User's Guide

Software Release Version 5.0

John P. Strupp
Center for Magnetic Resonance Research
University of Minnesota Medical School
385 East River Road; Minneapolis, MN 55455

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1 Introduction

Stimulate is a GUI (Graphical User Interface) based fMRI (functional Magnetic Resonance Imaging) analysis software package. It offers a comprehensive set of fMRI analysis tools integrated into a single package that was designed for both convenient and flexible data processing. The user-friendly GUI allows the user to simply "point and click" with the mouse to modify analysis or display variables. Activation maps can be calculated from the fMRI data and overlayed onto aMRI (anatomic MRI) image displays.

PARAMETER MAP GENERATION

The primary processing step in fMRI is the generation of activation maps to identify areas of brain activity[1]. An activation map is a subset of the more general class of parameter maps. A parameter map is the resultant image of some temporal data reduction. The intensity value at each voxel of a parameter map is a parameterization of a feature of its time course. There are currently three analysis methods implemented for parameter map generation: 1) Student t-Test, 2) Cross-Correlation, and 3) Temporal Statistics.

Student t-Test: The student t-Test method for parameter map generation allows the user to specify multiple t-Tests consisting of multiple control and stimulation periods. There are two parameter options for the map: 1) confidence level, and 2) percent intensity change. The confidence level option simply gives the result of the specified student t-test. The percent intensity change option is used for activation maps. A voxel is considered active when it exceeds a confidence threshold for all t-tests specified. The percent intensity change is that of the average intensity of the stimulation periods versus the control periods.

Cross-Correlation: The cross-correlation method for parameter map generation uses a specified model for correlation against the intensity time course of each voxel in the functional image[2, 3]. Stimulate allows two ways to specify this model, one simply uses periods to specify a "box-car" function and the other uses an ascii file of a time course. The "box-car" model is specified by high and low periods corresponding to the experimental paradigm of control and stimulation periods, respectively. This model is not constrained to being a pure "box-car," but allows for the sides to have a finite slope. Three types of parameter maps can be generated: 1) correlation value, 2) time shift or 3) percent intensity change. All three parameter types are reported for the time shift where the maximum correlation coefficient occurs.

Temporal Statistics: The temporal statistics method for parameter map generation simply calculates either the mean, standard deviation, minimum or maximum intensity value over a specified set of periods. The standard deviation map is useful for localization of vessels[4], while the other parameter types are useful for determination of background threshold values.

IMAGE DISPLAY

There are three greyscale display modes: 1) stimulation, 2) anatomic, and 3) mask. In each display mode, the user selects the planar offset and number of images to display. An interactive LUT (Look-Up Table) tool is provided for dynamic contrast adjustments.

The stimulation mode displays the fMRI (e.g. BOLD or flow contrast) images used in parameter map generation. For the anatomic mode, an aMRI set of images, typically of higher spatial resolution and T1 weighted, can be displayed to facilitate landmark identification. The aMRI and fMRI images are automatically aligned if different resolutions were used during their acquisition. Images for the mask mode are generated through algorithms specified by image processing operations. There are over 20 operations available from the following categories: data, threshold, logical, arithmetic and morphologic.

Stimulate uses a psuedocolor overlay for superimposing parameter maps on top of the greyscale images. A color palette editor is provided to select or modify the parameter map overlays for both positive and negative activation. The overlay can be limited to those voxels whose activation value are within a floor (minimum) to ceiling (maximum) range. In addition, a minimum connected component count can be specified.

A movie tool enables the viewing of a mosaic of planar images in a cine loop. This is particularly effective in highlighting physiologic or subject motion artifacts. Individual mosaic movie frames can be saved in TIFF format for photographic quality hardcopy. The aMRI or fMRI image volume with imbedded activation maps can be saved in an isotropic BOB (Brick of Bytes) format for import into a volume rendering software package.

TIME COURSE PLOTTING / TEMPORAL FILTERING

Plots of the intensity time course can be displayed for those voxels identified by a ROI (Region of Interest). ROIs can be drawn using either a point, rectangle, or polygon mouse tool. A zoom feature enables the accurate specification of the ROI down to the distinguishable individual voxel level.

The user can choose to view the time courses of each individual ROI voxel or as an ensemble average.

The plot is displayed in a popup window which provides a copy of the ROI and image, plus a statistical summary of both the time course ensemble and the activation. The contents of the entire popup window can be spooled to a printer as a postscript file. In order to correct for physiologic noise or baseline drift, a temporal filtering module enables for the algorithmic signal processing of the time courses. Algorithm components includes Fourier filtering (low, high and band pass), arithmetic, statistical and mathematical morphology operations.

TALAIRACH COORDINATES

Stimulate provides a method for the localization of activation in Talairach space[5]. This is accomplished by use of an overlay grid and mouse position display. The user must first calibrate the coordinates by loading a set of cardinal views (transaxial, sagittal, coronal) images, followed by identification of the anterior and posterior commissure, mid-plane and brain bounding box. From these specified points, a transformation is computed which converts the laboratory frame coordinates to Talairach space.

2 Preliminaries

2.1 Citation

If you use Stimulate in your research, you are requested to provide an acknowledgement in your publications using the following citation:

> J. P. Strupp. **"Stimulate: A GUI based fMRI Analysis Software Package."** *NeuroImage*, 3(3):S607, June 1996.

2.2 Disclaimer of Warranty and Limits of Liability

Permission is granted to any research institution to use and copy this software so long as it is not sold or used for profit. The University of Minnesota makes no representations about the suitability of this software for any purpose. It is provided "as is" without express or implied warranty.

The University of Minnesota shall not be liable in any event for incidental or consequential damages in connection with, or arising out of, the furnishing, performance, or use of this documentation, the program Stimulate or any additional software provided with Stimulate.

2.3 Environment Variables

There are two environment variables used by stimulate:

- STIMULATE_HOST
- STIM_PRINTERS

Environment variables are set using the "setenv" UNIX command and are usually placed in the users ".cshrc" or ".login" file.

The STIMULATE_HOST environment variable is required to provide a 14 letter authorization string[1] to Stimulate for each host where it is run. The authorization string is an encryption of the host_id which is obtained with the UNIX command "hostid".

An alternate syntax of "STIMULATE_HOST_*hostname*," is allowed. The optional _*hostname* is normally replaced by the actual hostname of the corresponding host from which the host_id was obtained. This allows users to run Stimulate on multiple hosts as long as there is an authorization string for each one. For example:

setenv STIMULATE_HOST_*hostA* abcdefghijklmn
setenv STIMULATE_HOST_*hostB* zyxwvutsrqponm

The STIM_PRINTERS environment variable is an optional environment variable which provides a list of printer names for use with an Auto Print option discussed in Section 13. The names used must be postscript printers and be in the system printcap file (See your System Administrator). Multiple names must be separated by a colon in the environment variable. For example, to specify the two printers named "al" and "cmrr," the syntax would be:

setenv STIM_PRINTERS al:cmrr

2.4 Manual Conventions

Throughout this manual are figures which show Stimulate's graphical user interface. On each of these figures, the individual widgets or groups of widgets are indexed with a number. Whenever a widget is referenced in the text of this manual, the widget label will be **boldfaced and underlined**. In addition, the figure number and index number will be given in parentheses: (figure#-index#).

[1] Previously 26 letters long.

2.5 GUI Widget Conventions

A set of example GUI Widgets is shown in Figure 1. The **Integer Field** (1-1) is used for input of integers by either keyboard entry or clicking the up/down icons. The **Text/Float Field** (1-2) is used for input of alphanumeric text or floating point numbers. The **Popup** button (1-3) has a trailing three dots, ("..."), which signifies that a popup window will appear when pressed. Pressing an **Option** check box (1-5) will toggle the option on and off, as indicated by the presense or absence of a checkmark, respectively. A **Choice** (1-6) allows for a selection in a "Radio" button fashion. The **Menu** button (1-4) has a down icon which signifies that a menu will appear when pressed.

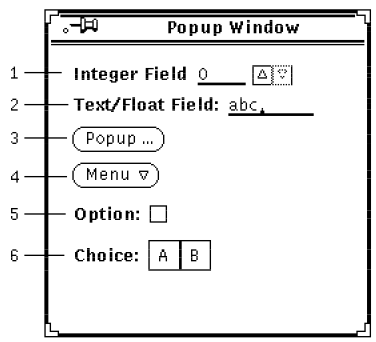

Figure 1: GUI widgets

2.6 Widget fonts

Stimulate uses the XView toolkit which was developed by SMI (Sun MicroSystems Inc) and thus when running Stimulate on a Sun workstation the default widget fonts are satisfactory. However, the SGI workstation default widget fonts are unacceptable and Stimulate will thus try to set them to "lucidasans-bold-8." This font is only available if the "X11 Optional Fonts" (i.e. x_eoe.sw.Xoptfonts) have been installed. Otherwise Stimulate will use the font "lucidasanstypewriter-bold-8," which gives a less than optimal appearance.

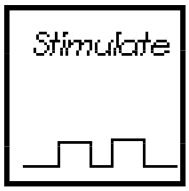

Figure 2: The Stimulate icon.

If you run Stimulate remotely from one workstation and display it locally on different type of workstation or on an Xterminal, the widget fonts may not be properly sized. To specify different widget fonts, they must be explicitly set by use of the "-xrm" switch when invoking Stimulate. To determine the new fontnames desired, use either of the two programs: "xlsfonts" or "xfontsel." Having selected new fontnames, for example "lucidasans-bold-8" and "lucidasans-medium-8," the syntax would be as follows:

```
stimulate -xrm OpenWindows.BoldFont:lucidasans-bold-8
          -xrm OpenWindows.RegularFont:lucidasans-medium-8
```

2.7 Program Invocation

To invoke the program, type "stimulate" at the prompt. Note that it is important to make sure to use a shelltool and not a commandtool. The latter tends to crash when its text buffer overflows. An icon will appear on the desktop as shown in Figure 2. Double click on the Icon to expand it to the Main Window (Figure 3). Stimulate prints out status messages during various processing stages in the shelltool from which it was launched. Thus it is desirable to arrange this shelltool such that at least the bottom portion is not obscured by Stimulate's main window.

2.8 Command Line Mode

Stimulate can be run in a command line mode to facilitate batch processing by use of option switch "-batch". The syntax for the command line mode can be displayed by using the option switch "-usage":

```
stimulate -usage

Usage: stimulate [-usage] [-verbose] [-batch stim.sdt file.xxx out.sdt]
       where xxx = { mp | pxc | txc | maskAlg }
```

Thus a shellscript can be written to generate activation maps on data collected using a standardize protocol. For example:

```
#! /bin/csh

set num = $1
stimulate -batch study{$num}.sdt verbal.mp verbalMap{$num}_mp.sdt
stimulate -batch study{$num}.sdt motor.pxc motorMap{$num}_pxc.sdt
stimulate -batch study{$num}.sdt combine.maskAlg comboMap{$num}.sdt
```

The "-verbose" option switch causes a multitude of messages to be printed to the screen and is intended only for use during debugging.

2.9 Stimulate Main Window

In Figure 3, the widgets on Stimulate's main window are grouped by functionality. See Table 1 for the section associated with each of these groups.

Group	Section	Title
1	3	File Load/Save
2	16	Talairach
3	15	Mask
4	17	Center of Mass
5	8	Look-Up Table
6	7	Display
7	13	Plot
8	11	Region of Interest
9	9	Parameter Maps
10	14	Movie Tool
11	10	Mouse Location

Table 1: Main Window Widgets functional groups versus sections

3 File Load/Save

Stimulate allows for loading and saving four types of images:

- Anat - a 3D high contrast, high resolution anatomical volume.

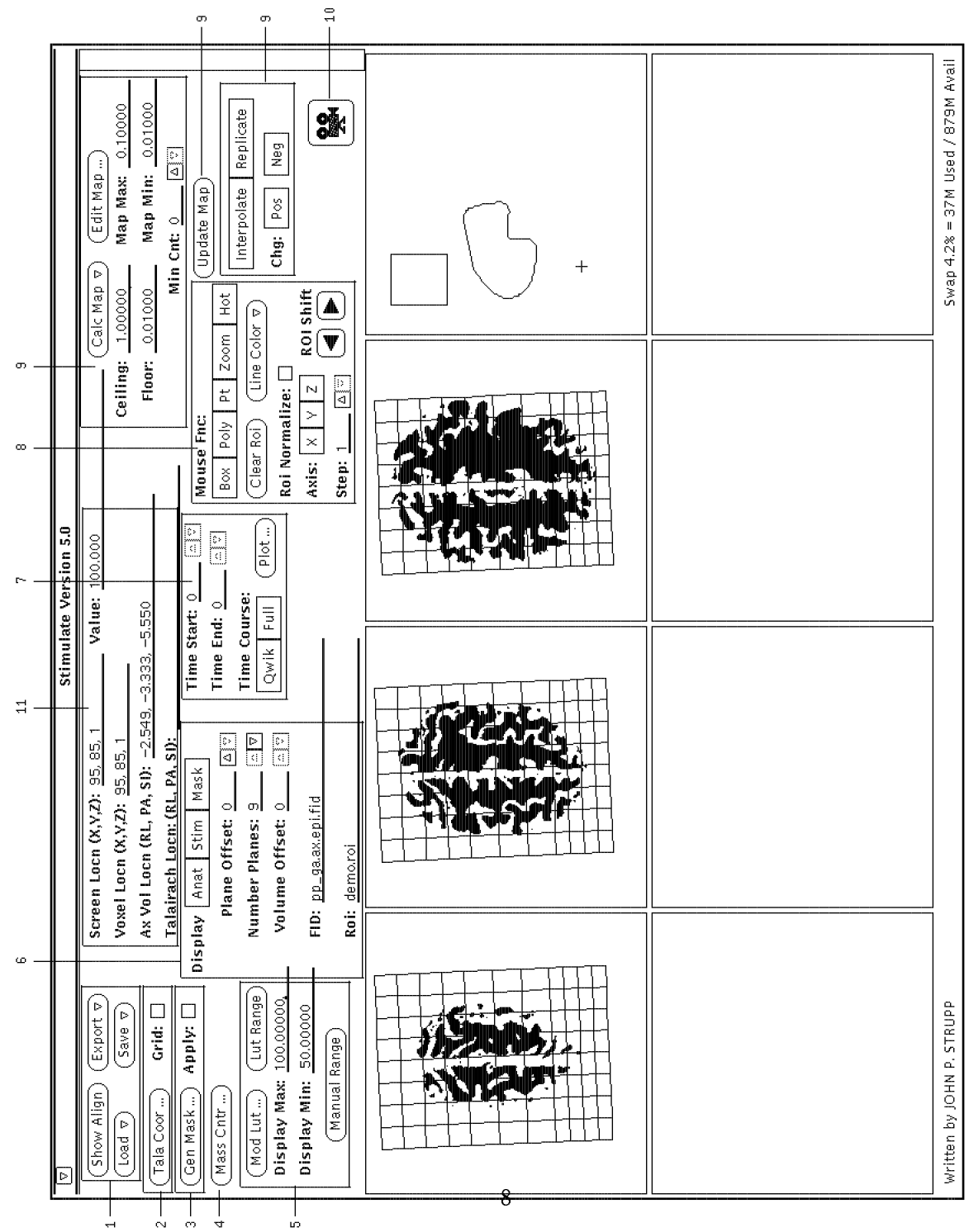

Figure 3: Main Window widgets functional groups.

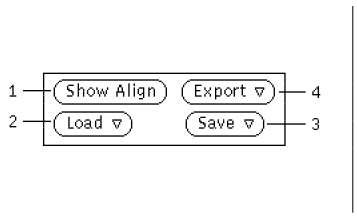

Figure 4: Main Window file input/output widgets.

- Stim - a 4D (3D spatial + 1D temporal) functional image volume set.
- Mask - a 4D (3D spatial + 1D process stage) image volume set.
- Map - a 3D parameter image (e.g. activation map).

Typically, the Anat images have high tissue contrast and high spatial resolution. The Anat and Stim images must be of the same orientation and have the same planar field of view. However, the Anat slice spacing can differ from that of the Stim as long as the slices are contiguous.[2] The current software version requires that the images have dimensions that are a power of two and that they have a centered field of view.

A subset of widgets on the Main Window (3-1) are used for file input/output as shown in Figure 4 with their corresponding pulldown menus shown in Figure 5. After a selection is made from one of the menus in Figure 5, a file browser will popup (See Section 5).

The "Roi" menu item under the **Save** button (5-2), will save a description of the current ROIs (See Section 11). The "Roi" menu item under the **Load** button (5-1) allows for subsequent retrieving of the ROIs. Note that when retrieving ROIs, the current ROIs will not be automatically cleared. If the the current ROIs have been cleared prior to loading a new set of ROIs, the file name will appear in the **Roi** field (14-6).

The "Grid" menu item under the **Save** button (5-2), will save the Talairach grid (See Section 16) as a ROI for subsequent loading as a ROI. This is useful for inclusion of the Talairach grid in a TIFF file (See Section 18.1).

[2]Non-consistent slice spacing is supported to a limited extent with fids, but is not encouraged.

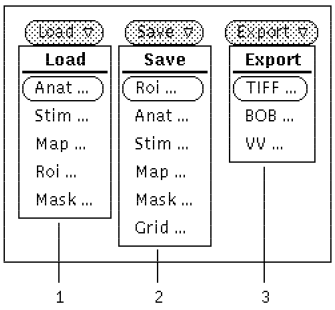

Figure 5: File input/output menus.

4 Alignment

Anat and stim images must have the same planar field of view and orientation, however, their slice spacing may differ. When the slice spacing does differ between the Anat and the Stim, the Map images generated from the Stim images will not be aligned to the Anat. To approximate the map values at the anat slices, linear interpolation between the nearest slice above and below are used to generate the color overlays. By pressing the **Show Align** button (4-1), an alignment report is printed out to the standard output (i.e. the shelltool window where stimulate was invoked).

An example of an alignment report is given in Figure 6. First the planar offset and corresponding slice position in centimeters is given for both the stim and anat images. Then the percentages used for the linear interpolation are given. For example, the anat image slice at offset 1 is located at 0.5 centimeters. There is no stim image slice located at this position. However, there is a stim image slice above and below it; specifically, stim offset of 1 at location 0.0 centimeters and stim offset of 2 at location 1.0 centimeters. To generate a map for this anat slice, 50% of the map intensity from the stim slice offset 1 and 50% of the map intensity from the stim slice offset 2 are used.

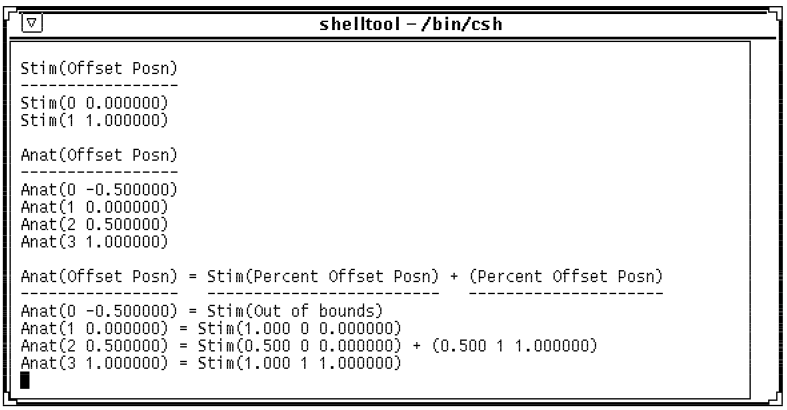

Figure 6: Example Alignment output.

5 File Browser

The file browser, as shown in Figure 7, is a general purpose popup window that is used for loading and saving files to disk.

The **Directory** (7-2) field specifies the current directory to be used to obtain a set of file and subdirectory names. The **Filter** (7-1) field is used to specify a subset pattern to limit which names are used in filling the scrolling list (7-5).

The filter specification can be one or more selection patterns to form a subset of file names from the current directory. Filter patterns are composed of combinations of the three special characters, star ('*'), question mark ('?') and slash ('/'), along with alphanumeric characters. The meaning of the special characters is given in Table 2.

*	star	Match any (zero or more) characters.
?	question mark	Match any single character.
/	slash	Match only directories (Must be last character).

Table 2: Filter pattern special characters.

Whenever an entry in the scrolling list is selected, the name appears in the **File** field (7-3). A trailing slash is appended to the names of subdirectories in the scrolling list. The current directory can be changed either by

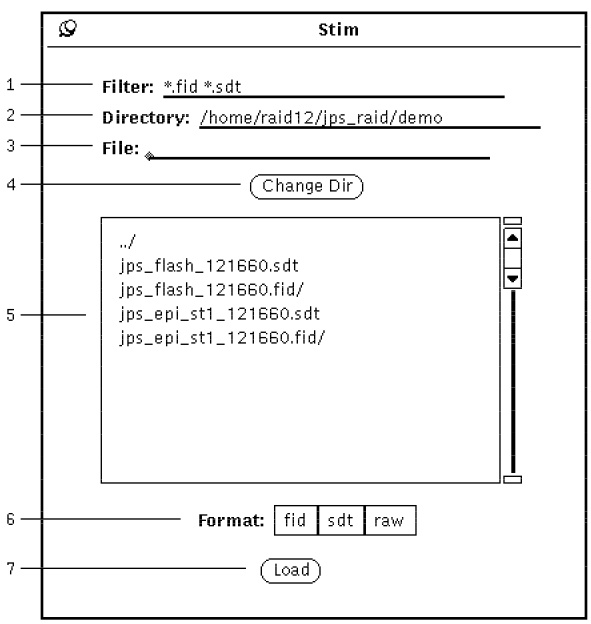

Figure 7: File Browser popup window

typing a new path in the Directory field and hitting the return key or by selecting a directory entry in the scrolling list and pressing the **Change Dir** button (7-4). Note that the parent directory, indicated by double dots with a slash ('../'), is always an entry in every directory listing.

Environment variables can also be used to specify directory names by prepending the variable name with a dollar sign (e.g. $PWD or $HOME). Custom environment variables can be specified with the UNIX command setenv. Any user's home directory can be specified by prepending that user's login name with a tilde (e.g. ~strupp).

Pressing the **Load/Save** button (7-7) will load or save the specified file as the case may be. One exception is when exporting an image using an **Export** menu (5-3) item and is detailed in Section 18. Another exception is when loading an image file, then pressing the **Load** button (7-7) will result in a second popup window being displayed dependent on the **Format** choice (7-6) selected. See Section 6 and Appendix A for a discussion about image file formats. When saving an image file, an additional choice of **Data Type** (not shown) is displayed with two options: "Real (4 Byte Float)" and "Word (2 Byte Short)." The "Word" data type results in a file that is half the size than that of "Real." To minimize the potential loss of intensity resolution, the image values are scaled to the full $\pm 2^{15}$ range.

6 Image File Load Options

As shown in Figure 7 there are three **Format** choices (7-5) available for loading image files.

- FID
- Sdt
- Raw

In the following subsections, the corresponding file load option popup windows for each format choice are discussed.

6.1 FID Load Option

For loading an image set with fid format[6], the options are shown in Figure 8. The fid can only have a single phase encode and must have the slcto or pss parameter set. The following is a list of steps for specifying options for the loading of an image with fid format:

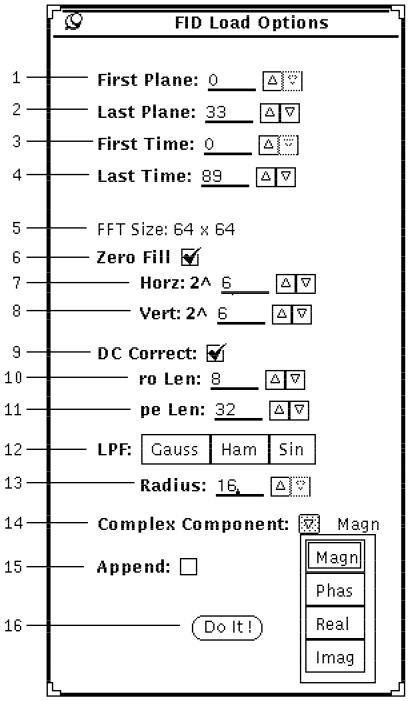

Figure 8: FID format options popup window

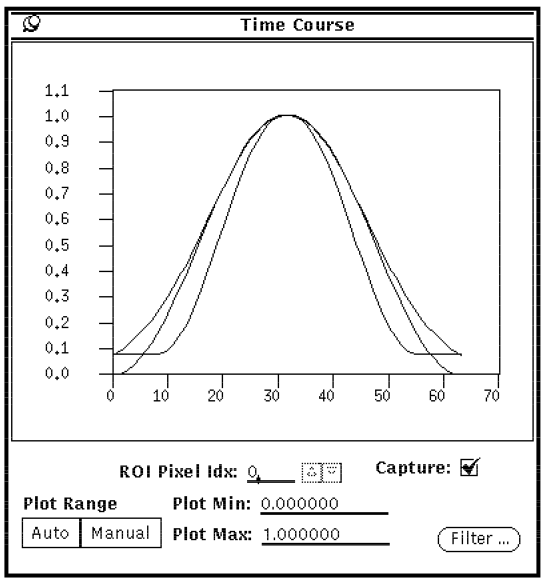

Figure 9: LPF 1D filter profiles

1. The first step in loading a fid image is to specify the spatial and temporal parameters. When the popup window comes up, the **First Plane** (8-1) and **Last Plane** (8-2) fields are set to the indices that yield the full spatial extent of the image volume. Thus the first plane is set to 0 and the last plane is set to the number of planes minus one. For stim files the temporal range is specified by the **First Time** (8-3) and **Last Time** (8-4) fields, and by default are set to yield the full temporal range. A subset of the data can be specified by modifying the planar and temporal range. As anat files are only 3D spatially, the last time field is not displayed, but the first time can be used to select a particular volume out of a 4D data set.

2. As fids require FFT processing, there are several processing options available. When the **Zero Fill** option (8-6) is selected, the fid can be buffered to any size that is a power of two in either or both of the **Horiz** (8-7) or **Vert** (8-8) planar dimension. The **FFT Size** (8-5) field displays the planar buffer size as it is modified.

3. When there is a DC offset in the fid data, the post-FFT image will exhibit a bright spot in the center of the image. Since the fid decays

to zero at the borders of the image, an effective correction method is to take an average of the fid tails and subtract this average from the entire pre-FFT image. By selecting the **DC Correct** option (8-9), the number of complex points along the read out direction (**ro Len** 8-10) and the phase encode (**pe Len** 8-11) direction for the tail average can be specified. An average complex value is calculated from points in each corner. Thus the average from these (4 x pe Len x ro Len) points is subtracted from every point in each planar image prior to the FFT.

4. If it is desired to reduce high frequency 2D spatial noise, a LPF (Low Passs Filter) can be used by selecting a **LPF** choice (8-12). Then prior to the FFT, the fid image is multiplied by the specified 2D filter. Examples of the LPF profiles are shown in Figure 9.

   The gaussian filter has a FWHM (Full Width - Half Maximum) equal to twice the radius specified in **Radius** field (8-13). The values, $g(n)$, of the gaussian filter are given for one dimension in Equation 1 for a $radius = r$ and an image width of N pixels.

$$g(n) = e^{\frac{(n-\frac{N}{2})^2}{-2N\sigma^2}} \quad n \in \{0, 1, 2 \ldots N-1\} \qquad \textit{where} \quad \sigma = \frac{-r^2}{2Nlog(0.5)} \tag{1}$$

   The values, $s(n)$, of the sinusoidal filter are given for one dimension in Equation 2 for a $radius = r$ (8-13) and an image width of N pixels.

$$s(n) = \begin{cases} cos(\frac{2x\pi}{r}) & \text{if } \mid x \mid \leq \frac{r}{2} \\ & \text{where } x = n - \frac{N-1}{2} \\ & \text{for } n \in \{0, 1, 2 \ldots N-1\}, \\ 0 & \textit{elsewhere} \end{cases} \tag{2}$$

   The values, $h(n)$, of the hamming filter are given for one dimension in Equation 3 for a $radius = r$ (8-13) and an image width of N pixels.

$$h(n) = \begin{cases} 0.54 - 0.46cos(\pi + \frac{2x\pi}{r}) & \text{if } \mid x \mid \leq \frac{r}{2} \\ & \text{where } x = n - \frac{N-1}{2} \\ & \text{for } n \in \{0, 1, 2 \ldots N-1\}, \\ 0.08 & \textit{elsewhere} \end{cases} \tag{3}$$

5. Normally the magnitude of the complex FFT result is desired. However, under certain experimental situations it may be desirable to use another complex component. The menu under the **Complex Component** button (8-14) allows the option of magnitude, phase, real or imaginary to be chosen.

6. When loading stim image files, the **Append** (8-15) option is available. When this option is selected, the image volume(s) specified for loading are appended across time to the currently loaded stimulation set of image volumes. Note that the new image volumes to be appended must have the same spatial dimensions as those currently loaded.

7. Lastly, when all the options are set, press the **Do It** button (8-16) to invoke the loading process. See Section 7 for the procedure to display the images.

6.2 Sdt Load Options

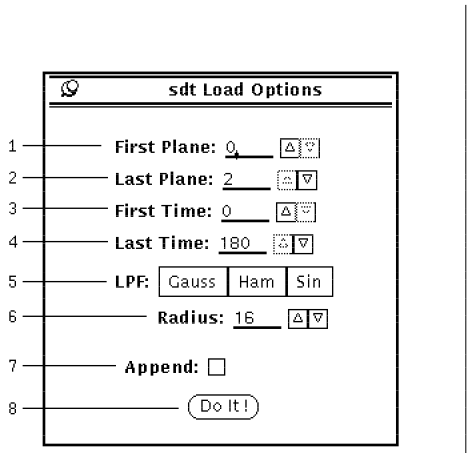

Figure 10: Sdt format options popup window

For loading an image set with sdt format, the options are shown in Figure 10. See Appendix A for a discussion on the sdt format. The following is a list of steps for specifying options for the loading of an image with sdt format:

1. The first step in loading a sdt image is to specify the spatial and temporal parameters. When the popup window comes up, the **First Plane** (10-1) and **Last Plane** (10-2) fields are set to the indices that yield the full spatial extent of the image volume. Thus the first plane is set to 0 and the last plane is set to the number of planes minus one. For stim files the temporal range is specified by the **First Time** (10-3) and **Last Time** (10-4) fields, and by default are set to yield the full temporal range. A subset of the data can be specified by modifying the planar and temporal range. As anat files are only 3D spatially, the last time field is not displayed, but the first time can be used to select a particular volume out of a 4D data set.

2. If it is desired to reduce high frequency 2D spatial noise, a LPF (Low Passs Filter) can be used by selecting a **LPF** choice (10-5). Then as each planar image is loaded, its inverse FFT is calculate. Then the resultant image is multiplied by the specified 2D filter, followed by a forward FFT. Examples of the LPF profiles are shown in Figure 9.

   The gaussian filter has a FWHM (Full Width - Half Maximum) equal to twice the radius specified in **Radius** field (10-6). The values, $g(n)$, of the gaussian filter are given for one dimension in Equation 1 for a $radius = r$ and an image width of N pixels.

   The values, $s(n)$, of the sinusoidal filter are given for one dimension in Equation 2 for a $radius = r$ (10-6) and an image width of N pixels.

   The values, $h(n)$, of the hamming filter are given for one dimension in Equation 3 for a $radius = r$ (10-6) and an image width of N pixels.

3. When loading stim image files, the **Append** (10-7) option is available. When this option is selected, the image volume(s) specified for loading are appended across time to the currently loaded stimulation set of image volumes. Note that the new image volumes to be appended must have the same spatial dimensions as those currently loaded.

4. Lastly, when all the options are set, press the **Do It** button (10-8) to invoke the loading process. See Section 7 for the procedure to display the images.

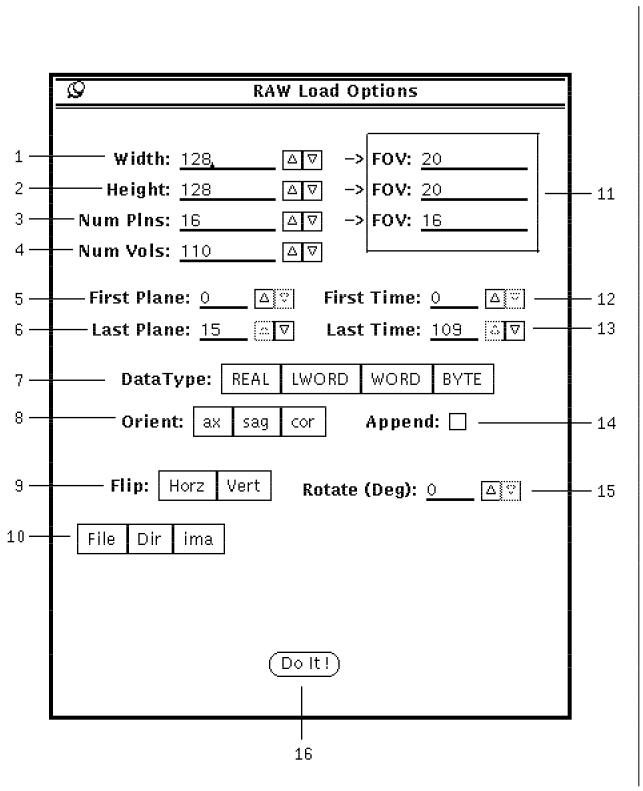

Figure 11: Raw format options popup window with "File" choice

6.3 RAW Load Option

For loading an image set with raw format, the options are shown in Figures 11, 12 and 13. There are three modes for loading a raw image set, dependent on whether the **File**, **Dir** or **ima** choice (11-10) is selected. For the File mode, the raw format is the same as the sdt format, except that it doesn't have a companion spr file. See Appendix A for a discussion of sdt format. For the Dir or ima modes, a set of sequentially numbered planar image files can be loaded to form a volume or set of volumes.

1. The first step in loading a raw image is to specify the spatial and temporal parameters. The **Width** (11-1), **Height** (11-2) and **Num Plns** (11-3) fields specify the horizontal, vertical and depth dimensions respectively, in units of pixels. For each of these spatial dimensions, the corresponding field of view must also be indicated (**FOV** 11-11).

Similarly, a value must be entered in the **Num Vols** field (11-4) to indicate the temporal extent of the data set. These fields must be set such that they yield the full spatial and temporal extent of the data.

2. If the entire data set is to be loaded, the spatial and temporal range must be set to the full extent. Thus the **First Plane** field (11-5) must be set to 0 and the **Last Plane** field (11-6) must be set to one less than the number of planes given in (11-3). Similarly the **First Time** field (11-12) must be set to 0 and the **Last Time** field (11-13) must be set to one less than the number of volumes given in (11-4).

   A subset of the data can be specified by modifying the planar and temporal range. The planar range is modified by setting the **First Plane** (11-5) and **Last Plane** (11-6) fields. For stim files the temporal range is specified by the **First Time** (11-12) and **Last Time** (11-13) fields. As anat files are only 3D spatially, the last time field is not displayed, but the first time can be used to select a particular volume out of a 4D data set.

3. When loading stim image files, the **Append** option (11-14) is available. When this option is selected, the image volume(s) specified for loading are appended across time to the currently loaded stimulation set of image volumes. Note that the new image volumes to be appended must have the same spatial dimensions as those currently loaded.

4. One of the **Data Type** choices (11-7) must be selected as described in Table 13. An orientation (See Table 5) must be specified for the data and can be set with the **Orient** choice (11-8). If the planar orientation of the images does not conform to one of the orientation choices, two options are available to flip and/or rotate the images about their centers. The **Flip** choice (11-9) allows for either a horizontal or vertical flip, and the **Rotate** (11-15) option allows for any arbitrary rotation. Note that if both options are specified, the flip is performed before the rotation.

5. When the **Dir** choice (11-10) is selected, there are five additional fields displayed as shown in Figure 12. The first field, **Header** (12-17) specifies the number of bytes, if any, at the beginning of each file that should be skipped prior to reading image data. The remaining four

fields specify the pattern for the names of the files to load. The pattern is composed of a file number preceded by the string specified by the **Prefix** (12-20) field and terminated by a dot (".") and the string specified by the **Extension** (12-21) field:

$$\{Prefix\}\{File\ Number\}.\{Extension\}$$

The file numbers are the inclusive sequential set between the **Start File Num** (12-18) and the **End File Num** (12-19) field values. Note that all leading zeros in the file number of a file name are ignored. For example, the file number strings "001" and "1" are equivalent. Table 3 gives a list of files that would be loaded for the values given in the fields of Figure 12.

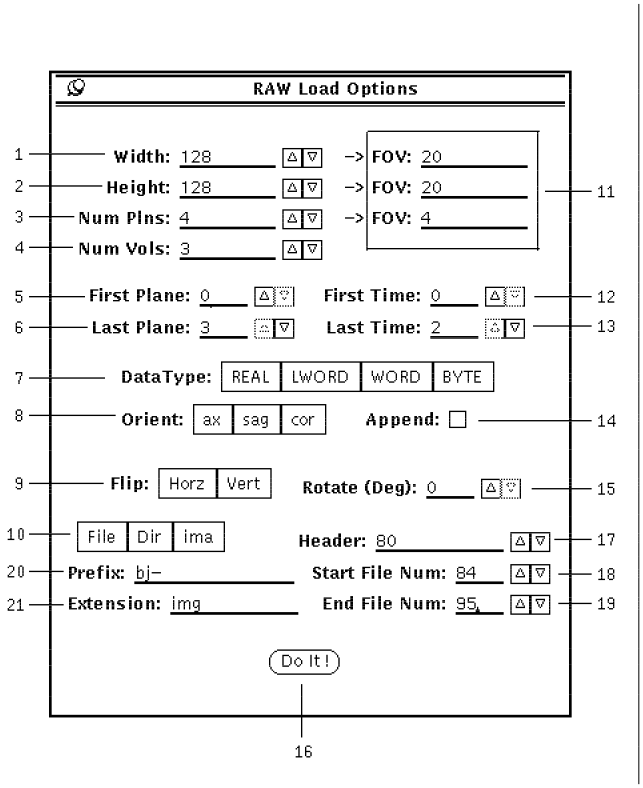

Figure 12: Raw format options popup window with "Dir" choice

Volume Index	Plane Index	File Name
0	0	bj-84.img
0	1	bj-85.img
0	2	bj-86.img
0	3	bj-87.img
1	0	bj-88.img
1	1	bj-89.img
1	2	bj-90.img
1	3	bj-91.img
2	0	bj-92.img
2	1	bj-93.img
2	2	bj-94.img
2	3	bj-95.img

Table 3: Example list of raw files for Dir mode.

6. When the **ima** choice (11-10) is selected, there are three additional fields displayed as shown in Figure 13. These three fields specify the first pattern of the names of the files to load. The pattern is composed of a the **Study ID** (13-17) field, the **First Volume ID** (13-18) field and the **First Image ID** (13-19) field. Each of these fields is separated by a dash "-" and the pattern is terminated by ".ima" to yield:

   {*Study ID*}-{*Volume ID*}-{*Image ID*}.*ima*

   The "Image ID" field is incremented by one for each file, and the "Volume ID" field is incremented by one after each **Num Plns** (13-3) files are loaded. Table 4 gives a list of files that would be loaded for the values given in the fields of Figure 13.

7. Lastly, when all the options are set, press the **Do It** button (11-16) to invoke the loading process. See Section 7 for the procedure to display the images.

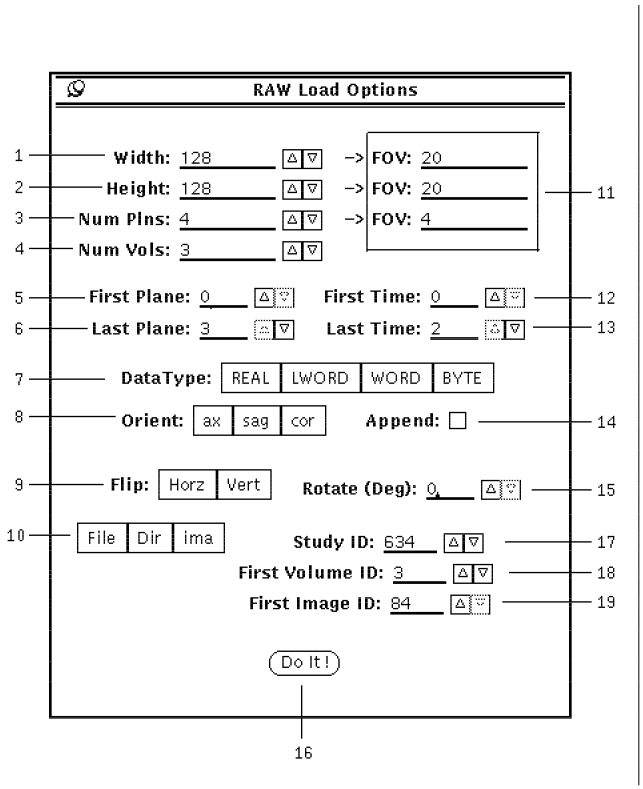

Figure 13: Raw format options popup window with "ima" choice

Volume Index	Plane Index	File Name
0	0	634-3-84.ima
0	1	634-3-85.ima
0	2	634-3-86.ima
0	3	634-3-87.ima
1	0	634-4-88.ima
1	1	634-4-89.ima
1	2	634-4-90.ima
1	3	634-4-91.ima
2	0	634-5-92.ima
2	1	634-5-93.ima
2	2	634-5-94.ima
2	3	634-5-95.ima

Table 4: Example list of raw files for ima mode.

7 Display

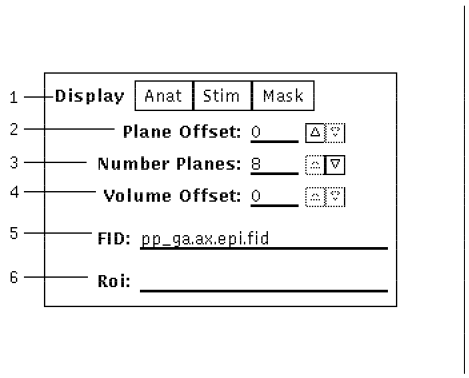

Figure 14: Main Window Display Widgets.

A subset of the widgets on the Main Window are used for controlling the display of images as shown in Figure 14. Once loaded, Anat, Stim and Mask planar images can be displayed in the eight image windows according to the **Display** choice (14-1). The greyscale contrast/brightness is controlled by the display range (See Section 8). Note that separate display ranges are maintained for each display choice. When a display choice is made, the file name is given in the **fid** field (14-5). The **Plane Offset** field (14-2) provides an index into the image volume to control which planar image is first displayed in the upper left hand image window. The subsequent number of images displayed across the row of image windows is controlled by the **Number Planes** field (14-3). The **Volume offset** field (14-4) provides a temporal index to the particular volume to display.

8 Look-Up Table

Stimulate stores images as an array of floating point numbers which must be mapped to greyscale "colors" for display. Most UNIX workstations can display 256 different colors simultaneously, of which usually about 160 are available for greyscale. By use of a Look-Up Table (LUT), image values are mapped to greyscale. The top of the LUT is initialized to white and the bottom to black, with greyscale linearly distributed in between. Image values are converted into integer LUT indices for display. The associated LUT controls are shown in Figure 15.

In order to convert the image values to LUT indices, **Display Max** (15-2) and **Display Min** (15-3) must be specified. The default values are ± 3 standard deviations from the mean image intensity. Image values that are below the Display Min are mapped to black and those above the Display Max are mapped to white. Intermediate values are linearly spread along the LUT address space. The Min or Max Display value can be changed by manual entry with the keyboard. However, for the LUT indices to be recalculated the **Manual Range** button (15-4) must be pressed.

Alternately, by pressing the **Mod LUT** button (15-1), the LUT mapping can be changed dynamically with the **Modify Lut** graphical tool as shown in Figure 16. The current mapping of greyscale can be seen in the color bar (16-2). This mapping can be modified by grabbing the LUT line (16-1) with the mouse and dragging it. The Lut line can be grabbed at either the top third, bottom third, or middle third to modify the display Max, Min or both, respectively. The original mapping can be restored by pressing the **Reset** button (16-3). Changing the mapping modifies only the LUT greyscale values. In order to recalculate the LUT indices, the **LUT Range** button (15-5) must be pressed.

Although greyscale is the most common LUT for displaying images in fMRI such that activation maps can be overlayed using color, other LUTs can be used. By pulling down the menu under the **LUT** button (16-4) eight other choices are available.

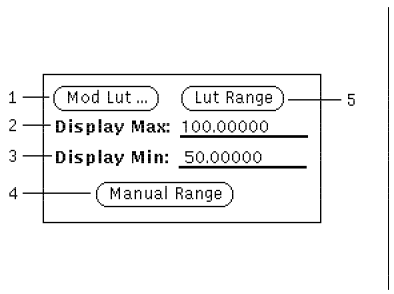

Figure 15: Main Window Look-Up Table widgets.

9 Parameter Maps

A subset of the widgets on the Main Window are used for generating and controlling the display of parameter map overlays as shown in Figure 17.

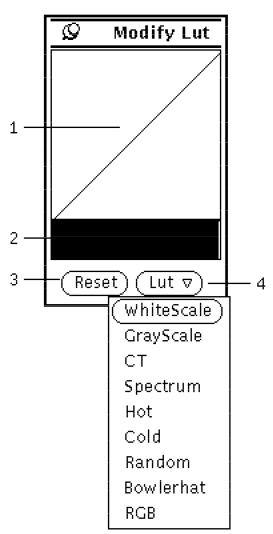

Figure 16: Modify Look-Up Table popup window.

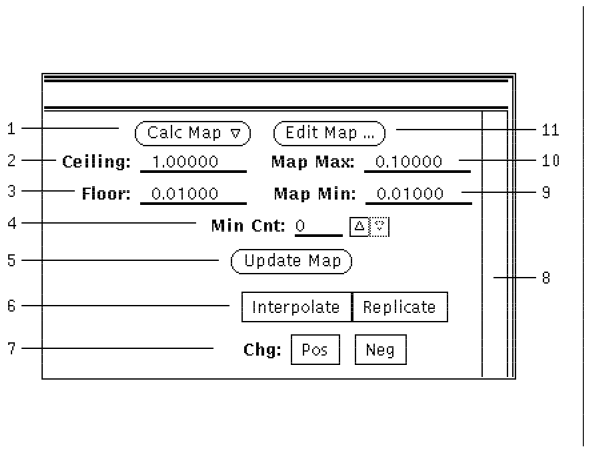

Figure 17: Main Window Map widgets.

Once a Map is generated (See Section 9.2) or loaded (See Section 3), it can be overlayed on the currently displayed anat or stim images.

9.1 Map Overlay

The overlay is limited to those voxels with map values that are within a **Floor** (17-3) to **Ceiling** (17-2) absolute value range. When the **Chg** field choices (17-7): Pos and/or Neg, are selected, the positive and/or negative map values are overlayed, respectively. To limit map values to those with high spatial consistency, a minimum connected component count can be specified in the **Min Cnt** field (17-4). Only those pixels whose value lies within the inclusive range, between the floor and ceiling are candidates for membership in a cluster. A pixel is deemed to be a member of a cluster based on 8-neighbor planar connectivity. Note that the count is performed on the map image resolution which is necessarily the same as the stim image resolution. The anat image resolution can differ and isolated groups of pixels below the min cnt may appear. This is especially true when the anat and stim images are not aligned (See Section 4).

The map is overlayed in color using the map LUT (Look-Up Table), shown in the color bar (17-8). The map range given by the **Map Max** (17-10) and **Map Min** (17-9) fields, are used for the display range with the overlay LUT. The LUT indices are calculated using the same method discussed in Section 8. One important difference is that the map range is

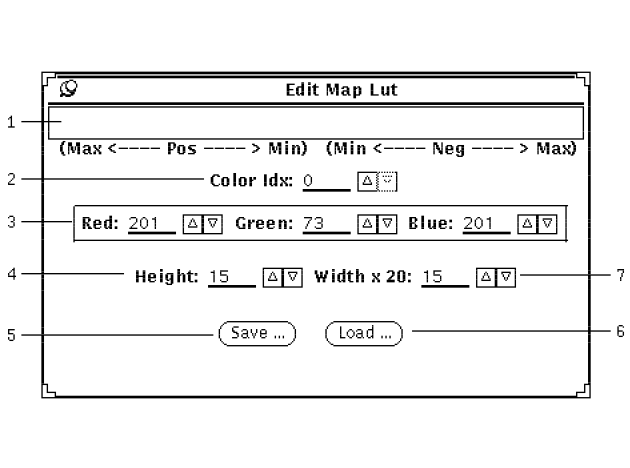

Figure 18: Edit Map LUT popup window.

used for the absolute value of the map values. The top half of the map LUT is used for positive values and bottom half for negative values. Whenever any change is made to the map display specification fields (i.e. 17-2,3,4,9 & 10), the **Update Map** button (17-5) must be pressed before the map is updated.

When the planar dimensions of the images are less than the fixed 256x256 image window size, they are resized to fill the window. Either linear interpolation or pixel replication can be specified by selecting the **Interpolate** or the **Replicate** choice (17-6). This is true for both the greyscale and the map overlays.

The default map LUT can be modified to personal preferences by pressing the **Edit Map** button (17-11) to popup the **Edit Map Lut** window as shown in Figure 18.

The color bar (18-1) shows the current map LUT. LUT entries are selected by either entering an index in the **Color Idx** field (18-2) or pressing the left mouse button over the a particular location on the color bar. The color is dynamically changed as its RGB values are modified in the **Red**, **Green** and **Blue** fields (18-3), The color bar can be saved as an indexed color TIFF file using the **Save** button (18-5). Map lut colors can be loaded with any indexed color TIFF file using the **Load** button (18-6). The TIFF image dimensions are **Height** (18-4) pixels tall by **Width** (18-7) times the number of lut colors pixels wide (i.e. $Height \times (Width \times 20)$).

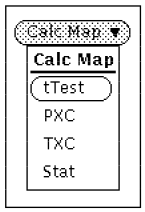

Figure 19: CalcMap pulldown menu.

9.2 Map Generation

There are four menu options under the **CalcMap** button (17-1) to select methods for calculating a parameter map as shown Figure 19.

- t-Test - Student's t Test
- PXC - Period Cross Correlation
- TXC - Time-course Cross Correlation
- STAT - Statistical

The following sections detail the procedures necessary to generate each type.

9.2.1 Student's t Test

A students t-Test is a statistic for measuring the significance of a difference of means between two distributions[7]. In conventional fMRI, the intensity of each voxel in an image is recorded temporally, a plot of which is referred to as its time course. During the experiment there are control (cntl) and stimulation (stim) periods. It is the set of intensity values during these periods that make up the distributions for the t-Test. The t-Test parameter popup window is shown in Figure 20.

1. The first step in calculating a t-Test map is to populate the **Time Course Periods** list (20-6). This is accomplished by entering a **Period Type** (20-7), **Start** time (20-8), **End** time (20-9), and then pressing **Add** (20-10). The **Change** (20-22) and **Delete** (20-23) buttons can be used for editing the currently selected period from the list (20-6).

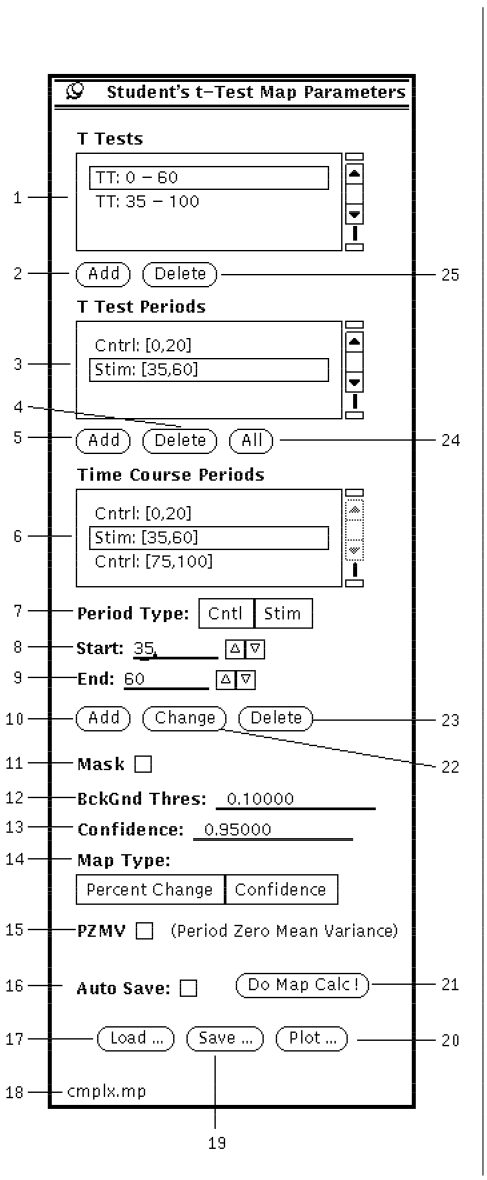

Figure 20: Student's t Test parameter popup window.

2. Then create a t-Test by pressing the **Add** button (20-2), which will make an entry in the **T Tests** list (20-1). Next an association must be made between particular periods to the currently selected t-Test. This is accomplished by selecting a period from list (20-6) and pressing the **Add** button (20-5). Or simply press the **All** button (20-24) to associate all the periods. The **Delete** button (20-4) can be used to remove an association. This procedure can be repeated if multiple t-tests are desired.

3. A graph of the time course periods can be displayed by pressing the **Plot** button (20-20). As shown in Figure 21, the lines at 1.0 show stimulation periods and the lines at -1.0 show control periods. Those periods which are associated to the currently selected t-Test have a second line at 1.5 and -1.5 for stimulation and control, respectively.

4. Next, one of two options can be specified to speed up the analysis by limiting which pixels are evaluated. If the **Mask** checkbox (20-11) is selected, the **BckGnd Thres** (20-12) is ignored and only those pixel locations with non-zero values in the currently loaded mask are evaluated. When the Mask option is not selected, then those pixels, whose cntl period mean value is below the BckGnd Thres value, are not evaluated.

5. Then specify the t-Test **Confidence** threshold (20-13). Only those pixels whose t-test result is above this threshold will pass and have non-zero map values. A value of zero is used in the map at pixel locations that are not evaluated or whose t-Test confidence value is less than the threshold. For multiple t-Tests, a pixels time course will be considered to have failed if it does not pass all of the specified t-Tests.

6. There are two **Map Type** (20-14) options which determine the non-zero values in the map. The **Confidence** option simply uses the t-Test confidence values. The **Percent Change** option calculates the ratio of the average intensity change between the control and stimulation periods as given in Equation 4.

$$\frac{\overline{stim} - \overline{cntl}}{\overline{cntl}} \tag{4}$$

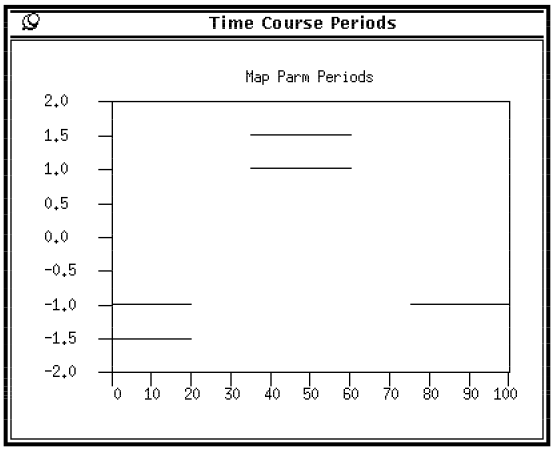

Figure 21: Plot of t-Test periods.

7. The **PZMV** (20-15) option stands for "Period Zero Mean Variance." and is useful when there exists a baseline drift in the time course and at least one distribution consists of more than one period. With the PZMV option, the calculation of the distribution variance is based on data where the period mean is subtracted from each point within its respective period.

8. Prior to calculating the t-Test map, the parameters must be saved to a file. Pressing the **Save** button (20-19) will popup the file browser (See Section 5). After the parameters are saved, the name of the file will appear in the lower left hand corner (20-18). When any parameter is changed the file name disappears since it is no longer consistent with the contents of the file. However, while a file name is displayed, the **AutoSave** option (20-16) can be selected. The AutoSave option will automatically save the parameters to the current file. The **Load** button (20-17) can be used to retrieve previously saved parameters.

9. Having all the parameters and options set, pressing the **Do Map Calc** button (20-21) invokes the calculation of the functional map. See Section 9.1 for the details on how to display the map.

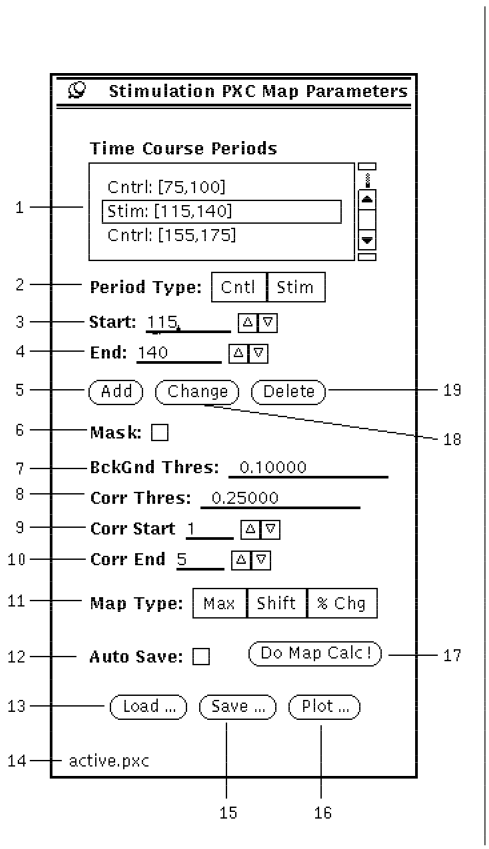

Figure 22: Period Cross Correlation Parameter popup window.

9.2.2 Period Cross Correlation

A Period Cross Correlation (PXC) gives a map as a measure of the correspondence of the shapes of a reference waveform and a functional time course[2], where the reference waveform is defined by periods. The reference waveform is nearly of "box-car" form, except that sloping sides may be specified. The PXC parameter popup window is shown in Figure 22.

1. The first step in calculating a PXC map is to populate the **Time Course Periods** list (22-1). This is accomplished by entering a **Period Type** (22-2), **Start** time (22-3), **End** time (22-4), and then pressing **Add** (22-5). The **Change** (22-18) and **Delete** (22-19) buttons can be used for editing the currently selected period from the

list.

2. A graph of the reference waveform can be displayed by pressing the **Plot** button (22-16). As shown in Figure 23, the lines at 1.0 show stimulation periods and the lines at 0.0 show control periods. Note that when there is a gap between a control and a stimulation period that the waveform is sloped.

3. Next, one of two options can be specified to speed up the analysis by limiting which pixels are evaluated. If the **Mask** checkbox (22-6) is selected, the **BckGnd Thres** (22-7) is ignored and only those pixel locations with non-zero values in the currently loaded mask are evaluated. When the Mask option is not selected, then those pixels, whose control period mean value is below the BckGnd Thres value, are not evaluated.

4. Then specify the **Corr Thres** (22-8). Only those pixels whose cross correlation is above this threshold will pass and have non-zero map values. A value of zero is used in the map at pixel locations that are not evaluated or whose cross correlation value is less than the threshold. For multiple cross correlations, a pixels time course will be considered to have passed if at least one passes.

5. When the reference waveform is shorter than the functional time course, multiple cross correlations can be calculated. Each of these multiple cross correlations are calculated with the reference waveform shifted in time by an offset. The offsets are specified by entering a value in the **Start** (22-9) and **End** (22-10) fields. Note that both of the offsets must be less than the difference of the lengths between the reference and functional time courses.

6. There are three **Map Type** choices (22-11). The **Max** choice results in the map that reflects the maximum correlation value over all of the shift offsets. The **Shift** choice results in the map that reflects the shift offset where the maximum correlation value occurs. The shift offset is expressed as a percentage of shift range per Equation 5.

$$\frac{1 + (t_{max} - t_{start})}{1 + (t_{end} - t_{start})} \tag{5}$$

The **% Chg** choice results in a map of the ratio of the average intensity change between the control and stimulation periods per Equation 4.

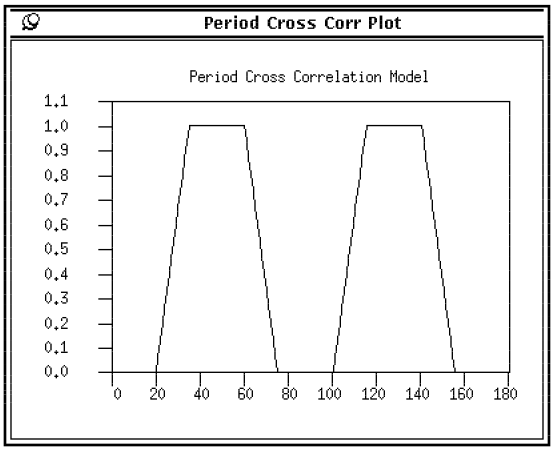

Figure 23: PXC reference waveform plot popup window.

7. Prior to calculating the correlation map, the parameters must be saved to a file. Pressing the **Save** button (22-15) will popup the file browser (See Section 5). After the parameters are saved, the name of the file will appear in the lower left hand corner (22-14). When any parameter is changed the file name disappears since it is no longer consistent with the contents of the file. However, while a file name is displayed, the **AutoSave** option (22-12) can be selected. The AutoSave option will automatically save the parameters to the current file. The **Load** button (22-13) can be used to retrieve previously save parameters.

8. Having all the parameters and options set, pressing the **Do Map Calc** button (22-17) invokes the calculation of the functional map. See Section 9.1 for the details on how to display the map.

9.2.3 Time-Course Cross Correlation

A Time-Course Cross Correlation (TXC) gives a map as a measure of the correspondence of the shapes of a reference waveform and a functional time course[2], where the reference waveform is specified as an ASCII file which contains one value per line. This allows any arbitrary reference waveform to be specified, such as poisson distribution[3] or an averaged time course (See Section 13, Button 30-5.) The TXC parameter popup window is shown in Figure 24.

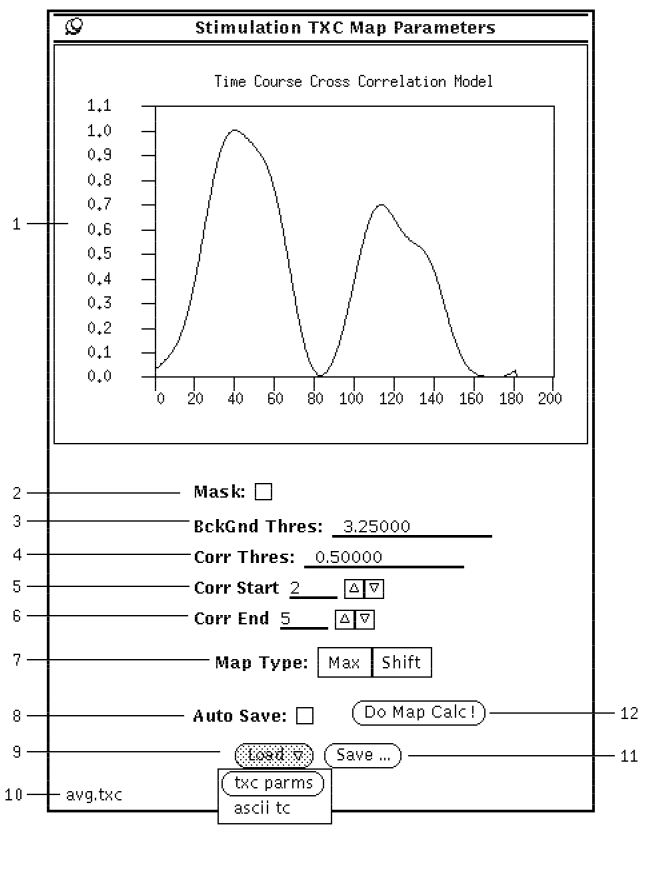

Figure 24: TXC Parameter popup window.

1. The first step in calculating a TXC map is to load a reference waveform as displayed (24-1). First, press the **Load** button (24-9) with the right mouse button to pull down the menu. Then select the "ascii tc" choice to popup the file browser and load an ASCII file with a ".asc" extension.

2. Next, one of two options can be specified to speed up the analysis by limiting which pixels are evaluated. If the **Mask** checkbox (24-2) is selected, the **BckGnd Thres** (24-3) is ignored and only those pixel locations with non-zero values in the currently loaded mask are evaluated. When the Mask option is not selected, then those pixels, whose time course mean value is below the BckGnd Thres value, are not evaluated.

3. Then specify the **Corr Thres** (24-4). Only those pixels whose cross correlation is above this threshold will pass and have non-zero map values. A value of zero is used in the map at pixel locations that are not evaluated or whose cross correlation value is less than the threshold. For multiple cross correlations, a pixels time course will be considered to have passed if at least one passes.

4. When the reference waveform is shorter than the functional time course, multiple cross correlations can be calculated. Each of these multiple cross correlations are calculated with the reference waveform shifted in time by an offset. The offsets are specified by entering a value in the **Start** (24-5) and **End** (24-6) fields. Note that both of the offsets must be less than the difference of the lengths between the reference and functional time courses.

5. There are two **Map Type** choices (24-7). The **Max** choice results in a map that reflects the maximum correlation value over all of the shift offsets. The **Shift** choice results in a map that reflects the shift offset where the maximum correlation value occurs. The shift offset is expressed as a percentage of shift range per Equation 5.

6. Prior to calculating the correlation map, the parameters must be saved to a file. Pressing the **Save** button (24-11) will popup the file browser (See Section 5). After the parameters are saved, the name of the file will appear in the lower left hand corner (24-10). When any parameter is changed the file name disappears since it is no longer consistent with the contents of the file. However, while a file name is displayed,

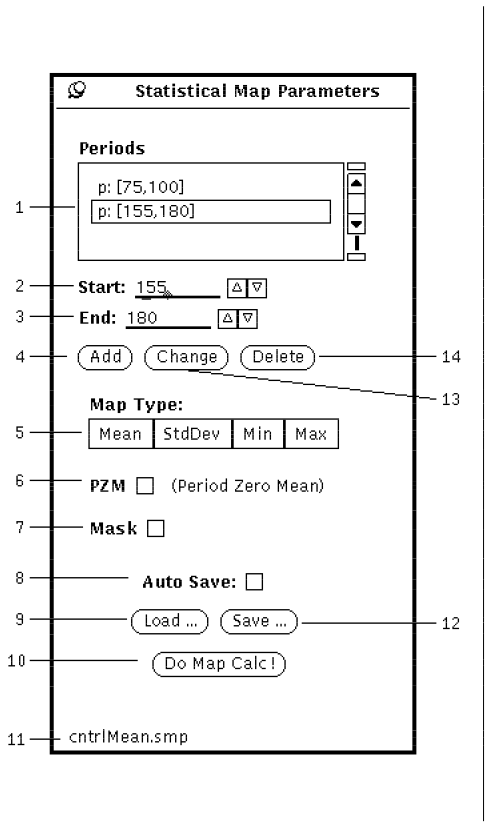

Figure 25: Statistical Parameter popup window.

the **AutoSave** option (24-8) can be selected. The AutoSave option will automatically save the parameters to the current file. The **Load** button (24-9) can be used to retrieve previously save parameters.

7. Having all the parameters and options set, pressing the **Do Map Calc** button (24-12) invokes the calculation of the functional map. See Section 9.1 for the details on how to display the map.

9.2.4 Statistical

A Statistical map gives a standard statistic of the functional time course over a specified set of periods. The Statistical parameter popup window is shown in Figure 25.

1. The first step in calculating a statistical map is to populate the **Periods** list (25-1). This is accomplished by first entering the **Start**(25-2) and **End** times (25-3), followed by pressing the **Add** (25-4) button. The **Change** (25-13) and **Delete** (25-14) buttons can be used for editing the currently selected period from the list.

2. There are four **Map Type** choices (25-5):

   - Mean
   - StdDev (Standard Deviation)
   - Min
   - Max

   The resulting map reflects the statistical value calculated over all the points within the specified periods.

3. The **PZM** (25-6) option stands for "Period Zero Mean," and is useful when there exists a baseline drift in the time course. With the PZMV option, the period mean is subtracted from each point within its respective period prior to the calculation of the statistic.

4. Next, the **Mask** option (25-7) can be selected to speed up the analysis by limiting which pixels are evaluated. When the mask option is selected only those pixel locations with non-zero values in the currently loaded mask are evaluated.

5. Prior to calculating the statistical map, the parameters must be saved to a file. Pressing the **Save** button (25-12) will popup the file browser (See Section 5). After the parameters are saved, the name of the file will appear in the lower left hand corner (25-11). When any parameter is changed the file name disappears since it is no longer consistent with the contents of the file. However, while a file name is displayed, the **AutoSave** option (25-8) can be selected. The AutoSave option will automatically save the parameters to the current file. The **Load** button (25-9) can be used to retrieve previously save parameters.

6. Having all the parameters and options set, pressing the **Do Map Calc** button (25-10) invokes the calculation of the statistical map. See Section 9.1 for the details on how to display the map.

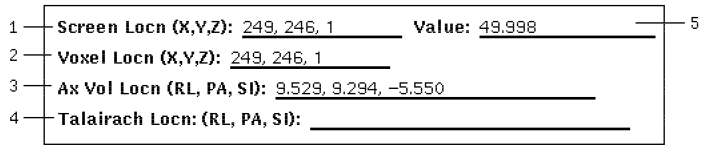

Figure 26: Mouse Location widgets.

10 Mouse Location

A subset of the widgets on the Main Window are used for displaying the location of the mouse as shown in Figure 26. When the mouse is moved over any of the image windows, its **Screen Location** (26-1) is given in pixel units of the 256x256 image window, and its **Voxel Location** (26-2) is given in voxel units of the image volume data. These locations are designated as (X,Y,Z) for Horizontal, Vertical and Plane, respectively. The greyscale intensity value of the pixel at this location is displayed in the **Value** field (26-5). When a map is being displayed, the map value is also given in parentheses.

The mouse location is also displayed in the **Vol Locn** (26-3) field using the "Field of View" coordinates. The anatomic relationship is dependent on the orientation[3] as given in Table 5. Starting at the upper left-hand corner of the image, the "→" indicates increasing horizontally from left to right, and vertically from top to bottom.

The **Talairach Locn** field (26-4) is a fourth display of the mouse location. See Section 16 for details.

11 Region of Interest

A subset of the widgets on the Main Window are used for creating and manipulating Regions of Interest (ROI) as shown in Figure 27. The **MouseFnc** choice (27-1) specifies three drawing modes: Box, Poly, Pt and a Hot and a Zoom mode (See Section 12). With the Box mode selected, the user can

[3]This is the convention typically preferred by Neuro-Scientists. An option to use the convention typically preferred by Radiologists is a planned future enhancement.

Orient	Horz	Vert	Pln
Sag	P → A	S → I	R → L
Ax	R → L	P → A	S → I
Cor	R → L	S → I	P → A

P	Posterior
A	Anterior
S	Superior
I	Inferior
R	Right
L	Left

Table 5: Anatomic orientation.

draw a rectangular ROI. To accomplish this, first move the mouse over one of the image windows and press the left mouse button to specify one corner of the ROI. Then drag the mouse to the desired diagonal second corner and release the mouse to complete the ROI. Similarly, to draw an arbitrary polygon, select Poly mode and drag the mouse to outline the ROI. Note that the polygon boundary will automatically be closed by connecting the location where the left mouse button was first pressed to where it was released. The third drawing mode, Pt, allows for specifying a single pixel location as indicate by a small crosshair where the left mouse button is first pressed. The current set of ROIs can be deleted by pressing the **Clear Roi** button (27-2). The default ROI color can be changed by selecting a color from the pulled down the menu under the **Line Color** button (27-7).

With the Hot mode selected, a plot of the timecourse under the cursor is dynamically displayed while the left mouse button is depressed. When the mouse button is released, a "Pt" roi is inserted at the current cursor position.

ROIs are based on a 256x256 coordinate system to match the fixed dimensions of the image canvases on the main window. Thus when a stim image with smaller dimensions is loaded there exists an ambiguity as to the precise ROI. By selecting the **Roi Normalize** option (27-3), the ROI is redrawn such that its path is restricted to the center of pixels at the resolution

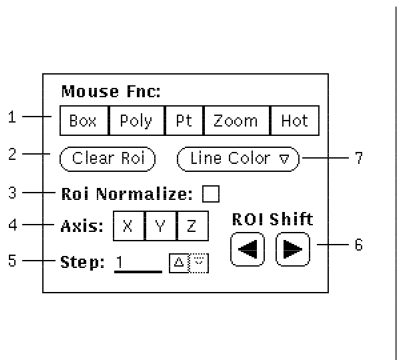

Figure 27: ROI Main Window widgets

of the image.

The **Roi Shift** buttons (27-6) allows for spatial shifting of the ROIs. The direction of the shift is specified by the **Axis** (27-4) choice, where X, Y and Z correspond to horizontal, vertical and planar motion, respectively. The magnitude of the shift is specified in pixels by the **Step** (27-5) field.

12 Zoom

The zoom mode (27-1) allows for expanding an image for detailed ROI drawing. When the zoom mode is selected, the image under the mouse when the left mouse button is pressed will be displayed in the **Zoom** popup window as shown in Figure 28. The image can be resized to any arbitrary power of two by changing the value in field 28-1. If the image is larger than the popup window, the scroll bars (28-3 & 28-5) can be used to move the viewing section (28-2). Alternatively, the entire popup window can be resized by pulling on the corner (28-4). With the Mouse in a drawing mode, ROIs can be drawn on the zoomed image. If an error is made, the zoomed ROI can be deleted by pressing the **Clear Roi** button (28-6). When a successful ROI is drawn, it can be transferred back to the original image window by pressing the **Xfer Roi** button (28-7). As the mouse is moved over the zoomed image, its location is displayed in field (28-8).

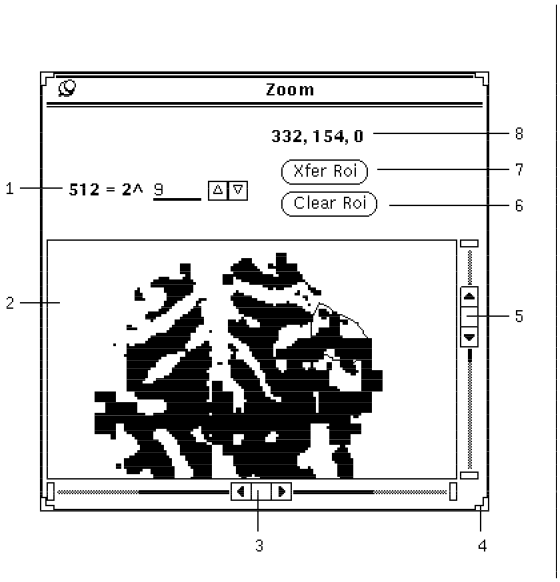

Figure 28: Zoom popup window

13 Plot

A subset of the widgets on the Main Window are used for graphing time course plots as shown in Figure 29. The **Time Start** (29-1) and **Time End** (29-2) fields specify the time period for the plot. When the **Plot** button (29-4) is pressed, either the Qwik (Figure 31) or Full (Figure 30) plot window pops up, dependent on which **Time Course** choice (29-3) is selected.

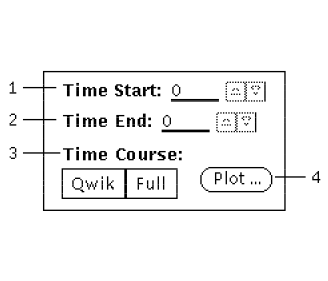

Figure 29: Time Course Plot widgets.

13.1 Full Plot

The Full plot graph (30-1) displays an average time course of the hot pixels in the current ROI when it first pops up. A pixel is considered to be *hot* when it has a map value overlayed on it. If no map is currently being displayed then all the pixels in the current ROI are considered to be hot. The thick bars on the bottom of the graph indicate the control and stimulation periods.

To illustrate where the time course came from, a mosaic of the greyscale images (30-2) and the map overlays (30-6) are provided. At the bottom of the popup window is a summary (30-3) which tells which files were used along with a variety of processing parameters and statistics as described in Table 6.

The **Save** button (30-5) has five options to save data from the popup window. The entire popup window can be saved as a postscript file by selecting the *PS plot* option. If a printer is selected from the **Auto Print** choice (30-4), the file is spooled to the printer when it is saved. The printer names are taken from the UNIX environment variable "STIM_PRINTERS" (See Section 2.3). If it has not been set, the default printer will be used. The summary can be saved to disk as an ascii file by selecting the *Stats* option. The single average time course or the entire ensemble of time courses can be saved in an ASCII file by selecting the *ASCII Avg TC* or *ASCII Raw TC*, respectively. The ensemble can also be save in a floating point sdt file using the *Sdt TC.*

13.2 Qwik Plot

The Qwik plot window (31-1) initially displays an average time course of the ensemble of time courses from hot pixels in the current ROI. By changing the **ROI Pixel Idx** (31-2) field, the user can sequence through the individual time courses of the ensemble that make up the average. The pixel location of the time course is displayed above the graph (31-8). The **Capture** (31-7) option allows for the plotting of multiple time courses simultaneously. The **Plot Range** option (31-3) allows for either the plot range to be determined automatically or to be fixed as manually entered in the **Plot Min** (31-6) and **Plot Max** (31-4) fields.

13.3 Temporal Filtering

Pressing the **Filter** button (31-5) displays the Filter popup window (Figure 32) for interactive filtering of the current time course. To filter a time

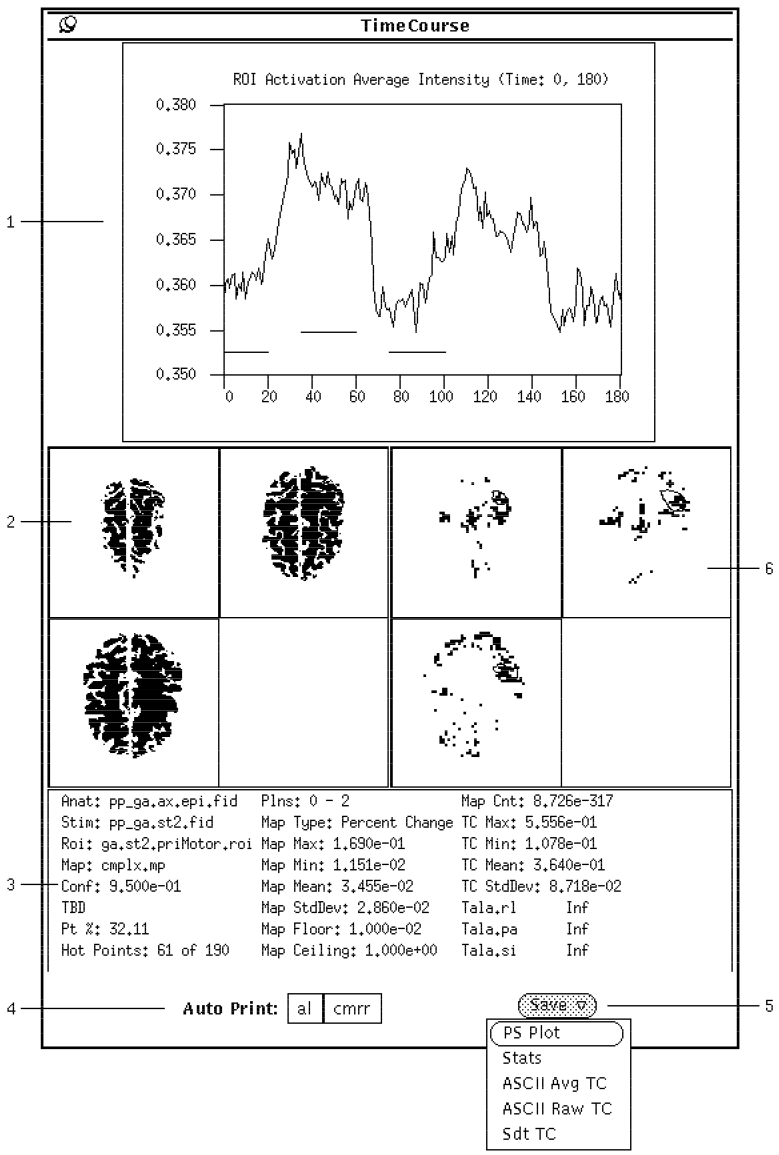

Figure 30: Full Time Course plot window.

Anat	Anat file name.
Stim	Stim file name.
Roi	Roi file name.
Map	Map file name.
Conf	Map confidence threshold.
Pt %	Percent of hot pixels in the ROI.
Hot Points	Number of hot pixels out of all ROI pixels.
Plns	Range of ROI planes.
Map Type	Type of map.
Map Max	Hot map values maximum.
Map Min	Hot map values minimum.
Map Mean	Hot map values mean.
Map StdDev	Hot map values σ
Map Floor	Map floor threshold.
Map Ceiling	Map ceiling threshold.
Map Cnt	Connected components threshold.
TC Max	Time course ensemble intensity maximum.
TC Min	Time course ensemble intensity minimum.
TC Mean	Time course ensemble intensity mean.
TC StdDev	Time course ensemble intensity σ.
Tala.rl	Right-Left Talairach Hot center of mass.
Tala.pa	Posterior-Anterior Talairach Hot center of mass.
Tala.si	Superior-Inferior Talairach Hot center of mass.

Table 6: Full Time Course Plot summary

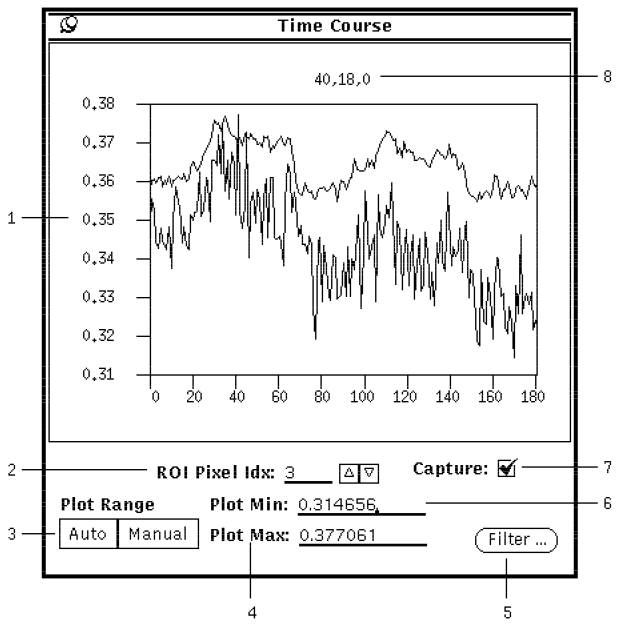

Figure 31: Qwik Time Course plot window.

course, an algorithm consisting of a sequence of equations must be specified in the **Algorithm** list (32-1). The first item in the list is always the current time course. Its designation "S0" stands for Signal at index 0. Each equation is composed of a resultant signal (i.e. time course), an operation and a set of operands. There are 12 operations available as follows:

FT Performs a Fast Fourier Transform.

IFT Performs an Inverse Fast Fourier Transform.

Fill Pads or interpolates a signal to a new length.

Win Generates a Low, High or Band pass window.

Cmplx Combines a pair of signals into a complex signal.

RIMP Decomposes a complex signal into its Real, Imaginary, Magnitude or Phase component.

Mult Arithmetic multiply of two signals.

Add Arithmetic addition of two signals.

Mean Calculates the statistical mean of a specified range of a signal.

DC Generates a constant amplitude waveform signal.

Open Performs a mathematical morphologic opening.

Close Performs a mathematical morphologic closing.

After an **Operation** choice (32-3) is selected, the required operand fields are displayed. For example, for the "Add" operation, two source signals are required and thus the **Source 1 Idx** (32-4) and **Source 2 Idx** (32-5) fields are displayed. After the operation and operands have been specified, the **Add** button (32-2) inserts the filtering equation into the algorithm list. Pressing the **Delete** button (32-9) will remove the last item in the algorithm list. When any item in the algorithm list is selected, the resultant signal is displayed back in the Qwik plot window (31-1). The **Save** (32-6) and **Load** buttons (32-7) can be used to store and retrieve the algorithm to/from a file. The **Apply Filter** button (32-8) will perform the filter algorithm on the time courses of every voxel in the entire stim volume.

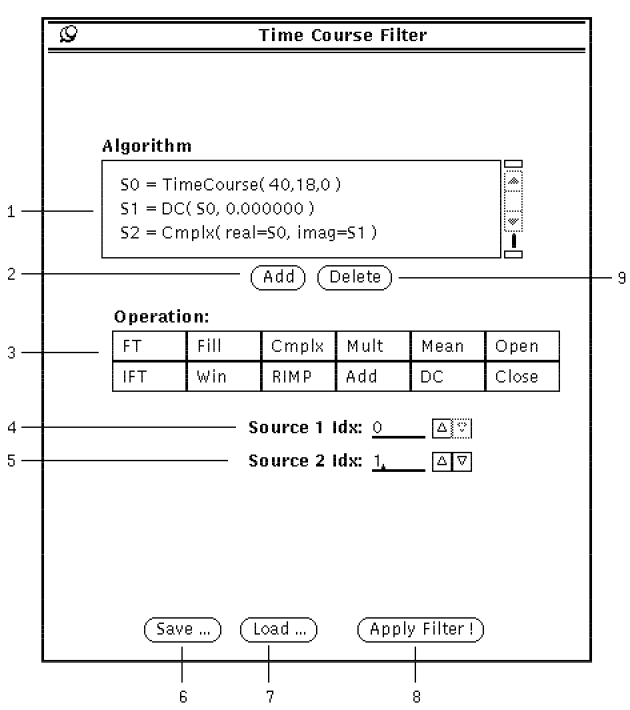

Figure 32: Time Course filter window.

14 Movie Tool

To invoke the Movie Tool, press the icon (3-10) and the Movie Tool Control popup window is displayed as show in Figure 33. See Section 14.1 for the procedure on how to create a movie.

There are three movie **Motion** choices (33-1) as follows:

- Repeat - Displays movie frames front→back repeatedly
- Rock - Display movie frames front→back and then back→front, repeatedly
- Step - Display a single movie frames as indexed by the **Time** field (33-6).

When in the Repeat or Rock motion mode, the "Running Horse" button (33-4) and the "Stop Sign" button (33-3) are used to start and stop the cine loop, respectively. The **Delay** field (33-2) can be used to slow down or speed up the cine loop. In the Step mode, each press of the "Running Horse" will advance the movie one frame forward.

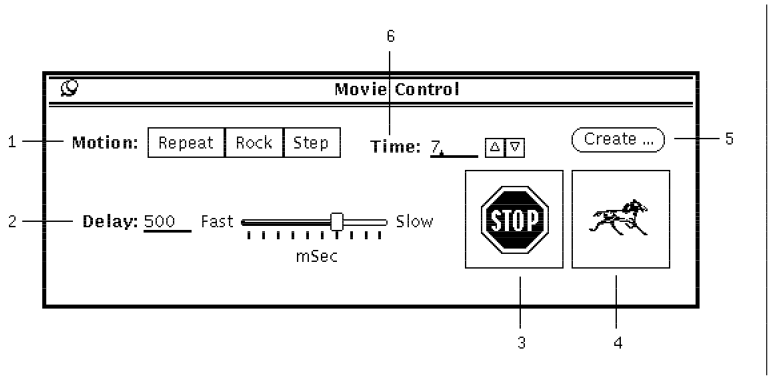

Figure 33: Movie Tool Control popup window.

14.1 Movie Generation

By pressing the **Create** button (33-5), the Create Movie popup window (Figure 34) is displayed. Once all the movie parameters are specified, pressing the **Create It** button (34-16) will generate the cine loop of image mosaics. An example is shown in Figure 35. Multiple movies can be generated,

but the refresh rate diminishes as the number of movies running simultaneously is increased.

There are a number of option parameters that can be specified as follows:

1. The **Axis** choice (34-1) allows for reslicing the image volumes along the cardinal axes. See Table 7 for the relationship between the orientations of the original volumes to those after reslicing. The combinations not found in Table 7 are non-standard orientations.

2. By setting the **FirstPlane** (34-2) and **LastPlane** (34-3) fields, a spatial subset of the volume can be specified. Adjacent slices can be skipped by setting the the **Plane Step** (34-4) field greater than one.

3. A temporal subset of the time range can be specified by setting the **First Time** (34-5) and **Last Time** (34-6) fields. Time periods can be skipped by setting the the **Time Step** (34-7) field greater than one.

4. The dimensions of the slices in the movie mosaic can be resized by setting the the **Plane Width** (34-8) and **Plane Height** (34-9) fields. The resizing method is determined by the **Zoom** choice (34-12). The slice images can be buffered by setting the **Border Space** (34-10) field greater than zero.

5. There are three **Mode** choices (34-13) for different types of cine loops. The "Normal" mode creates a cine loop using the image intensity values. The "Diff" mode creates a cine loop of the remainder of a subtraction from a reference image. The reference image is specified as a time index in the **Base Time** field (not shown). The "Thres" mode creates a cine loop that is black for image values below the **Threshold** field (not shown) value and white for image values above.

6. As in the Section 8, the **Display Max** (34-14) and **Display Min** (34-15) fields must specify a display range. Note that the display range is normally significantly smaller in the "Diff" mode.

Original	Axis	Resliced
Sagittal	X	Coronal
Coronal	X	Sagittal
Coronal	Y	Axial
Axial	Y	Coronal
Sagittal	Z	Sagittal
Coronal	Z	Coronal
Axial	Z	Axial

Table 7: Movie Axis Reslice Orientations.

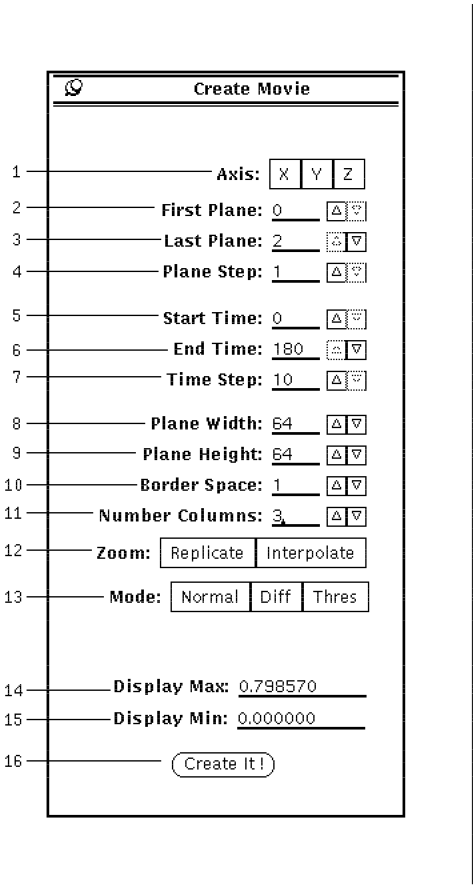

Figure 34: Movie Tool Create popup window.

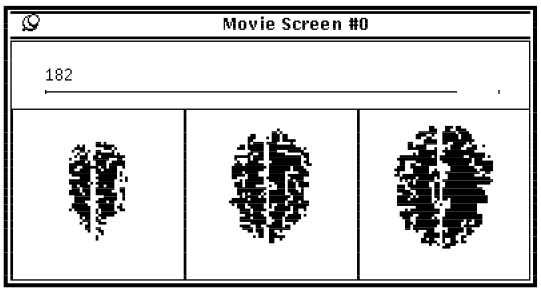

Figure 35: Movie Screen popup window.

Figure 36: Main Window Mask widgets.

15 Mask

A mask is simply a 4D image volume set with the same spatial dimensions as the currently load stim file. Note that only a single 3D volume of the 4D set is active at any one time. The active volume is specified by the **Volume offset** field (14-4) when "Mask" is selected for the **Display** choice (14-1). The logical state for every voxel in a mask is "TRUE" unless it is exactly equal to zero and thus "FALSE". A mask is useful in a number of situations such as limiting analysis to a subset of a volume (See Section 9.2) or suppressing background noise in hardcopy or visualizations (See Section 18). As maps necessarily have the same spatial dimensions as their parental stim images, they also can be manipulated as masks. Thus the mask tools can be used to combine and compare maps. After saving a mask to a file on disk, it can subsequently be loaded as a map (See Section 3).

A subset of the widgets on the Main Window are associated with the mask feature as shown in Figure 36. Pressing the **Gen Mask** button (36-1) will display the **Generate Mask** popup window (Figure 37). See Section 15.1 for the procedure on how to create a mask. When the **Apply** option (36-2) is selected, the mask is applied to the currently displayed images. Those pixels in the mask with a FALSE logic value (i.e. equal to zero) will make the corresponding pixel in the displayed image appear black. Those pixels in the mask with a TRUE logic value (i.e. not equal to zero) will not change the appearance of the corresponding pixel in the displayed image. Applying the mask does not change the data, but only how the data is displayed.

15.1 Mask Generation

Mask images are generated by an algorithm consisting of a sequence of equations. Each equation is composed of a resultant destination, an operator

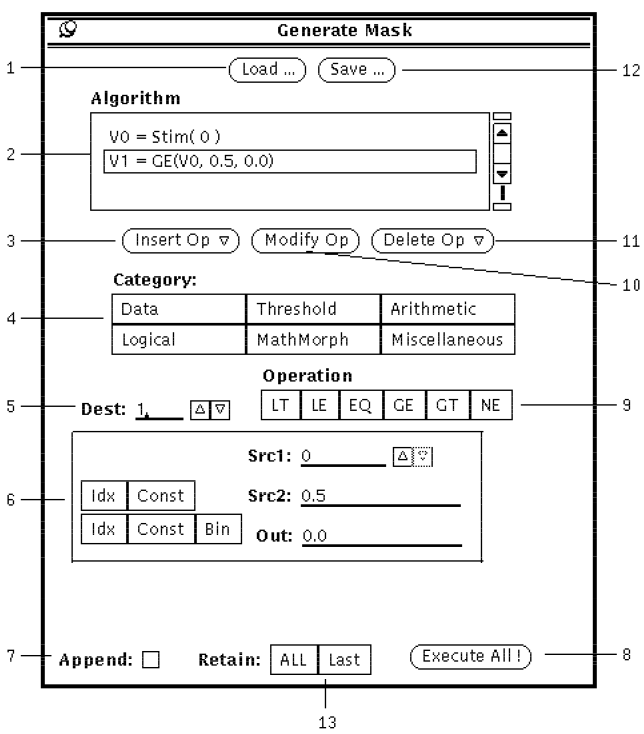

Figure 37: Generate Mask popup window.

and a set of operands. The result of each operation is a 3D volume with the same spatial dimensions as the currently loaded stim volume. The resultant destination, specified by the **Dest** field (37-5), is an index into the 4D mask image. Thus the output of executing an algorithm is a 4D image consisting of the resulting 3D volume images from the individual equation operations.

In order to generate a mask, an algorithm must first be specified in the **Algorithm** (37-2) list. By pressing one of the six **Category** choices (37-4), the corresponding operators are displayed in the **Operation** choice (37-9), as listed in Table 8. Dependent on the operator selected, a group of widgets are displayed (37-6) for specifying the required operands. The following subsections detail the operators and operands.

Category	**Operators**
Data	Stim Map ROI Mask File
Logical	AND OR
Threshold	LT LE EQ GE GT NE
MathMorph	Opn Cls Dil Ero
Arithmetic	Add Sub Mult Div
Miscellaneous	Frame Smooth Cluster

Table 8: Mask Operator categories

Once the operator and associated operands have been specified, an equation can be entered into the **Algorithm** list (37-2) using one of the menu items under the **Insert Op** button (37-3). The four menu items allow for insertion into the algorithm list at the *Top*, *Bottom* and *Before* or *After* the currently selected equation. Similarly, the **Delete** button (37-11) has two menu items to remove *All* the equations or just the *Selected* one. Whenever an equation is selected from the list, its operator and operands are displayed. This makes it convenient to edit the equation by modifying the parameters and pressing the **Modify Op** button (37-10) to change the equation.

The algorithm equations can be stored as a file by pressing the **Save** button (37-12) which will popup the file browser (See Section 5). The **Load** button (37-1) can be used to retrieve previously saved algorithms.

Once an algorithm is specified, pressing the **Execute All** button (37-8) will initiate its execution. If the "Last" option is selected from the **Retain** choice (37-13), only the last image volume in the mask algorithm will be

saved. Otherwise, selecting the "All" option will result in all of the image volumes in the mask algorithm being saved. Upon successful execution, the current mask will either be replaced by or appended with the resultant image volume(s) dependent on whether the **Append** option (37-7) is selected. The mask can be viewed as described in Section 7. Note that the **Volume offset** field (14-4) and the display range (**Display Min** (15-3) and **Display Max** (15-2)) will be set to display the last volume in the 4D image. Mask images are unlike Stim files which have a relatively consistent display range as different volumes are indexed temporally with the **Volume offset** field (14-4). When different mask volumes are indexed for display, the pixel value ranges can be drastically different. Hence, the display range will often need to be adjusted (See Section 8).

15.1.1 Common Operands

Except for the **Data** category, all operations are performed on one or two 3D image volumes previously defined in the algorithm at the volume offsets specified by the *Src1* and *Src2* operands.

For both **Logical** and **Threshold** operations, the result image is dependent on the *Out* operand. There are three options for the *Out* operand:

- *Bin* option: When selected, those pixel locations where the operation result is TRUE, the value in the result image are set to 1.0, and where FALSE they are set 0.0.
- *Const* option: When selected, those pixels locations where the operation result is TRUE, the value in the result image are set to the value specified by the *Const* operand. Pixel locations where the operation result is FALSE are unaltered.
- *Idx* option: When selected, those pixel locations where the operation result is TRUE, the value in the result image is set to the pixel value from the same location in the volume image offset specified in the *Idx* operand. Pixel locations where the operation result is FALSE are unaltered.

15.1.2 Data Operators

There are 5 operators in the **Data** category:

Stim Copies a 3D image volume from the currently loaded stim at temporal offset specified in the *Vol_Idx* operand.

Map Copies a 3D image volume from the currently loaded map.

ROI Generates a binary 3D image volume based on the interior region of the current ROI.

Mask Copies a 3D image volume from the currently loaded mask at the volume offset specified in the *Vol_Idx* operand.

File Loads a 3D image volume from the sdt image file specified by the *path* operand. If the image is 4D, a volume is extracted at the volume offset specified in the *Vol_Idx* operand.

15.1.3 Logical Operators

The **Logical** operators consider the logical state for every voxel in an image as "TRUE" unless it is exactly equal to zero and thus is considered "FALSE". As discussed in Section 15.1.1 the result image is dependent on the *Out* operand. There are 2 operators in the **Logical** category as follows:

AND Performs a logical "AND" operation between corresponding pixels from the two 3D image volumes at the offsets specified in the *Src1* and *Src2* operands (i.e. $Src_1 \cap Src_2$).

OR Performs a logical "OR" operation between corresponding pixels from the two 3D image volumes at the offsets specified in the *Src1* and *Src2* operands (i.e. $Src_1 \cup Src_2$).

15.1.4 Threshold Operators

For **Threshold** operations, the result image is dependent on the *Out* operand, as discussed in Section 15.1.1. There are 6 operators in the **Threshold** category:

LT Performs a "less than" operation between corresponding pixels from the two 3D image volumes at the offsets specified in the *Src1* and *Src2* operands (i.e. $Src_1 < Src_2$).

LE Performs a "less than or equals" operation between corresponding pixels from the two 3D image volumes at the offsets specified in the *Src1* and *Src2* operands (i.e. $Src_1 \leq Src_2$).

EQ Performs an "equals to" operation between corresponding pixels from the two 3D image volumes at the offsets specified in the *Src1* and *Src2* operands (i.e. $Src_1 == Src_2$).

GE Performs a "greater than or equals" operation between corresponding pixels from the two 3D image volumes at the offsets specified in the *Src1* and *Src2* operands (i.e. $Src_1 \geq Src_2$).

GT Performs a "greater than" operation between corresponding pixels from the two 3D image volumes at the offsets specified in the *Src1* and *Src2* operands (i.e. $Src_1 > Src_2$).

NE Performs a "not equals to" operation between corresponding pixels from the two 3D image volumes at the offsets specified in the *Src1* and *Src2* operands (i.e. $Src_1 \neq Src_2$).

15.1.5 Mathematical Morphology Operators

For **MathMorph** operations[8, 9], the result image is dependent on the *Mode* operand. When in the "Binary" mode, the value of the pixels in the result image is dependent on the operation result at the pixels location. They are set to 1.0 where the operation result is TRUE and are set to 0.0 where the operation result is FALSE. When in the "Greyscale" mode, the pixel value in the result image is simply the result of the operation. There are two structuring elements available as specified by the *SE* operand. The *Box* SE must have its dimensions specified by the *Half Width* and *Half Height* operands. The *Disc* SE must have its dimensions specified by the *Radius* operand. As these structuring elements are only 2D, they can be applied on any orthogonal plane as specified by the *Axis* operand. In order to avoid edge effects, it may be useful to prepare the image first with a Frame operation (See Section 15.1.7).

There are 4 operators in the **MathMorph** category:

Opn Performs a "Opening" operation on the 3D image volumes at the offsets specified in the *Src1* operands (i.e. $Src_1 \circ SE$).

Cls Performs a "Closing" operation on the 3D image volumes at the offsets specified in the *Src1* operands (i.e. $Src_1 \bullet SE$).

Dil Performs a "Dilation" operation on the 3D image volumes at the offsets specified in the *Src1* operands (i.e. $Src_1 \oplus SE$).

Ero Performs a "Erosion" operation on the 3D image volumes at the offsets specified in the *Src1* operands (i.e. $Src_1 \ominus SE$).

15.1.6 Arithmetic Operators

The arithmetic operators require two operands, one of which must be a volume offset specified in the *Src1* operand. The second operand can either be another volume offset or a constant value dependent on the *Src2* operand being set to *Idx* or *Const*, respectively.

There are 4 operators in the **Arithmetic** category:

Add Performs an arithmetic "Addition" operation between corresponding pixels from the two 3D image volumes or one 3D image volume and a constant value (i.e. $Src_1 + Src_2$).

Sub Performs an arithmetic "Subtraction" operation between corresponding pixels from the two 3D image volumes or one 3D image volume and a constant value (i.e. $Src_1 - Src_2$).

Mult Performs an arithmetic "Multiplication" operation between corresponding pixels from the two 3D image volumes or one 3D image volume and a constant value (i.e. $Src_1 * Src_2$).

Div Performs a arithmetic "Division" operation between corresponding pixels from the two 3D image volumes or one 3D image volume and a constant value (i.e. Src_1 / Src_2).

15.1.7 Miscellaneous Operators

There are 3 operators in the **Miscellaneous** category:

Frame For each plane in the 3D image volumes at the offset specified in the *Src1* operand, the frame is filled with the constant specified by the *Value* operand. The vertical and horizontal borders of the frame are of thickness specified by the *Width* and *Height* operands, respectively.

Smooth Performs a convolution with a "flat" rectangular structuring element of dimensions specified by the *Width* and *Height* operands. As the structuring element is only 2D, it can be applied on any orthogonal plane as specified by the *Axis* operand.

Cluster Performs a planar connected components analysis such that each pixel in the result image has a value equal to the number of pixels in the cluster to which it belongs. Only those pixels whose value lies within the inclusive range, specified by the *Ceiling* and *Floor*, are candidates for membership in a cluster. A pixel is deemed to be a member of a cluster based on 8-neighbor planar connectivity.

16 Talairach

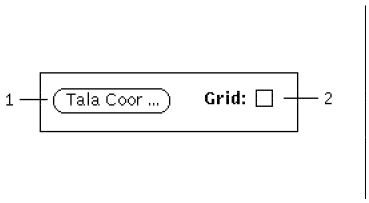

Figure 38: Main Window Talairach widgets.

A subset of the widgets on the Main Window are associated with the Talairach coordinates[5] feature as shown in Figure 38. Pressing the **Tala Coor** button (38-1) will display the **Talairach Coordinates** popup window (Figure 39). After the Talairach Coordinates have been configured (See Section 16.1), the **Grid** option (38-2) can be selected. When it is selected, a Talairach grid is overlayed on top of the currently displayed Main Window images and the **Talairach Locn** field (26-4) displays the location of the mouse.

16.1 Talairach Coordinate Configuration

The following is the procedure to configure the Talairach Coordinate feature.

1. The first step is to input three cardinal orientation image volumes[4] of the subject brain using the **Load** button (39-9). This is accomplished by pulling down the load menu as shown in Figure 40 and sequentially selecting each orientation menu item (i.e. Sag, Ax & Cor). As each orientation menu item is selected the file browser popup window will be displayed (See Section 5). When loaded, the image filename appears under the respective display window (39-2).

[4]Currently only 3D floating point images in *sdt* format can be loaded.

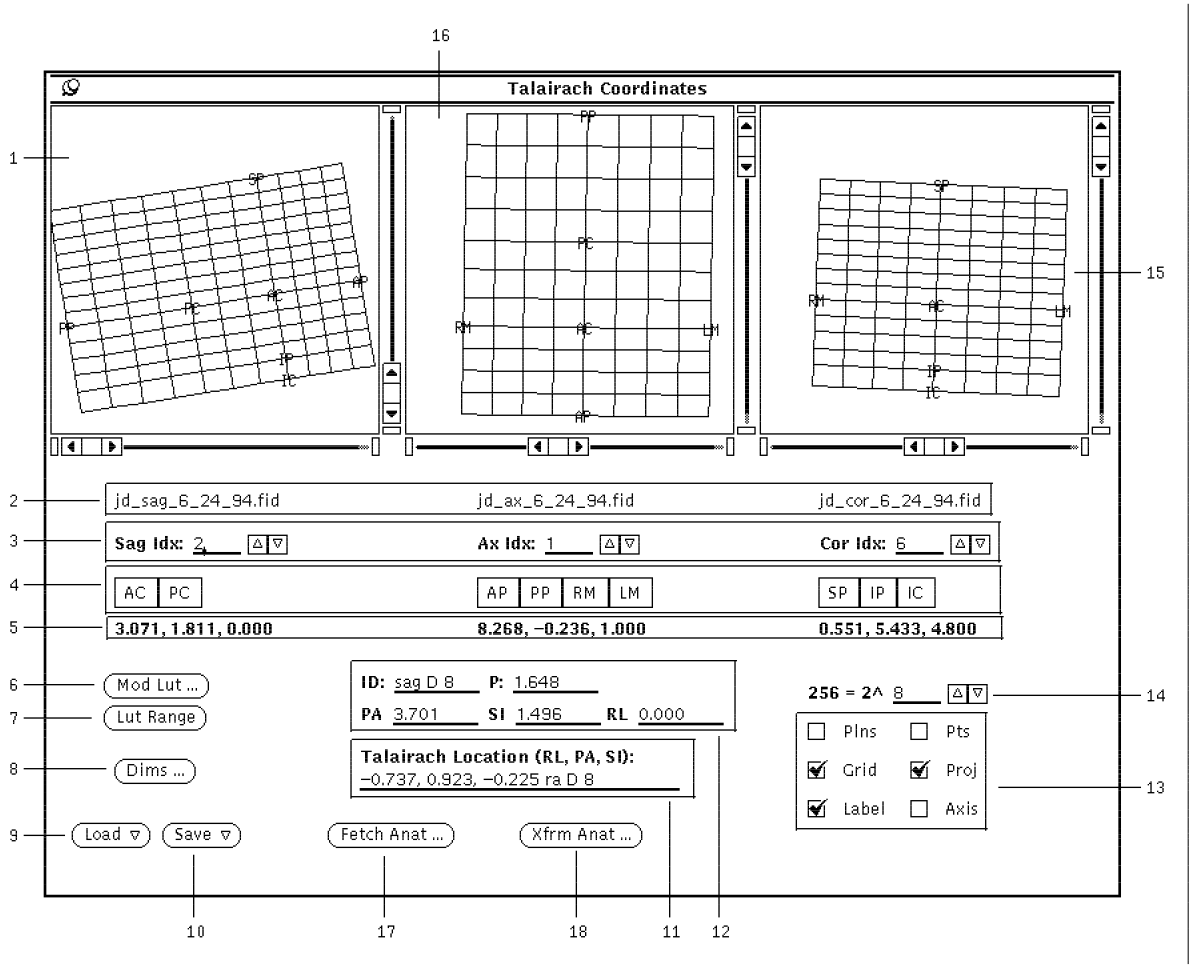

Figure 39: Talairach Coordinates popup window

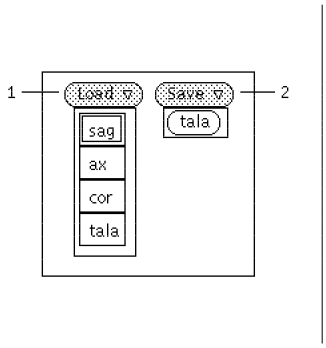

Figure 40: Talairach Load/Save menus

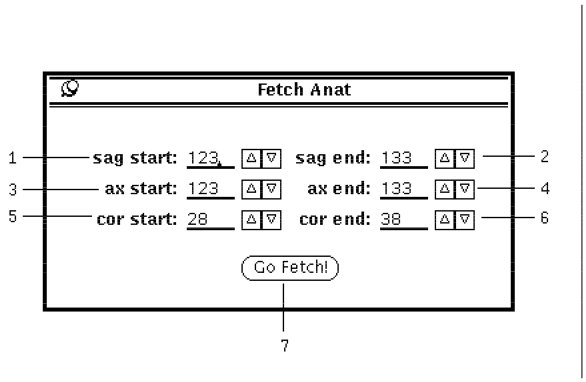

Figure 41: Talairach Fetch Anat popup window.

An alternative to loading three different files is to extract the three cardinal views from the currently loaded Anat image volume. This is accomplished by pressing the **Fetch Anat ...** button (39-17) and specifing the desired planes on the **Fetch Anat** popup window (Figure 41). The default cardinal planes are ± 5 from the volume center (41-1:6). Then by pressing the **Go Fetch!** button (41-7), those planes specified are extracted and loaded into the three orthogonal view image displays (39-1,15,16).

2. The contrast and brightness of the images can be adjusted using the **Mod Lut** button (39-6) to display the **Modify Lut** graphical tool as shown in Figure 16. After adjusting the LUT mapping, pressing the **LUT Range** button (39-7) will recalculate the LUT indices as discussed in Section 8.

3. The orientations can be checked by selecting the **Axis** option (39-13) as shown in Figure 42 and described in Table 5. A summary of the orientation conventions is provided below each image (39-5). Also shown in Figure 42 is the effect of the **Plns** option (39-13). The relationship between the image planes is displayed as a vertical and horizontal lines as described in Table 10. When any of the planar indices (39-3) are changed, the corresponding plane of the image volume is displayed and the planar lines in the other two image display windows are moved accordingly.

4. Each of the Talairach landmarks listed in Table 9 must be specified on the indicated plane. To specify a landmark, select one of the landmark choices (39-4) and click the mouse in the corresponding planar image at the proper anatomic location. If the **Pts** option (39-13), is selected a crosshair will appear to indicate the chosen location as shown in Figure 43. The images can be resized by powers of two as specified in (39-14) and landmark adjustments can be made by repeated mouse clicks. Note that the landmark crosshair only appears on the planar image where the mouse was clicked. If a planar index (39-3) is changed, the landmark crosshair will not be seen. However the line between related pairs of landmarks will continue to be displayed.

   Note that the "Inferior Cerebellum" (IC) is not a standard talairach landmark. The IC has been added to allow inclusion of the full cerebellum into an extended talairach volume. The IC can be disabled by setting to 0.0 the **IP→IC** dimension field (45-1).

5. The landmark crosshairs can be replace with its acronym when the **Pts** and **Labels** options (39-13) are chosen as shown in Figure 44. The interhemispherical medial plane is calculated from the three points: AP, PP and SP. Then the specified AC and PC locations are projected onto this plane. The projected AC and PC points can be seen on the Axial slice when the **Proj** option (39-13) is selected. Similarly, the RM and LM points are projected normal from the medial plane at the AC location.

6. Once the landmarks are accurately specified, the **Grid** option (39-13) will overlay a Talairach proportional grid on the planar images. Each particular parallelogram has a unique identifier using the axis index labeling scheme as described in Table 11. When the mouse is moved into a grid, the location of the corresponding parallelogram is displayed in **ID** field (39-12). The **RL**, **PA** and **SI** fields (39-12) display the mouse location using the image field of view.

7. To more precisely define a location in the Talairach grid, the normalized dimensions can be specified by pressing the **Dims** button (39-8). The **Talairach Dims** popup window (Figure 45) will then be displayed. Except for the PP and IC dimension, each dimension is relative to the AC point. Hence the AC dimension must necessarily always be zero. The PP dimension is relative to the PC point. and the IC dimension is relative to the IP point. After entering the dimensions in the fields (45-1), the **Apply** button (45-2) must be pressed. The **Talairach Location** field (39-11) will then display the mouse location in normalized dimensions.

8. When the Talairach coordinates are fully configured, the landmarks and normalized dimensions can be saved to a file using the **Save** button (40-2). Subsequently, they can be retrieved using the "tala" menu item under the **Load** button (40-1).

9. The currently loaded Anat and Map image volumes can be tranformed to the specified Talairach coordinates and normalized dimensions by first pressing the **Xfrm Anat ...** button (39-18) to display the **Xfrm Talairach** popup window Figure 46. The length of each axis in centimeters is shown in fields 46-1,2,3, as specified in the Talairach Dimensions popup window (Figure 45). The length of each axis in pixels is given in the **Dim** column (46-6). These **Dim** lengths are

Landmark Name	Acronym	Plane
Anterior Commissure	AC	Sagittal
Posterior Commissure	PC	Sagittal
Anterior Point	AP	Axial
Posterior Point	PP	Axial
Right Medial	RM	Axial
Left Medial	LM	Axial
Superior Point	SP	Coronal
Inferior Point	IP	Coronal
Inferior Cerebellum	IC	Coronal

Table 9: Talairach Landmark Acronyms and Specification Planes.

Pln	Horz	Vert
Sag	Ax	Cor
Ax	Cor	Sag
Cor	Ax	Sag

Table 10: Relationship between the Horizontal and Vertical Lines of the Plns option to that of the orientation of the image plane.

set relative to the specified **Resolution** (46-8). For the planar axes, the lengths are set to the nearest greater than or equal power of 2. The horizontal and vertical planar axes are denoted by and "H" and "V" respectively in the last column (46-7). Note that the planar axes change as different **Oreint** choices (46-9) are selected. The **Width** column (46-4) gives the number of pixels for the corresponding length at the current **Resolution**. The **Buffer** is just the difference between the **Dim** and the **Width**. After specifing the desired **Resolution**, **Oreint** and **Buffer**, press the **Do It!** to invoke the transformation. The resultant Anat and Map image volumes can then be displayed on the Main Window (Figure 3).

Talairach Axis	Grid Index Labels
Anterior → Posterior	$A, B, C, D, E_1, E_2, E_3, F, G, H, I$
Right → Left	rd,rc,rb,ra,la,lb,lc,ld
Superior → Inferior	1,2,3,4,5,6,7,8,9,10,11,12,CB

Table 11: Talairach Grid Axis Index Labels.

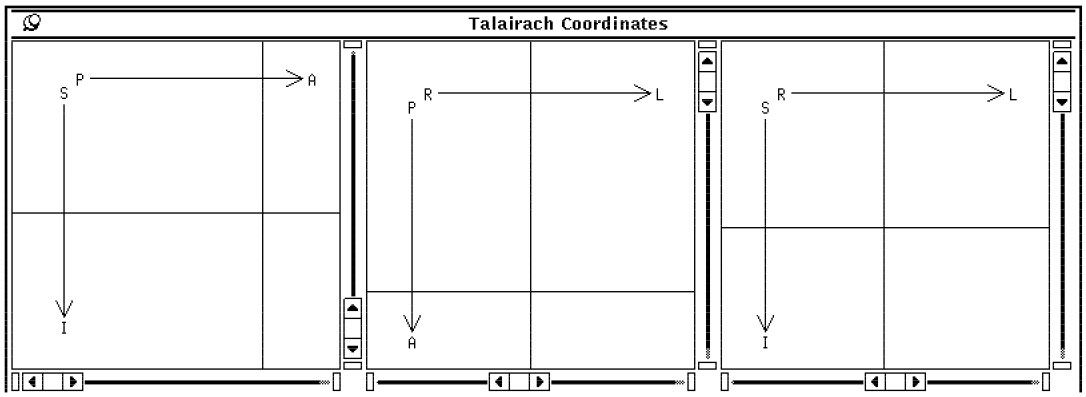

Figure 42: Talairach Image Windows with **Axis** and **Plns** options.

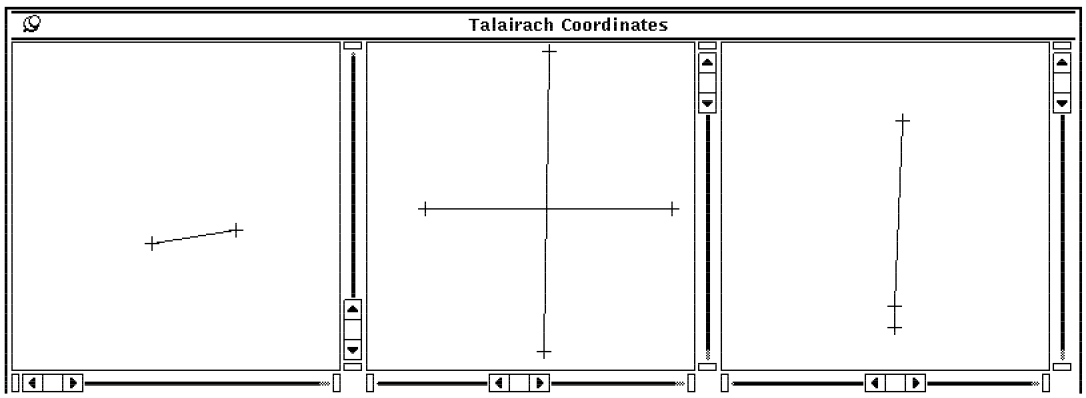

Figure 43: Talairach Image Windows with **Pts** option.

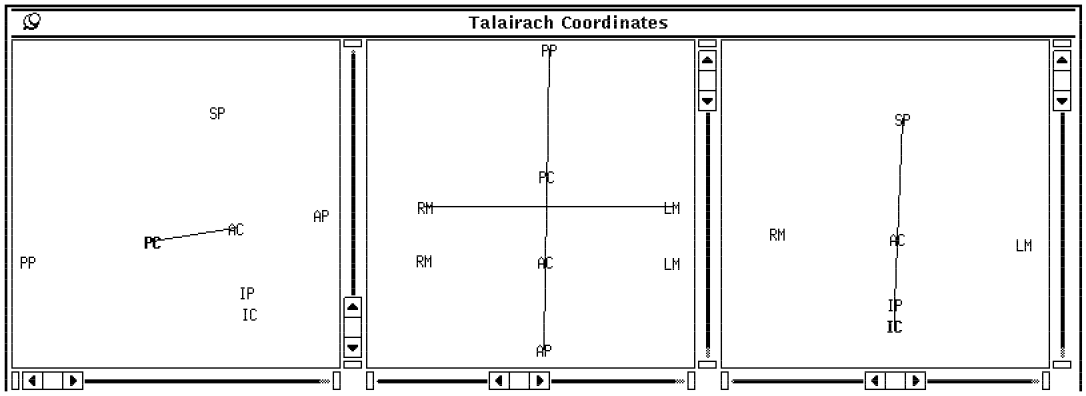

Figure 44: Talairach Image Windows with **Pts**, **Proj** and **Label** options.

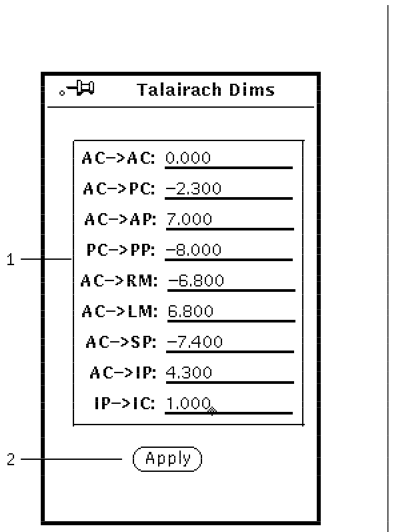

Figure 45: Talairach Dimensions popup window.

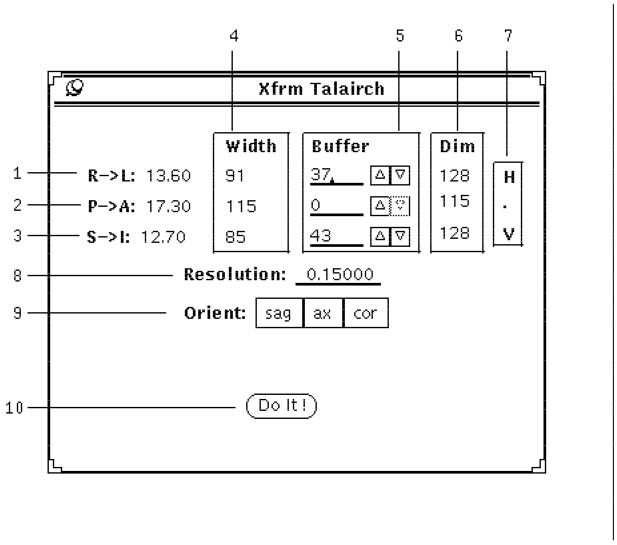

Figure 46: Xfrm Talairach popup window.

17 Center of Mass

In order to help detect motion, a center of mass calculation is available by pressing the **Mass Ctr** button (3-4). The center of mass is calculated for each stim volume over the entire temporal range. If the Mask **Apply** option (36-2) is selected, only those voxels with non-zero values in the current mask are considered. As shown in Figure 47, a graph of the center of mass in voxel units over time is displayed in the center of mass popup window. Dependent on the **Plot** choice (47-2) of X, Y or Z, the graph (47-1) shows the corresponding component. Pressing the **Save** button (47-3) will dump all three components to an ASCII file called "massCtr.asc."

18 Export

As shown in Figure 5 there are three menu items under the **Export** button (4-4). Whenever one of these menu items is selected, the file browser popup window is displayed (See Section 5). After a filename is specified, a second popup window is displayed giving export options.

When exporting an image it is important to set the **Display Min** field (15-2) to a value greater than the background (See Section 8). Otherwise the background will appear noisy instead of black. Alternatively, the mask **Apply** option (36-2) can be used to mask off the background (See Section 15).

18.1 Tagged Image File Format

The "TIFF" (Tagged Image File Format)[10] option allows for saving an image mosaic as an 8 bit, index color tiff image. The TIFF option popup window is as shown in Figure 48. The **Plane Offset** field (14-2) and the **Number Planes** field (14-3) on the Main Window, determine which planes are used in the tiff image mosaic. The **Image Width** field (48-3) allows for expanding the image by multiples of its original dimension. If a border around each image in the mosaic is desired, the **Border Width** field (48-4) allows multiples of 8. The color of the border is shown in the color bar (48-1) and is selected by the **Border Color** field (48-2). The **Number of Columns** field (48-5) specifies how many image columns are used in the mosaic. The size of a Right Hand Side (RHS) fiducial for Axial and Coronal image volumes can be specified with the **RHS Fiducial Width** field (48-6). The **Layout** choice (48-7) allows for the mosaic to be either

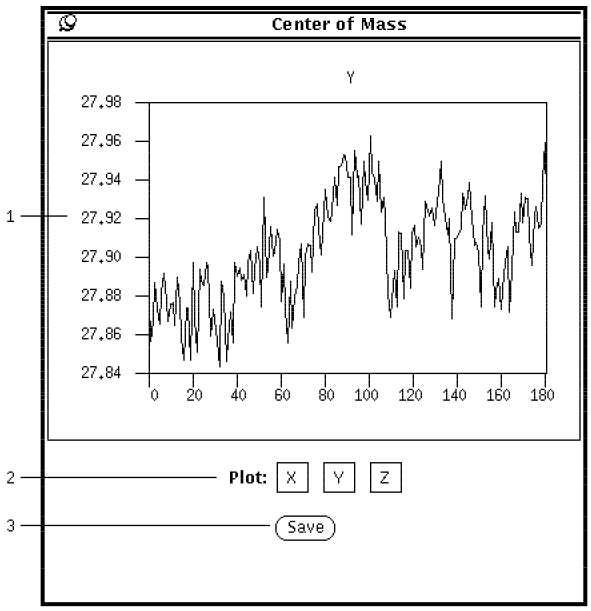

Figure 47: Center of mass plot.

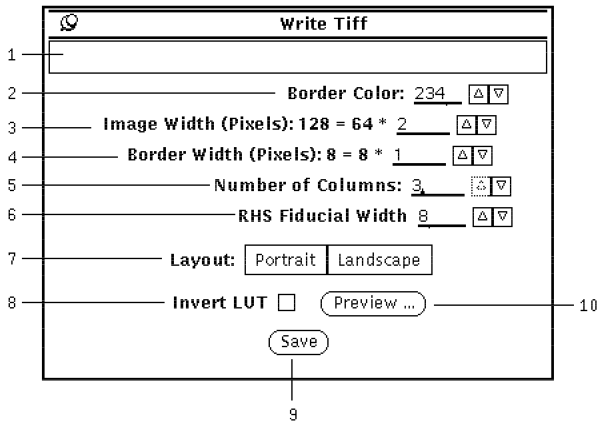

Figure 48: Export TIFF Options popup window.

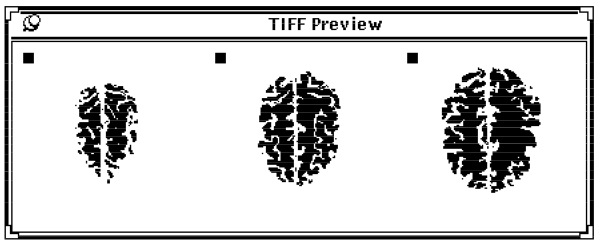

Figure 49: TIFF image mosaic preview popup window.

"Portrait" or "Landscape". Since most images with the default grayscale lut have large black areas, the default is to have the **Invert Lut** option selected (48-8), in order to save ink on color printers. Prior to saving the image, the **Preview ...** button (48-10) allows for viewing of the mosaic with the current options specified. An example of a 3 column tiff image mosaic preview is shown in Figure 49. When the mosiac options are set as desired, pressing the **Save** button (48-9), will write the tiff image mosaic to a file.

18.2 Brick of Bytes

The "BOB" (Brick of Bytes) option allows for saving an image set in a single file which is made of a volume of bytes. BOB files can be imported into a 3D visualization software package called GVLware developed at the AHPCRC (Army High Performance Computing Research Center). The program runs on the Silicon Graphics Iris and can be downloaded via anonymous ftp from:

ftp.arc.umn.edu:/pub/GVL/gvl.tar.gz

Table 12 lists the Look-Up Table (LUT) for the byte values in the volume. The **Plane Offset** field (14-2) and the **Number Planes** field (14-3) on the Main Window, determine which planes are used in the volume. The BOB option popup window is as shown in Figure 50. The **X** (50-1), **Y** (50-2), and **Z** (50-3) fields allow the user to specify the output dimensions of the BOB volume and the resulting resolution is displayed. By selecting the **Isotropic** option (50-4), the closest dimensions that result in isotropic voxels is calculated using the highest current resolution. Multiple selection/deselection of this option iterates the calculation. The greyscale values in the volume are linearly interpolated to the specified dimensions. The Map overlay values are calculated either by linear interpolation or by nearest neighbor, dependent on the Main Window choice of "Interpolate" or "Replicate" in field (17-6),

Encoding	Pixel Value
ROI	255
Map Pos (Max → Min)	254 → 245
Map Neg (Min → Max)	244 → 235
Greyscale (White → Black)	234 → 0

Table 12: BOB & VV Look-Up Table

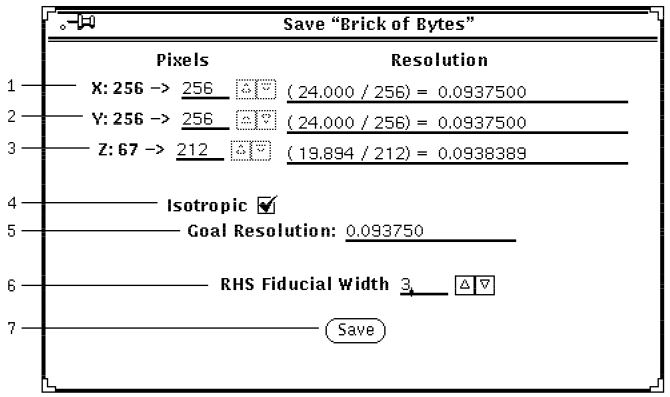

Figure 50: BOB & VV Options popup window

respectively. The size of a Right Hand Side (RHS) fiducial for Axial and Coronal image volumes can be specified with the **RHS Fiducial Width** field (50-6).

18.3 Voxel View

The "VV" option stands for "Voxel View," which is a commercial volume visualization program[11]. The VV option popup window is the same as for BOB as shown in Figure 50. The difference between BOB and VV is that instead of the single 3D volume file, VV is a directory of sequentially numbered 2D planar files. There are also 2 parameter files, "load.param" and "⊥ut", produced.

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A Appendix: Sdt File Format

The sdt file format actually consists of a file pair designated by the extensions, ".sdt" and ".spr".

.sdt Contains the **S**ignal **D**a**T**a and consists of only raw binary data.

.spr Contains the **S**ignal **P**a**R**ameters and consists of ASCII attribute:value pairs.

The ".spr" file has one ASCII parameter string per line (i.e. newline '\n' terminated). The parameters format consists first of a colon terminated attribute name, followed by a newline terminated value.

There are three mandatory parameters:

numDim The number of dimensions for the data.

dim The number of data points in each dimension.

dataType The data type. There are five data types supported as given with their corresponding sizes in Table 13.

Attribute Values	**Size**
BYTE	sizeof(char)
WORD	sizeof(short)
LWORD	sizeof(int)
REAL	sizeof(float)
COMPLEX	2 * sizeof(float)

Table 13: Supported Values for the **dataType** Attribute.

A minimal ".spr" example:

```
numDim:     4
dim:        64 64 27 110
dataType:   REAL
```

Optional parameters:

origin Position of the center of the first voxel. One value for each dimension. If the origin is not specified, but the fov is, then the image is assumed to be centered:

$$origin = -\frac{fov}{2.0} + \frac{interval}{2.0}$$

fov Field of view: The distance between the outside edges of the first and last voxel along each dimension; one value for each dimension. If the fov is not specified it is calculated according to:

$$fov = interval * dim$$

interval The center to center distance between adjacent voxels along each dimension; one value for each dimension. If the interval is not specified it is calculated according to:

$$interval = fov/dim$$

displayRange Two values giving the low_value and high_value. Voxel values below the low_value will be displayed as black and voxels with values above the high_value will be displayed as white. Voxels with values within the display range are displayed with a grey value that is scaled linearly between the low_value and high_value.

A typical stimulate ".spr" example:

numDim:	4
dim:	128 128 20 150
origin:	-10.000000 -10.000000 0.000000 0.000000
fov:	20.000000 20.000000 2.000000 15.000000
interval:	0.156250 0.156250 1.000000 1.000000
dataType:	REAL
displayRange:	0.000000 347.904358
fidName:	stimFid.sdt
sdtOrient:	sag

B Appendix: Changes Version 4.0 to 5.0

Section 2.1 Acknowledgement via citation is requested.

Section 2.3 The STIMULATE_HOST environment variable is now 14 letters long instead of 26.

Section 2.5 The X resource "OpenWindows.SelectDisplaysMenu: True" is now automatically set and is no longer needed in the user's .Xdefaults file. Thus menus are now pulled down with either the right or left mouse button.

Section 2.6 Added section on Widget fonts.

Section 2.8 Command line mode added to facilitate batch processing.

Section 5 **Change Dir** button (7-4) added to replace double clicking the items in the scrolling list (7-5).

Section 6.1 **Apply Gauss** option for load fid has been replaced with a variable width **LPF** (Low Pass Filter) option (8-12) having Gaussian, Sinusoidal or Hamming filter shapes.

Section 6.2 Added variable width **LPF** (Low Pass Filter) option (10-5) for load sdt having Gaussian, Sinusoidal or Hamming filter shapes.

Section 6.3 Added **ima** choice (13-10) to RAW Load Option.

Section 8 Added WhiteScale (i.e. photo-negative of GrayScale) to Lut menu (16).

Section 10 Added **Voxel Location** (26-2) to display the mouse position in voxel units of the image volume data.

Section 11 Added "Hot" to **MouseFnc** choice (27-1) for dynamic display of time course plots.

Section 14 Increased the maximum delay from 100 milliseconds to 750 milliseconds in the **Delay** field (33-2) to allow for slower movie cine loops.

Section 15 Added **Retain** choice (37-13) to specify whether all of the image volumes in the mask algorithm be saved or just the last one.

Section 16 Added **Fetch Anat ...** button (39-17) to extract the three cardinal views from the currently loaded Anat image volume.

Section 16 Added an "Inferior Cerebellum" (IC) landmark (39-4) to allow inclusion of the full cerebellum into an extended talairach volume.

Section 16 Added **Xfrm Anat** button (39-18) to tranform currently loaded Anat image volume and map to the specified Talairach coordinates and normalized dimensions.

Section 18.1 Added **RHS Fiducial Width** field (48-6) to mark the Right Hand Side (RHS) on Axial and Coronal mosaics tiff images.

Section 18.1 Added **Layout** choice (48-7) allows for the tiff mosaic to be either "Portrait" or "Landscape".

Section 18.1 Added **Invert Lut** option in order to save ink on color printers.

Section 18.1 Added **Preview ...** button (48-10) to allow viewing of the tiff mosaic with the current options specified prior to saving to a file.

Section 18.2 Added **RHS Fiducial Width** field (48-6) to mark the Right Hand Side (RHS) in "BOB" (Brick of Bytes) and "VV" (Voxel View) image volumes.

Section 18.3 Updated export VoxelView to generate "load.param" file instead of obsolete "_dimensions" file.