1 Introduction

In the past, most voxel-based programs had to run on very expensive SGI workstations to achieve near real-time rendering speeds. Recently, VolumePro voxel processors have been used to provide rendering speeds on PCs similar to SGI systems for much less money. But VolumePro boards still significantly increase the cost of a PC-based 3D imaging systems. Consequently, we developed a program (Voxx) that uses the 3D graphics processors already present on many low-cost video boards found in office and lab PCs, such as the NVIDIA GeForce family of processors. These processors can achieve rendering speeds similar to VolumePro voxel processors and the graphics subsystems used on many SGI workstations. The combination of our free Voxx program and such low-cost video boards should make near real-time volume rendering systems available to a larger number of users.

Voxx is written in C++ and uses OpenGL, GLUT, and GLUI to make the bulk of the code independent of the host window system. The program currently runs on Windows 98/NT/2000, with Apple MacOS and Linux ports underway. The executable version (but not source code) of Voxx is freely available to researchers for non-commercial applications. If anyone is interested in commercial applications, feel free to contact us.

2 Installation

2.1 System Requirements

Voxx should work on most PCs running Windows 98/NT/2000 provided that OpenGL and GLUT are present, and the PC contains a video board equipped with an NVIDIA GeForce2 or GeForce3 graphics processor.

We currently recommend that users only equip PCs with video boards using NVIDIA GeForce2 GTS, GeForce2 Ultra, Quadro2 Pro, or GeForce3 graphics processors. Note that future versions of Voxx will include support for some features that are presently available on GeForce3-based boards. Also, in order to maximize rendering speeds, one should only use AGP 4x (not PCI) versions of video boards, and they should be equipped with at least 64 MB of DDR memory. Voxx can run on PCs using video boards which don't use NVIDIA GeForce/Quadro chips, but such OpenGL hardware/software must support two OpenGL extensions in order for Voxx to provide real-time color and opacity table editing: paletted 2D texture maps, and shared texture palettes. We have found very few 3D video boards for PCs that support these extensions.

The memory requirements of the program depend on the number and size of the image stacks and the number of color channels per stack. We recommend that PCs running Windows 2000 be equipped with at least 256-384 MB of memory for rendering "small" stacks (e.g. 64x512x512 images, with 1-3 color channels). For "larger" stacks (e.g. 128-256x512x512, with 1-3 color channels), we recommend 512-768 MB of memory. So having a PC with memory expandability to 1 GB may be desirable for users interested in working with large multi-channel datasets.

2.2 Downloading

You will need to download a self-extracting Zip file (voxxe.exe) from our website, which contains the program, user notes, and sample voxel and palette files. Note that you must "register" (i.e. enter a user name and e-mail address, then click on the Download button) before you can actually download the file.
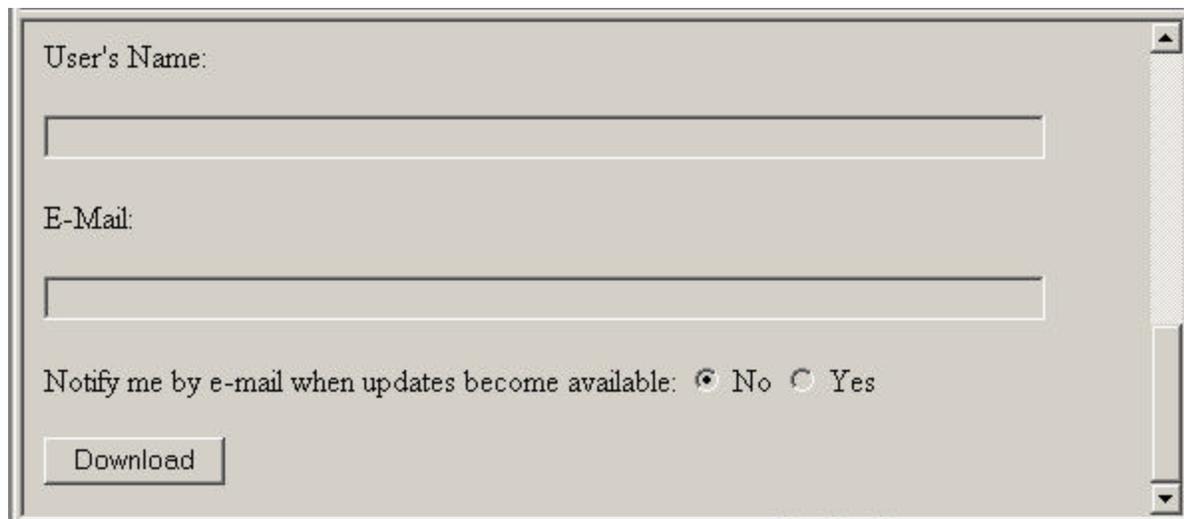
  http://nephrology.iupui.edu/imaging/voxx/download

Once downloaded, run voxxe.exe. It will try to create the following Voxx subdirectory, then copy the above-mentioned files into it. Note that if you are installing the program on a PC running Windows 2000, you may need to log in as an Administrator before running voxxe.

  C:\Program Files\Voxx

We also recommend that you download and use only the latest NVIDIA OpenGL driver for GeForce-based video boards, and NOT use drivers supplied by the manufacturer of your video board. Some manufacturers modify the NVIDIA drivers, and we have encountered bugs in some of those customized drivers. The latest OpenGL driver for GeForce-based boards can be downloaded from NVIDIA's website at:

 http://www.nvidia.com/view.asp?PAGE=drivers
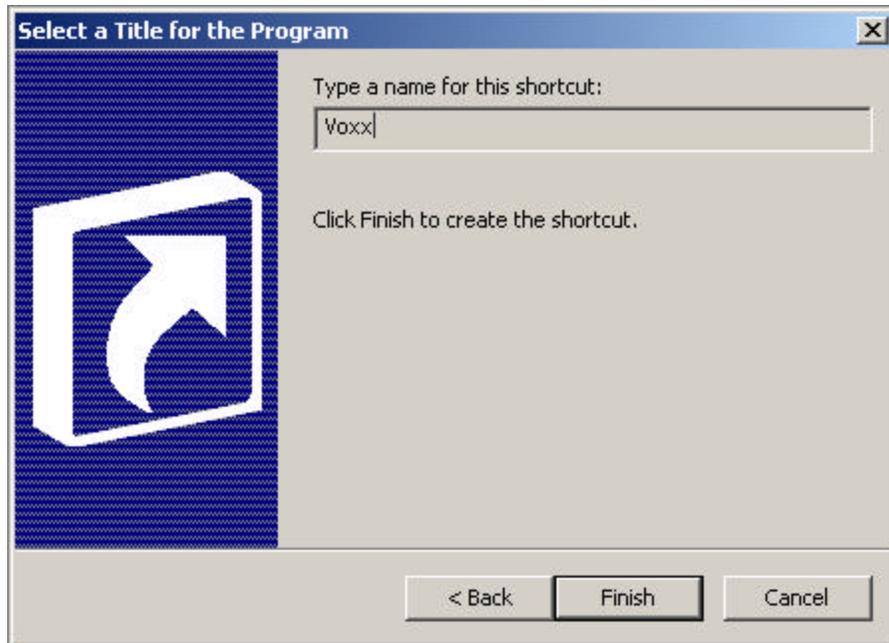
2.3 Desktop Shortcuts

Most users seem to want to run Voxx by double-clicking on an icon on the Windows desktop/screen. So once the EXE and DLL files have been put in the appropriate subdirectories, you should create a shortcut/icon on each user's desktop.

Position the cursor in an empty region of the screen (away from other shortcuts/icons), then click the right button on the mouse. Select the New option on the popup menu, then select the Shortcut command on the New submenu.
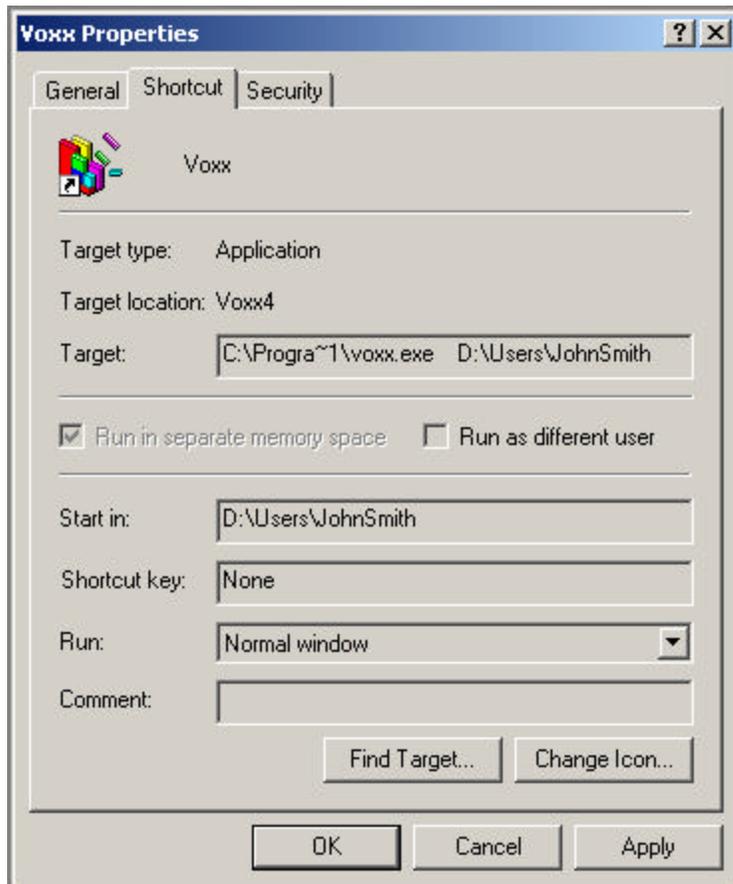
Enter the following command in the Create Shortcut dialog box's "Type the location of the item" field, or click on the Browse button and locate the Voxx executable file, then click on the Next button: C:\Progra~1\Voxx\Voxx.exe
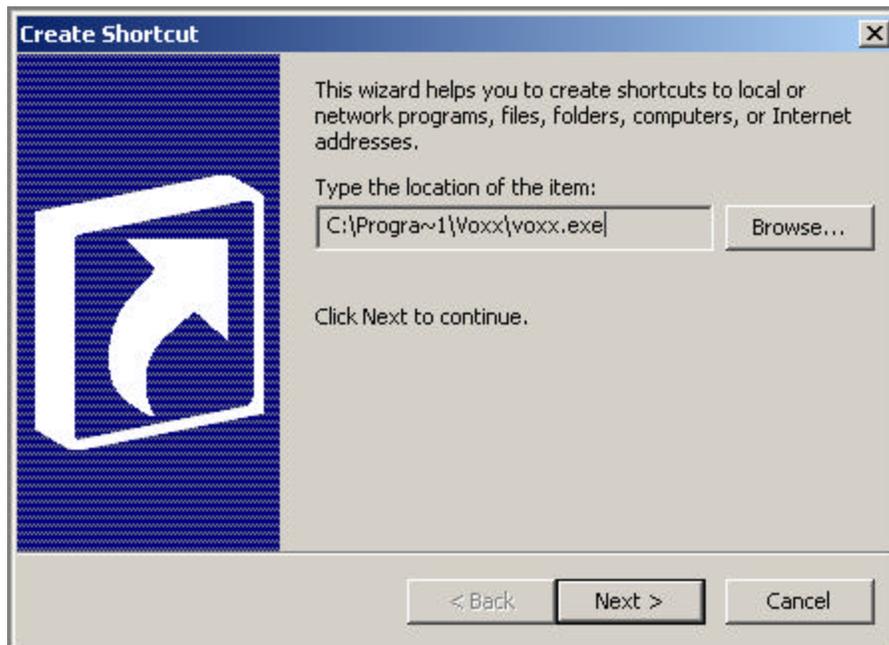
Next, enter the following in the "Type a name for this shortcut" field, then click on the Finish button: Voxx

Select a Title for the Program

Type a name for this shortcut:

Voxx

Click Finish to create the shortcut.

< Back | Finish | Cancel

Now position the cursor on the newly created shortcut/icon and click the right button on the mouse, then select the Properties command on the popup menu.

Voxx Properties

General | Shortcut | Security

Voxx

Target type: Application

Target location: Voxx4

Target: C:\Progra~1\voxx.exe   D:\Users\JohnSmith

☑ Run in separate memory space   ☐ Run as different user

Start in: D:\Users\JohnSmith

Shortcut key: None

Run: Normal window

Comment:

Find Target... | Change Icon...

OK | Cancel | Apply

If you include a drive\path in the Start In field and after the program
path\name in the Target field in the Properties dialog box, then the program
will use it as the default directory when looking for files to load/save. One
possible way to configure the Voxx shortcut(s) on multi-user PCs is to have each
user enter the path for their private/project subdirectory in the Target and
Start In fields in this dialog box.

One should not use a subdirectory in C:\Program Files as the default Voxx
directory on Windows 2000, because the default security settings for ordinary
users will prevent them from storing data (i.e. voxel, image, palette) files in
such subdirectories.

And assuming that you don't like Microsoft's default white-and-blue shortcut
icon, the final step is to click on the Change Icon button in the Properties
dialog box, then select a less unpleasant-looking icon for the Voxx shortcut.
Then click the OK buttons to close all of the dialog boxes.
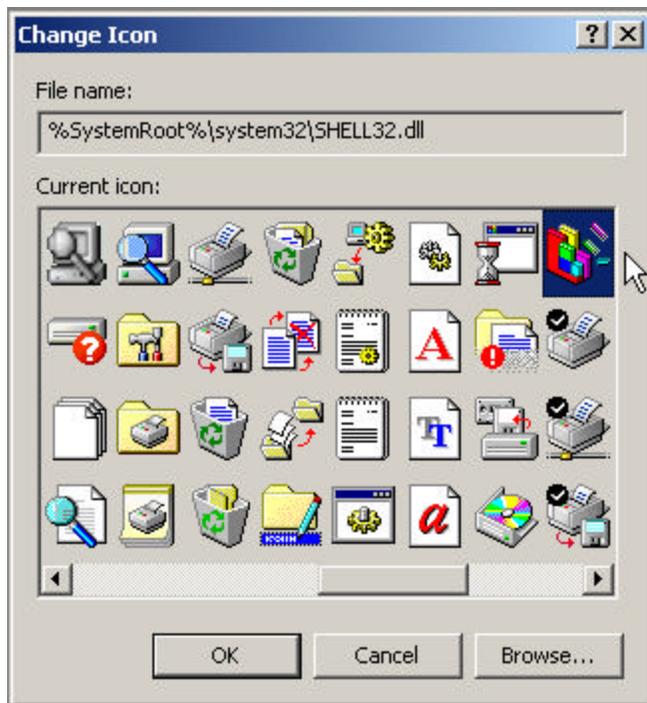
At this point, if you double-click on the shortcut/icon, a single empty black
Voxx window should appear on the screen.

2.4 Command-Line Options

It is possible to run the program from the DOS-style command-line shell, which
is still available on Windows 98/NT/2000. If you just type the program name, it
opens a window, then waits for you to select and load one or more voxel-palette
file pairs using the popup menus and dialog boxes. For example, the following
two commands would cause the program to initially look in the Voxx subdirectory
for voxel and palette files.

    cd C:\Progra~1\Voxx
    voxx

If you include one option on the command line, the program uses it as the
default directory when looking for files to load/save. So these commands would
cause the program to initially look for voxel and palette files in the JohnSmith
subdirectory.

    cd C:\Progra~1\Voxx
    voxx C:\Users\JohnSmith

You can also load between one and four 8-bit voxel-palette file pairs, or a
single 32-bit RGBA voxel file, from the command line. This is sometimes useful
when running demos using batch files. If you only provide filenames (i.e. no
numeric options), it assumes that you are loading Bio-Rad PIC voxel files and
text versions of RGBA palette files. You cannot load Zeiss LSM or TIFF files
from the command line. It loads ALL of the images in the voxel files. Here are
examples loading one-color, two-color, and three-color Bio-Rad image stacks.
Note that the choice of colors used in the palette files is completely arbitrary
- any pseudo-color palette will do.

    voxx vox1.pic red.map
    voxx vox1.pic red.map vox2.pic green.map
    voxx vox1.pic red.map vox2.pic green.map vox3.pic blue.map

If you include ANY numeric options after the filenames, the program assumes that
the voxel files are RAW (not Bio-Rad PIC) format, and you must specify all of
the information needed to load a voxel file: first image, last image, image
width and height (in pixels), and the byte offset to the images (i.e. header
size).

    voxx voxels palette first_image last_image width height offset

This example shows how to load 128 512x512 8-bit images from the middle of a
BioRad PIC file, starting with image 100:

    voxx voxels.pic palette.map 100 227 512 512 76

You can also load a 32-bit RGBA voxel array, but only as a RAW image stack,
which again requires all the numeric info. Here is an example that again loads
the middle 128 images, using 0 for the offset (i.e. no header):

    voxx voxels.raw 100 227 512 512 0

3 Main Window

The main window, which is the first window to appear when Voxx is run, is used to display two-dimensional projections of the three-dimensional voxel arrays. Pressing various keyboard keys, arrow keys, and mouse buttons while the cursor is inside the main window will enable/disable various editing commands which modify the appearance of the voxel arrays.
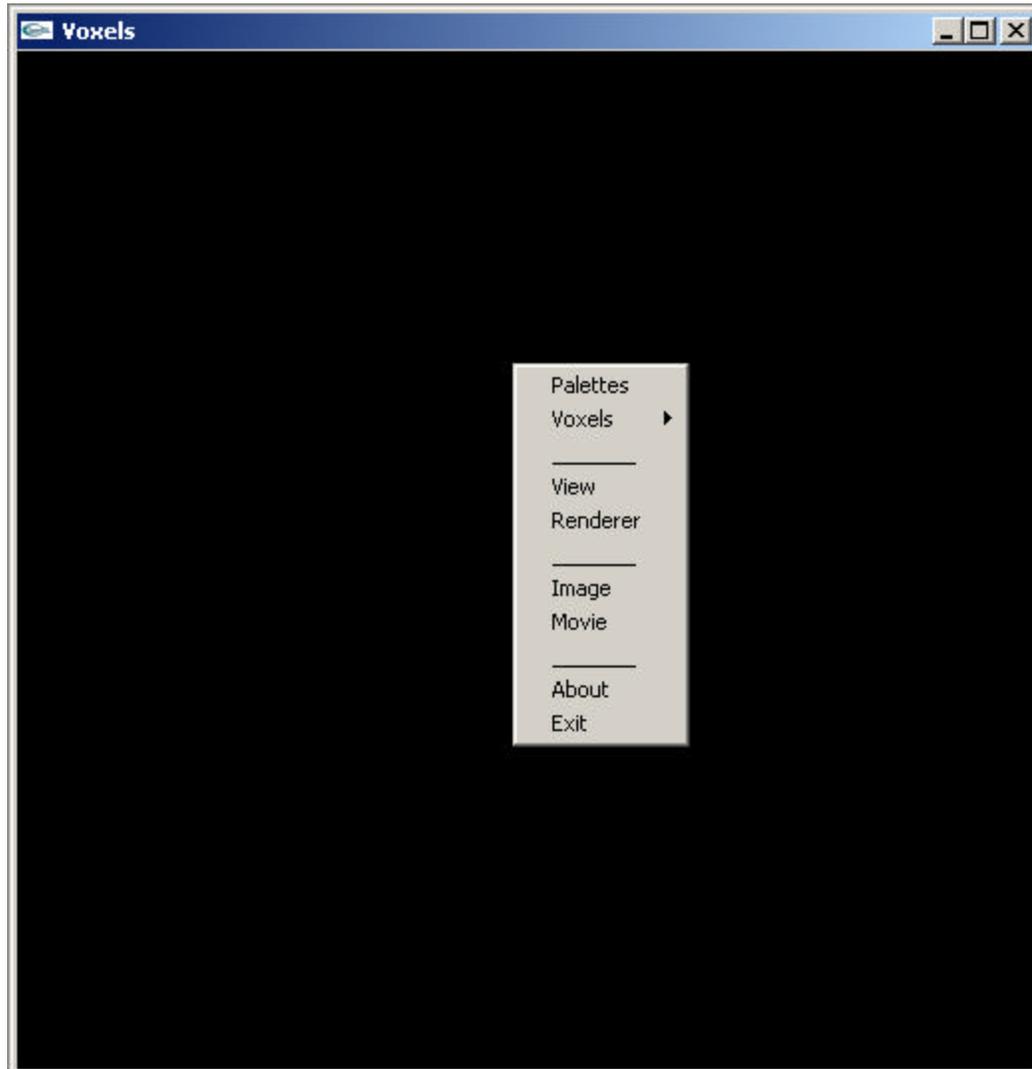
3.1 Mouse

If you use the mouse to position the cursor inside the main window, somewhere away from the title bar (which can be used to move the window) and the left/right/bottom borderlines (which can be used to resize the window), then click the RIGHT mouse button, a menu will appear which displays a set of command which affect this window.

If the main window is displaying voxel data, then moving the mouse while holding the LEFT mouse button down will rotate the voxel array. If the window does not contain any voxel data, then the left button does nothing. If you "push" the voxel arrays (by holding the left button down, moving the mouse slightly in the direction that you want the voxel array to rotate, then releasing the left button) – the voxel arrays can be made to continuously rotate.

3.1 Keyboard

The arrow keys on the keyboard can also be used to rotate the voxel arrays. The up/down arrows rotate the arrays around the x-axis, the left/right arrow keys rotate around the y-axis, and rotation around the z-axis can be performed by holding down the SHIFT key when using the arrow keys. There is no way to make the voxel arrays rotate continuously using the arrow keys, but the arrow keys do affect an already rotating voxel array.

Various "shortcut" keys are available on the keyboard which can be used to turn several of the most commonly used options or commands on/off without having to switch to another window or dialog box. All keyboard shortcuts use upper-case letters to turn options on, and lower-case to turn options off. For example, the F key turns a Frame rate display (in frames per second) option on, while f turns it off. The M key can be used to switch Maximum intensity projection mode on (which can also be done in the Renderer dialog box), or switch back to alpha blending via the m key. Other commonly used shortcut keys are the R, G, B, and A keys which enable editing of the red, green, blue, and alpha tables/graphs in the palette editor, while the r, g, b, and a keys disable editing (which is functionally equivalent to clicking on the Edit checkboxes in the Palette Editor window).

3.3 Menu

The popup menu in the main window contains the following commands: Palette, Voxels, View, Renderer, Image, Movie, About, and Exit. Each of these commands opens an additional window, most of which display additional information about the state of the program and its datasets.
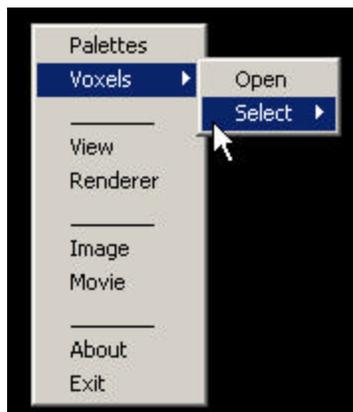
3.3.1 Voxels

The Voxels menu cotains commands and submenus which are used to select the voxel array(s) which will be selected and displayed in the main window. The menu contains one command (Open) and one submenu (Select).

Invoking the Open command will cause a File Open dialog box to appear on the screen. This dialog box is used to browse subdirectories and select one or more voxel data files to copy from the disk into memory. File formats currently supported are Bio-Rad PIC, Zeiss LSM, and "raw" voxel files. The code for TIFF files is still being debugged.

The Select submenu displays a list of the file names of all voxel arrays which have been loaded into memory. When you use the mouse to position the cursor on one of those filenames and click the left button on the mouse, that voxel array and its associated palette are "selected" for editing. Note that if you have the palette editor window open when you make such a selection, you will see the RGBA graphs and voxel intensity histogram switch to the current voxel arrays graphs. You can also select a voxel array by pressing a numeric key 1-9. You can always tell which voxel array/file is selected because the filename and array number are displayed in the title bar of the main window.

3.3.2 Close All

Invoking the Close All command will delete the voxel arrays and palettes currently in memory. This command must be invoked before you can load a new set of voxel and palette arrays.

3.3.3 View

Invoking the View command will cause the Viewport dialog box to appear on the screen. It contains user-editable parameters which control the position, size, and orientation of the voxel arrays displayed in the main window. It also permits users to change the size of the main window.

3.3.4 Renderer

Invoking the Renderer command will cause a dialog box to appear on the screen which contains user-editable parameters and user-selectable display options which control how the voxel arrays are rendered in the main window. Currently, the only user-selectable option is the Mode listbox, which permits users to select either Maximum Intensity Projection (Maximum) or back-to-front alpha blending (Emission) display modes.

3.3.5 Image

Invoking the Image command will record a "snapshot" of the image in the main window, then open a File Save dialog box to permit the user to store that Image in a file. Currently, supported output image file formats include 8-bit grayscale TIFF, 24-bit RGB TIFF, and "raw" (i.e. headerless) 8- or 24-bit pixel files.

3.3.6 Movie

Invoking the Movie command will cause a dialog box to appear on the screen which contains buttons which can be used to start/stop an image recorder and optionally store those images in image files. The command buttons are: Record, Play, Stop, Save, and Close.

3.3.7 About

The About command displays the version of Voxx and copyright information. The executable version (but not source code) of Voxx is currently made available by the developers only for non-commercial applications. If anyone is interested in commercial applications, contact us.

3.3.8 Exit

The Exit command shuts the program down. Note that clicking on the X button in the upper right corner of the title bar in ANY Voxx window also shuts the program down! Currently the program does not save any state information or user-defined preferences on exiting, but a future version probably will.

4 File Open/Save dialog

The File window can be used to load and save several different kinds of files, including: voxel arrays, palettes, movies, images, and settings. The window contain four subwindows or panels: directory/template, file name/type, file namelist, and details.
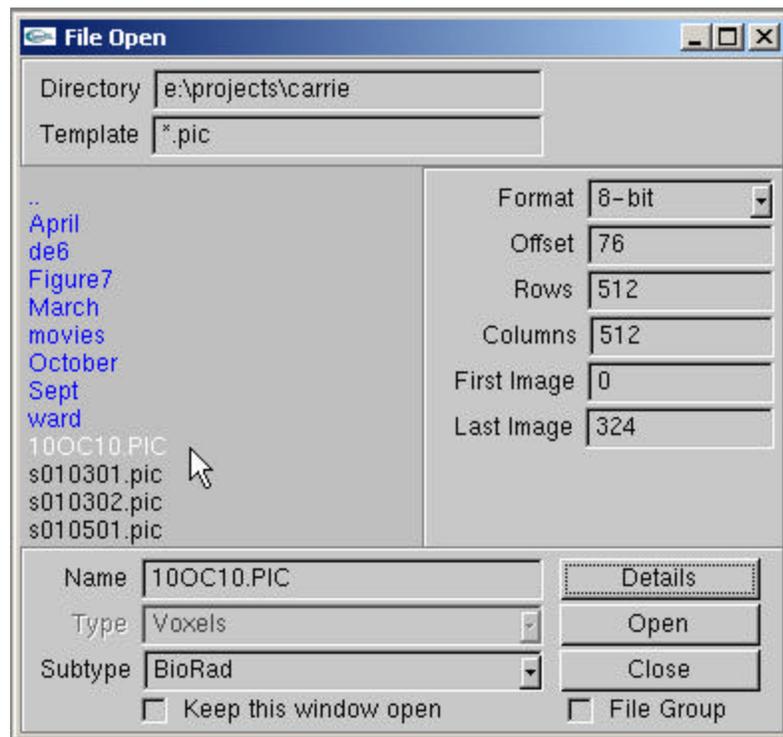
4.1 Directory/Template subwindow

The top subwindow controls the subdirectory and subset of files that will be displayed in the file namelist subwindow.

4.1.1 Directory

The user may type the path for a subdirectory from which files should be retrieved (e.g. \Users\JohnSmith), or click on subdirectory names in the file namelist subwindow. In order to switch to another disk drive, you must include the drive letter as a prefix on the path (e.g. D:\Users\JohnSmith).

BUG: There is a known bug in the File Open/Save code which occasionally causes it to not display the file namelist for subdirectories which have been previously viewed in the File Open/Save dialog box. The work-around for this is to change the directory path as follows: if there is no trailing backslash on the path (e.g. C:\Data), append a backslash to the path (C:\Data\), but if a trailing backslash is present, erase it. Then move the cursor outside of the Directory field (e.g. in the empty space to the right of the Directory field, in the namelist subwindow, etc.), then click the left button on the mouse. This forces to code to reload/display the file namelist.

4.1.2 Template

File name templates are used to specify the set of files located in the currently selected directory that will be displayed in the file namelist subwindow. Templates are also used to specify the sets of files that are to be transferred when a single File Open/Save command is invoked.

Sets of images are sometimes stored in a single file (e.g. voxel array (e.g. BioRad PIC), movie (AVI, MPEG, QuickTime), etc.), and sometimes stored in a set of image files (e.g. TIFF). If a file name contains any wildcard characters, then it is treated as a file name template, and it assumed that the images are stored (one image per file) in files that match the template.

The usual wildcard characters '?' and '*' may be used in templates to display a subset of the files contained in the current subdirectory in the file namelist subwindow. The question mark character matches any character, while the star character matches any sequence of characters. For example, "*.*" will display all the files in the currently selected directory, "*.tif" will display all files with tif extensions.

Voxx also used the '#' number sign as a wildcard character. The number sign character matches only digits 0-9. For example, when loading or saving a sequence of TIFF image files, "image###.tif" can be used to specify a numbered set of up to 1000 files (image000.tif through image999.tif). For example, when you invoke the File Save command in the movie dialog box, you will see that such a numbered template is used – "movies" are stored as numbered sets of TIFF files.

4.2 Name/Type subwindow

The bottom subwindow controls the type of files which are displayed in the file namelist subwindow, and shows the currently selected file name. The buttons in this subwindow can be used to load/display all or part of the data contained in the currently selected file.

4.2.1 Name

The name field contains the name of the currently selected file. The name may be selected clicking on a file name in the file namelist window, or directly typed by the user. If any wildcard characters "?*#" are included in the file name, it will be interpreted as a template and be automatically copied into the template field in the top subwindow.

If a file name does not contain any wildcard characters "?*#", then it is assumed that a set of images is contained in that file. But if the file name contains any wildcard characters, then it is it assumed that the images are stored (one image per file) in files that match the template.

4.2.2 Type

The type field contains a list of the types of files which the program can load/save: voxel arrays, palettes, movies, images, and settings.

A voxel array is a set of images, which may be stored in a single file or a set of numbered image files. They are intended to be displayed in 3D as a stack of

closely spaced parallel images. These are the raw data files exported by confocal microscopy systems.

Palette files contain color and/or opacity data which are used to control the appearance of voxel arrays.

Movies are sets of images stored in one of several common file formats (e.g. AVI, MPEG, QuickTime). They usually contain a sequence of images showing different views of the voxel arrays. Currently, the program doesn't support movie files – instead generating numbered TIFF files which can be imported into QuickTime Pro, Adobe Premiere, or other movie maker programs.

Image files (e.g. TIFF) are used to store a snapshot of a single view of the voxel arrays. Unlike movies, they contain only one image per file.

Session files contain the user-defined settings used by the program. This includes window position and sizes, scale factors, directory paths, etc. Session files are used to save the current state of the program, so that the next time a user runs it, everything is as the user left it when the program was last run. A session file (voxx.ini) is saved in the currently selected directory whenever the Exit command is invoked. It is recommented that each user run the program from their private/project directory, so each user's personal settings are preserved. Since the program automatically saves and reloads session files, users rarely need to manually load such a file using the File Open dialog (e.g. loading settings from a network file server, another user's settings, etc.).
...
Code supporting session files has not been implemented yet.

4.2.3 Subtype

The subtype field contains a list of the different kinds of each type of file which the program can load/save. For example, there are several different file formats used to store voxel arrays (e.g. BioRad PIC, Zeiss TIFF, etc.).

Many file subtypes have commonly used file extensions associated with them. So when a user selects a subtype, that extension is automatically copied into the template field in the top window, and is used to control which file names are displayed in the file namelist subwindow. For files which do not have a common extension, "*.*" is used. Users may replace the default file extension for any subtype by entering a template in the template field in the top subwindow or the file name field in the bottom subwindow. For example, TIFF image files commonly use "*.tif" for the file extension/template, but a user could change it to "*.tiff" or whatever.

4.2.4 Details Button/Panel

The details button may be used to display and sometimes change data which specifies the internal format of the currently selected file. It can be used both when loading and saving/creating files.   The kind of formatting information which is displayed, and which fields may be changed by the user, depends on which file subtype has been selected. Currently, details are only available for BioRad PIC and raw voxel files, plus TIFF and raw image files.

When the Details button is pressed, a pop-in panel appears on the right side of the namelist subwindow. When the button is pressed again, the panel disappears.

The formatting information displayed in most details panels includes: image
format (i.e. 8/24/32-bits per pixel), image size (i.e. number of rows and
columns of pixels), number of images, byte offset to the first image, and pixel
scale factors (e.g. dots/inch). Since the details are extracted from file
headers (without loading the entire file), a user can quickly examine key file
information merely by clicking on the file names in the namelist subwindow.

If the details panel is visible, then format options in the panel are used when
the File Open/Save command is invoked. But when the panel is not visible, the
program may choose to ignore certain user-modifiable panel settings when
appropriate. For example, the program will load all of the images in a voxel
file if the details panel is not visible. But if the panel is visible, it will
load only the image subset specified by the user using the "First Image" and
"Last Image" fields in the panel.

The file format field in the panel specifies the format of a voxel, image, or
movie file. The three main formats are 8-bits per pixel (for grayscale or
pseudo-color), 24-bits per pixel (for RGB true-color), and 32-bits (for RGBA =
RGB + opacity). These three formats are supported for images and movies, but
only the 8-bit and 32-bit formats are currently supported for voxel files.
Note also that when saving image and movie files, several other options appear
in the format list: 8-bit red, 8-bit green, 8-bit blue, 8-bit alpha, 24-bit RGB,
32-bit RGBA, etc. Images displayed on the screen use the 32-bit RGBA format,
but often users do not need/want 32-bits per pixel. For example, if the user is
displaying an 8-bit voxel array using a grayscale palette (i.e. R=G=B), then it
is only necessary to save one of the color channels. So the additional 8-bit
options permit the user to save any the 4 RGBA channels in a 4x smaller 8-bit
image file.

4.2.5 Open/Save buttons

Once a file name has bee selected, the Open button can be pressed to copy that
file from the disk file into memory. Pressing the Save button will copy the
image(s) from memory into the disk file. If the selected file name is a
template (i.e. contains any wildcard characters "*?#"), then all files that
match the template will be loaded/saved.

4.2.6 Close button

The close button will remove the File Open/Save dialog box from the screen.
Note that the file window will not appear on the taskbar.

4.2.7 Keep Open checkbox

The "Keep this window open" checkbox permits one to prevent the file dialog box
from automatically closing after pressing the Open/Save buttons. This can be
useful when loading multiple palette or voxel files. Note that the close button
does work even when this box is checked.

4.2.8 File Group checkbox

The "File group" checkbox can be used to load a set of files which have the same
name but different extensions (e.g. brain.pic, brain.map, brain.grd, etc.).
Currently it is only used when opening voxel files. When the box is checked,
the program will first try to load a (sometimes optional) palette file, then
load the voxel file(s). In the future, it will also try to load an optional 3D

gradient file which can be used for gradient-based shading. Voxel and palette
file pairs with different names can be loaded by leaving the box unchecked,
but the user must invoke the File Open command twice.

Note that this group loading scheme is also used (internally) to load RGBA
palettes which are split between an RGB and an alpha file (e.g. VoxBlast's *.pal
and *.opa files).

4.2.9 Overwrite checkbox

The "Overwrite" checkbox only appears when loading Palette files.
Ordinarily when you load a palette file, you are loading both a color (RGB)
table and an opacity or alpha (A) table from a single file. But not all palette
files contain both RGB and A. For example, palette files created by Adobe
Photoshop and many other imaging programs only store RGB in their palette files.
Similarly, some voxel programs such as VoxBlast, store a color table in one file
(*.pal) and its associated opacity table in another file (*.opa). The purpose
of the Overwrite option in Voxx is to permit you to replace or overwrite just
the color table or the opacity table of the currently selected palette with the
contents of an RGB-only or opacity-only file created by some other imaging
program. The most common approach is to use the New command in the Palette
Editor to create linear RGBA tables, then overwrite part of those tables using
the File Open command with the Overwrite option enabled. It is also sometimes
useful to keep your current color table while overwriting/viewing various
opacity tables, or vice versa.

4.3 File Namelist subwindow

The largest subwindow shows a scrollable list of subdirectory names (colored
blue) and file names contained in the selected directory which match a file name
template (colored black).

The list may be scrolled up and down by either using the up and down arrow keys
on the keyboard, or by holding down the left button on the mouse and sliding it
forward or backward. If you want to use the mouse to scroll up/down, make sure
that you position the cursor in the empty portion of the namelist subwindow to
the right of the file names before you press the left button.

A file name is selected by either releasing the left button after having
scrolled through the list, or positioning the cursor over a filename in the list
(with no buttons pressed) then clicking the left mouse button. The currently
selected file name is colored white. Clicking on a subdirectory name will
display the list of file names contained in that subdirectory. One can return
to the previous subdirectory by clicking on the double-dot ".." file name, which
is always present at the top of the scrollable list of file names (although you
may need to scroll the namelist up in order to see it).

5 Palette Editor

Palette files contain the color (24-bit RGB) and opacity (8-bit A) tables used
to control the appearance of voxel arrays. Each 8-bit voxel value is used as an
index into a 32-bit RGBA table, and it is these color and opacity values (not
the raw voxel intensities) that are used when rendering a voxel array.

Each 8-bit voxel array must have a color and opacity table associated with it.
You can either load an existing set of tables from palette files, or create new
tables using the palette editor. Note that a palette must be loaded/created
BEFORE you load its associated voxel array (otherwise, nothing will be displayed
in the main/voxel window). This is one of the most common mistakes that users
make when using Voxx – forgetting to load/create palettes before loading voxel
files. Also note that if you create the palette(s) after having loaded the
voxel array(s), the rendering process will misbehave (e.g. you will generally
see white boxes/rectangles appear and disappear while the voxel arrays are
rotating in the main window).

The palette editor window displays the contents of the color and opacity table,
and the intensity histogram of the currently selected voxel array/file as a set
of graphs. The intensity histogram is colored black. The graphs of the red,
green, and blue color tables are colored red, green, and blue. The graph for
the opacity table is colored white. There is also a vertical line cursor in the
window, which is also colored white.
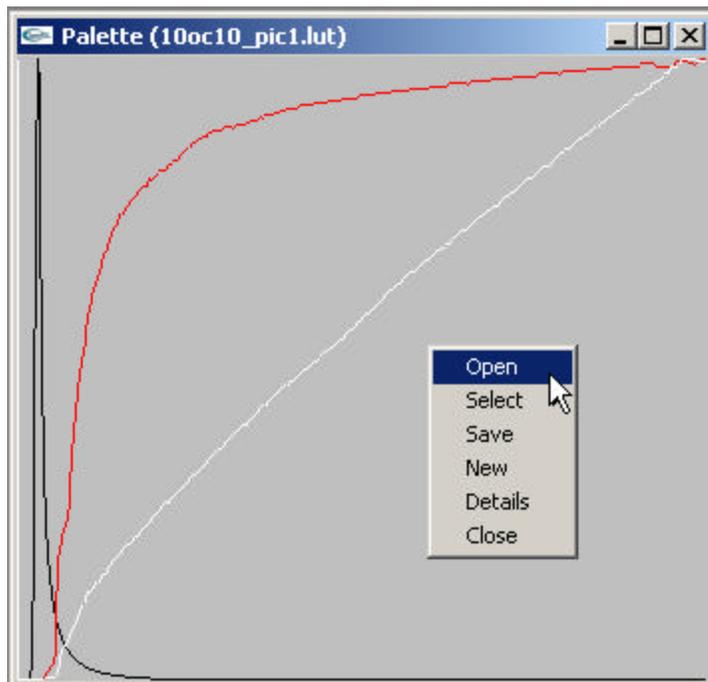
5.1 Mouse

If you use the mouse to position the cursor inside the palette editor window, somewhere away from the title bar (which can be used to move the window) and the left/right/bottom borderlines (which can be used to resize the window), then click the RIGHT mouse button, a menu will appear which displays a set of command which affect this window.

If the palette editor window contains graphs and editing is enabled, then moving the mouse while holding the LEFT mouse button down will change/redraw the portion of the currently selected graphs nearest the cursor. If the window does not contain any graphs, then the program will create a news set of graphs. If the SHIFT key is held down before the left button is pressed, the motion of the mouse will move the selected graphs up/down/left/right.

5.2 Keyboard

The up/down arrow keys on the keyboard can be used to modify the selected graphs when the SHIFT key is not pressed. If the arrow keys are used while the SHIFT key is pressed, the selected graphs will be moved up/down/left/right.

Various "shortcut" keys are available on the keyboard which can be used to turn several of the most commonly used palette editing options or commands on/off. All keyboard shortcuts use upper-case letters to turn options on, and lower-case to turn options off. For example, R, G, B, and A can be used to activate editing of the red, green, blue, and alpha graphs, respectively. The r, g, b, and a keys turn of editing of the red, green, blue, and alpha graphs. If the Details panels are visible, you will see the Edit checkboxes get checked/unchecked when these shortcut keys are used. The numeric keys 1-9 can be used to switch between up to 9 palettes.

5.3 Menu

The popup menu in the palette editor window contains the following commands: Open, Select, Save, New, Details, and Close. Each of these commands opens an additional window, most of which display additional information about the state of the program and its datasets.

5.3.1 Open

Selecting the Open command will cause a File Open dialog box to appear on the screen, which can be used to load one or more color+opacity tables from palette files.

5.3.2 Select

The Select submenu shows a list of the file names of all palette file which have been loaded into memory. The file name of the currently selected palette is displayed in the title bar of the palette editor window.

If more than one palette has been created or loaded from a file, then you can change the palette that is associated with the currently selected voxel array using either the Select submenu or the numeric keys 1-9 on the keyboard. You switch palettes merely by selecting a different filename in the Select submenu, or by pressing one of the numeric keys on the keyboard. After selecting a new palette, the appearance of the image in the Voxels window should change accordingly. You can always tell which palette is selected because the filename and palette number are displayed in the title bar of the palette window.

5.3.3 Save

Selecting the Save command will canse a File Save dialog box to appear on the screen, which can be used to store the currently selected color+opacity tables in a palette file.

5.3.4 New

Selecting the New command creates a new linear color+opacity table.
Linear tables are commonly used as the starting point when rendering using Maximum Intensity projections.

5.3.5 Details

Selecting the Details command will enable/disable the display of additional panels in the palette editor window, some of which display information about the color and opacity tables, voxel intensity histogram, or graph editor/display options.

5.3.6 Close

Selecting the Close command hides the palette editor window.
The window can be redisplayed by selecting the Palettes command in the menu in the Voxels window.

5.4 Details

The Details panels in the palette editor window display information about the color and opacity tables, voxel intensity histogram, and graph editor/display options.
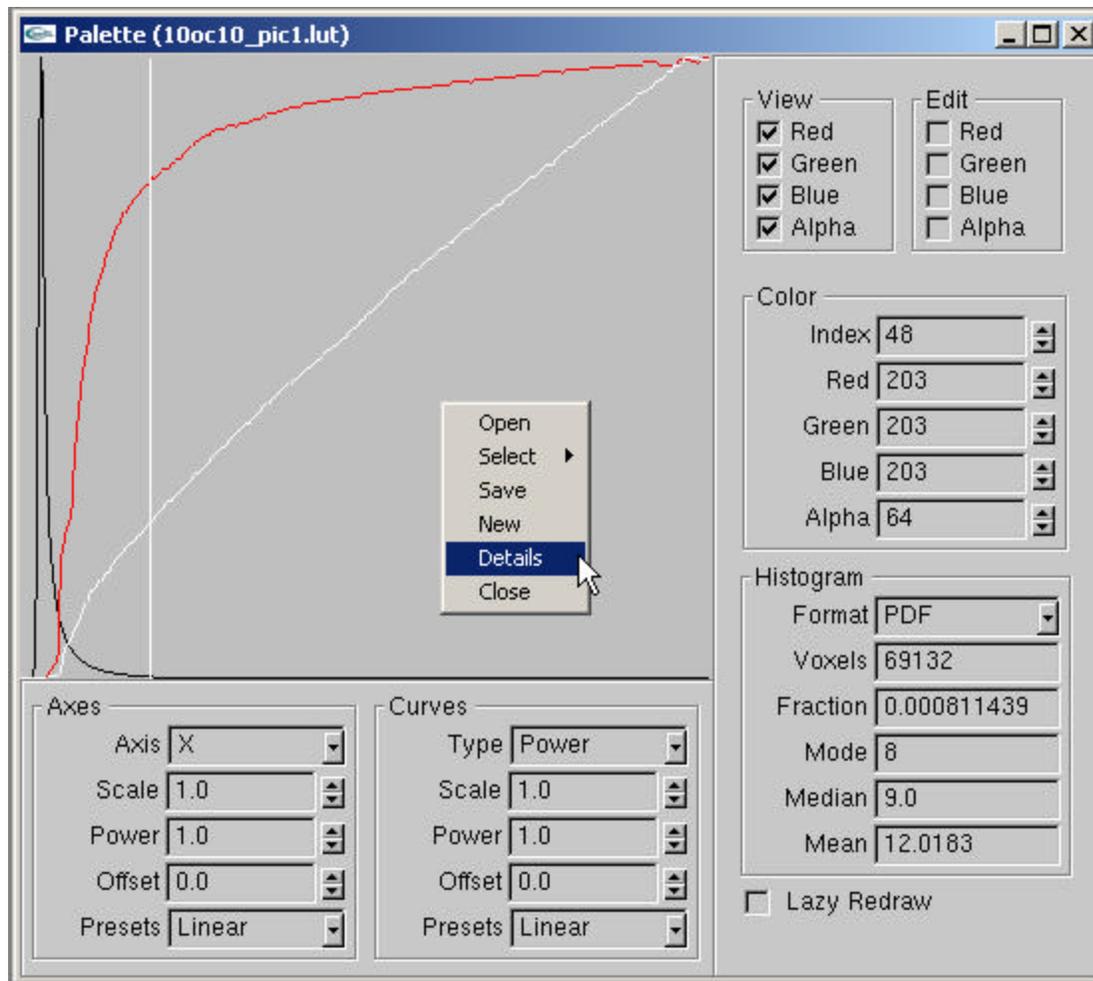
5.4.1 Axes panel

The X and Y coordinates used in the graphs can be scaled and offset as needed to improve the visibility of (e.g. small) features of interest in the voxel histogram. Power-law scaling can also be applied (instead of the default linear scaling), to approximate log or other nonlinear functions.

5.4.2 Curves panel

This power-law function generator lets one create reproducible RGBA curves.

5.4.3 View panel

The checkboxes in the View panel permit one to hide or display any combination of the color (RGB) and opacity or alpha (A) graphs.

5.4.4 Edit panel

The checkboxes in the Edit panel enable/disable the editing of the color (RGB) and opacity or alpha (A) graphs. These for checkboxes are usually the only items in the Details panels that many users change.

5.4.5 Color panel

The Color panel displays the color (RGB) and opacity or alpha (A) values at the specified table index. The position of the index is highlighted in the graph subwindow by a vertical white line/cursor. The line cursor is only active/movable when all of the checkboxes in the Edit panel are unchecked.

5.4.6 Histogram panel

The Histogram panel displays the number and proportion of voxels associated with each bin in the intensity histogram of the voxel array, along with various intensity statistics. It can also display cumulative histograms.

6 View dialog

Invoking the View command will cause the Viewport dialog box to appear on the
screen. It contains user-editable parameters which control the position, size,
and orientation of the voxel arrays displayed in the main window. It also
permits users to change the size of the main window.
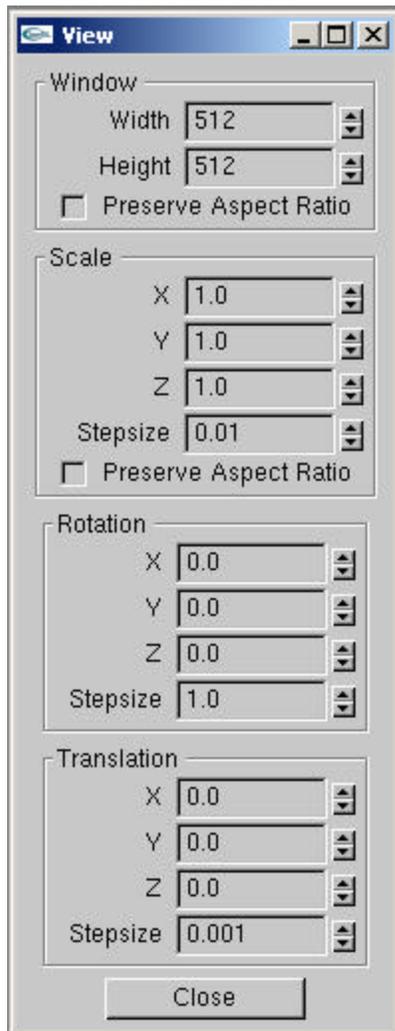
7 Movie dialog

Clicking on the Record button starts recording the viewpoint (i.e. position, orientation, and scale factors used to display the voxel arrays) in the main window. Note that it does NOT actually record the images seen in the window (which would require lots of memory and slow down rendering a lot), and it does not record changes made to the color and/or opacity tables during the recording session. Recording of color/opacity table changes will be added to a future version of the program.

Clicking on the Stop button will turn off the recorder. You then typically click on the Play button to review the recorded image sequence. If the sequence is not acceptable, merely click on the Record button again – which erases that sequence and begins recording a new sequence. If the sequence is acceptable, click on the Save button to open a File Save dialog box, which permits you to store the images in one or more image files. Currently, the program stores these "movies" as numbered sequences of 8-bit grayscale or 24-bit RGB TIFF files. These files can then be converted into real movie files (i.e. AVI, MPEG1, or QuickTime) using various movie making programs like Apple QuickTime Pro ($30), Adobe Premiere, etc.

In the near future, Voxx will be able to directly produce AVI, MPEG, and QT files, without the need for TIFF intermediate files or third-party movie making programs.

8 Renderer dialog

Invoking the Renderer command will cause a dialog box to appear on the screen which contains user-editable parameters and user-selectable display options which control how the voxel arrays are rendered in the main window. Currently, the only user-selectable option is the Mode listbox, which permits users to select either Maximum Intensity Projection (Maximum) or back-to-front alpha blending (Emission) display modes.
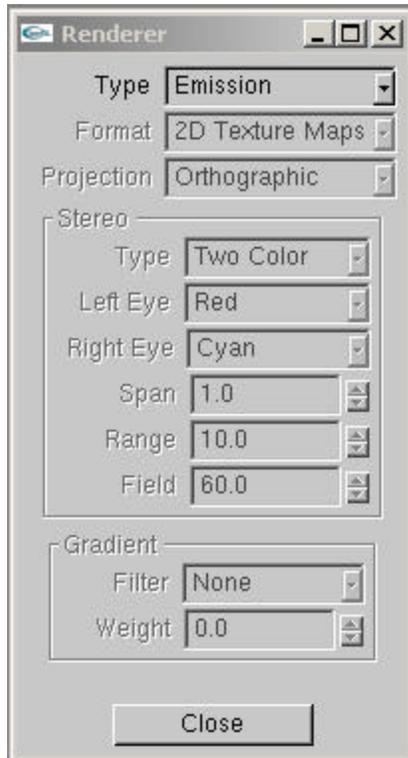
9 Example

Here is one step-by-step procedure to load a two-color sample dataset showing a dividing cell. You must load two (voxel, palette) file pairs: (tubgreen.pic, tubgreen.map), and (tubred.pic, tubred.map).

1) double-click on the Voxx icon on the desktop, to run the program,
2) position the cursor in the Voxels window, click the right mouse button,
3) select the Palettes command in the popup menu (by left clicking on it),
4) position the cursor in the Palettes window, click the right button,
5) select the Open command in the popup menu (by left clicking on it),
6) position cursor on "Keep this window open" checkbox, click left button,
7) position cursor on tubgreen.map in File window, click left button,
8) position cursor on the big Open button in File window, click left button,
9) position cursor on tubred.map in File window, click left button,
10) position cursor on the big Open button in File window, click left button,
11) position cursor in Voxel window (again), click right mouse button,
12) select Voxels in menu, then select Open in submenu, click left button,
13) position cursor on tubgre.pic in File window, click left button,
14) position cursor on the big Open button in File window, click left button,
15) position cursor on tubred.pic in File window, click left button,
16) position cursor on the big Open button in File window, click left button,
17) position cursor on big Close button in File window, click left button.
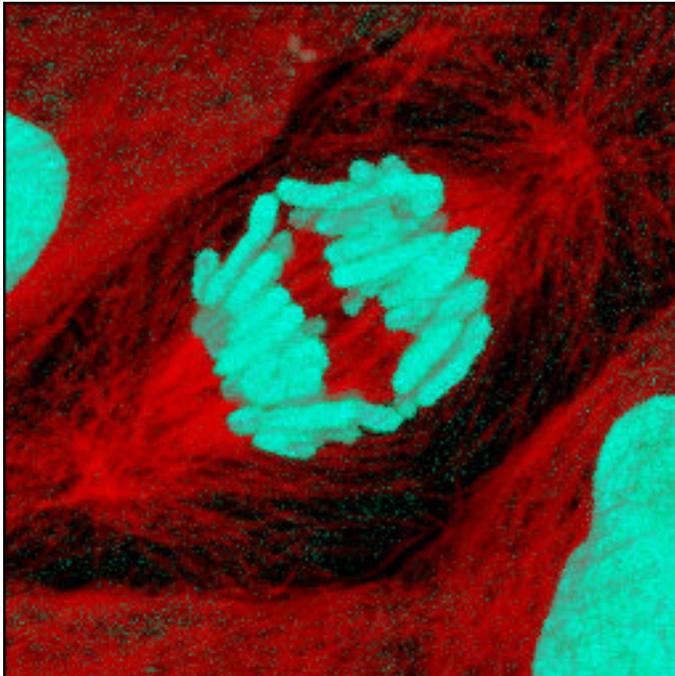
After you have loaded the files, the red-green voxel arrays should be displayed in the Voxels window. Next, position the cursor in that window (again), hold down the left button on the mouse, and then move the mouse – the voxel arrays should rotate as the mouse moves. Once you are finished inspecting the dataset, you can stop the program by left clicking on the X icon/button in the title bar of any Voxx window.

10 Bugs, Anomalies, and Common Mistakes

Voxx is built on top of OpenGL, GLUT, and GLUI function libraries – which makes
most of our software independent of the host window system and operating system.
However, this cross-platform programming environment is not quite perfect.
The implementation of GLUT for Windows behaves slightly differently than GLUT on
Unix or GLUT on MacOS, so there are a few behavioral differences that users must
put up with. There are also a few minor behavioral differences between these
GLUT-based programs and most other Windows-based programs. And there are also a
few known bugs in the current prerelease version of Voxx. Here are some of the
most common complaints/problems from users of the Windows version of Voxx:

You must remember to click inside a window or subwindow to select it – so that
subsequent keyboard key presses, mouse button clicks, and mouse movements will
be directed to the desired fields in the desired (sub)window. On Unix, this
(sub)window selection, or shifting of the program's "focus" from one (sub)window
to another, is done automatically as the cursor moves between (sub)windows –
with no clicking required.

If you want to type data in a field in a dialog box, the cursor needs to stay
within that field while you are typing. You must also remember to either press
the Enter key, or move the cursor outside of a dialog box field and then click
the left mouse button, after typing text or numeric data in a field in a dialog
box – otherwise the program doesn't know when you are finished entering the new
data. The voxel and palette windows do not get redrawn using such newly entered
data until after the enter keypress or mouse click. The easiest/quickest way to
tell the program that you are done typing data in a field in a dialog box is
often to shift the cursor a fraction of an inch outside of that field, but still
inside the dialog box, then click the left mouse button.

On Windows you must remember to not click on the X button on the title bar in
any of the Voxx windows, expecting it to close just that window. The X button
closes ALL of the Voxx windows then shuts down the program!

You must remember to depress the Shift and/or Alt keys BEFORE you press the
arrow keys, mouse buttons, or move the mouse – in order for the Shift/Alt
options in the main window and palette editor windows in Voxx to be activated.
Remember, they work just like the Caps Lock key – which also must be pressed
BEFORE you press a letter key if you want to produce an upper-case letter.

Make sure that none of the Voxx windows or dialog boxes overlap with the main
voxel display window – otherwise, the region of overlap will appear blank in
image and movie files.

It is recommended that you load palette files, or create new palettes, BEFORE
you load voxel files in Voxx. The program will automatically create linear
palettes if you don't load/create them, and you can later edit them or overwrite
them with other palette files, but a bug causes the rendering code to
occasionally misbehave.

The dimensions of the images in the voxel arrays must be powers of two
(256x256, 512x512, 256x512, etc.) if you are running Voxx on video boards which
do not use NVIDIA GeForce/Quadro chips, but the number of images in the stacks
does NOT need to be a power of two.