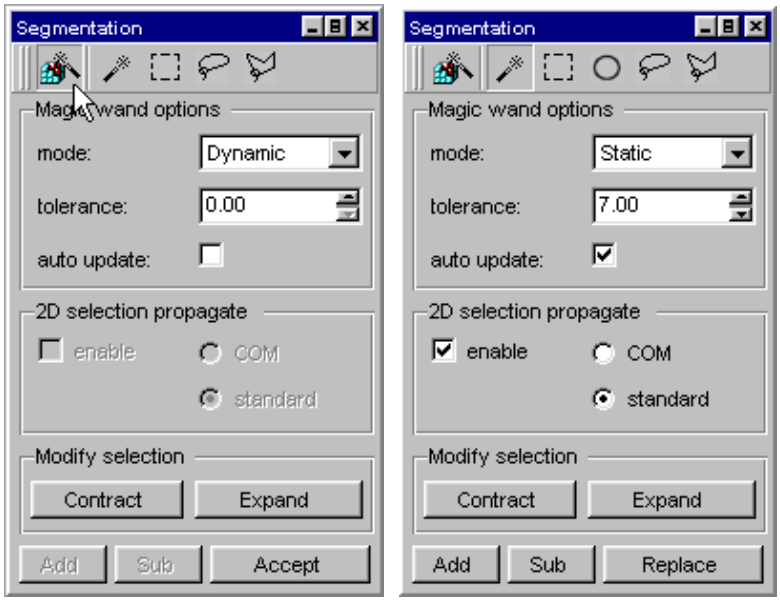


Fig. 190 Segmentation tool when section [0] is selected (left) and when any other section than section [0] is selected (right).

Depending on which section is selected the segmentation tool will include an Accept or a Replace button. The Accept button shows the user that he will create a new section from current his working selection. The Replace button shows the user that he may replace the current selected section (other than section [0]) by his current working selection as well as he is able further modify the current section by adding or subtracting the current working selection.

Increasing the data size while segmenting data

If the current data value range within your volumetric data set is to large to allow the storage of a new sections tag information within the data set a warning dialog will appear (*see Fig. 191*). If you choose **Yes** the data set will be expanded to the next larger data type, clicking **No** will make no new segment.

Fig. 191 If you create a new section, VGStudio MAX 1.0 might warn you, if the data range allows no further section.

Reminder: You will double the memory requirement of your volumetric data set when you expand the data set size.

4.6.11 Filter

VGStudio MAX includes a set of different 3D filter algorithms like Gaussian, Median, Gradient and Non Linear Diffusion filters. The different filters can be selected within the Filter type selection of the Filter tool.

Reminder: You can **not apply** Gauss, Gradient or Non linear diffusion filters **to 32-bit color data**. The Filter tool remains disabled as long as no voxel data set or a polygonal data set is selected.

Reminder: The **memory requirements** of several filter operations **may become very large**! In some cases you will need up to five times of the memory of the original data set.

Fig. 192 The Filter tool of VGStudio MAX.

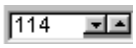
To apply a filter to an object, select the desired object, select the filter type, adjust the filters parameter and press **Start.**

Use the Filter tools **Preview** capabilities to see the effect of the selected filter and settings to the data by activating the filter preview checkbox..

Reminder: The preview may differ slightly form the final result. The reason for the slight differences result from the fact that the preview is calculated on the 2D preview image only while the final filter is calculated in 3D.

The Preview window includes two scrollbars to pan large images as well as two **zoom** buttons, a slice **orientation** button and one slice selection box. The orientation button in the lower right corner shows the axis orthogonal to the displayed slice colored in the VGStudio MAX color scheme.

A xy-slice is displayed if a blue z is displayed as shown in the example above. Use the slice selection box in the lower left corner of the slice windows to scroll through the image stack by clicking the up and down arrows or to select a specific slice by typing in the slice number and then clicking into another window. The selected slice will then be displayed.



Use the **zoom in** and **zoom out** buttons in the lower right corner of the preview windows to zoom in on an image (i.e. enlarge the image) or to zoom out (i.e. reduce the image). The images will then be enlarged or reduced by a preset zoom factor.

When clicking into the preview window with the right mouse button, a context menu will be opened. The context menu includes the **Zoom** option. The preview window may be zoomed in (enlarged) or zoomed out (reduced). The **Fit to window** option allows to zoom the image so that it is displayed with maximum zoom factor. The **Actual Pixels** option applies a zoom factor so that one pixel in the image of the slice window will be one pixel on your screen. These functions may also be applied by using the zoom buttons in the lower right corner of the preview windows. The images will then be enlarged or reduced by a preset zoom factor.

The **Use Classification** option allows you to decide if filter operation should be performed on the original data set or on the data set after the classification tools opacity lookup table is applied. You may use the filter preview to see the effect of this option.

The Gaussian Filter

The Gaussian Filter allows to blur the selected data set. Choose a Filter Mask Size from 3x3x3 up to 9x9x9.

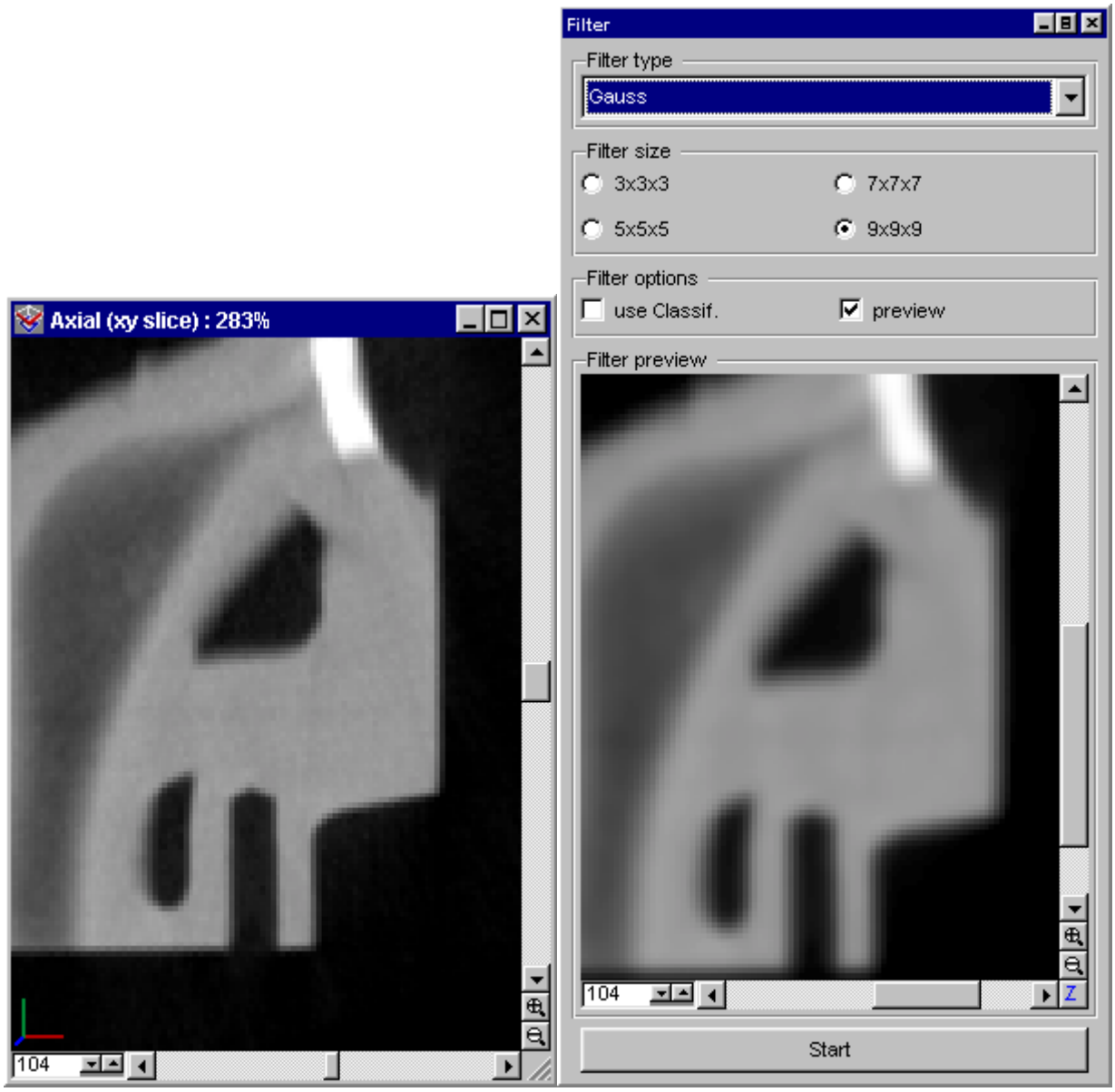


Fig. 193 VGStudio MAX filter preview. Original data left. Gaussian filtered data right.

The Median Filter

Reduces noise in an image by blending the brightness of pixels within a data set. The filter searches the applied mask size of a data set for pixels of similar brightness, discarding pixels that differ too much from adjacent pixels, and replaces the center pixel with the median brightness value of the searched pixels. This filter is useful for eliminating or reducing the effect of motion on an image. Choose a Filter Mask Size from 3x3x3 up to 9x9x9.

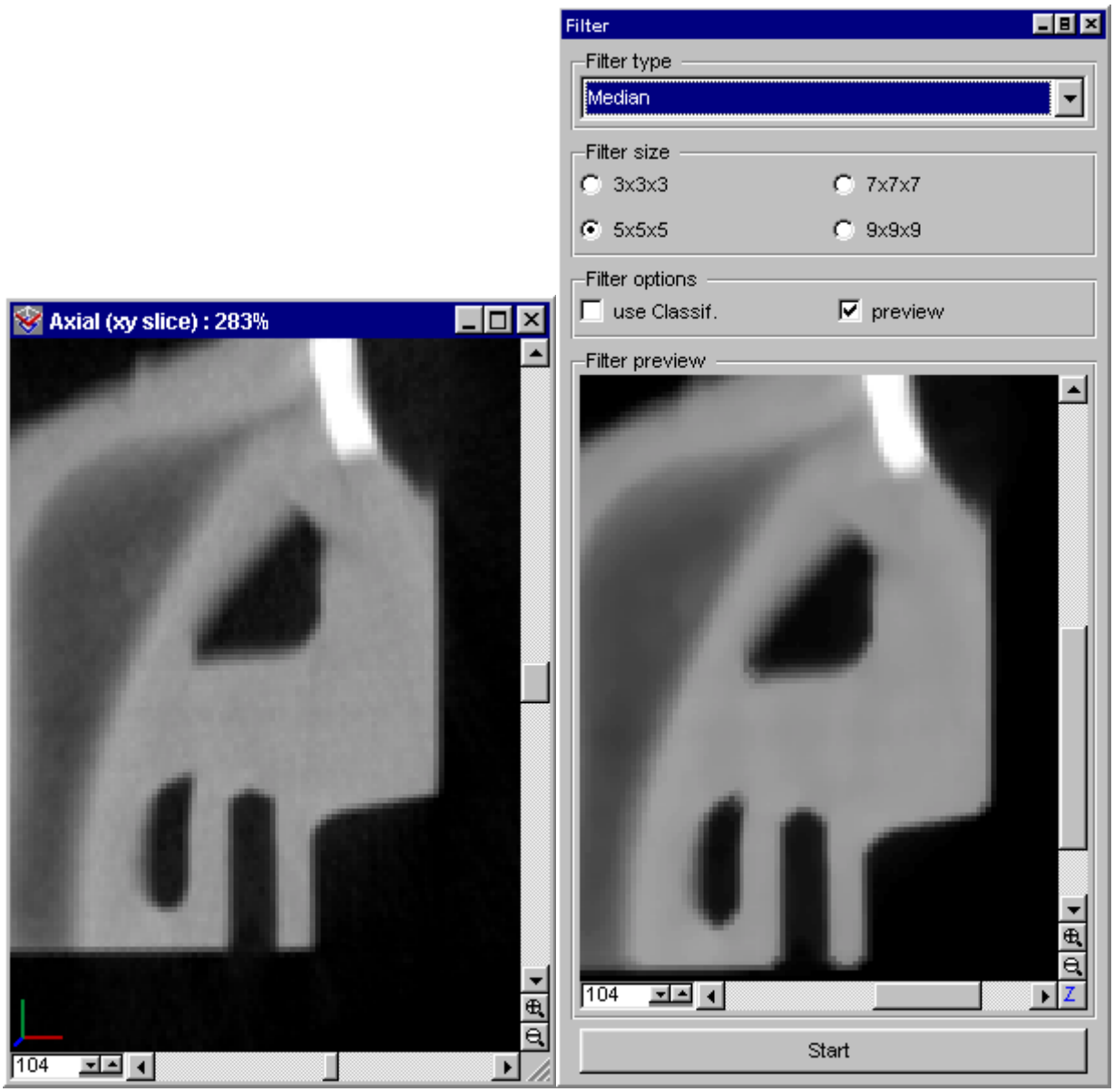


Fig. 194 VGStudio MAX filter preview. Original data left. Median filtered data right.

The Gradient Filter

The Gradient filter accentuate the areas of contrast and edges in the data. It identifies the areas of the data with significant transitions and emphasizes the edges. Choose a Filter Mask Size from 3x3x3 up to 9x9x9. The local gradient will be calculated more precise when using larger filter masks.

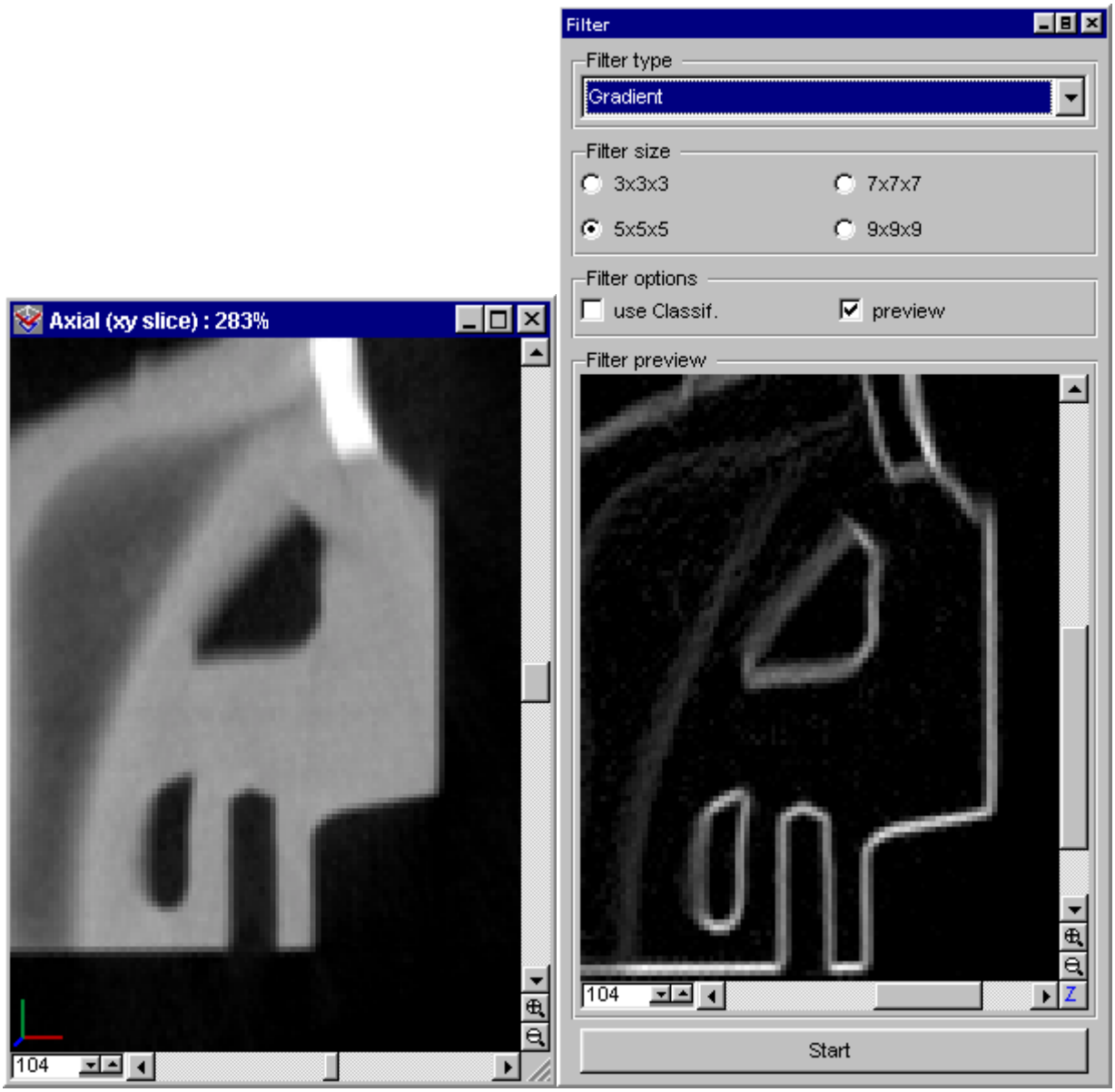


Fig. 195 VGStudio MAX filter preview. Original data left. Gradient filtered data right.

The Non Linear Diffusion Filter

The Non Linear Diffusion Filter is a useful tool to remove noise within the selected data set while preserving the edges.

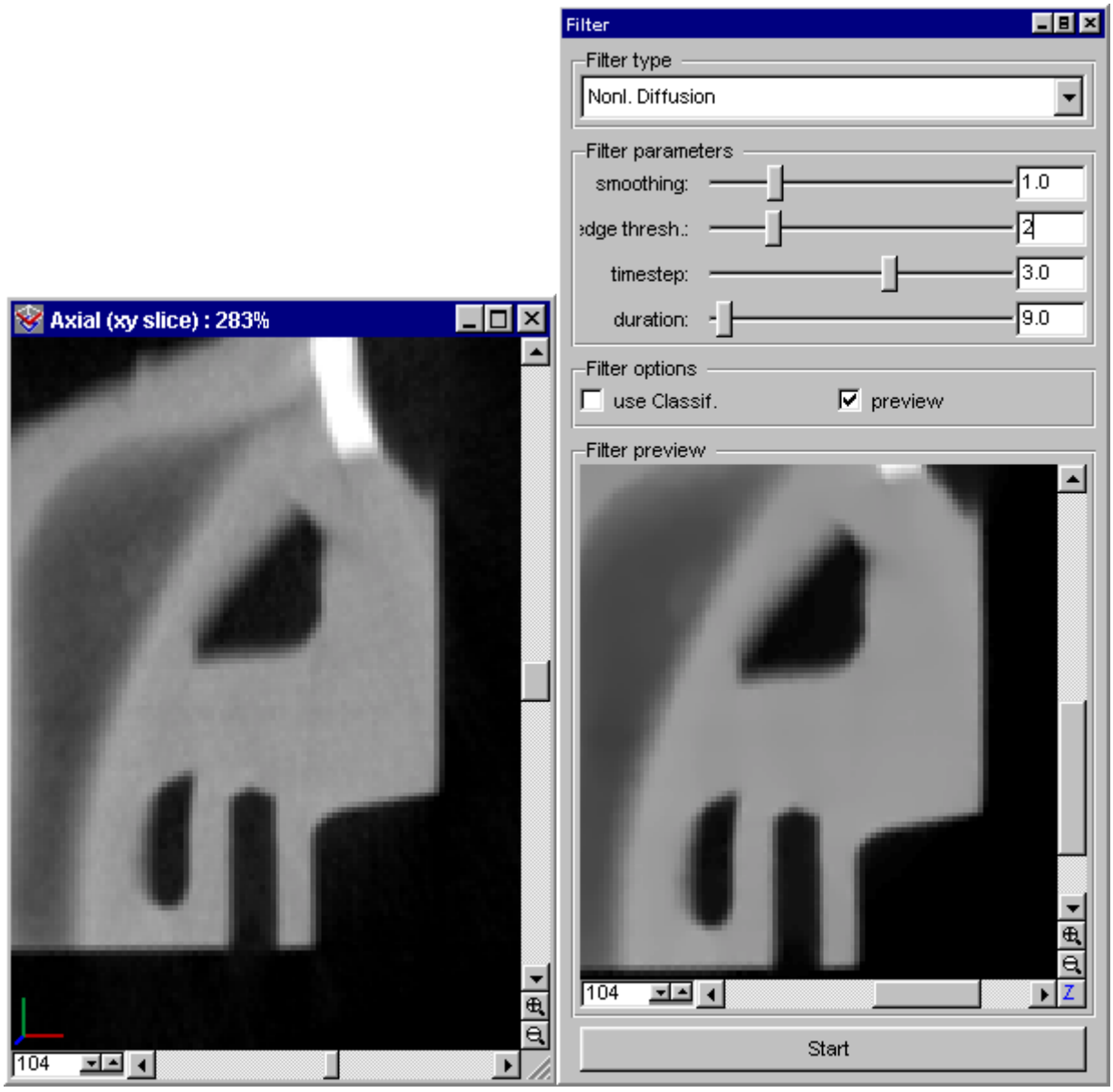


Fig. 196 VGStudio MAX filter preview. Original data left. Non Linear Diffusion filtered data riaht.

4.6.12 Registration

Image coregistration is crucial to a variety of advanced image analyses. Although most 3D imaging modalities are inherently in registration slice-to-slice, volume-to-volume coregistration is needed e.g. to combine partly overlapping sub volumes of an object scanned in two passes or to combine single volumes from multiple modalities. VGStudio MAX' 3-D Registration module provides a algorithm which allows the user to coregister two sets of user defined points. The user may place an arbitrary number of points to be registered within each data set. The registration algorithm functions by minimizing an error function, i.e. the distances between two corresponding points of the two point sets.

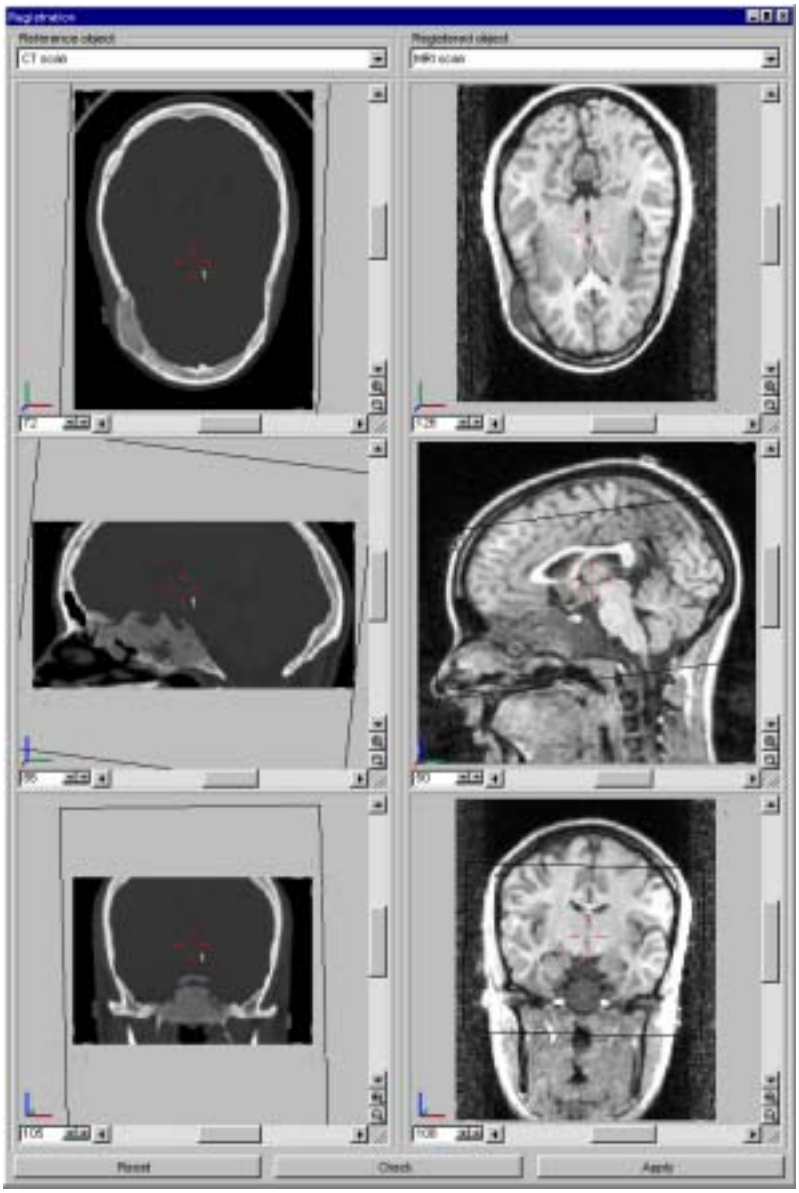


Fig. 197 The Registration tool of VGStudio MAX.

:

“Registration” is the calculation of an optimal transformation between the “reference” object and the “registered” object. Conceptually, the registered object will be moved relative to the reference object. To register two data set load the first data set by using the **Open** command or VGStudio MAX' import features. Load the second data set by using the **Merge** command or VGStudio MAX' import features. Activate the Registration tool in the Tools menu if it is not

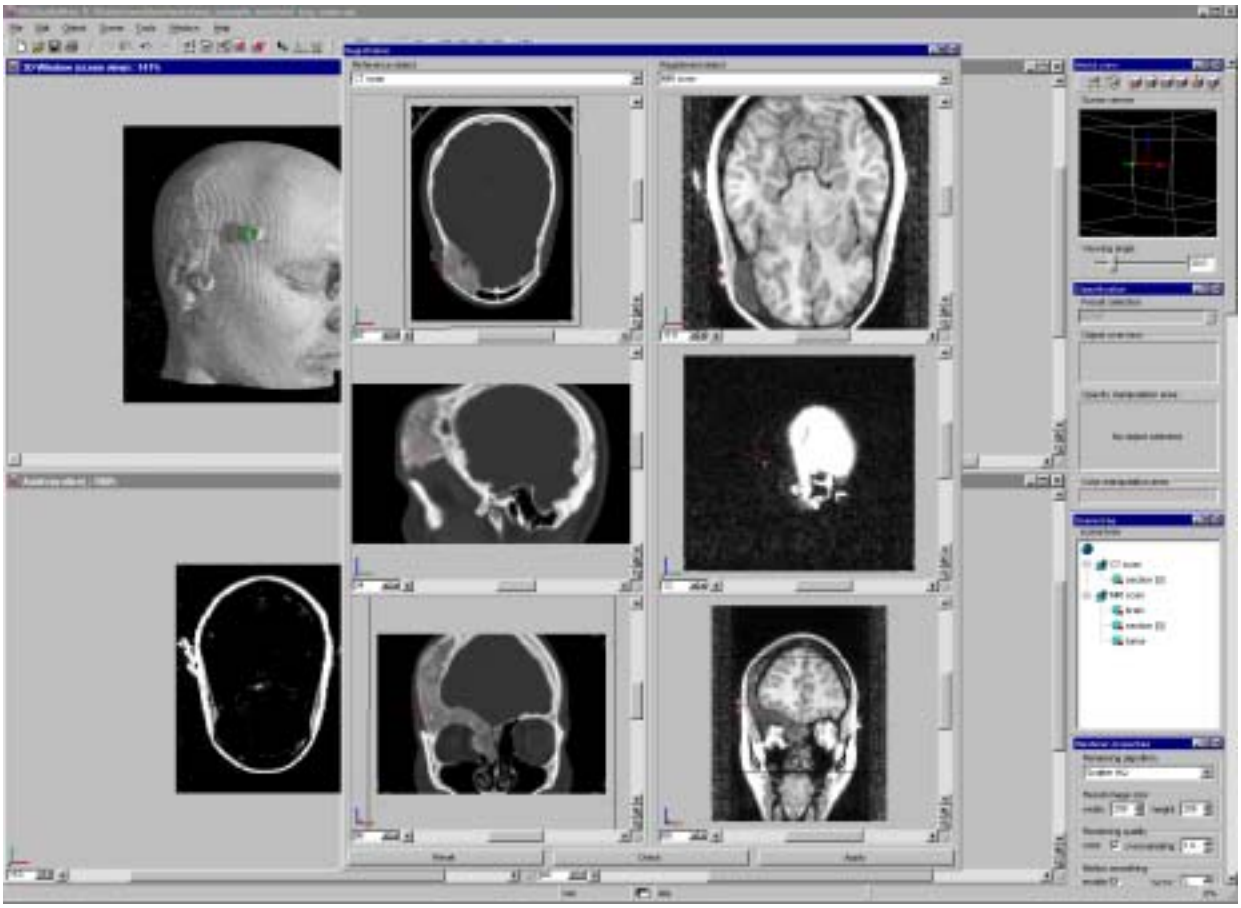


Fig. 198 Registration tool dragged out of the toolbox.

already activated. Drag the registration tool out of the toolbox and resize it for optimal working conditions. The registration tool consists of two columns with an object-selection-pull-down and three orthogonal slice images each. The slice images include the same features like VGStudio MAX' slice images, e.g. zooming, slice no. selection scrollbars and a context menu which can be activated by a right mouse click (Please refer to *Chapter 4.5.1 Slice Windows and Multiplanar Reformatting*).

Now select the reference object from the pull down selection on top of the left image column. Practically, the reference object should be the object of greater resolution and extent. Select the object to be registered from the pull down selection on top of the right image column. Now the user can start placing corresponding landmarks in the two data sets. Select a position within the reference object and left click on it. The marker No. 1 will be placed at this position. Now place the marker No. 1 in the registered object. Optimize the positions of the two corresponding markers within the three orthogonal slices of each data set.

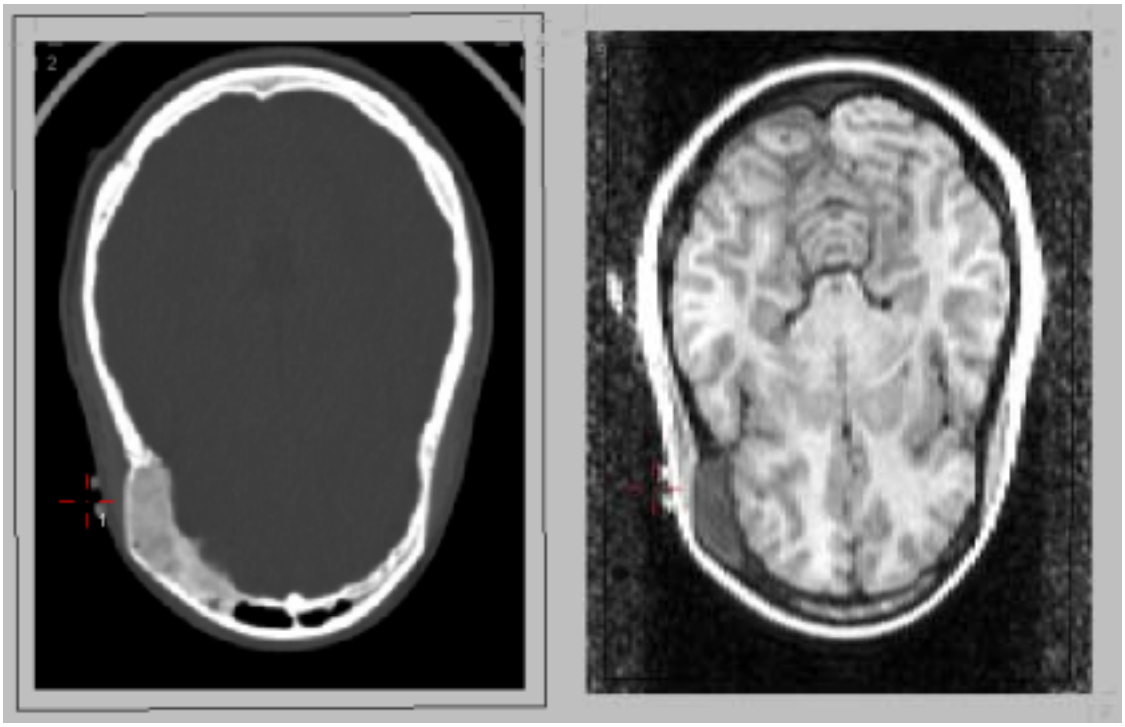


Fig. 199 CT-scan (left), MR-scan (right) with registration marker no. 1 placed on the corresponding landmark.

The placement of the markers can also be verified in the 3D window.

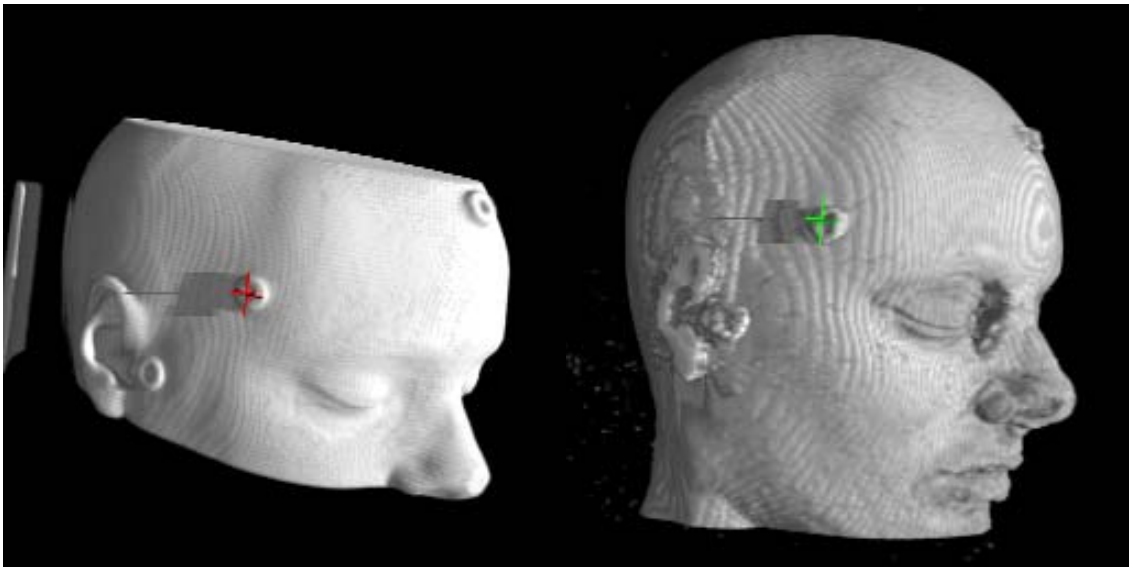


Fig. 200 CT-scan (left), MR-scan (right) with registration marker in 3D window.

Select the second marker by right click into on of the Registration tools image windows. Select the **Select Marker** option out of the context menu and select **Marker 2** from the sub menu. The active marker appears checked in the menu. Only the position of the active marker can be modified by the user. Now after the second marker is selected place the second marker to the corresponding landmarks in both data set. Redo this procedure for as many markers as you like. As a

minimum 4 markers have to be positioned into the two data sets to perform a registration. The resulting registration will be the better the more linear independent the three vectors formed by the markers are. Use the **Add Marker** option in the registration tools context menu to add an additional pair of markers. A pair of markers may be removed by selecting the pair to be removed as active marker and then using the **Remove Marker** option in the registration tools context menu. Once all markers have been placed the user may check the relative error of each pair of markers by pressing the **Check** button.

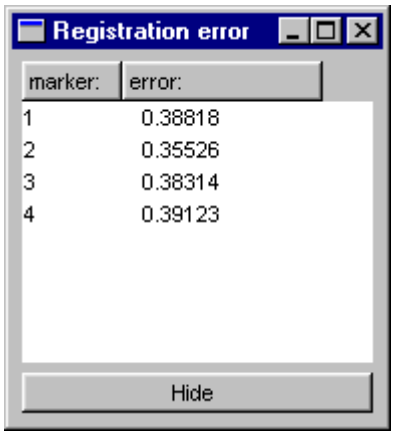


Fig. 201 The registration error window.

The Registration error window will appear with a list of each marker pairs error. The user may now optimize the position of individual markers to reduce the error. To update the Registration error windows content press the **Check** button again. Once an acceptable setting has been achieved, the object to be registered may then be "transformed" by pressing the **Apply** button.

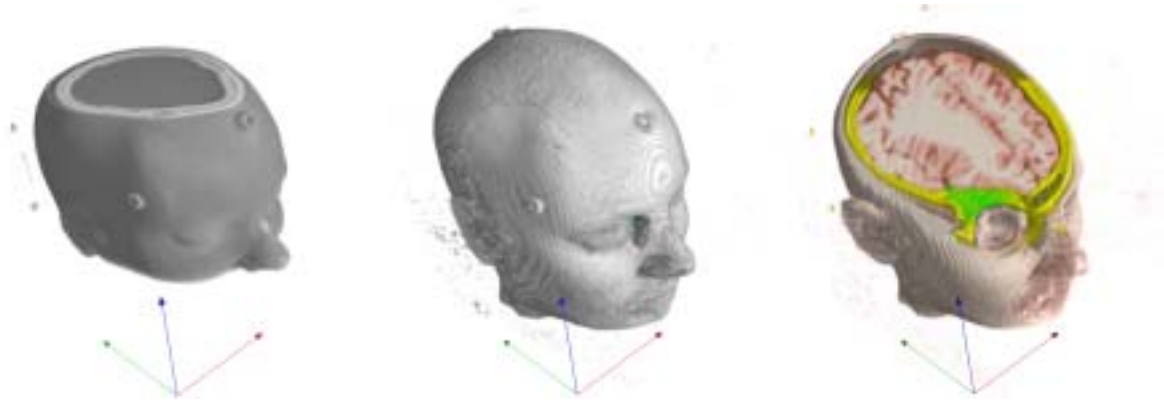


Fig. 202 CT-scan (left), MR-scan (middle) and result of registration and segmentation.

The objects will now appear registered in the 3D window. The objects may now e.g. be grouped by selecting both objects and using VGStudio MAX' Group feature. The objects may then be clipped like it can be seen in Fig. 202.

4.6.13 Polygonal Surface Extraction

VGStudio Max includes a powerful, easy to use tool to generate polygonal surface models from volumentric data sets. The polygonal models may be exported as STL file which can be used in many further processing steps and applications, e.g. in the construction of physical replicas through the use of rapid prototyping machinery or nominal/actual value comparison of the model with a CAD construction drawing.

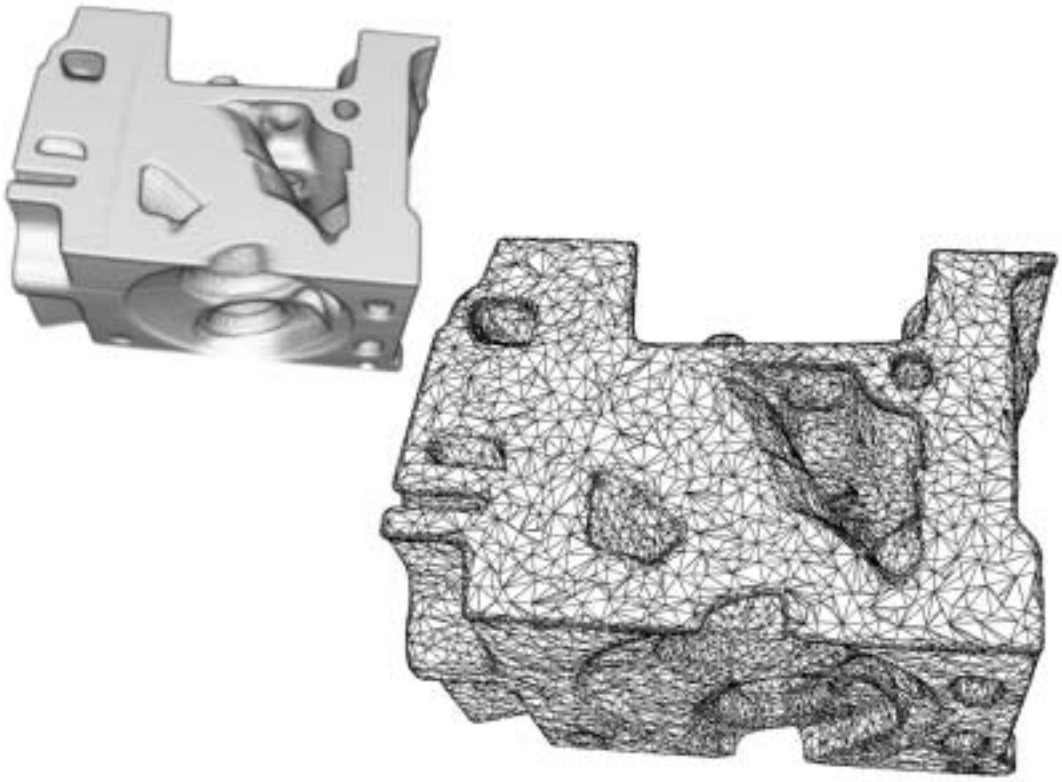


Fig. 203 Volumetric data set of a cylinder-head and an extracted polygonal model (STL file).

The Polygonal Surface Extraction tool provides two different interfaces: the **iso-gray-value surface extraction** and **the iso-opacity-value surface extraction** interface.

Iso-gray-value-surface extraction

The first interface is used to extract polygonal models of an **iso-gray-value-surface** The iso gray-value which defines the surface within a volumetric data set can be applied by the user or the **Auto detect** option can be used for a WYSIWYG style (What You See Is What You Get) determination of the iso-surface extraction gray value (see Fig. 205).

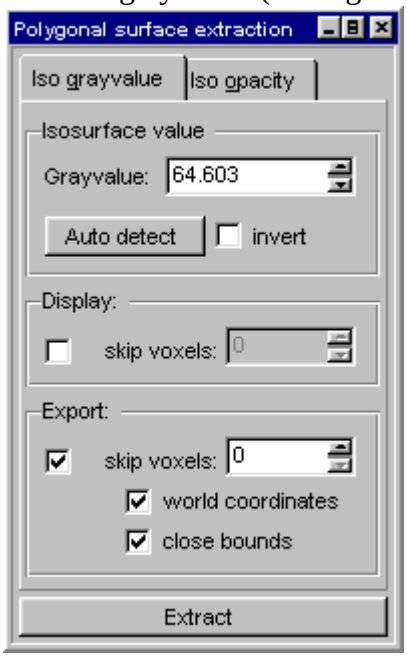


Fig. 204 The Iso-gray-value-surface extraction interface.

The Auto detect feature will compute a gray value for the surface extraction depending on the opacity lookup table setting applied in the Classification tool. The Auto detect gray value is computed as shown in Fig. 206.

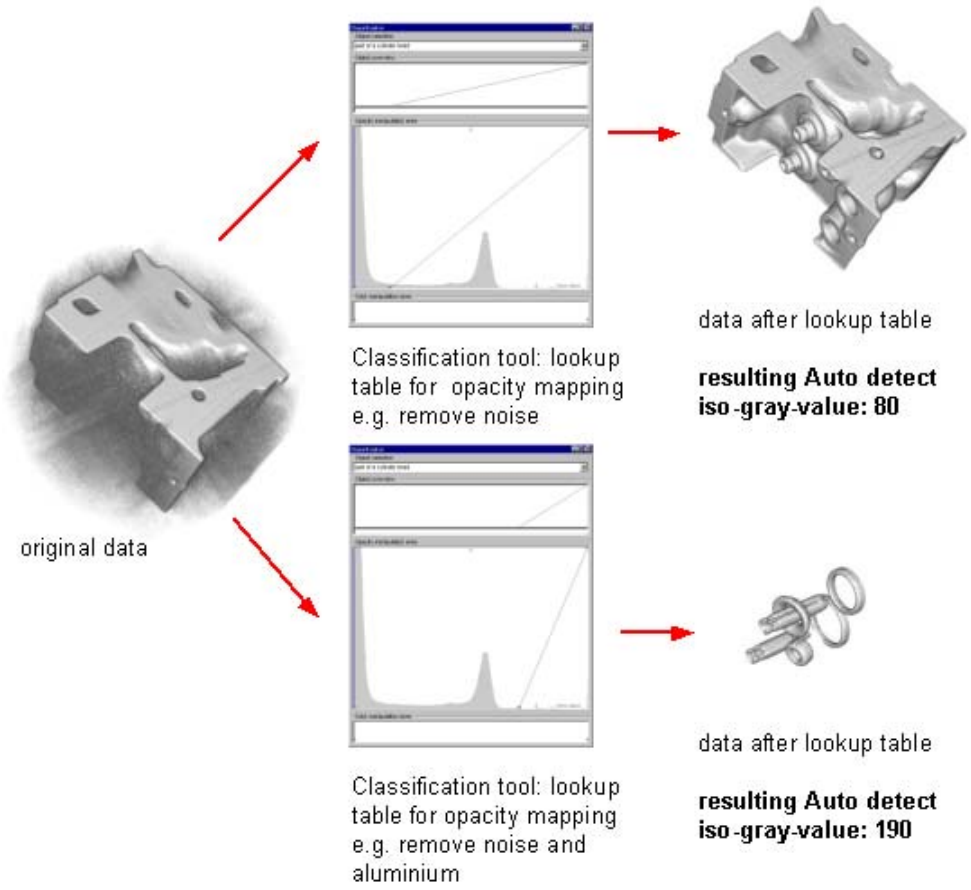


Fig. 205 Opacity lookup table setting and the resulting volumetric data of which the polygonal model is computed.

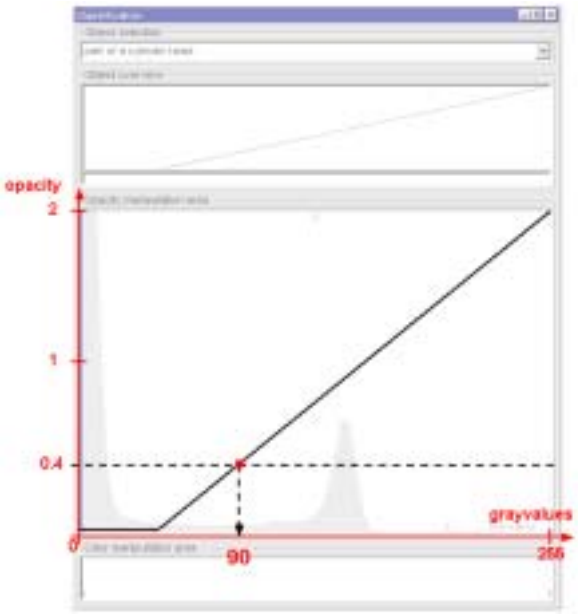


Fig. 206 Gray value Auto detect.

The gray value is taken at the position where the 0.4 opacity intersects the opacity function applied in the classification tool. The gray value determined by the Auto detect feature may be used as an initial extraction gray value which could be optimized manually. The quality and accuracy of the generated polygonal model depends strong on the extraction gray value.

Iso-opacity-value-surface extraction

The second interface is used to extract polygonal models of surfaces defined by an **iso-opacity-value.** The main difference between the iso-gray-value and the iso-opacity surface extraction functions is that the iso-opacity value takes the classification lookup table into account which maps each gray value to a defined opacity value before extracting an iso-opacity-surface. The gray value to opacity mapping is done within VGStudio MAX' Classification tool (see *Chapter 4.6.1 Classification Tool*).

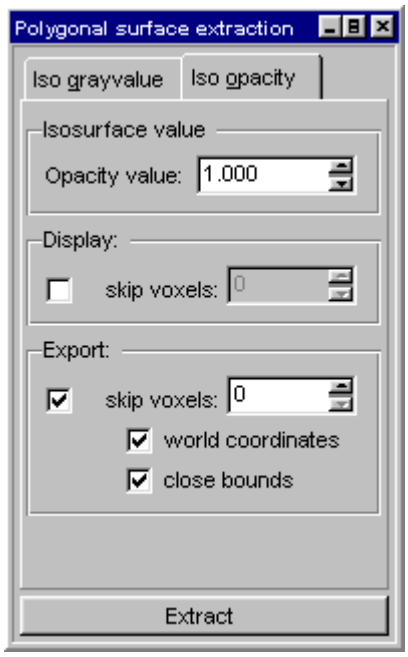


Fig. 207 The Polygonal Surface Extraction tool of VGStudio MAX, advanced mode.

While the extraction of an iso-gray-value surface is limited to extract a single surface defined by a single gray-value at a time the iso-opacity-value extraction process allows to extract a polygonal shell defined by several gray-values. An example is shown in Fig. 208. The user has applied a peaked opacity function in the classification tool and an extraction opacity value of 1.2.

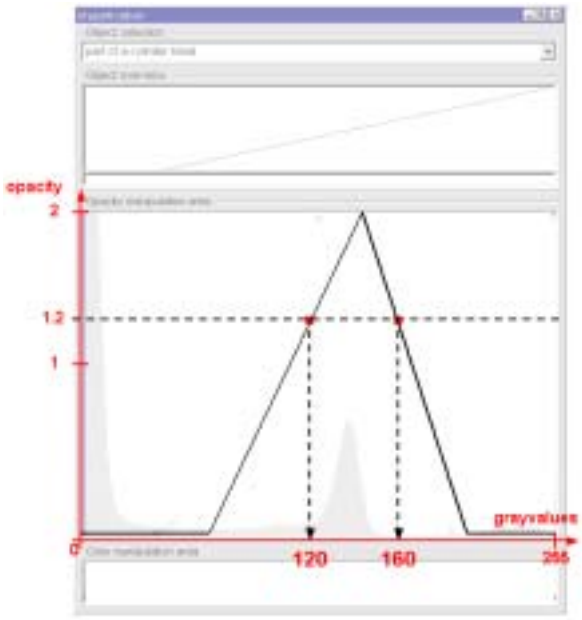


Fig. 208 Iso-opacity-extraction

Within this example the resulting extracted shell will consist of two iso-gray-value surfaces extracted at the gray-values 120 and 160. Depending on the applied opacity function the iso-opacity-value extraction allows to extract shells with and arbitrary number of iso-gray-value surfaces.

The Display and Export sections

Each of the two interfaces, the iso-grayvalue and the iso-opacity interface, allow to extract the polygonal model for display within the current VGStudio MAX scene and for export as an STL or OFF file. Activate the appropriate checkbox within the tools Display or Export section to extract the polygonal model for display and/or export.

Use the **skip voxels** parameter to adjust the number of voxels taken into account during the polygonal surface extraction process, A Skip voxels factor of 1 will skip every second voxel in x-, y- and z-direction so that the total number of voxels taken into account will be only 1/8 of the origional data set. The full data set will be taken into account if this factor is set to 0, this will also lead to maximum accuracy of the extracted model. The number of polygons generated by the polygonal extraction process will become less by using larger Skip voxels factors. However the accuracy will decrease at the same time. The Skip voxels parameter may be adjusted for display and export purposes separately.

A polygonal model extracted from an object which is bordered by the bounding box of the volumetric data set can be extracted in two ways. The model can be extracted in a way that the model will be closed at the borders of the data set or the model can be left open since the surface at the border can be seen as an artificial surface.

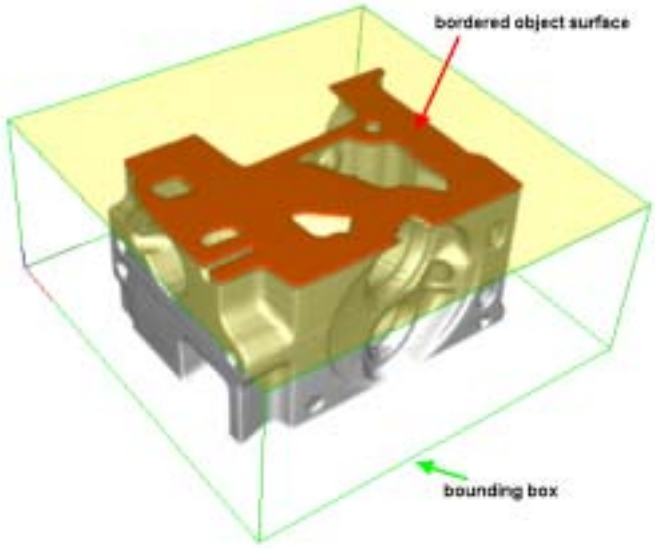


Fig. 209 Extract polygonal model with closed bounds deactivated(left) activated (right)

Activate the **close bounds** checkbox to close the polygonal model at the data set boundaries.

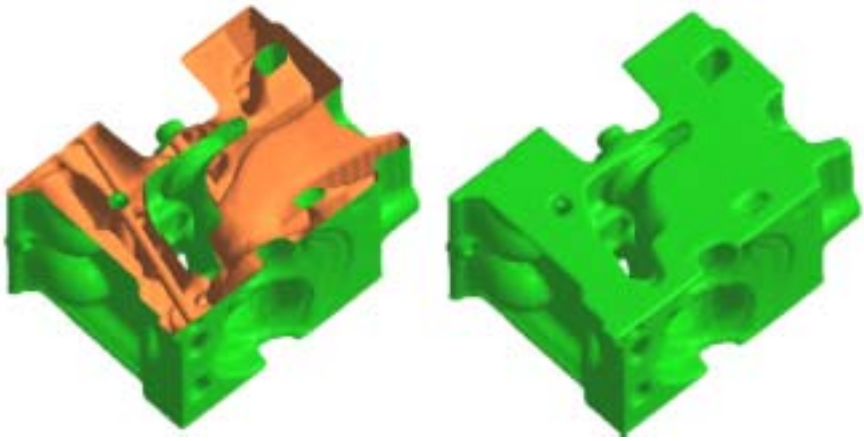


Fig. 210 Extract polygonal model with closed bounds deactivated(left) activated (right)

To finally extract a polygonal model press the **Extract** button. A popup will appear which will appear which includes information about the number of triangles extracted and the surface area of the extracted shell. This feature can be used to measure the surface area of any object. Press **Ok** to export the polygonal model or press **Cancel** to abort the process. If **Ok** was pressed a file dialog will popup where you have to key in a file name where you can select a file type.

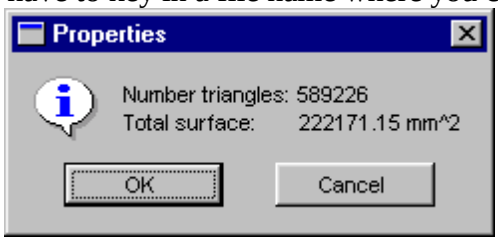


Fig. 211 Polygonal model extract popup.

Accuracy of the polygonal surface extraction

VGStudio MAX's extraction tool computes an iso-gray-value-surface out of the volumetric data set. The achieved accuracy mainly depends on the spatial resolution of the volumetric data set under investigation, e.g. you will achieve a resolution in the order of 0.2 mm within a data set with a spatial voxel resolution of 0.2 mm.

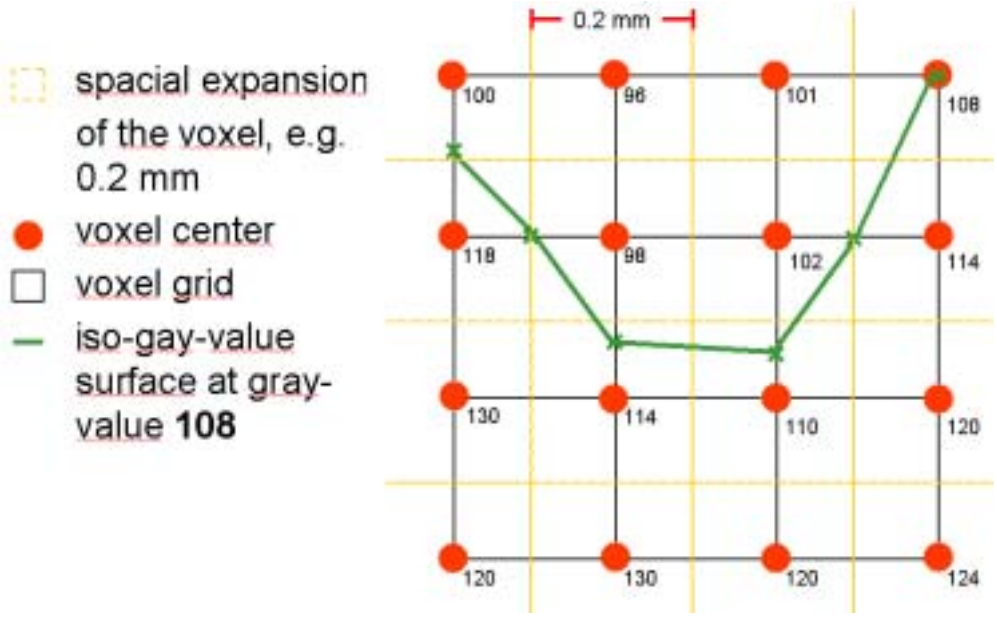


Fig. 212 Iso-gray-value-surface extraction example in 2D. Vertices will be tri-linear interpolated in 3D-space.

The vertex positions will be calculated by a tri-linear interpolation of the surrounding voxels gray values. By this the vertices of the resulting polygonal model are computed at sub-voxel accuracy. Please refer to Fig. 212 which shows an simplified 2D example of the extraction of an iso-surface at gray value 108. However even if the vertex position is calculated on sub-voxel accuracy the magnitude of the achieved accuracy will mainly depend on the spatial resolution of the volumetric data set.

4.6.14 Keyframer

VGStudio MAX 1.0 includes a powerful tool - the Keyframer - to render fascinating animations, e.g. flying around or even through your data. The concept of the Keyframer is to define an arbitrary path for the camera "flying" through the scene. The path - the camera trajectory - is defined by an arbitrary number of points of support - the Keyframes - within the scene. The path in between these points is defined by curves, so called bezier splines, which may be adjusted by the user. After the setup of the camera trajectory the Keyframer will render a user defined number of images while the camera moves down the camera trajectory. The render quality and the rendered image size can be adjusted in the **Renderer properties** tool (*Chapter 4.6.3 Renderer Properties*) and the **Light properties** tool (*Chapter 4.6.4* Light Properties).

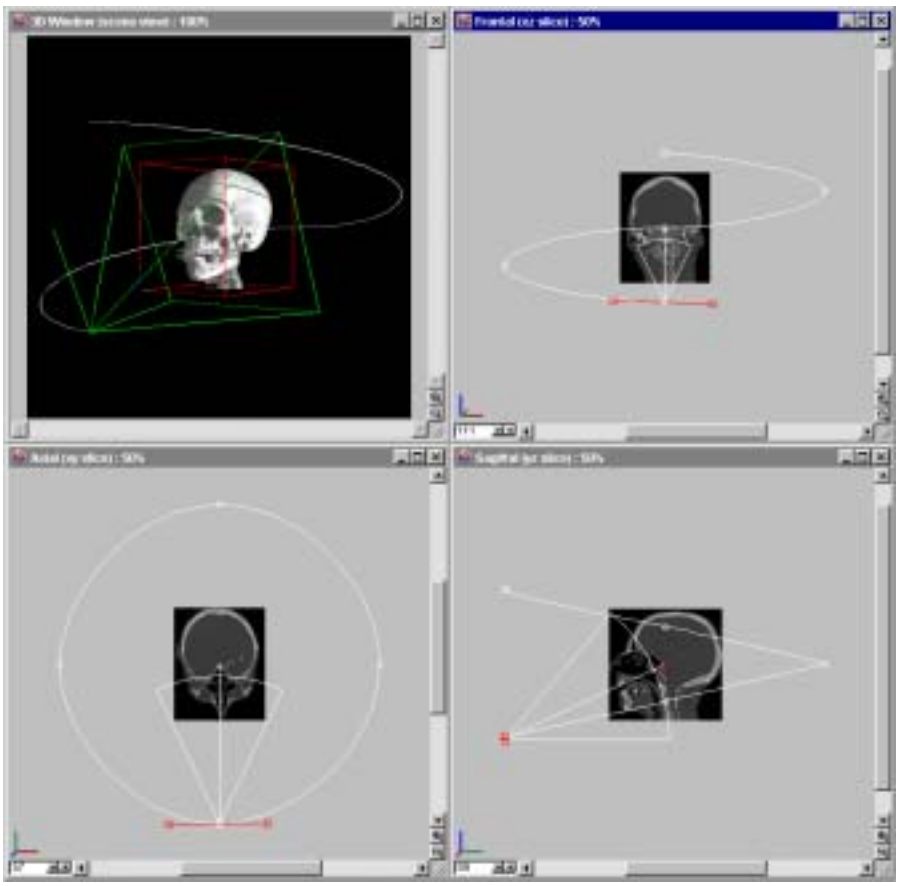


Fig. 213 A scene with activated Keyframer rendered in World View mode. The example shows a spiral shaped camera trajectory around a CT scan of a human head.

The Keyframer is activated/deactivated by the **Keyframer Icon** in the VGStudio MAX Icon Bar.

The camera symbol with view frustum and a circle shaped camera trajectory will appear within the slice windows after activating the Keyframer for the first time within a scene. The circle is placed within the xy-slice. The Camera and Camera tool is deeply connected to the Keyframer.

For details about the handling of the camera and its symbol within a slice window please refer to *Chapter 4.5.3 World and Camera View.*

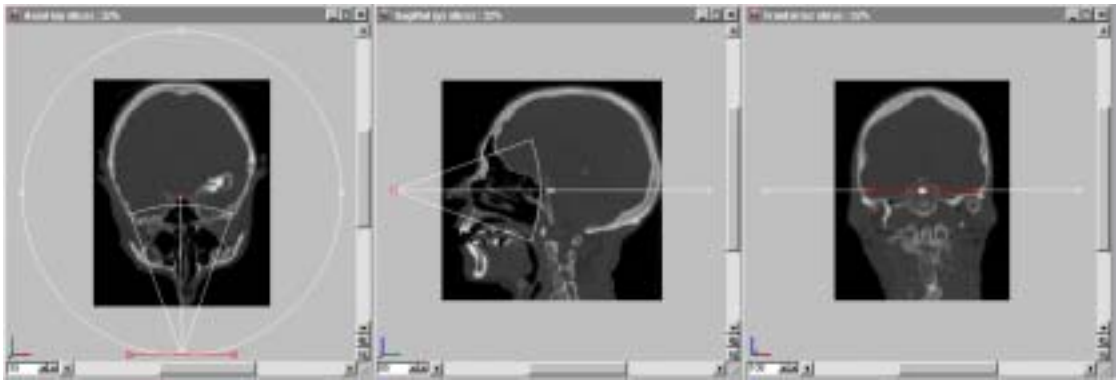


Fig. 214 Slice windows with activated Keyframer and default xy-circle camera trajectory.

The camera trajectory consists of several Keyframe handles. The position of a Keyframe handle can be adjusted by the user. By doing this the user may adapt the whole camera trajectory. Grab a Keyframe handles by clicking it with the left mouse key and dragging it around while the left mouse button is pressed. The handle may be moved anywhere within 3D space even outside the data set by using all three orthogonal slice windows. Zoom the Slice Windows so that you can place the Keyframe handle to the desired position.

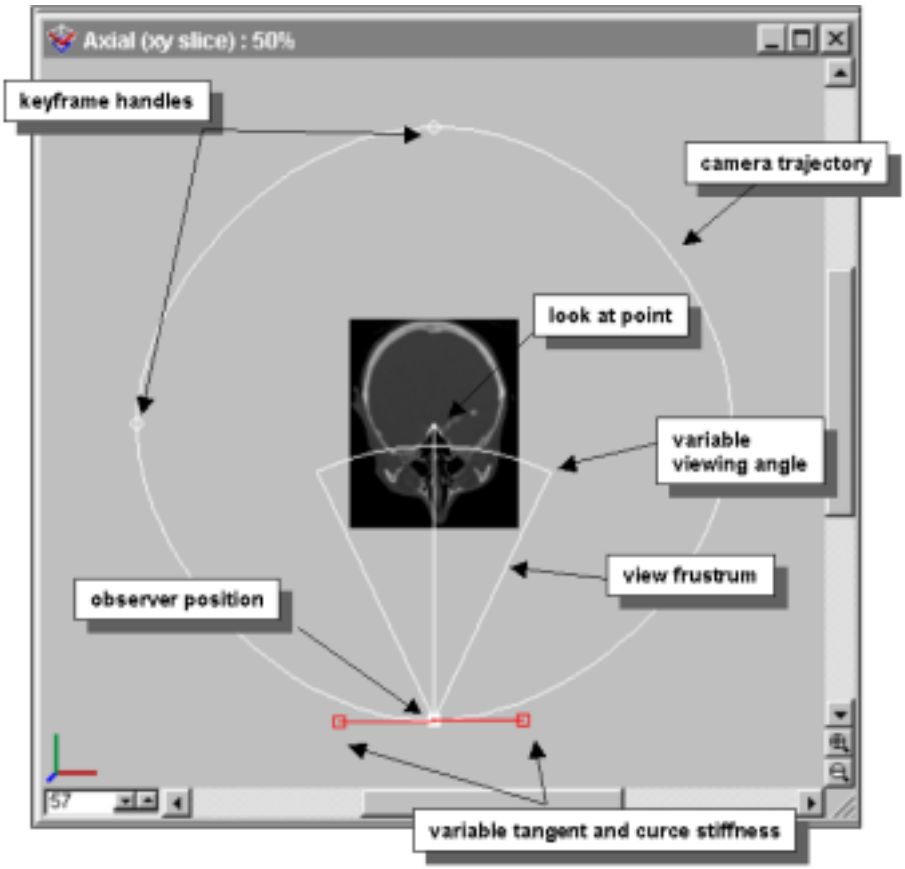


Fig. 215 Elements of a camera trajectory displayed in the slice windows.

Setting up a camera trajectory

As default trajectory a circle within the xy-slice will appear when the keyframer is activated for the first time (see *Fig. 214*). This trajectory allows a simple flight around the object so that is rotates in front of the “users eye”.

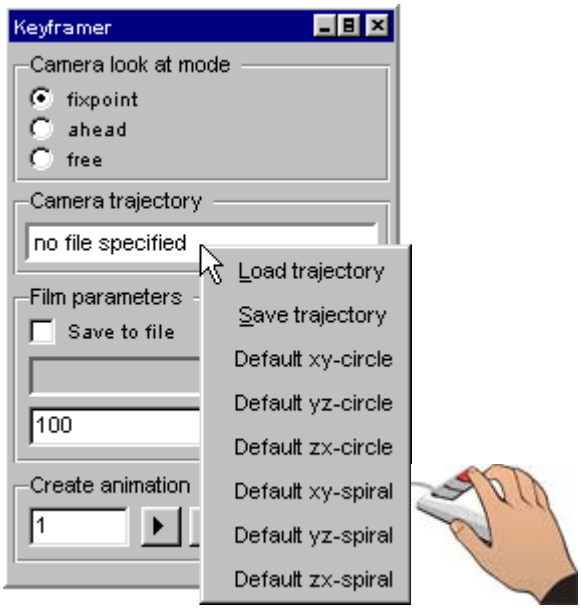


Fig. 216 The Keyframer tool with thedefault trajectory selection.

VGStudio MAX’ provides a set of predefined trajectories. The user may access these trajectories by **right click** the **Camera trajectory** section within the Keyframer tool . A context menu will pop up as shown in *Fig. 216*.

- **Load trajectory –** This option allows the user to load a camera trajectory from a trajectory file (trj file extension).
- **Save trajectory –** This option allows the user to save the current camera trajectory to a separate file (trj file extension).
- **Default xy-/yz-/xz-circle –** These options allow to apply a circle shaped camera trajectory within the xy-, yz- or xz slice orientation .
- **Default xy-/yz-/xz -spiral –** These options allow to apply a spiral shaped camera trajectory within the xy-, yz- or xz slice orientation.

The default camera trajectories may be used to render standard animation sequences very easily. However the default trajectories can be used as a starting point to setup user defined trajectories. VGStudio MAX provides a set of features to generate most complex trajectories and therefore high quality animation sequences. The user may:

- modify the position of each keyframe handle and therefore the position of the camera
- modify the tangent and curve stiffness at each keyframe handle

- add/remove keyframe handle
- modify the look at point at each keyframe handle (in free mode only)
- modify the viewing angle and up vector of the camera at each keyframe handle.

All camera parameters will be interpolated in between two keyframe handles so that a smooth movement of the camera or zooming effects are possible.

To modify a camera trajectory simply grab a keyframe handle and place it to the desired position within the slice image windows. Use the orthogonal slice images to position the keyframe handles in 3D.

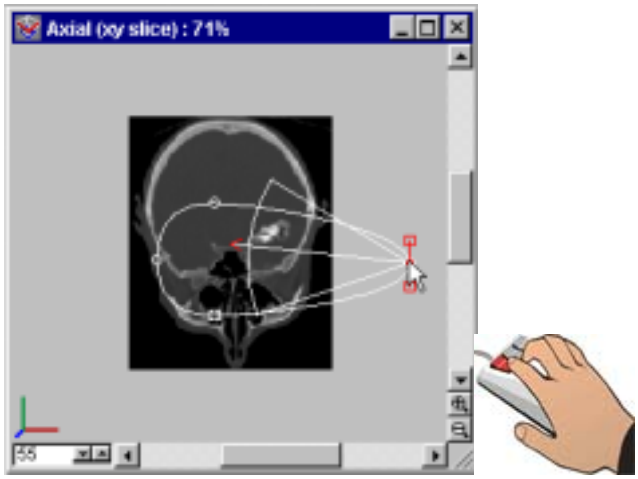


Fig. 217 Move a Keyframer handle.

The camera will jump at the position of the keyframe handle grabbed by the user. The 3D image will be rendered according the actual camera position when VGStudio MAX is set to camera mode (please refer to *Chapter 4.5.3 World and Camera View)* each time the user modifies any relevant parameters. The user may switch between Camera and World View while adjusting the camera trajectory to get an optimal overview. The red colored tangent and stiffness handle of the camera trajectory will be shown at the current selected keyframe handle. Grab one of the two squared red handles with a left click and move the handle while the left mouse button is pressed. The resulting camera trajectory can be seen immediately in the three Slice Windows.

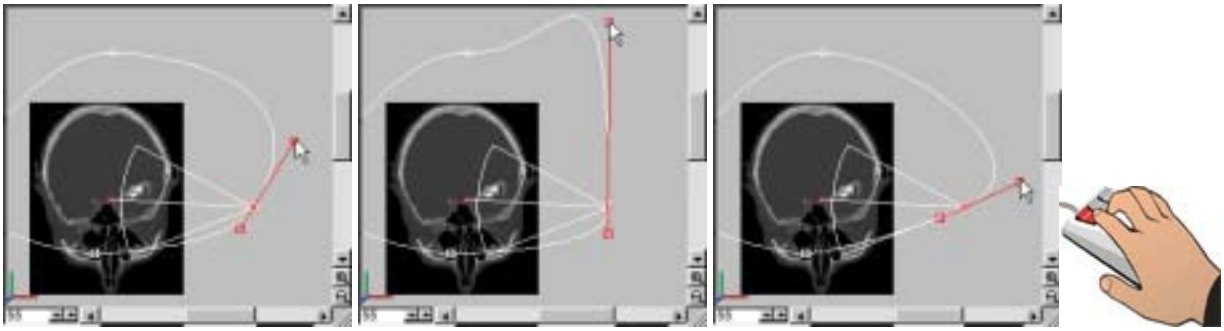


Fig. 218 Modifying the camera trajectory byits tangent and stiffness handles.

The camera trajectory may be modified by the stiffness handles also in 3D space by using the handles in the three Slice windows. Each of the two stiffness handles on each side of the Keyframe handle may be adjusted independent from the opposite one. The user may modify the stiffness of the camera trajectory symmetrically by keeping the **Shift key pressed** while moving one stiffness handle.

The user may add or remove additional keyframe handles by using the middle mouse button. A new keyframe handle will be placed in between two existing handles when the middle mouse button is pressed with the mouse cursor above the trajectory. A new keyframe handle will be added at the position clicked and connected to the next end (beginning or end) of the keyframer trajectory if the middle mouse button is pressed anywhere in the slice windows. Remove a keyframer handle by middle click on the keyframe handle.

For some reasons it might be important not to move a keyframe handle while grabbing it by a left mouse klick, e.g. not to modify a camera trajectory since it is used to render the same sequence in several passes with different settings. Use the **Shift key** to avoid moving the Keyframe handle when grabbing it. The Keyframe handles position can not be modified by left clicking it as long as the **Shift key** is pressed.

The Keyframer tool

The Keyframer tool includes the **Camera look at mode** section, the **Camera trajectory** section, the **Film parameter** section and the **Create animation** section. The tool may be activated/deactivated with the **Keyframer** option in the **Tools** menu. The Keyframer tools sections will be disabled as long as the Keyframer hasn't been activated with the Keyframer icon in the Icon Bar.

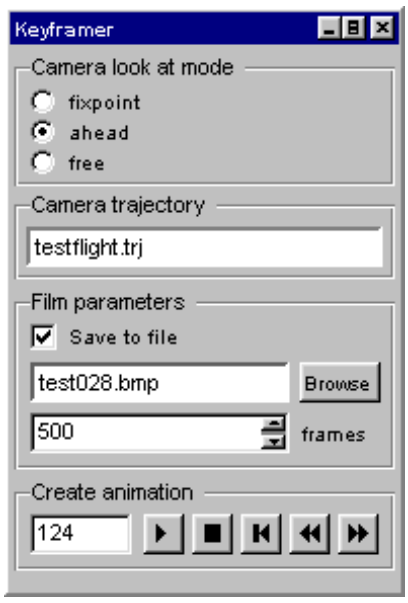


Fig. 219 The Keyframer tool of VGStudio MAX.

The VGStudio MAX Keyframer includes three **Camera look at modes**:

Fixpoint Mode —Select this mode if the camera should look at the same position while moving along the whole camera trajectory, e.g. while flying around an object. Adjust the look at point within the slice windows or the camera tool for one keyframe. The look at point will then be adjusted for all keyframes.

Ahead Mode —Select this mode if the camera should look ahead tangential to the camera trajectory while moving along the trajectory, e.g. while flying through an object. It is not possible to adjust the look at point manually in the slice windows or within the camera tool when using the keyframer in Ahead mode.

Free Mode —Select this mode if you want to define the viewing direction in each keyframe. The viewing direction will be interpolated between two keyframes. Use the camera symbol in the slice window or the camera tool to adjust the camera look at point in each keyframe.

The **Camera trajectory** section displays the filename of the camera trajectory in case that the trajectory is saved to a separate file. Use the Save/Load camera trajectory option in the File menu to save the current camera trajectory or to load an existing camera trajectory. You may also load a camera trajectory from an existing vgi file by choosing the vgi file type in the Load camera trajectory file dialog. Press the right mouse button within the Camera trajectory section to bring up the context menu. The context menu include the Load/Save Camera trajectory option as well as 6 default trajectories. There are 3 circular trajectories, for each plane one and 3 spiral trajectories, which lie perpendicular to the main planes, too. Each default trajectory will be adjusted to the current scene in that way, that nearly the whole scene will be visible from any point of the trajectory. In each of the trajectories, the cameras will look at the center of the scene.

The Film parameters section is used to define how many frames should be rendered on the cameras path. The applied number of frames will be spread equidistant over the total camera path. The default number of frames is 100. Activate the **Save to file** checkbox and apply a file prefix to save each frame of your animation to the hard disc. Press the Browse button to bring up a file selection box. Select the directory where all file should be saved and enter a file prefix and a file type (BMP, TIF, JPG, PPM), e.g. enter the prefix “movie” and select BMP as file type. The rendered frames will then be saved as movie001.bmp to movie100.bmp.

The **Create animation** section displays the frame where the camera is actually located. You may enter a frame number to move the camera to the specified frame. The Create animation section also includes a recorder style interface to steer the animation rendering. Press the **Play** button  to render the animation. The animation will be rendered in preview quality as long as the **Save to file** option is not activated and the **Motion smoothing** option is activated in the **Renderer properties** tool (*Chapter 4.6.3 Renderer Properties*). The animation will be rendered in high quality when the Save to file option is activated. The Play button will then appear in the record shape  . The render quality and the rendered image size can be adjusted in the **Renderer properties** tool. Press the Rewind button  to jump to frame number 1. Use the Forward and back buttons to step through the animation frame by frame.

Saving Keyframer settings

All Keyframer settings will be saved together with the scene when using the **Save** or **Save as** option in the **File** menu. The resulting vgi file includes the whole camera trajectory and camera informations. A camera trajectory itself can be saved by the **Save camera trajectory** (file exten-

sion: trj) option in the file menu. You can load a camera trajectory from a trj file or even a trajectory saved with a whole scene in a vgi file with the **Load camera trajectory** option in the File menu.

Reminder: The Keyframer settings will also not be lost when deactivating the Keyframer by pressing the Keyframer Icon. You may switch the Keyframer off and on again at any time to continue your work.

4.7 Status Bar

The status bar is displayed at the bottom of the main window.

In the first field of the status bar you will find information about the measurement tools and the segmentation process. If the 3D instrument is activated, its position is displayed in voxel coordinates of the current object (in peaked brackets) and in object coordinates in scene units. The gray value at the 3D cursor's position is also displayed. If the distance tool is active, the current distance will be displayed in scene units. If the angle tool is active, the angle in degree will be displayed. And finally if segmentation is activated, the segmented area will be displayed instead.

The second section of the status bar displays the current scene unit, e.g. µm, mm, cm, m. All numerical coordinates and measurement information displayed in VGStudio MAX refers to the unit setting displayed in the status bar. If no unit was applied to any data set during the import process or within the Object properties tool "units" will be displayed in the status bar. All numerical coordinates and measurement information displayed will be counted in voxel units. Double click on the unit area in the status bar to open the Preferences dialog (*Chapter 4.3.3 Setting Preferences)* where you can change the scene unit settings.

The third section shows the current drawing colors, where the color of the hidden rectangle is the background color and the fully visible rectangle shows the current foreground color. When no object is activated, the field will be empty. For more information about drawing, see *Chapter 4.4.3 3D Instrument*. Double click on the drawing color area will open the **Grid, Axes & Instrument properties** dialog (see *Chapter 4.3.5 Scene Menu*), with instrument properties active, here you can change the drawing color, brush size and brush mode.

The fourth section of the status bar includes information about the current process performed in VGStudio MAX and the progress of the different processes.

5 Importing & Exporting Data

This chapter provides information on the data I/O capabilities of VGStudio MAX. Detailed information on

- importing data and
- exporting data

will be given in this chapter.

5.1 Importing Data

5.1.1 The VGI - Volume Graphics Info - file concept

VGStudio MAX allows its users to import a wide variety of different data files and data types. The voxel or volume data my be provided as a single data file or as a stack of several image data files.

Stack of Image Slices	
BMP	color and grayscale
TIFF	color and grayscale (8 bit only for grayscale)
JPEG	color and grayscale
PPM	color and grayscale
DICOM	See Appendix
HDF	See Appendix
RAW	signed/unsigned 8 bit integer
RAW	signed/unsigned 16 bit integer
RAW	signed/unsigned 32 bit integer (20 bit effective range)
RAW	32 bit float
RAW	32 bit RGBA
Volumes	
DICOM	
HDF	
Analyze™	
RAW	signed/unsigned 8 bit integer
RAW	signed/unsigned 16 bit integer
RAW	signed/unsigned 32 bit integer (20 bit effective range)
RAW	32 bit float
RAW	32 bit RGBA

Select the **Import** option in the **File** menu and choose the appropriate option to import the different data types and files.

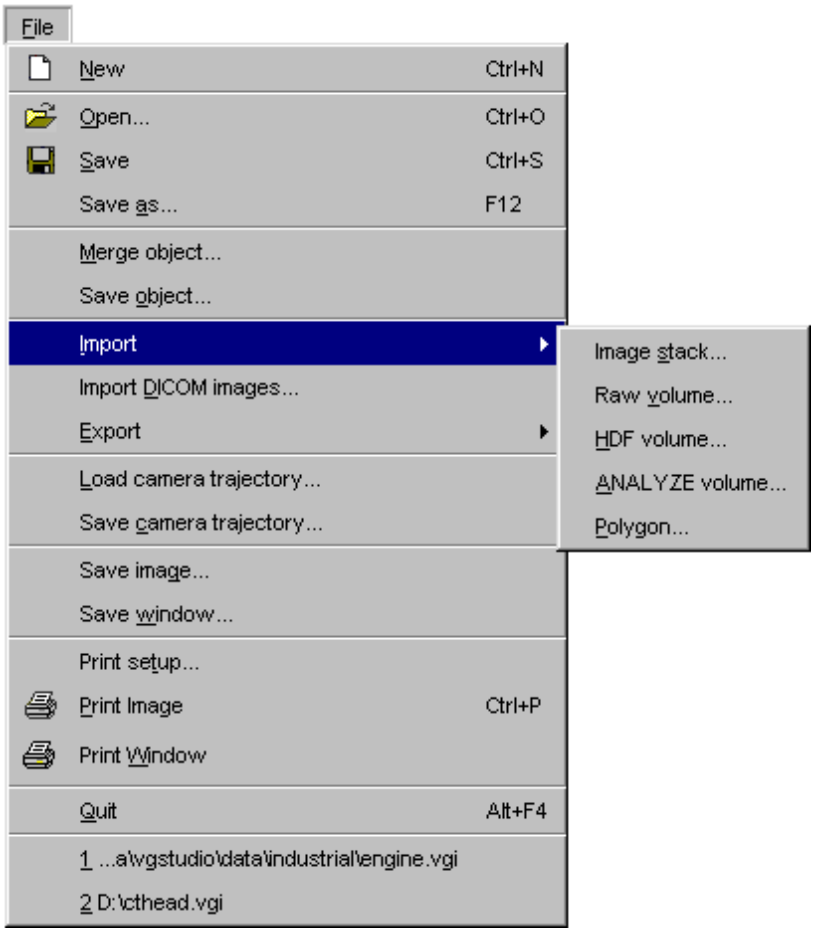


Fig. 220 Select Import in the File menu and choose the appropriate option to import the different data types.

After having imported the data, you may save your scene. Saving a scene with the S**ave** or S**ave as** option in the **File** menu will generate a Volume Graphics Info file (.vgi extension). The vgi file contains all information needed by VGStudio MAX 1.0 to load data again by using the **Open** command in the **File** menu. You do not have to use the import procedure again. The vgi file contains data-relevant information such as data file names and the path to the data files, data type, file type, file size, and data mapping as well as scene-relevant information such as light settings, rendering algorithm, or background color.

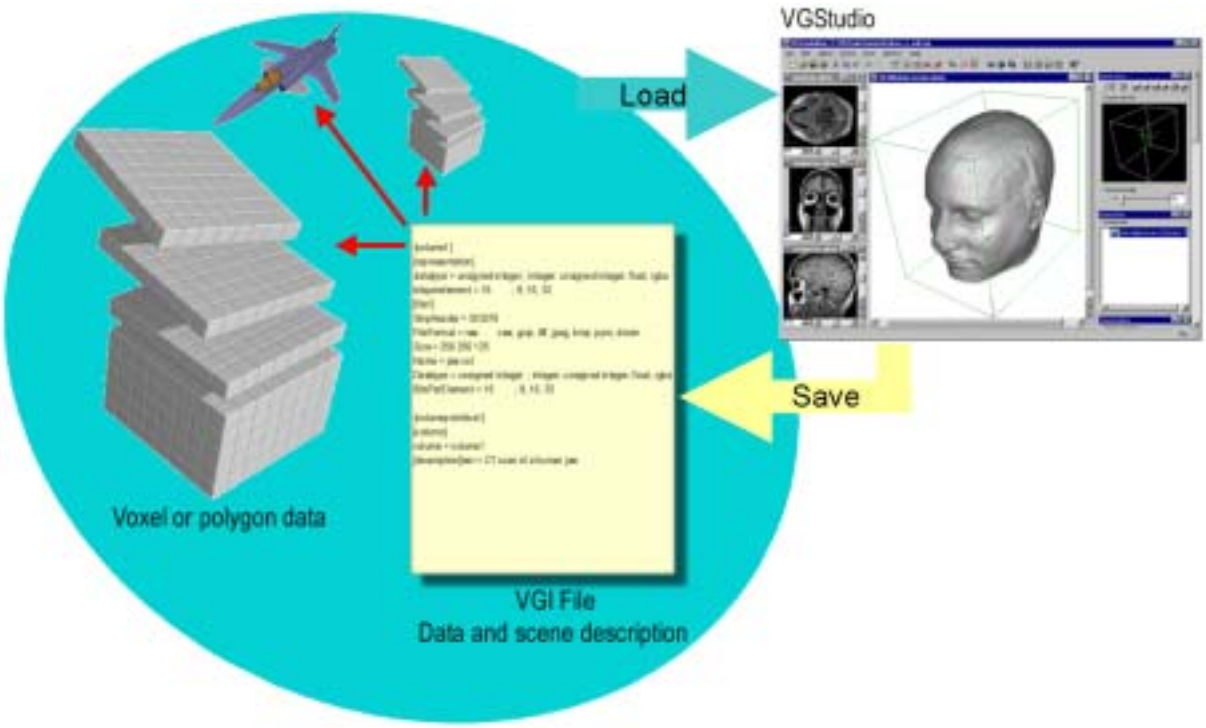


Fig. 221 Import data into VGStudio MAX and then save the scene by using the save or save as command in the File menu to generate a vgi file.

Data saved in VGStudio MAX always consists of two elements, i.e. the data file(s) and the Volume Graphics Info file. A vgi file contains references to all data included in the scene so that a complex scenario can be restored by loading a single vgi file. The concept of VGStudio MAX's data handling is to leave the original data untouched. All information on how data has to be processed during the import will be saved in a vgi file.

Example:

A voxel data set includes 32 bit floating point data but the dynamics of the data is very low so that it will fit into a 8 bit integer (256 gray value) representation. During the import procedure, the user may specify that data should be converted into a 8 bit data representation. This will reduce the amount of RAM needed on your PC or workstation by a factor of 4! This conversion will be done automatically while loading the data into VGStudio MAX. The original data set on your hard disk will remain untouched and no second 8 bit data set, which would increase your disk capacity requirements, has to be generated. However, VGStudio MAX allows its users to export the data in the internal data representation chosen by the user (see *Chapter 5.2 Exporting Data*).

If you save your current work to a vgi file all the conversion information will be saved along with all the other scene-specific data. The next time the vgi file is loaded, the conversion will be carried out automatically.

5.1.2 Importing Stacks of Image Slices

To import a stack of images, click **File** in the menu bar and select **Import**. Then click **Image Slices** in the **Import** menu to open the **Image Slices Import Wizard**.

The **Image Slices Import Wizard** will guide you through the whole import process step by step. Click the **Next** or **Previous** buttons to go through the different steps of the import process. The different steps will be explained in the following:

Step 1: File type selection

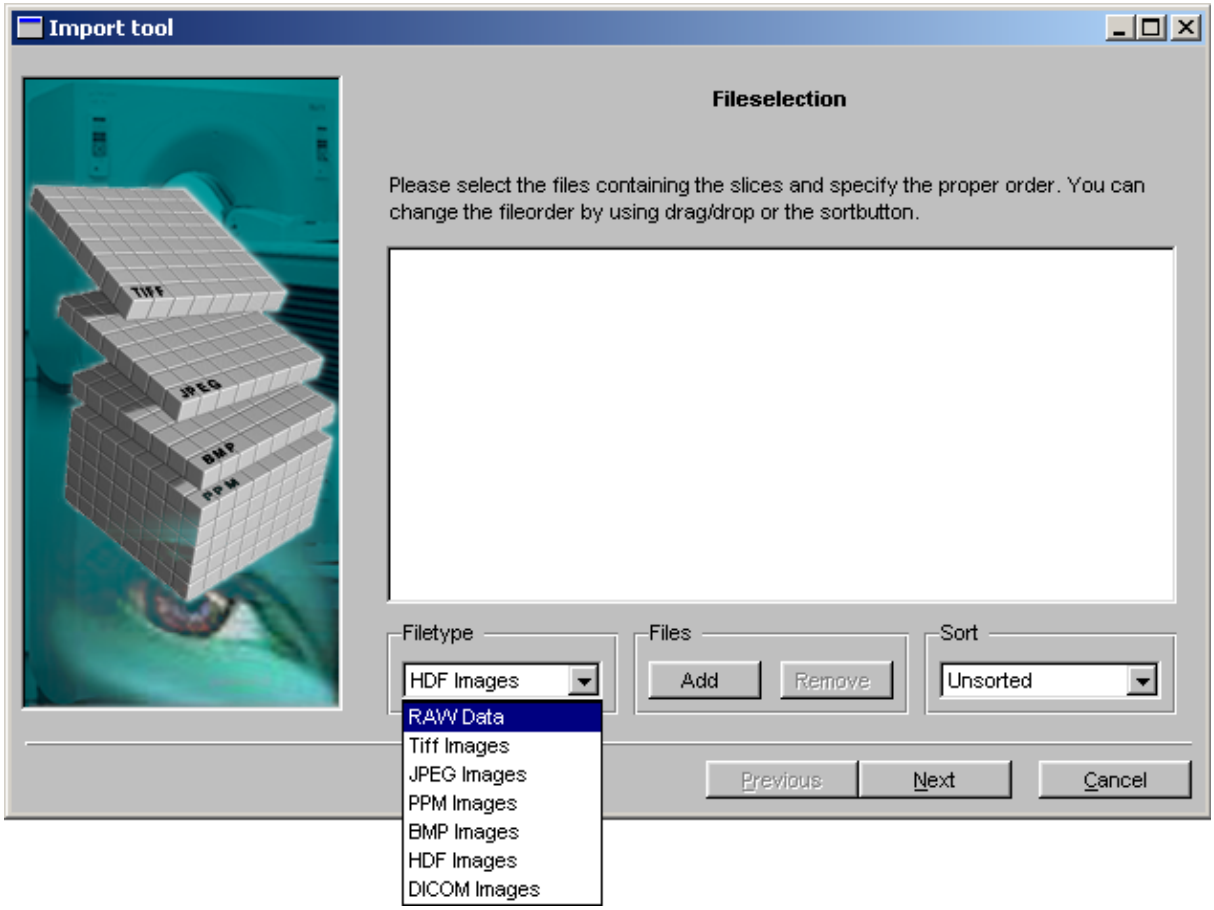


Fig. 222 Select the file type in the Import tool window.

Select the **File type** from the File type list. You may choose between RAW data, TIFF, JPEG, PPM, BMP, HDF and DICOM images.

Step 2: File selection

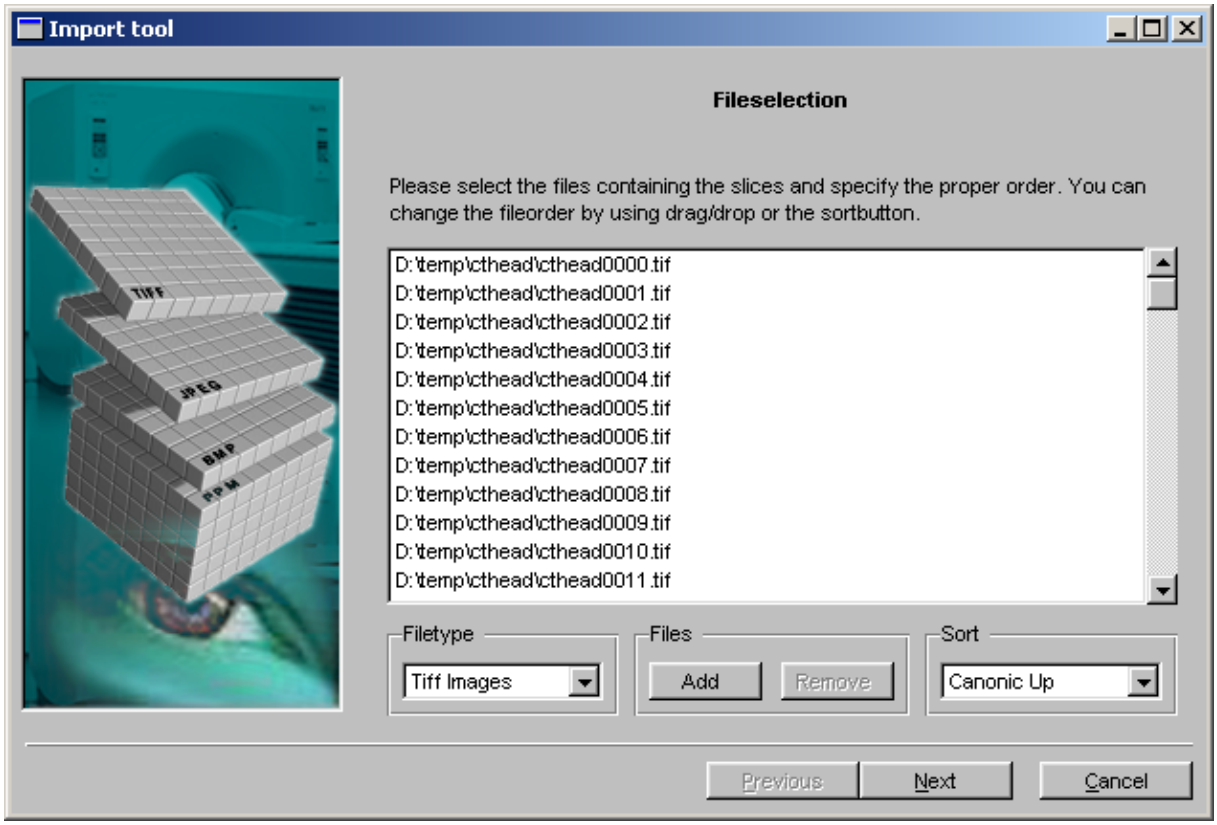


Fig. 223 Select the files you want to import and add them to the list.

Click **Add** to open a file selection dialog. Select one or several files and click **Open**. The list with the selected files will then be displayed in the **Import tool** window. To add more files to the list click again **Add** and repeat the procedure.

To remove files from the list select one or several files and click **Remove**. You may also drag the selected files on the remove button to delete them from the list. The files will only be removed from the list and will not be deleted from the hard disk or other data source.

Step 3: File order

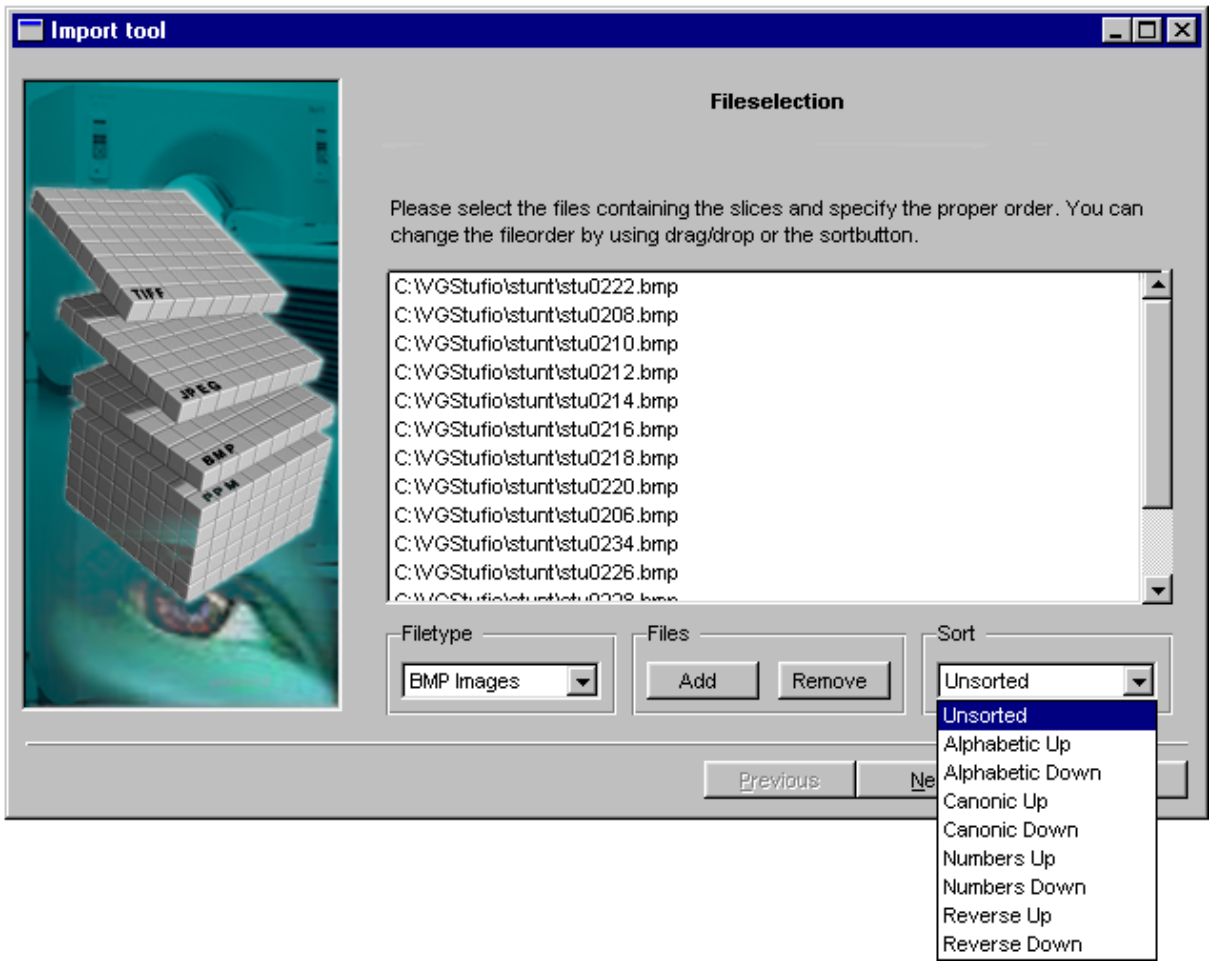


Fig. 224 Sort the files by using the Sort function of the Import tool window.

To sort the files, you may use the **Sort** function of the **Import tool** window; there, you may choose the order in which you wish to sort the files, e.g. alphabetical order. You may also use drag and drop to bring the files into the correct order.

Click **Next** to continue with the import process.

Step 4: Data type selection (for RAW data only)

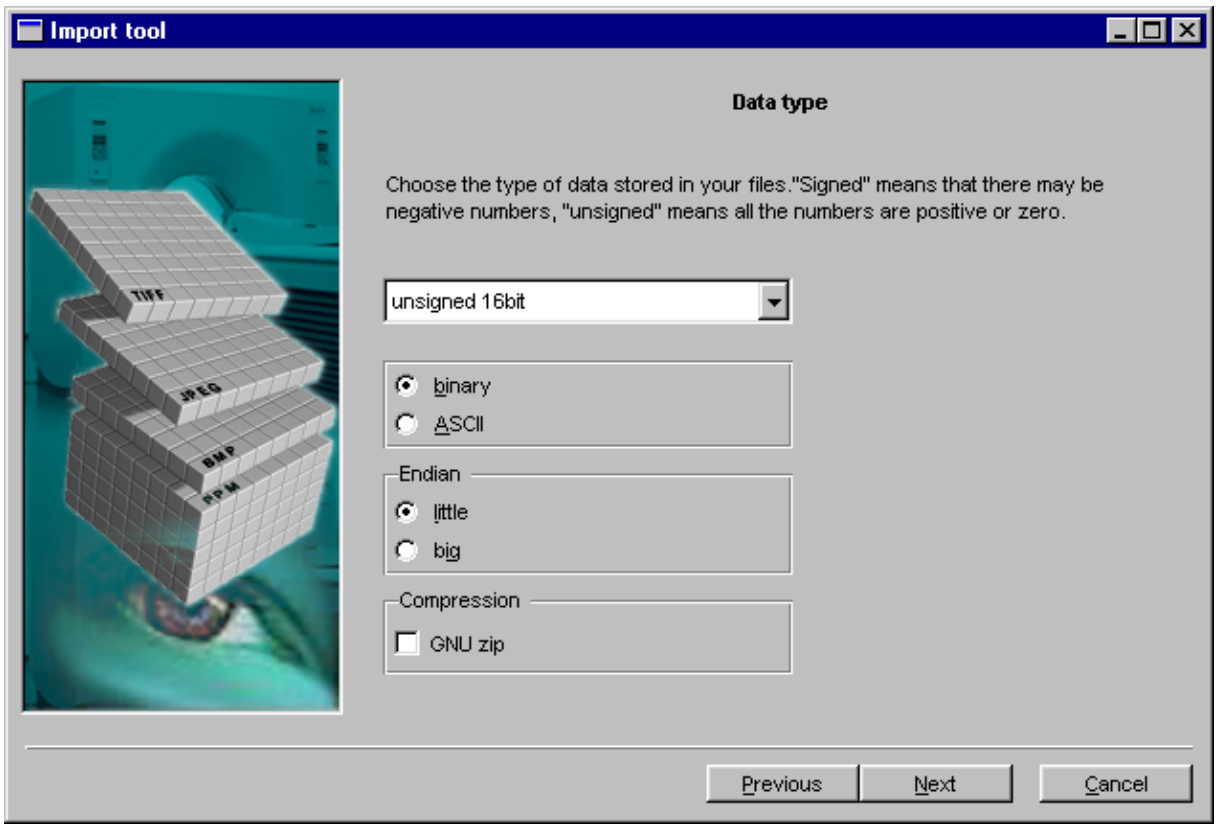


Fig. 225 Specify the data type for RAW images.

The data type has to be specified if the file type RAW was selected. Select the data type of the chosen file from the pulldown menu. Possible data types are:

- signed or unsigned 8bit, 16bit, or 32bit
- 32bit float
- 32bit RGBA

Decide whether the data is to be stored in binary or in ASCII format and select the byte order.

VGStudio MAX is capable to import GNU zip compressed data files. Mark the GNU zip check-box to import compressed data.

Reminder: Compression will not work in conjunction with ASCII data.

Step 5: Data type selection (for TIFF, JPEG, BMP, and PPM images only)

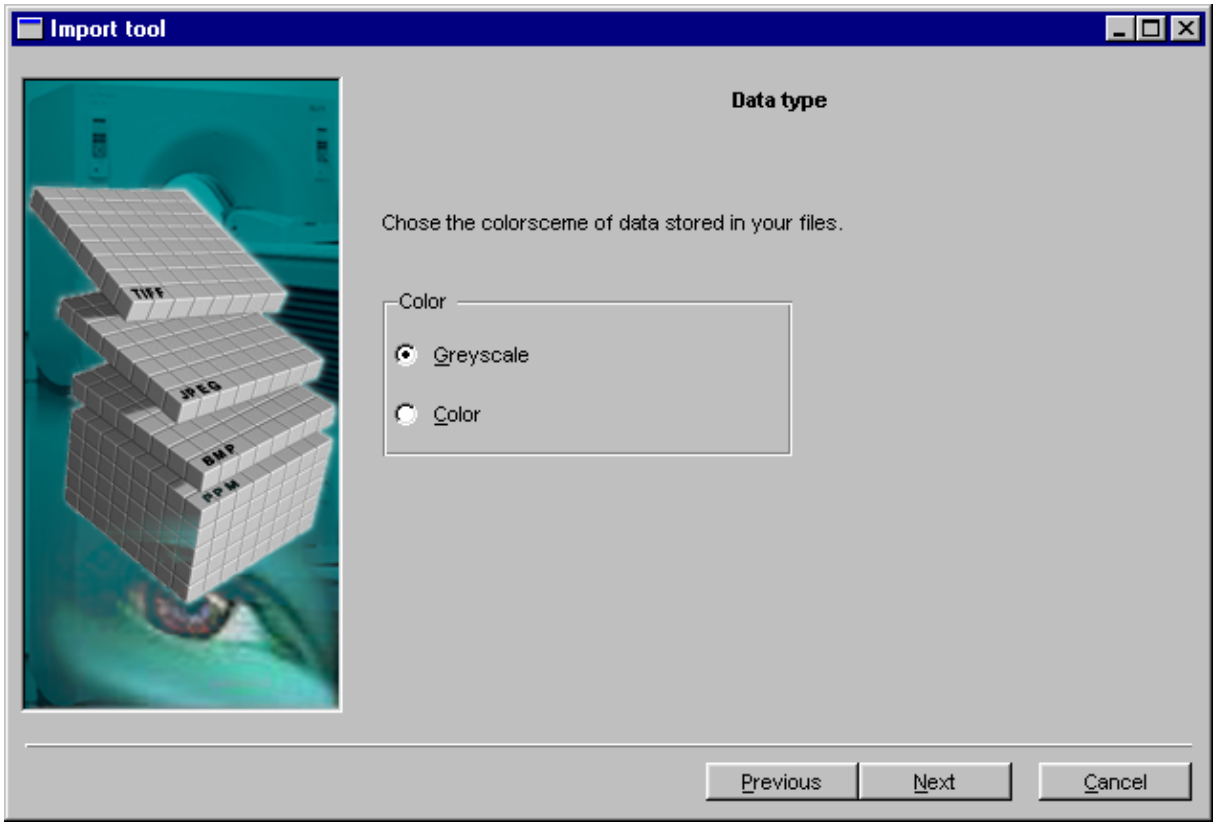


Fig. 226 Select the data type for TIFF, JPEG, BMP, and PPM images.

Image slices may be imported as grayscale or color data.

Step 6: Image size selection (for RAW data only)

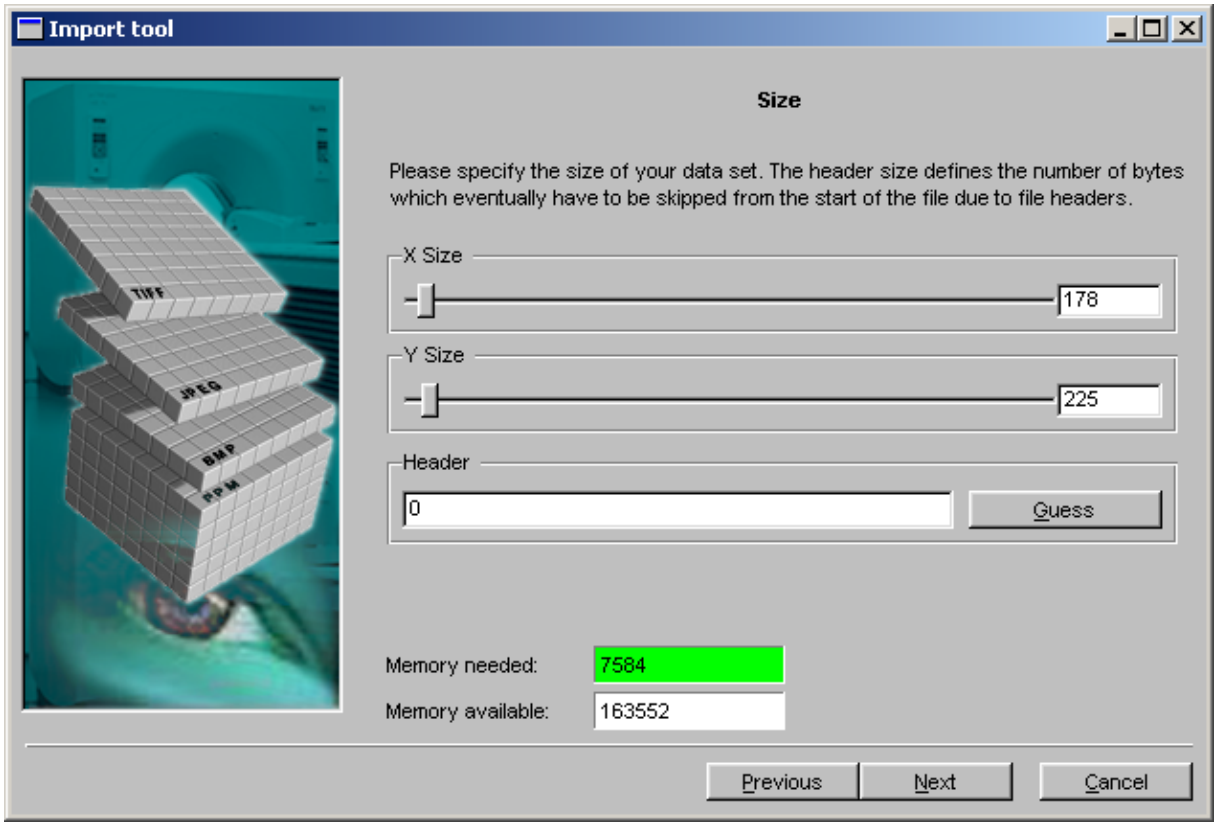


Fig. 227 Select the image and header size for RAW data by dragging the sliders or typing in the desired values.

The image size and header size in bytes has to be specified if the file type RAW was selected.

Use the sliders or type in the x-, y-, and z-size of the volume data. If the volume data set includes a header enter the header size in bytes. The header has to be located at the beginning of the data file and will be skipped while loading. You can use the **Guess** button after having entered the size to compute the header size automatically.

Since the size of the volume has been settled, the memory consumption can be computed. It will be displayed in this and every following page of the import dialog. The field **Memory needed** shows the memory consumption of the volume, the field **Memory available** shows the amount of system memory, that is available. If the memory needed is greater than the memory available, memory needed will be displayed red, so that you can free some memory on your machine or reduce the volumes size, its region of interest or its skip factor (for the two latter items see next step).

Step 7: ROI and Skip selection

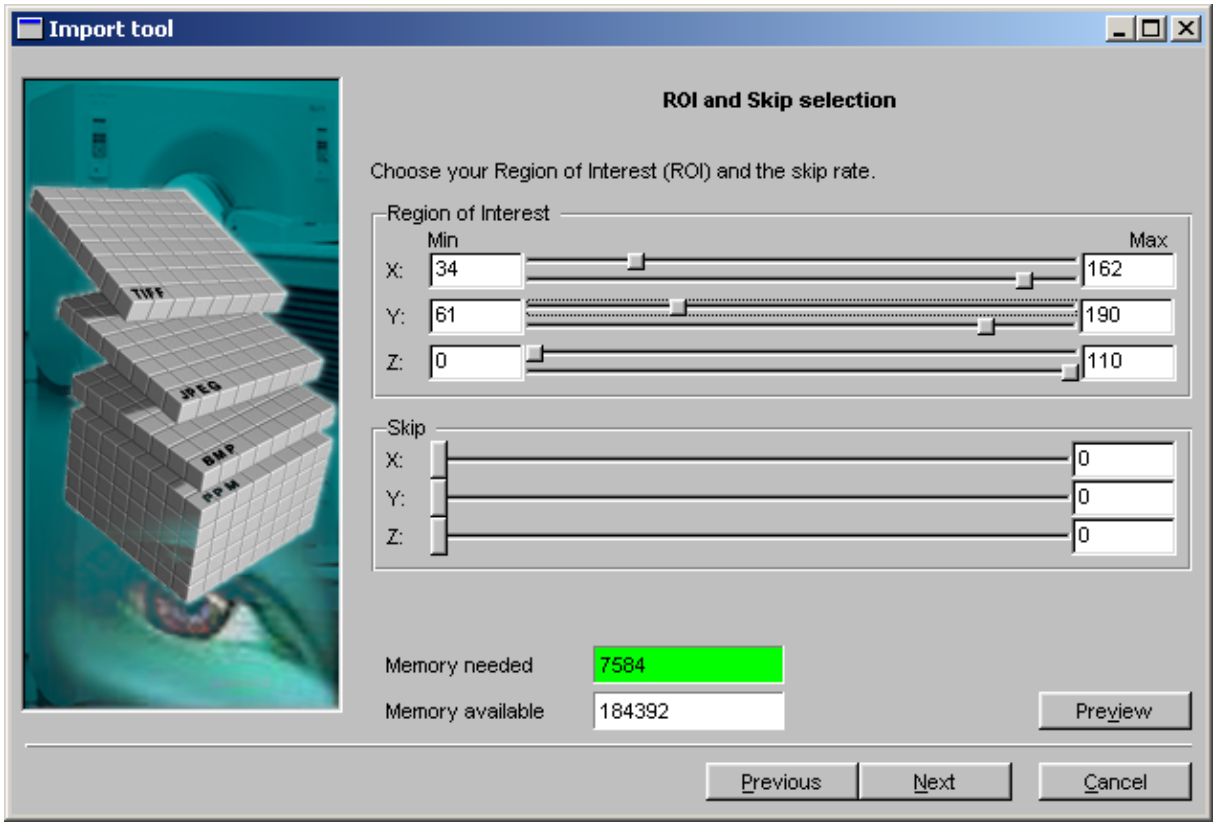


Fig. 228 Define Regions of Interest and choose the skip rate.

Use this dialog of the import wizard to define a region of interest within the imported stack of images or to define the number of voxels to be skipped in each direction of the image planes by dragging the sliders or typing in the desired values. These functions may be of special interest for very large data volumes in order to reduce the amount of data loaded in VGStudio MAX.

Use the six **Region of Interest** sliders to define a sub volume within the data set which should be loaded into VGStudio MAX.

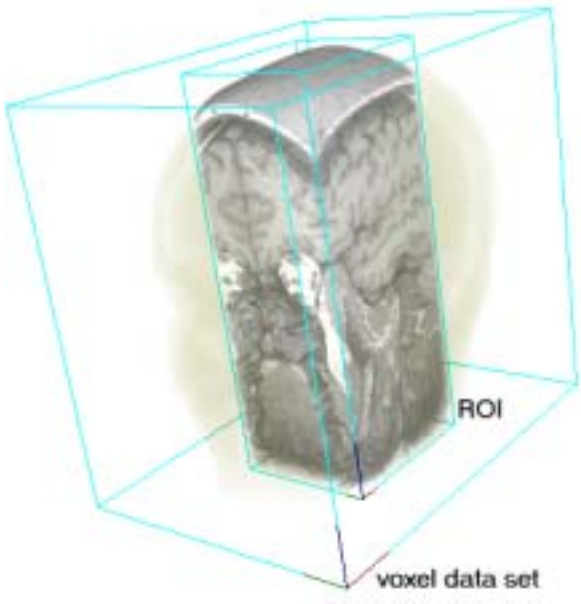


Fig. 229 Define a Region of Interest that is to be loaded into VGStudio MAX.

Use the three **Skip** sliders to specify the number of voxels to be skipped in x-, y- and z-direction. When choosing a value of 1, every second voxel will be skipped in the selected direction. To skip voxels in z-direction remove the appropriate files from the list of selected files (see step 1 and step 2).

The **Preview** function allows you to preview the new settings.

The **Memory needed** will be updated immediately in the corresponding field.

Step 8: Internal data representation

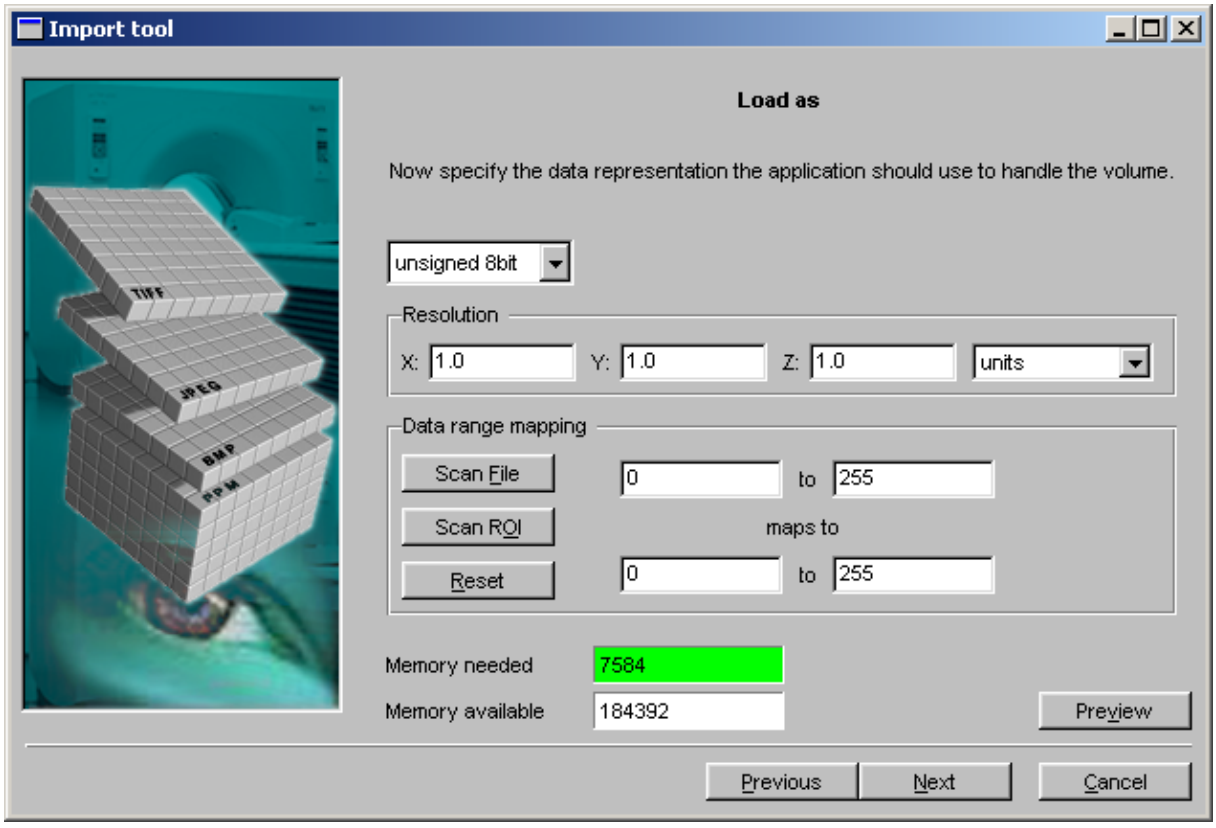


Fig. 230 Specify the data representation.

The data type may be changed while loading data into VGStudio MAX, e.g. a 32 bit floating point data set on your hard disk may be mapped to a 16 bit integer data representation. In this case, this would reduce the amount of memory needed for visualization by a factor of two, which can be observed in the **Memory needed** field.

Any data type may be mapped to any other data type. The only exception are RGBA data sets.

Reminder: RGBA data cannot be mapped to any other data representation. Also, monochrome data types may not be mapped to RGBA data.

unsigned 8bit signed 8bit unsigned 16bit signed 16bit unsigned 32bit signed 32bit 32bit float	May be mapped to	unsigned 8bit signed 8bit unsigned 16bit signed 16bit unsigned 32bit signed 32bit 32bit float
32bit RGBA	only possible mapping	32bit RGBA

The voxel **Resolution** may be adjusted for data sets with non-isotropic voxel dimensions.

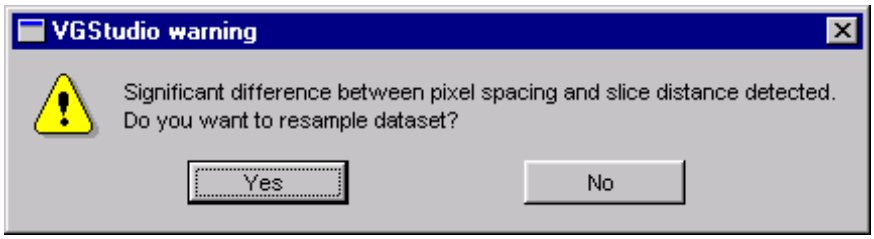


Fig. 231 Resampling warning Pop up.

A Warning dialog may come up in case that you import data series with Significant difference in voxel Resolution. Press **Yes** to resample the data. The software will calculate additional slices by trilinear resampling. This will result in a better 3D image quality. However keep in mind that slice images will be generated out of your original data which are not generated by the scanning device. The resampling will also result in an additional amount of memory needed by the VGStudio application. This process may exceed the available memory installed in your computer depending on your initial image data. Press **No** to skip the resampling process so that only the original image data is loaded. However this may result to low 3D image quality.

The **Data range** may be mapped arbitrarily within a maximum data range for the different data types. The maximum values will appear as default values when opening the dialog for the first time. Pressing the **Reset** button will restore these default values.

The maximum data ranges for the different data types that can be handled by VGStudio MAX are listed in the following table:

Data type	**Min value incl.**	**Max value incl.**	**Effective resolution**
unsigned 8bit	0	255	8 bit
signed 8bit	-128	127	8 bit
unsigned 16bit	0	65535	16 bit
signed 16bit	-32768	32767	16 bit
unsigned 32bit	0	1048575	20 bit
signed 32bit	-524288	524287	20 bit
32bit float	---	---	16 bit

Reminder: For best results while working with scenes including several floating point data sets you should map the floating point data values of all data sets to the same data range.

Press the **Scan file** button to determine the data range included in the data set to be loaded.

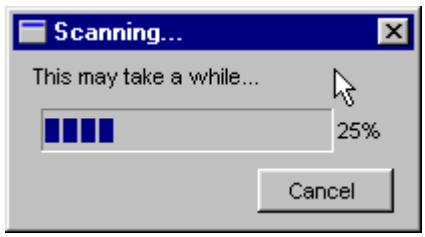


Fig. 232 Use the Scan function to determine the data range.

Clicking **Cancel** will stop the scan process, but the values determined during the partial scan will be displayed in the dialog.

Step 9: Optional data preview

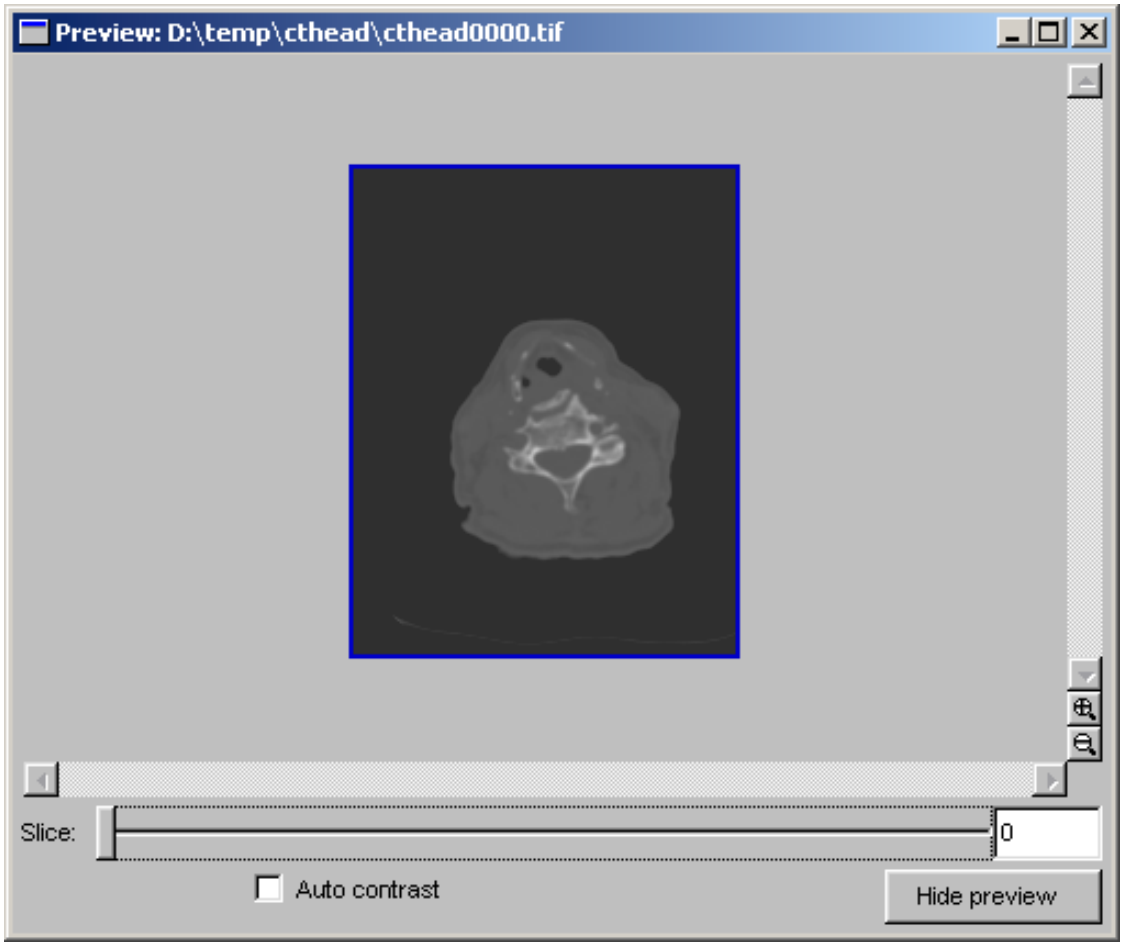


Fig. 233 Before starting the import procedure, you may preview your data as slice images.

The **Preview** window may be used to view your data as slices before starting the import process. This may help you to choose the right parameters. If you are not satisfied with the results, you may always go back to any of the previous steps and change the settings and then check the results again in the **Preview** window. Use the slice selection slider to select the slice to be displayed.

A region of interest (ROI) may also be defined. To do so, grab one of the corners of the blue frame around the region of interest or grab the frame itself by clicking it with the left mouse button. You may now resize the region of interest by dragging the frame to the desired position while holding the left mouse button pressed.

Use the **Auto contrast** checkbox to automatically scan the currently displayed slice for optimal gray value mapping.

Use the **Flip view to X/Z** button to preview the slices in the x/z plane or the **Flip view to X/Y** button to preview the slices in the x/y plane.

Press the **Hide Preview** button to hide the preview window (after finishing the import of an volume the preview hides automatically).

Reminder: The preview performance might be low when viewing ASCII or compressed data files.

Step 10: Manipulation of the object coordinate system

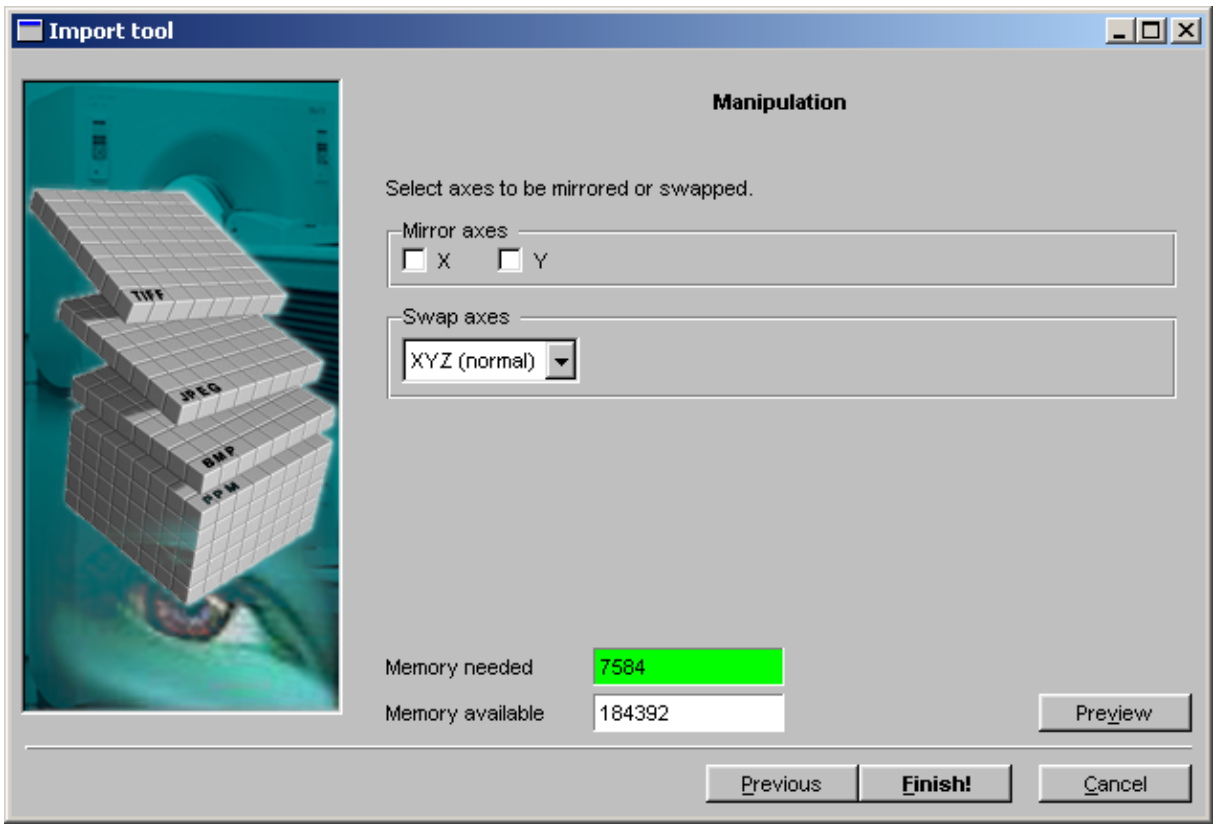


Fig. 234 Mirror or swap the x- and y-axes of the data set.

The coordinate system of the imported data may be manipulated arbitrarily. The x- and y-axes of the data set may be mirrored. To mirror the z-axis change the sorting order in the file selection dialog (step 1). The order of the axes may be swapped.

You may now start the import procedure by clicking **Finish**.

5.1.3 Importing Raw Volume Data

To import Raw volume data, click **File** in the menu bar and select **Import**. Select **Raw Volume** from the **Import** menu to open the **Raw Volume Import Wizard**.

The **Raw Volume Import Wizard** guides you step by step through the whole import process. Click the **Next** or **Previous** buttons to go through the different steps of the import process. The different steps will be explained in the following:

Step 1: File selection

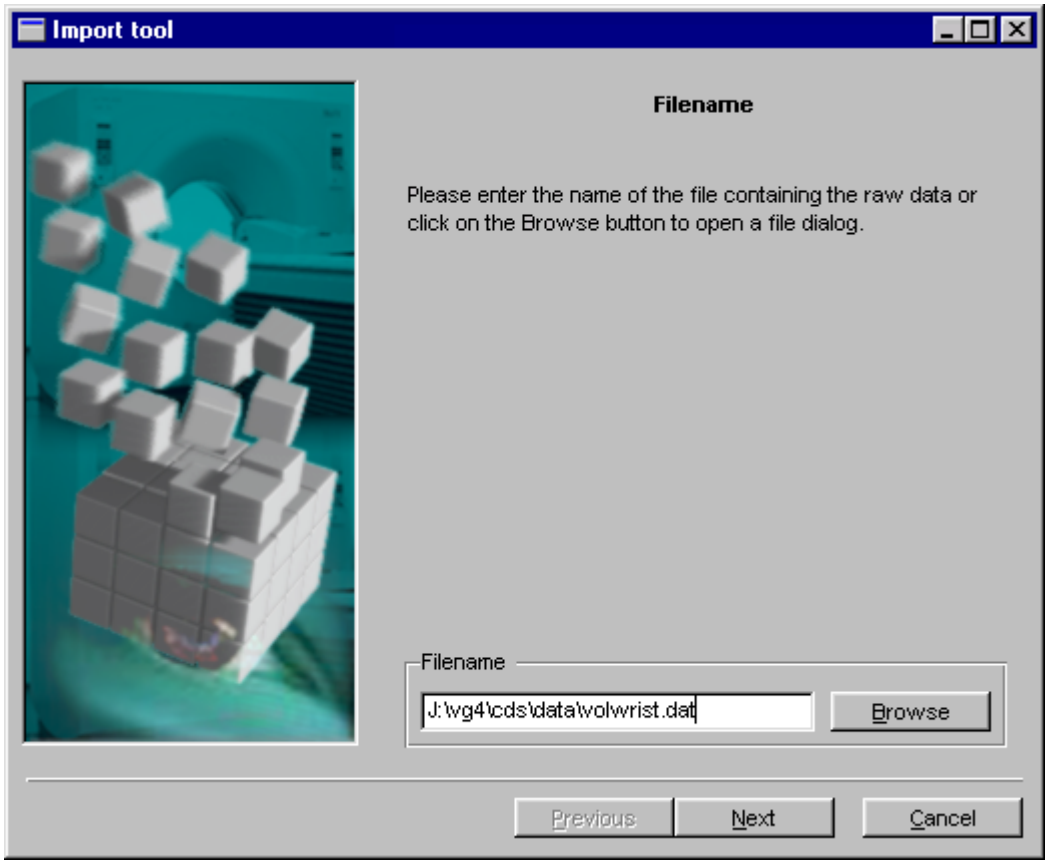


Fig. 235 Select the file you want to import.

Click **Browse** to open a file selection dialog. Select one file and click **Open**. The selected path and filename will appear in the **File name** section of the **Import Wizard**. Then click **Next** to continue.

Step 2: Data type selection

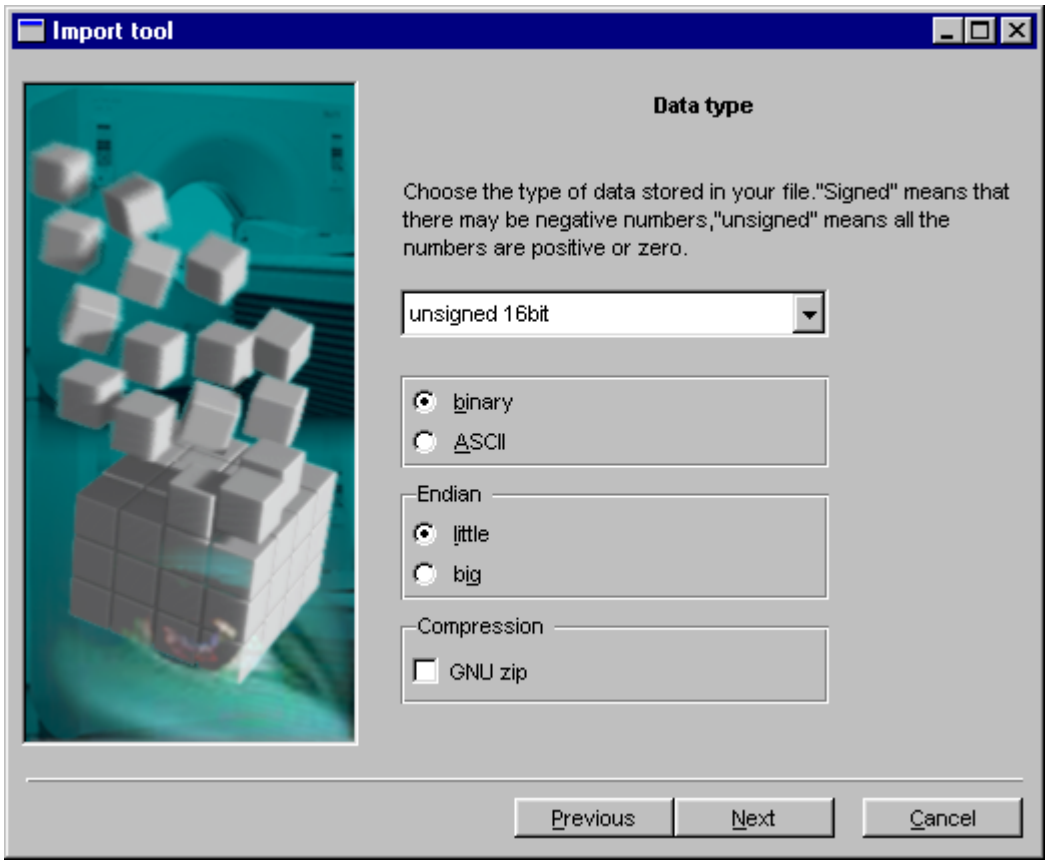


Fig. 236 Specify the data type for Raw images.

The data type has to be specified. Select the data type of the chosen file from the pulldown menu. Possible data types are:

- signed or unsigned 8bit, 16bit, or 32bit
- 32bit float
- 32bit RGBA

Decide whether the data is to be stored in binary or in ASCII format and select the byte order.

VGStudio MAX is capable to import GNU zip compressed data files. Mark the GNU zip check-box to import compressed data.

Reminder: Compression will not work in conjunction with ASCII data.

Step 3: Image size

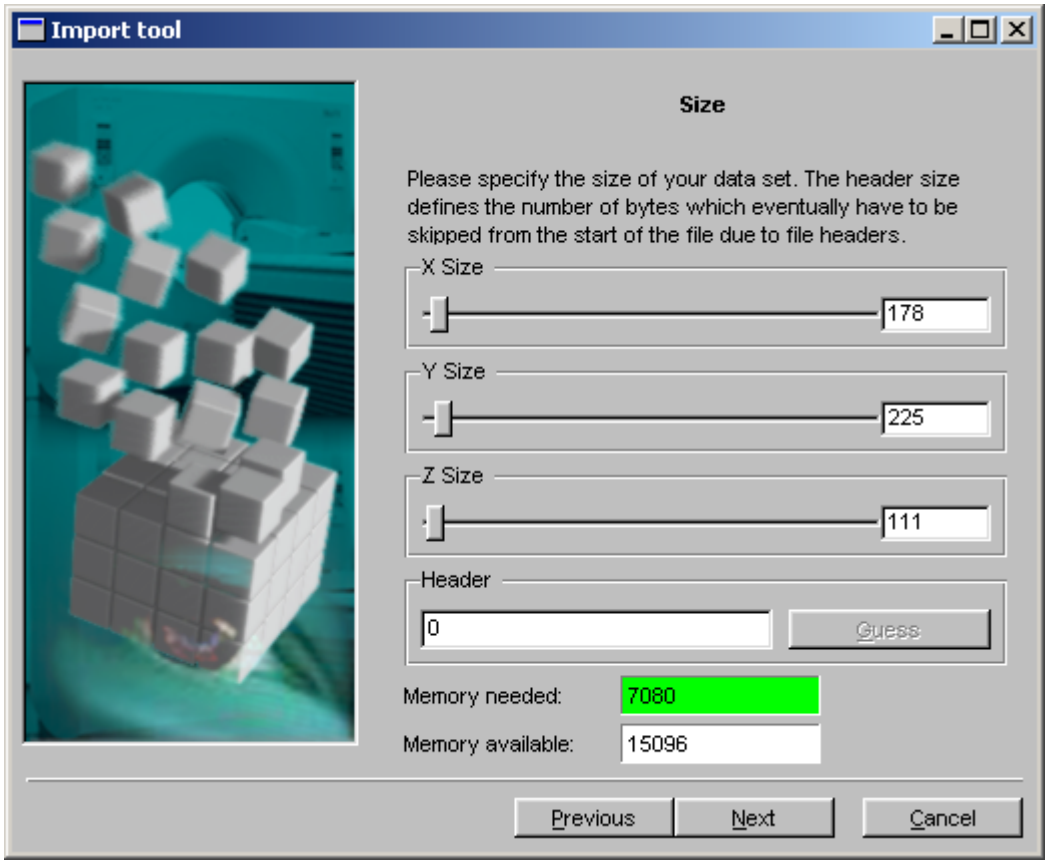


Fig. 237 Select the image and header size by dragging the sliders or typing in the desired values.

Use the sliders or type in the x-, y-, and z-size of the volume data. If the volume data set includes a header enter the header size in bytes. The header has to be located at the beginning of the data file and will be skipped while loading. You can use the **Guess** button after having entered the size to compute the header size automatically.

Since the size of the volume is known the memory consumption can be computed. It will be displayed in the field **Memory needed**, the system memory available will appear in the field **Memory available**. The memory needed will be displayed in all further pages of the raw volume image import. If the memory available will not be enough for the volume to be loaded, the memory needed will be displayed in a red field. The memory needed will be always kept up to date, whether you change the data type, the size of the volume, the region of interest, skip factors or the data type, the volume might be changed to while loading. See further steps.

Step 4: ROI and Skip selection

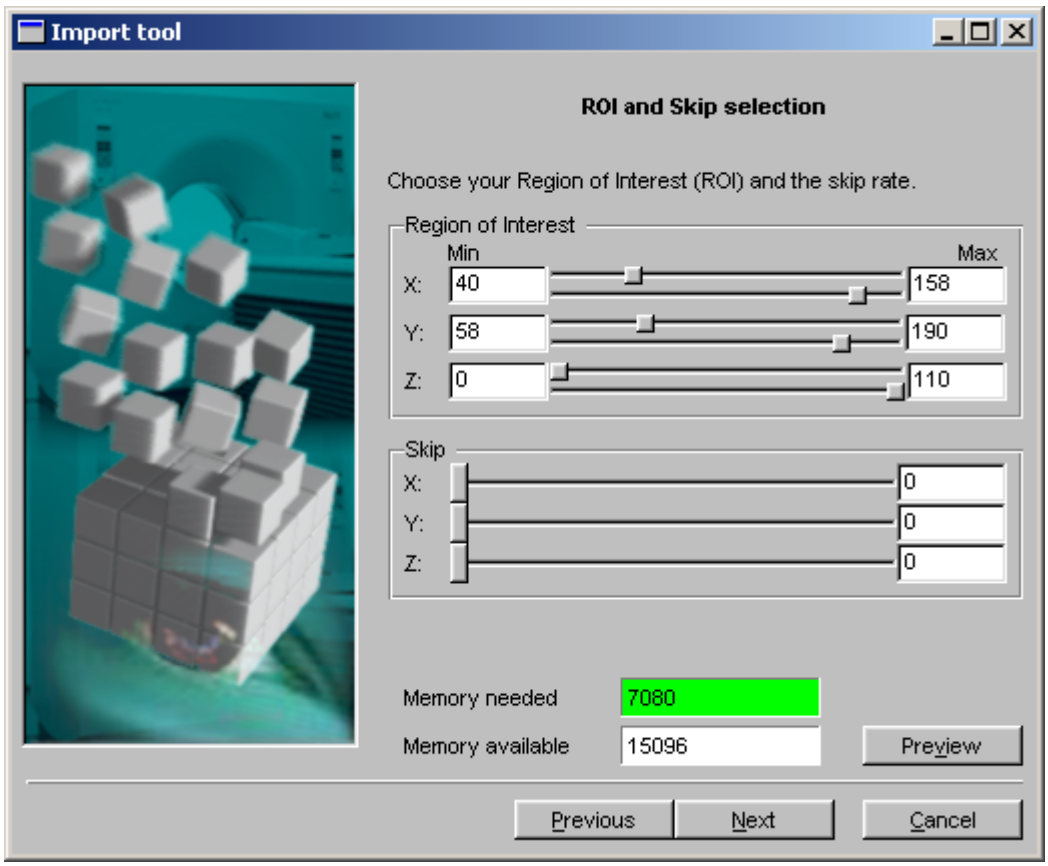


Fig. 238 Define Regions of Interest and choose the skip rate.

Use this dialog of the import wizard to define a region of interest within the imported stack of images or to define the number of voxels to be skipped in each direction of the image planes by dragging the sliders or typing in the desired values. These functions may be of special interest for very large data volumes to reduce the amount of data loaded in VGStudio MAX.

Use the six **Region of Interest** sliders to define a sub volume within the data set which should be loaded into VGStudio MAX.

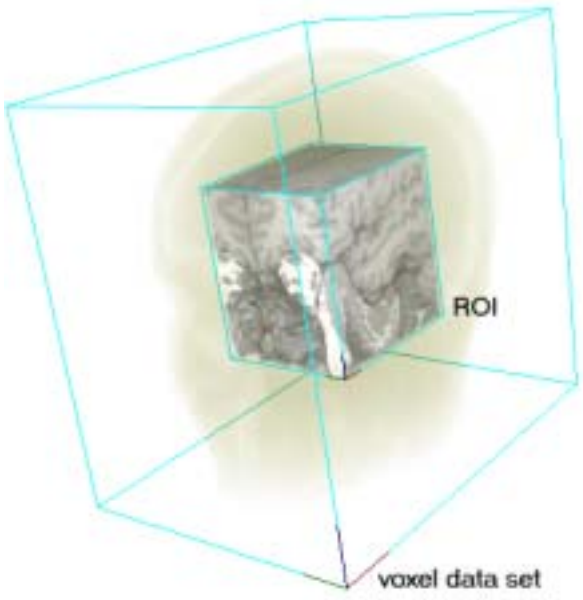


Fig. 239 Define a Region of Interest that is to be loaded into VGStudio MAX.

Use the three **Skip** sliders to specify the number of voxels to be skipped in each direction. When choosing a value of 1, every second voxel will be skipped in the selected direction. The following image shows the example for skip values of 1 in each direction.

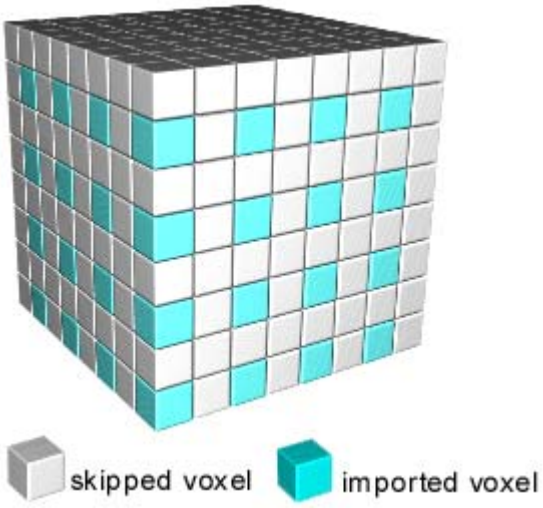


Fig. 240 For each direction, a skip value of 1 was chosen.

Step 5: Internal data representation

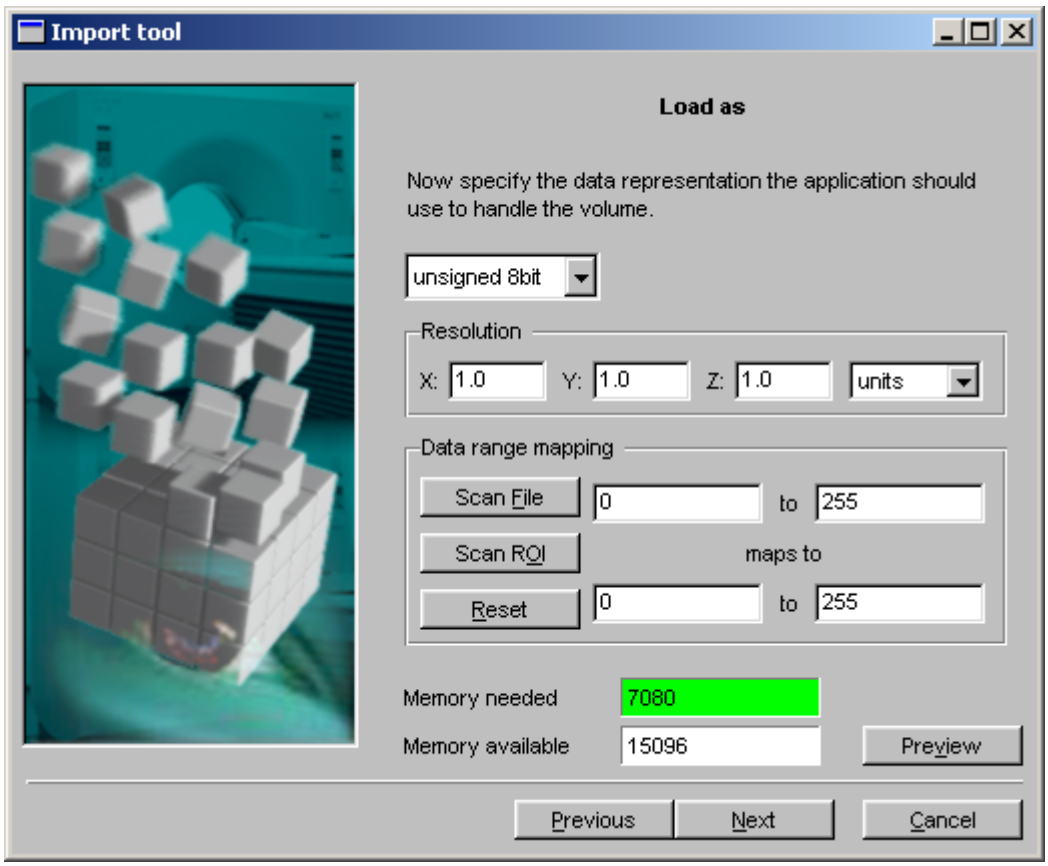


Fig. 241 Use this dialog to specify the internal data representation.

The data type may be changed while loading data into VGStudio MAX, e.g. a 32 bit floating point data set on your hard disk may be mapped to a 16 bit integer data representation. In this case, this would reduce the amount of memory needed for visualization by a factor of two, which can be immediately observed in the **Memory needed** field.

Any data type may be mapped to any other data type. The only exception are RGBA data sets.

Reminder: RGBA data can not be mapped to any other data representation. Also, monochrome data types may not be mapped to RGBA data.

unsigned 8bit signed 8bit unsigned 16bit signed 16bit unsigned 32bit signed 32bit 32bit float	may be mapped to	unsigned 8bit signed 8bit unsigned 16bit signed 16bit unsigned 32bit signed 32bit 32bit float
32bit RGBA	no mapping possible	32bit RGBA

The voxel **Resolution** may be adjusted for data sets with non-isotropic voxel dimensions.

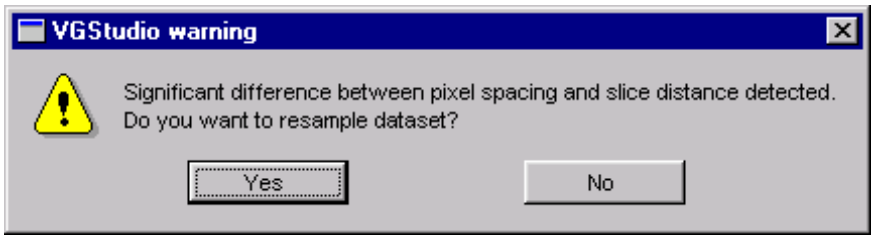


Fig. 242 Resampling warning Pop up.

A Warning dialog may come up in case that you import data series with Significant difference in voxel Resolution. Press **Yes** to resample the data. The software will calculate additional slices by trilinear resampling. This will result in a better 3D image quality. However keep in mind that slice images will be generated out of your original data which are not generated by the scanning device. The resampling will also result in an additional amount of memory needed by the VGStudio application. This process may exceed the available memory installed in your computer depending on your initial image data. Press **No** to skip the resampling process so that only the original image data is loaded. However this may result to low 3D image quality.

The **Data range** may be mapped arbitrarily within a maximum data range for the different data types. The maximum values will appear as default values when opening the dialog for the first time. Pressing the **Reset** button will restore these default values.

The maximum data ranges for the different data types that can be handled by VGStudio MAX are listed in the following table:

Data type	Min value incl.	Max value incl.	Effective resolution
unsigned 8bit	0	255	8 bit
signed 8bit	-128	127	8 bit
unsigned 16bit	0	65535	16 bit
signed 16bit	-32768	32767	16 bit
unsigned 32bit	0	1048575	20 bit
signed 32bit	-524288	524287	20 bit
32bit float	---	---	16 bit

Reminder: For best results while working with scenes including several floating point data sets you should map the floating point data values of all data sets to the same data range.

Press the **Scan file** button to determine the data range included in the data set to be loaded.

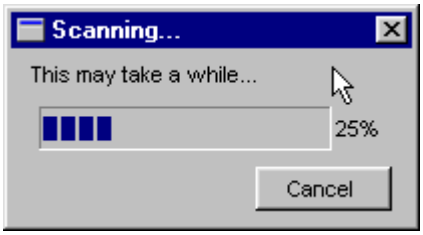


Fig. 243 Use the Scan function to determine the data range.

Clicking **Cancel** will stop the scan process, but the values determined during the partial scan will be displayed in the dialog.

Step 6: Optional preview

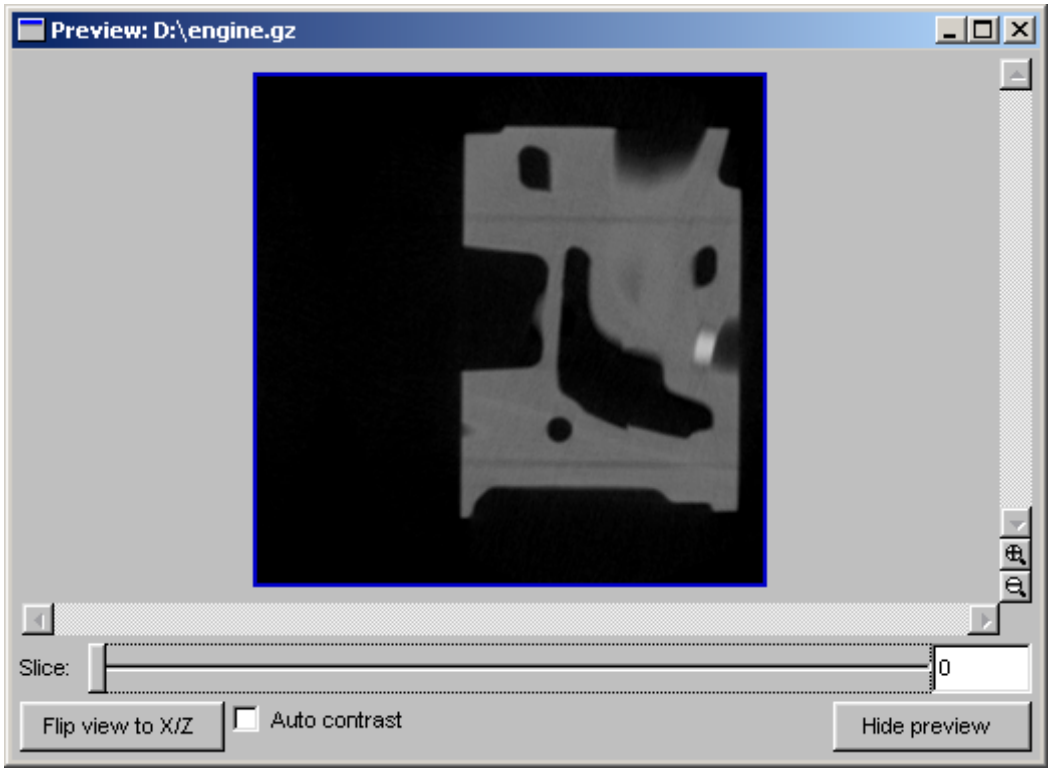


Fig. 244 Before starting the import procedure, the Raw volume data may be previewed as slice images.

The **Preview** window may be used to view your data as slices before starting the import process. This may help you to choose the right parameters. If you are not satisfied with the results, you may always go back to any previous step and change the settings and then check the results again in the **Preview** window. Use the slice selection slider to select the slice to be displayed.

A region of interest (ROI) may also be defined. To do so, grab one of the corners of the blue frame around the region of interest or grab the frame itself by clicking it with the left mouse button. You may now resize the region of interest by dragging the frame to the desired position while holding the left mouse button pressed.

Use the **Auto contrast** checkbox to automatically scan the currently displayed slice for optimal gray value mapping. The **Auto contrast** function will modify any previously adjusted data range mapping performed in step 5.

Reminder: The preview performance might be low when the viewed slice is flipped or when viewing ASCII or compressed data files.

Step 7: Manipulation of the object coordinate system

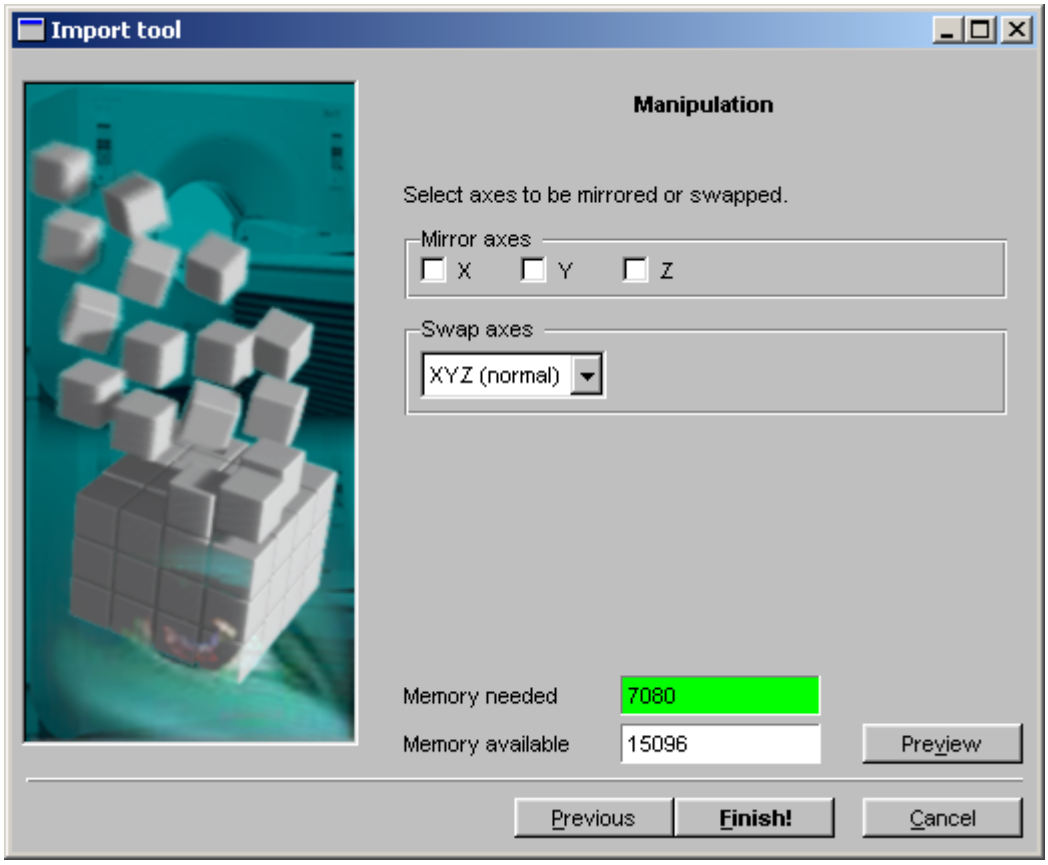


Fig. 245 Mirror or swap the x-, y-, and z-axes of the data set.

The coordinate system of the imported object may be manipulated arbitrarily. All three axes of the data set to be imported may be mirrored. The order of the axes may be swapped.

You may now start the import procedure by clicking **Finish**.

5.1.4 Importing HDF Data

VGStudio MAX is capable to import image and volume data stored in the **H**ierarchical **D**ata **F**ormat (HDF 4.x). Select the **Import HDF volume** option in the **File** menu to load HDF volume data files into VGStudio MAX. More information on HDF data can be found under the following internet address: http://hdf.ncsa.uiuc.edu.

Select the HDF file you want to import in the file dialog. If the HDF file contains several data sets, a dialog will appear, where you can choose one or several data sets to import (*see* ***Fehler! Verweisquelle konnte nicht gefunden werden.*** *The Import HDF dialog.*).

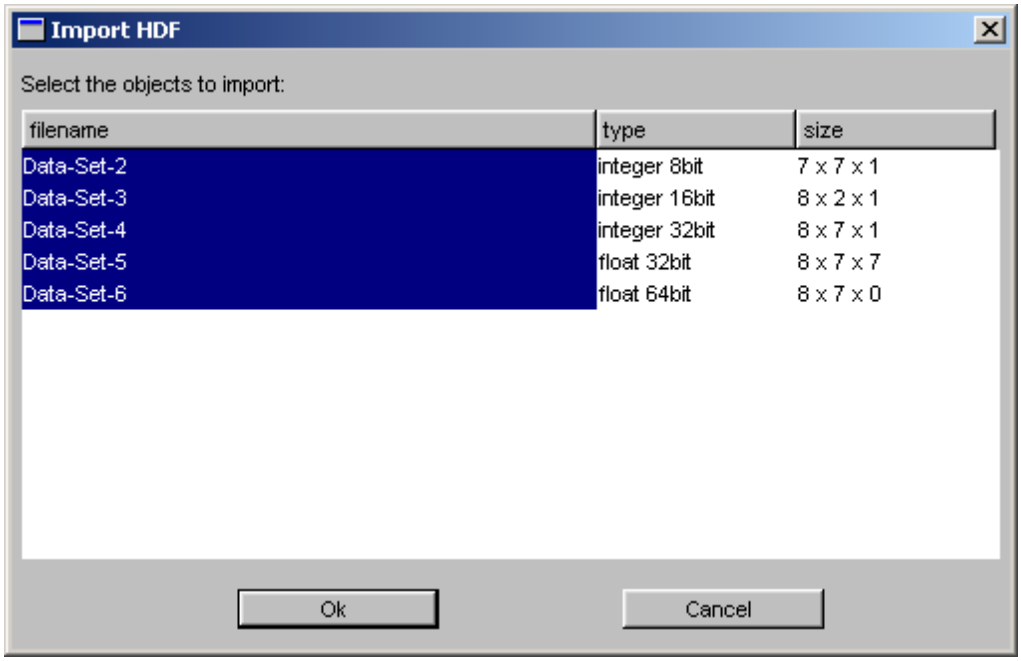


Fig. 246 The Import HDF dialog.

5.1.5 Importing ANALYZE™ Data

VGStudio MAX is capable to import data stored in the Analyze™ file format.

Select the **Import Analyze volume** option in the **File** menu to load Analyze™ volume data files into VGStudio MAX. More information on the Analyze™ file format can be found under the following internet address: http://www.mayo.edu/bir/analyze/AnalyzeFileInfo.html.

5.1.6 Importing DICOM Data

Select the **Import DICOM image** option in the **File** menu to load DICOM volume data or image files into VGStudio. Use the file dialog to select one or several data files. The Dicom import dialog will pop up. Select a study and one or more acquisitions to be imported. Press **OK** to load the data or **Cancel** to abort the operation.

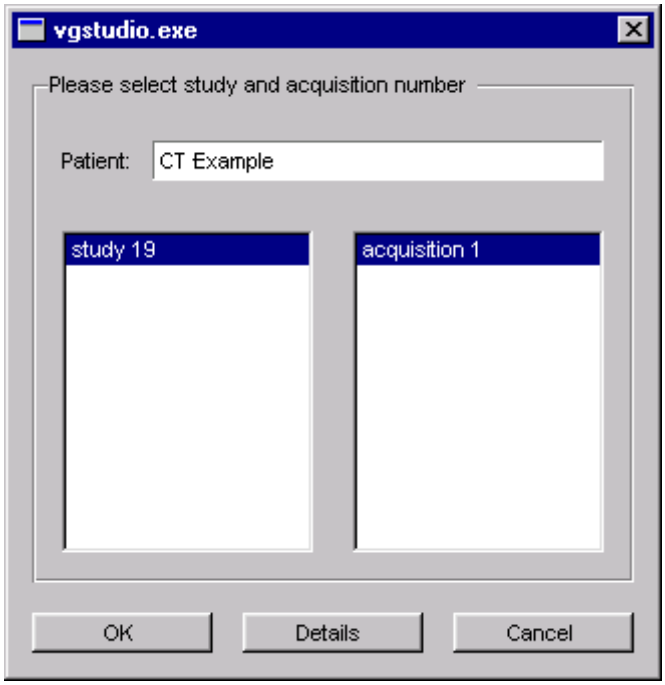


Fig. 247 The Import Dicom files window.

A Warning dialog may come up in case that you import DICOM image series with non equal slice distances or in case that the slice distance is more than three times the pixel resolution within the slices. Press **Yes** to resample the data. The software will calculate additional slices by trilinear resampling. This will result in a better 3D image quality. However keep in mind that slice images will be generated out of your original data which are not generated by the scanning device. The resampling will also result in an additional amount of memory needed by the VGStudio application. This process may exceed the available memory installed in your computer depending on your initial image data. Press **No** to skip the resampling process so that only the original image data is loaded. However this may result to low 3D image quality.

Press the **Details** button to get an detailed overview of the selected DICOM acquisitions which will be displayed in the **Import Dicom files** window along with other information included in the files such as patient name, date of birth, position etc.

You may select or deselect one or several files. By clicking the Delete key you delete the currently selected files.

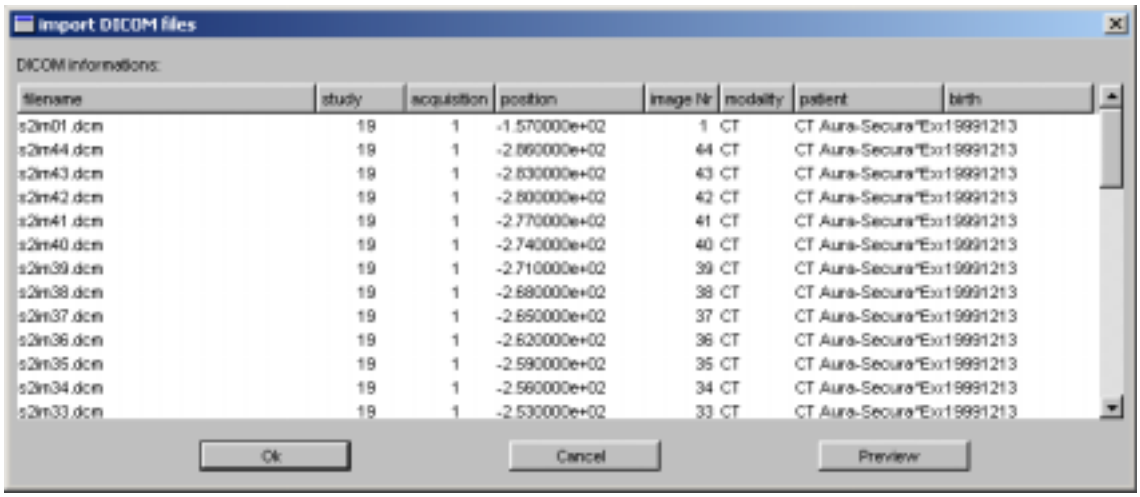


Fig. 248 The Import Dicom files window.

The **Preview** window may be used to view your data as slices before starting the import process. This may help you to choose the right parameters. If you are not satisfied with the results, you may always go back to any previous step and change the settings and then check the results again in the **Preview** window. Use the slice selection slider to select the slice to be displayed.

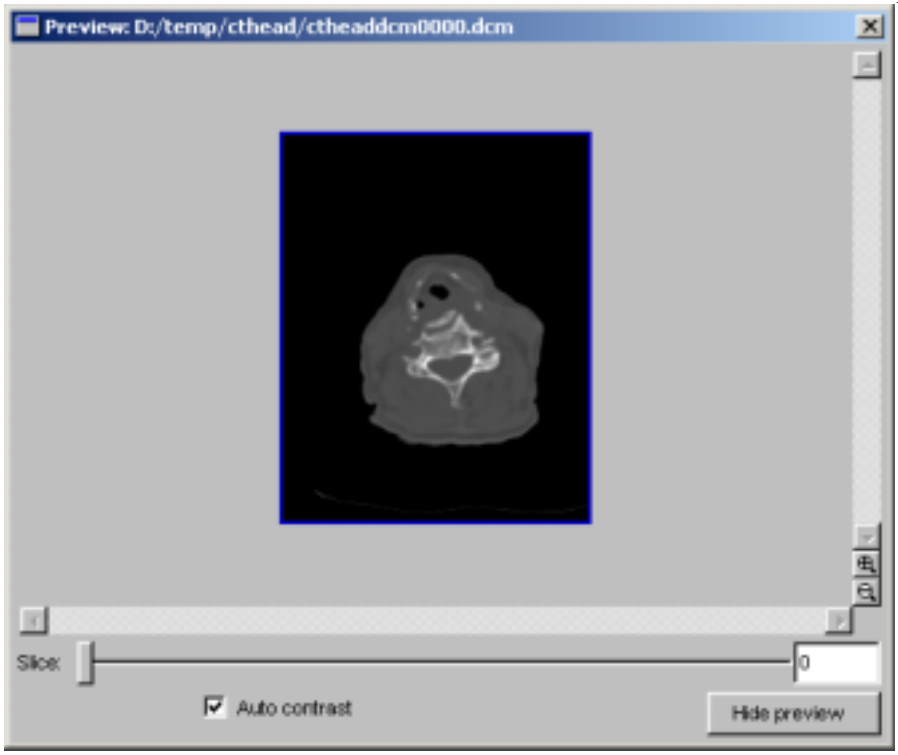


Fig. 249 The Import Dicom files window.

A region of interest (ROI) may also be defined. To do so, grab one of the corners of the blue frame around the region of interest or grab the frame itself by clicking it with the left mouse button. You may now resize the region of interest by dragging the frame to the desired position while holding the left mouse button pressed.

Use the **Auto contrast** checkbox to automatically scan the currently displayed slice for optimal gray value mapping.

5.1.7 Importing Polygon Data

VGStudio MAX is capable to import polygonal data stored in **Off file** format. More information on the off file format can be found in the Geomview Manual which can be accessed via the following internet address: http://www.geom.umn.edu/software/geomview/geomview_toc.html. The manual is provided by the Geometry Center of the University of Minnesota.

5.2 Exporting Data

A single volume object can be exported to different file formats, e.g. as a stack of Images, as a Raw volume data file, a HDF file, an Analyze™ volume or a Dicom image series. To do so, select **Export** and the desired format in the **File** menu.

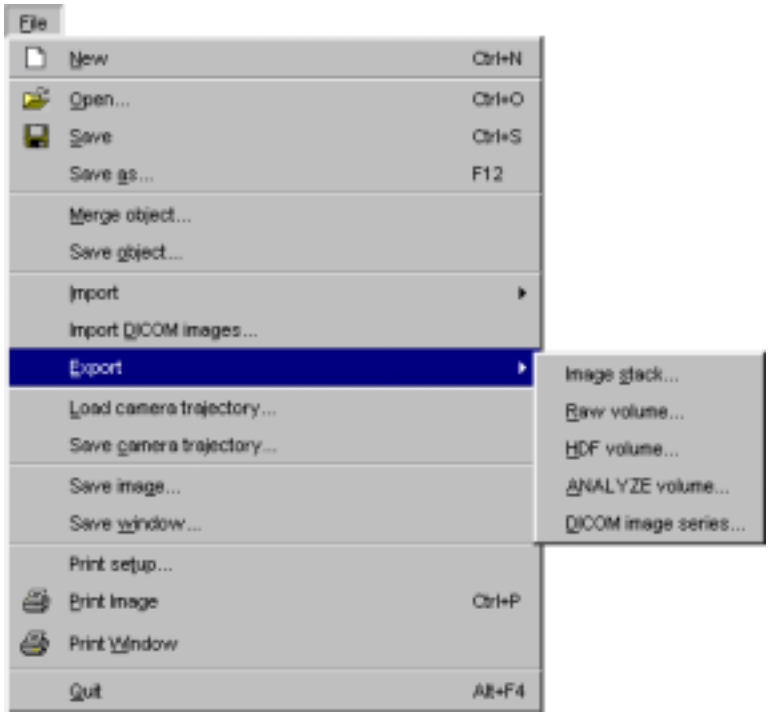


Fig. 250 Select Export / Raw volume to export a single volume object e.g. as a Raw volume data file.

The export options remains disabled if no object is selected or if the active object is a polygon object or a group of objects.

Before every export a message box arises, asking you whether the current scene should refer to the currently saved data. That means, if in the present scene an object refers to Analyze-data and you saved that object as a raw volume and you chose **Yes** in the **Replace volume info** message box, the next time you load the scene, the vgi file will refer to the raw volume (provided you saved the scene).

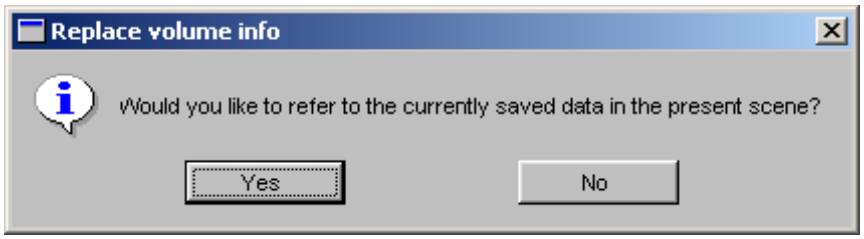


Fig. 251 VGStudio MAX will ask whether you want the object in the present scene should refer to the currently saved data.

Sometimes referring to saved data is no good idea, because some exports will lead to a loss of data, e.g. exporting a 32 bit integer volume as a stack of **BMP** images will reduce the data range to 8 bit.

After the data files were written to disk the following dialog box will pop up.

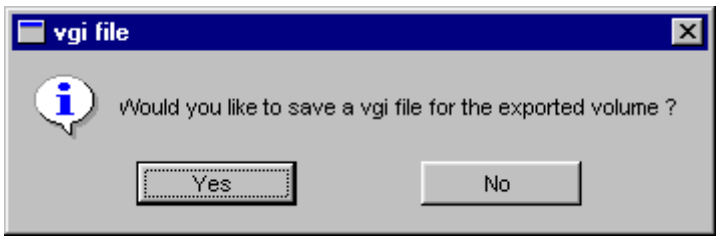


Fig. 252 VGStudio MAX will ask you whether you want to save a vgi file for the exported volume.

Click **Yes** if you want to save a vgi file (Volume Graphics Info file) for the exported volume. The vgi file will contain only the minimal information to reload the volume, that is the information about the files to load, information about the units (if necessary) and the data range of the volume. Use this option, if you want to merge the exported volume to another scene as an comfortable alternative to importing the data to a scene. Select **No** to skip this step.

In the following the specific differences of the various export types as listed in the **Export** section of the **File** menu will be described.

5.2.1 Exporting Image Stacks

If you chose export image stack, a save file dialog will appear. You can chose out of a variety of file types: binary, ASCII or compressed raw export or in one of the supported image formats (BMP, JPEG, TIFF, PPM). The file name you enter or chose from the file list will be the basic file name. Each slice will consist of the name you entered, followed by a 4 digit slice number and completed by the image type specific file suffix.

Since the data range of BMP, JPEG and PPM is practically 8 bit and the data range of TIFF is 8 or 16 bit sometimes you will loose data if you continue export.

If you export BMP, JPEG or PPM images and the volume has a data range greater than 8 bit, VGStudio MAX will warn you with the message below. If the loss of data is acceptable to you, you can click **YES**, to continue export. Clicking on **NO** will stop the export.

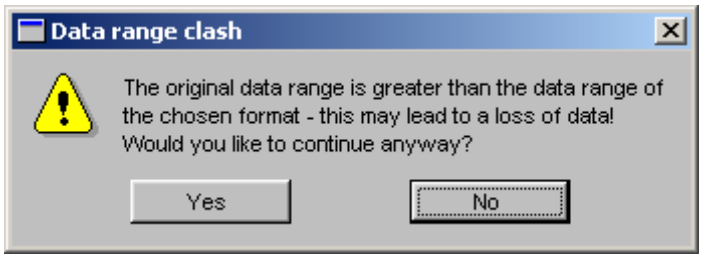


Fig. 253 If the data range does not fit the image format, VGStudio MAX will warn you, that you might loose data.

BMP, JPEG and PPM images produced by VGStudio MAX will always be RGB images with 8 bit for every color channel. If the volume exported is not of type RGBA it will be exported as an gray value image.

Exporting JPEG images will confront you with a small dialog to specify the image quality in a range from 5 to 100, where 5 means the poorest quality, but best compression factor and 100 means best quality, but nearly no compression at all. The default value of 78 is a trade of, that should satisfy most needs.

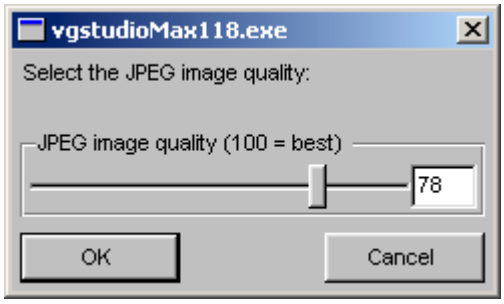


Fig. 254 Exporting JPEG images will confront you with the choice of the image quality.

If you want to export to TIFF and the data range of your data is 16 bit or greater VGStudio MAX will come up with this message box:

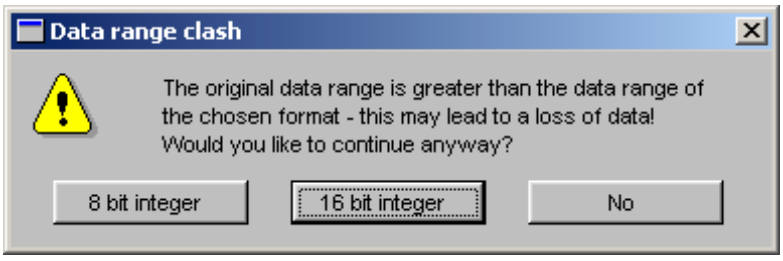


Fig. 255 Exporting non RGB volume data to a TIFF image stack will give you the choice of the data range.

If you choose **8 bit integer**, you will export the active volume as an image stack of 8 bit TIFF images, if you click on **16 bit integer**, you will export the active volume as an image stack of 16 bit TIFF images. If neither 8 bit nor 16 bit export satisfy your needs click **No** to cancel TIFF export.

TIFF export in VGStudio MAX supports 8 and 16 bit gray value and 8 and 16 bit RGBA export.

5.2.2 Exporting RAW Volumes

The user may select from the Filetype selection within the file dialog box the file format in which the raw data file should be written to disk. The file could be written as a single raw data file, a ASCII data file or as gzip'ed raw data file. A single raw data file will be written to disk in the same data type (e.g. 8, 16, 32 bit unsigned/signed integer, 32 bit float, or 32 bit RGBA) the object was represented in VGStudio MAX. For example, a data set which was loaded as 16 bit unsigned integer data into VGStudio MAX will be written to disk as 16 bit unsigned integer data. The byte order will be the original byte order of your hardware. The voxel at position (0,0,0) will be written first, x is the inner loop variable, y the second loop variable, and z the outer loop variable.

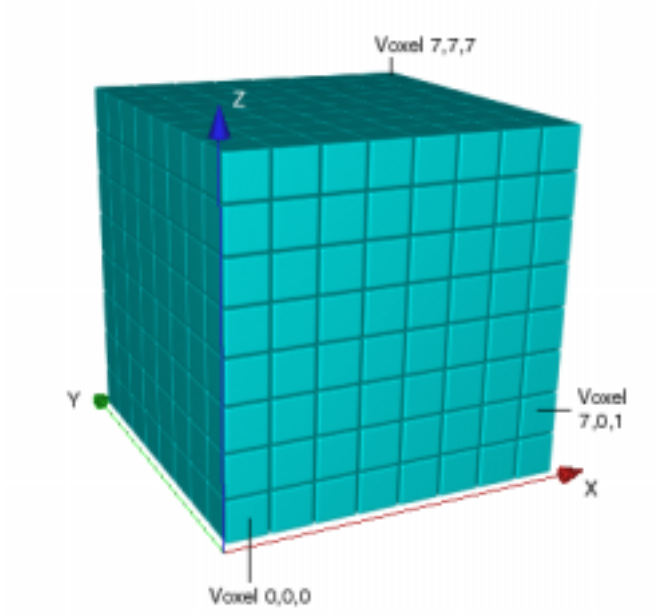


Fig. 256 The voxel at position (0,0,0) will be written first, x is the inner loop variable, y the second loop variable, and z the outer loop variable.

5.2.3 Exporting HDF Volumes

VGStudio MAX is capable to export image and volume data in the **H**ierarchical **D**ata **F**ormat (HDF 4.x).

Select the **Export HDF volume** option in the **File** menu to save the current volume as a HDF volume data file. More information on HDF data can be found under the following internet address: http://hdf.ncsa.uiuc.edu.

5.2.4 Exporting Analyze™ Volumes

VGStudio MAX is capable to export data in the Analyze™ file format.

Select the **Export Analyze volume** option in the **File** menu to save the current active volume as an Analyze volume data file. More information on the Analyze™ file format can be found under the following internet address: http://www.mayo.edu/bir/analyze/AnalyzeFileInfo.html.

5.2.5 Exporting DICOM Image Series

Select the **Export DICOM image series** option in the **File** menu to save the current active volume as a series of Dicom files.

If the volume to export has been previously loaded from an Dicom image series itself, the exported Dicom files will contain as much of the Dicom information as will be displayed in the Import Dicom Files window (see *Fig. 248 The Import Dicom files window.*). If the volume is not Dicom based the exported Dicom files contain no further information, than the slice number and the name of the object as patient's name.

Reminder: Any Dicom data written by VGStudio MAX will be tagged as derived data!

6 Appendix

6.1 VGStudio MAX 1.0 and memory consumption

6.1.1 Memory consumption of voxel data

A data set loaded into VGStudio MAX is divided into sub-volumes of the size 16x16x16 voxels. The dimensions of a data set of the size 252x252x204 will be rounded up to a size of 256x256x208 in memory. This is called the **D**ata **S**ize in **M**emory (DSM). Every data set in memory needs an additional amount of memory which is needed for performance optimization reasons. It is called the "**S**paceleaping **D**ata" (SD). The SD has the same dimensions as the original data in memory but it allocates only one byte per voxel, independent of the data type of the original data. In addition to the DSM and SD a few kByte additional memory are needed.

Memory consumption of data set of different data types: (size 252x252x204)

Data type	**DSM in MB**	**SD in MB**	**Total Size in MB**
8 Bit	13	13	26
16 Bit	26	13	39
32 Bit	52	13	65
RGBA	52	13	65

Memory consumption of objects in a VGStudio MAX 1.0 scene

Original data	DSM + SD
Copy of an object	SD
References of an object	few kByte

6.1.2 Rendering large high quality images

The rendering of large images - VGStudio MAX allows the user to render images up to 4096x4096 pixels which is 64 MB - requires large amounts of memory.

The amount of memory may be reduced by reducing the image size and the oversampling rate.

6.2 Limitations and Known Bugs

- The shadows appear to be bent.

  The shadows rendered by VGStudio MAX 1.0 are bent due to the lighting model used in VGStudio MAX's renderer. This behavior will be corrected in one of the next VGStudio MAX releases.

- Windows NT 4.0 crashes when visualizing very large amounts of data.

  Under certain conditions, Windows NT 4.0 with Service Pack 3 or lower may crash when visualizing very large data amounts using up almost all available memory (RAM + Swap) on your system. To correct this fault, install the latest Windows NT 4.0 Service Pack.

- VGStudio MAX 1.0 crashes during printing on a Linux system.

  VGStudio MAX 1.0 crashes when printing on a Linux system where no valid printer is configured. Please refer to your Linux distribution's manual and set up a printer.

7 Index