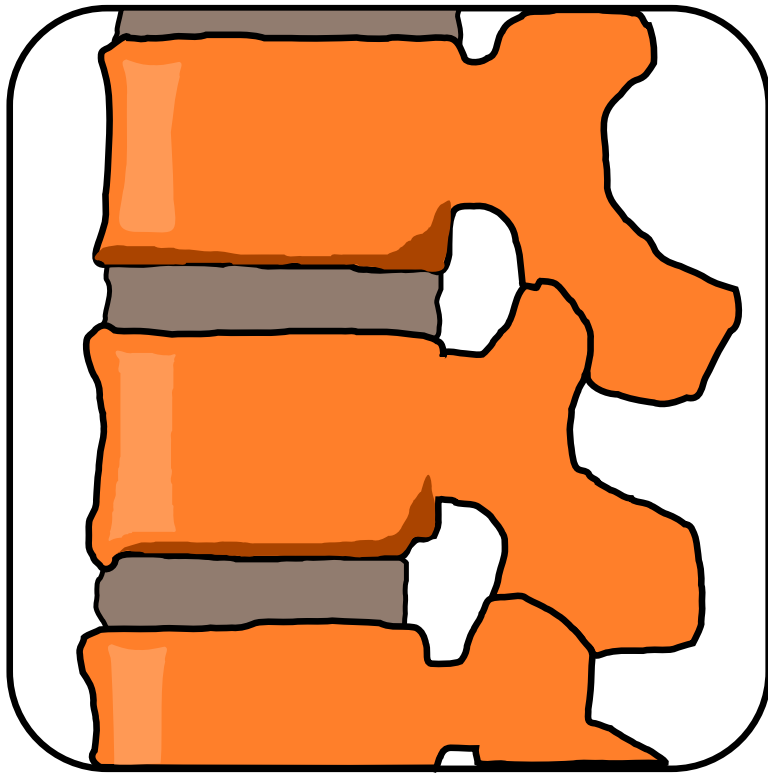# SpineSeg – Semi-Automatic Spinal Cord Segmentation

Usage Guide

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SpineSeg – Semi-Automatic Spinal Cord Segmentation

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Version History:

| 2011.02.03 | first version of the guide, written for SpineSeg 2.0. |

Contents

CHAPTER 1

Installation

1.1 Introduction

SpineSeg is a medical image analysis tool developed to evaluate spinal cord atrophy in MR volumes. It is distributed with source code under the terms of the GNU General Public License, version 2. SpineSeg is based on the GTK+ toolkit and works on Unix-like systems such as Linux, FreeBSD and Mac OS X.

1.2 SpineSeg Installation

SpineSeg is distributed in source code form and its compilation requires a working set of Unix-compatible development utilities, the GNU C++ compiler and the GTK+ toolkit with development headers installed, version 2.6.0 or later. These are easily found on most current Linux operating system distributions.

The SpineSeg source code package can be downloaded from `http://www.liv.ic.unicamp.br/~bergo/spineseg`, and the following commands can be used to unpack, compile and install it:

```
tar zxvf spineseg-2.0.tar.gz
cd spineseg-2.0
./configure
make
make install
```

By default, the install prefix will be set to `/usr/local`. The user running the last step

(make install) must have write permission to the installation prefix. The installation prefix can be customized with

```
./configure --prefix=/custom/path
```

SpineSeg uses the GNU autotools for package configuration, and further customization options can be listed with

```
./configure --help
```

With the default prefix, the spineseg program executable will with installed in `/usr/local/bin`, icons will be installed in `/usr/local/share/pixmaps`, documentation and sample MR data in `/usr/local/share/spineseg`.

SpineSeg is known to work in the following operating systems and distributions:

- Fedora Linux (tested with versions 12, 13 and 14).

- Ubuntu Linux (tested with version 10.10)

- CentOS Linux (tested with versions 4.4, 5.1, 5.2, 5.3)

- FreeBSD 6.1

- Mac OS X (tested with version 10.6 (Snow Leopard))

1.3 Image Conversion Utilities

To convert images from standard formats such as DICOM and Analyze to SpineSeg's SCN, users will want dicom2scn, IVS and/or Aftervoxel. **dicom2scn** is an open source command-line utility for format conversion, it converts DICOM to SCN and also includes utilities to convert between SCN and the popular Analyze format. dicom2scn can be downloaded from

```
http://www.liv.ic.unicamp.br/~bergo/ivs
```

and compiled and installed with

```
tar zxvf dicom2scn-2010.2.tar.gz
cd dicom2scn-2010.2
make
make install
```

The dicom2scn installation prefix is defined as `/usr/local` in the Makefile. To change it, edit the Makefile.

IVS and Aftervoxel are graphical medical image processing applications for Linux, distributed as freeware (no source code available). IVS can read/write SCN and Analyze formats, and includes dicom2scn as a command-line tool. Aftervoxel can read DICOM, SCN and Analyze, and write SCN and Analyze. Aftervoxel provides a graphical interface for DICOM importing, and may be desirable for users not used to command-line utilities. IVS and Aftervoxel can be downloaded from the addresses below:

```
http://www.liv.ic.unicamp.br/~bergo/ivs
```

```
http://www.liv.ic.unicamp.br/~bergo/aftervoxel
```

CHAPTER 2

User Interface

2.1 Running SpineSeg

SpineSeg can be started with

```
spineseg &
```

Started with no parameters, it will interpolate axial slices to 0.50 mm. The following command-line options can be used:

-debug Enable debugging actions. In the current version, it will save intermediary segmentation results to SCN files in the current working directory.

-r value Overrides the axial interpolation resolution to the given value in millimeters.

-c Enable axial slice compositing. With compositing enabled, each slice is averaged from the nearest 3 slices, effectively multiplying thickness by 3.

-g value Overrides the morphological gradient radius used for tree pruning preprocessing. The default is a 1.0-pixel radius. Larger radii increase the gradient border barriers for tree-pruning, reducing leaking.

-h Shows a summary of command-line options on the standard output and exits.

2.2 Loading Volumes

SpineSeg can only read volumes in the SCN format (created at the Institute of Computing, Unicamp). Volumes can be loaded with the *File* ▶ *Load Volume* and *File* ▶ *Load Special* commands. The first one requires that volume files be in sagittal orientation, with the Z coordinate increasing from left to right. The second command allows the user to choose orientation, as well as override slice compositing and axial resolution interpolation (Figure 2.1).
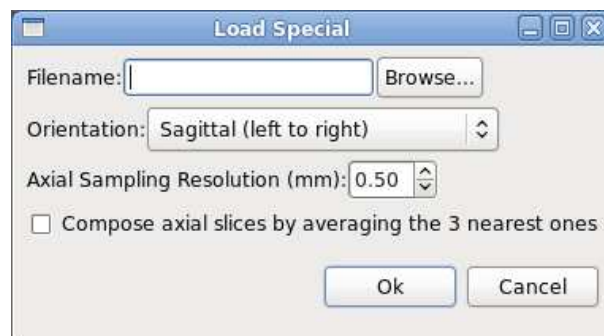

Figure 2.1: Load Special dialog.

2.3 Tools

Once a volume has been loaded, the main window will appear as illustrated in Figure 2.2. The left pane displays either a sagittal or coronal view, and the right pane displays an axial view. The six buttons on the top left allow the user to switch between tool modes (Zoom, Pan, Reslice, Semi-automatic segmentation, Manual Segmentation and Distance Measurement, respectively). The Window, Opacity, Show PIP and Show fit controls on the bottom right control the viewing parameters.

2.3.1 Sagittal/Coronal Alternation

When "Show PIP" checkbox is activated, a small window with a sagittal or coronal slice is shown on the top right corner of the left image pane. Clicking on the small preview will switch between Sagittal and Coronal views.
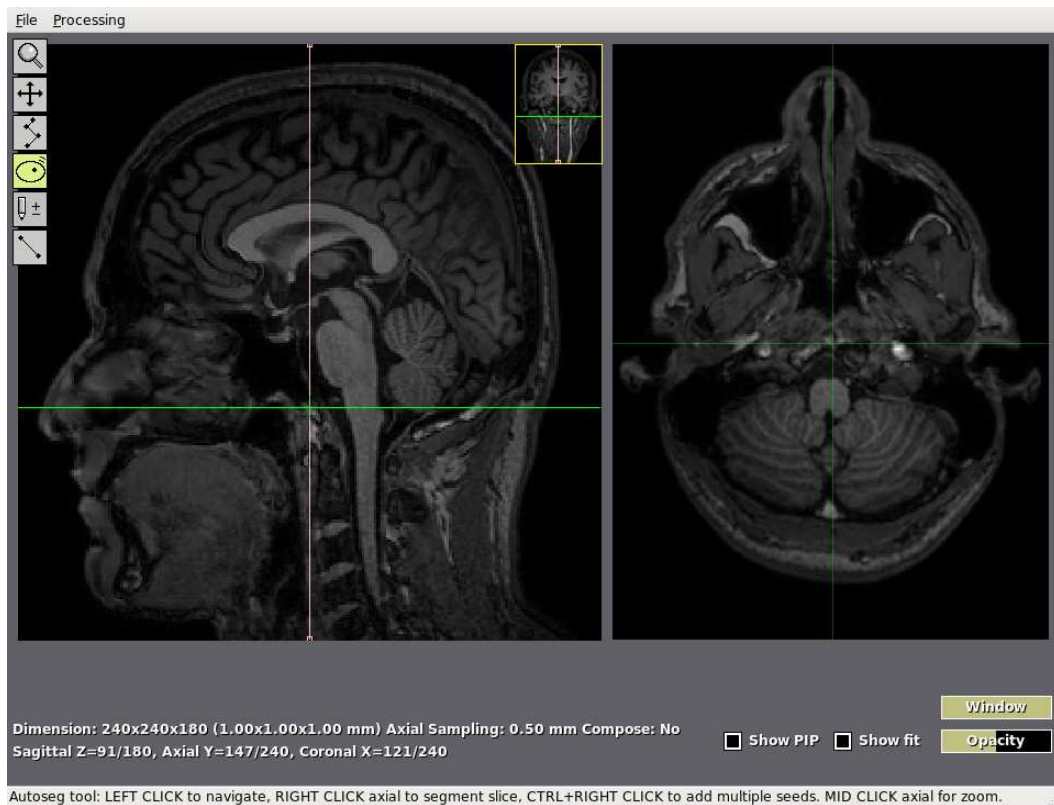
Figure 2.2: Main window after loading a volume.

2.3.2 Window Control

The "Window" control on the bottom right of the main window controls the visualization brightness. In the default (maximum) setting, the highest voxel intensity is displayed as white. Reducing the window level lowers the white saturation point, enhancing brightness and contrast of the the displayed image. This control only affects visualization and has no effect on any image processing algorithm within SpineSeg.

2.3.3 Right Pane Zoom

An additional zoom level of 2X, 4X or 8X can be set for the right pane. The zoom modes can be switched by clicking the right pane with the middle mouse button, or with the 'Z' key on the keyboard. When the right pane zoom is set to anything but 1X, the zoom level is shown between square brackets on the right pane.

2.3.4 Zoom Tool

When the Zoom tool is activated, clicking with the left mouse button anywhere on the screen will control the overall zoom level. A zoom level bar will be displayed and can be controlled by dragging the mouse horizontally. To reset the zoom level to fit the window, click anywhere with the right mouse button while this tool is selected.

2.3.5 Pan Tool

When the Pan tool is activated, dragging the mouse with the left button pressed will pan (translate) the entire view within the window. To reset the pan state, click anywhere with the right mouse button while this tool is selected.

2.3.6 Reslice Tool

The reslice tool allows the user to edit the guiding curves (pink lines on the left pane) on the sagittal and coronal views and regenerate the axial slices such that they are orthogonal to them. When the reslice tool is selected, two buttons are shown near the tool button. "Linear/Spline" indicates the curve interpolation mode, and can be clicked to alternate between them (Figure 2.3). "Reslice" interpolates all axial slices to fit the current guiding curves. When the curves have been edited, and the axial view is invalid, the right pane will be tonalized in red. Clicking with the left mouse button on the left pane adds a control point to the guide curve, and clicking with the right mouse button (on the left pane) deletes the nearest control point. Left-clicking the right pane moves the cursor, allowing the user to view different slices on the left pane.
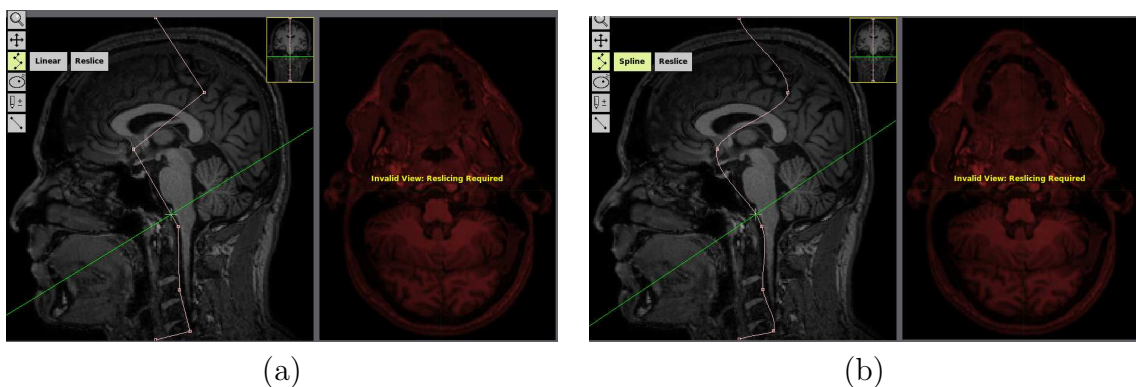

(a)   (b)

Figure 2.3: Reslice Tool: (a) Linear interpolation. (b) Spline interpolation.

2.3.7 Semi-Automatic Segmentation Tool

When this tool is selected, clicking on any image pane with the left mouse button moves the cursor, changing the current slice. Clicking on the right pane with the right button performs tree-pruning segmentation on that slice with a single seed at the point clicked. To add more seeds, click with the right button while holding the *Ctrl* key. Seeds are shown as red pixels. Once an object has been segmented, it is tonalized in yellow on the right pane, its ellipse fitting is drawn in cyan. The opacity of the object tonalization can be changed at the "Opacity" control on the bottom right. The display of the ellipse fit can be toggled with the "Show fit" checkbox. An orange marker is shown on the left pane for each slice where some segmentation has been performed. The segmentation measurements and fitted ellipse properties are shown on the third line of text below the image panes. Figure 2.4 illustrates a slice with semi-automatic segmentation performed.
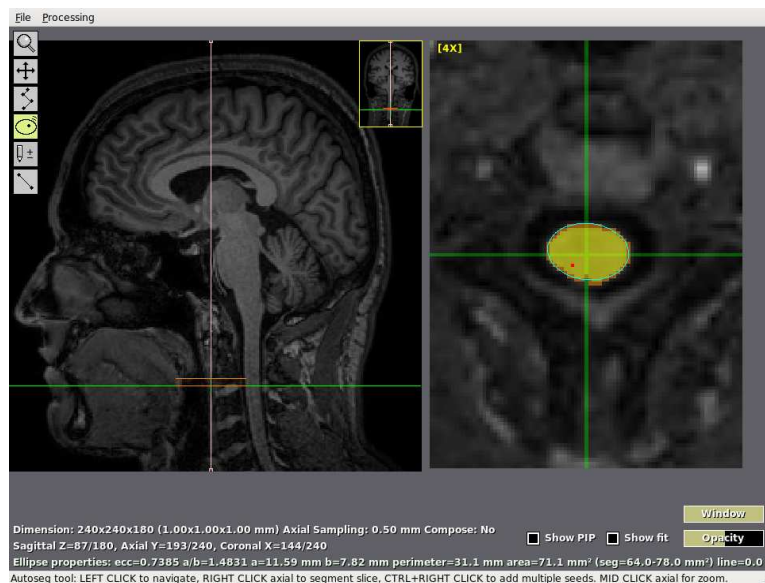

Figure 2.4: Interface showing a slice with semi-automatic segmentation.

2.3.8 Manual Segmentation Tool

When this tool is selected, clicking on the right pane adds (left button) or removes (right button) border points. When at least 6 points are present on a slice, an ellipse is fitted to them. Figure 2.5 shows an ellipse fitted to manual border points. Clicking on the left pane moves the cursor and changes the slice currently displayed.
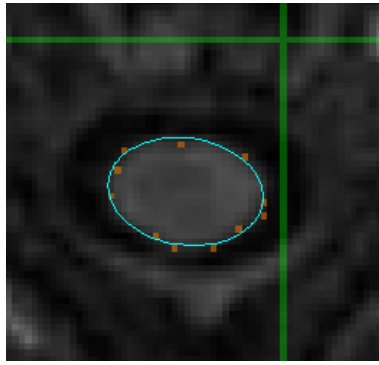
Figure 2.5: Ellipse fitted to manually-added border points.

2.3.9 Distance Measurement Tool

When this tool is selected, clicking on the right pane sets the endpoints of a ruler (show in magenta, Figure 2.6). SpineSeg supports only one distance measurement per slice, and the distance measured is shown on the third text line below the image panes. Clicking on the right pane when a ruler is already set moves the nearest endpoint to the clicked location. Clicking on the left pane moves the cursor and changes the slice currently displayed.
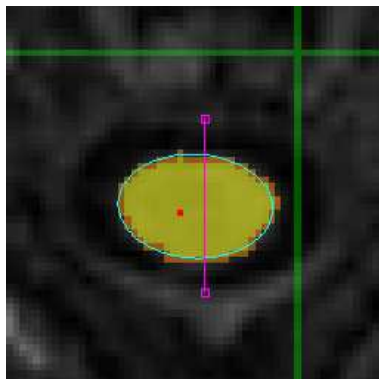

Figure 2.6: Distance measurement (Ruler).

2.4 Keyboard Controls

SpineSeg provides several keyboard shortcuts, which are independent of the current tool selection:

Key	Action
F1	Select the Zoom tool.
F2	Select the Pan tool.
F3	Select the Reslice tool.
F4	Select the Semi-automatic segmentation tool.
F5	Select the Manual segmentation tool.
F6	Select the Distance measurement tool.
Del	Clear segmentations and measurements on the current slice.
Esc	Clear segmentations and measurements on the entire volume.
Arrow Keys	Move the cursor (up and down move along axial slices, left and right move perpendicularly, depending on the sagittal/coronal state of the left pane).
F	Toggle Show fit.
L	Load volume.
S	Alternate opacity between 0% and 50%.
Z	Alternate between right pane zoom modes (1X, 2X, 4X, 8X).
-/+	Control the Window setting.
9/0	Control the Opacity setting.

2.5 Mouse Controls Summary

The tables below summarize the action of each mouse button on each pane according to the current tool.

2.5.1 Left Pane

Tool	Left	Middle	Right
🔍	Overall zoom	Right-pane zoom	Reset overall zoom
✛	Pan	Right-pane zoom	Reset pan
🗲	Add control point	Right-pane zoom	Remove control point
⊚	Navigate	Right-pane zoom	
🖊±	Navigate	Right-pane zoom	
⬊	Navigate	Right-pane zoom	

2.5.2 Right Pane

Tool	Left	Middle	Right
🔍	Overall zoom	Right-pane zoom	Reset overall zoom
✛	Pan	Right-pane zoom	Reset pan
🗲	Navigate	Right-pane zoom	
⊚	Navigate	Right-pane zoom	Segment
🖊±	Add point	Right-pane zoom	Remove point
⬊	Add endpoint	Right-pane zoom	

2.6 The Processing Menu

The *Processing* menu provides two image processing filters, *Gaussian Blur* and *Median Filter* that can be used to smooth noisy images. The Gaussian blur filters each axial slice with the kernel

$$\begin{bmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{bmatrix}$$

The median filter processes each axial slice setting each pixel's intensity to the median with the 3×3 block centered on it.

The processing menu also provides the *Clear Volume* and *Clear Slice* commands, that remove segmentations and rulers from the entire volume and from the current slice, respectively.

2.7 Saved States

The state of a volume can be saved with the *File ▶ Save state* command. This command saves all segmentations, reslicing state, and interface settings. The user must have writing permissions to the directory where the volume was originally loaded from. Save states are automatically loaded by the *Load Volume* and *Load Special* commands.

The *File ▶ Clear Saved State* deletes the state files related to the current volume, if they exist.

Naming and format of the state files are discussed in Chapter 4.

CHAPTER 3

Usage Example

In this chapter we show the typical procedure to measure the spinal cord area using
SpineSeg. The axial resolution is study-dependent and should be chosen in advance.
For this example, we choose 0.60 mm. To convert an image retrieved from the MR
scanner in DICOM format, you can use *dicom2scn* utility described in Chapter 1. To
convert a file named `IM1000.DCM` located in the current directory with *dicom2scn*, do:

```
dicom2scn IM1000.DCM example.scn
```

To run SpineSeg with the chosen resolution set, type in a terminal:

```
spineseg -r 0.60 &
```

After the main window is shown, select *File ▶ Load Volume* and pick the file `example.scn`
converted on the previous step. Once the volume is displayed on the main window, se-
lect the Reslice tool and use the *left* and *right* keyboard arrow keys to locate a sagittal
slice where the vertebrae and the spinal cord are clearly visible. Click on the left pane
to add control points such that the curve follows the anterior contour of the spinal
cord (Figure 3.1). Click on the Coronal PIP to switch between coronal/sagittal, use
the left/right arrow keys to locate a coronal slice where the vertebrae are visible, and
add control points such that the curve follows the center line of the spine (Figure 3.2).

Clock on the *Reslice* button and wait until reslicing is complete. Select the semi-
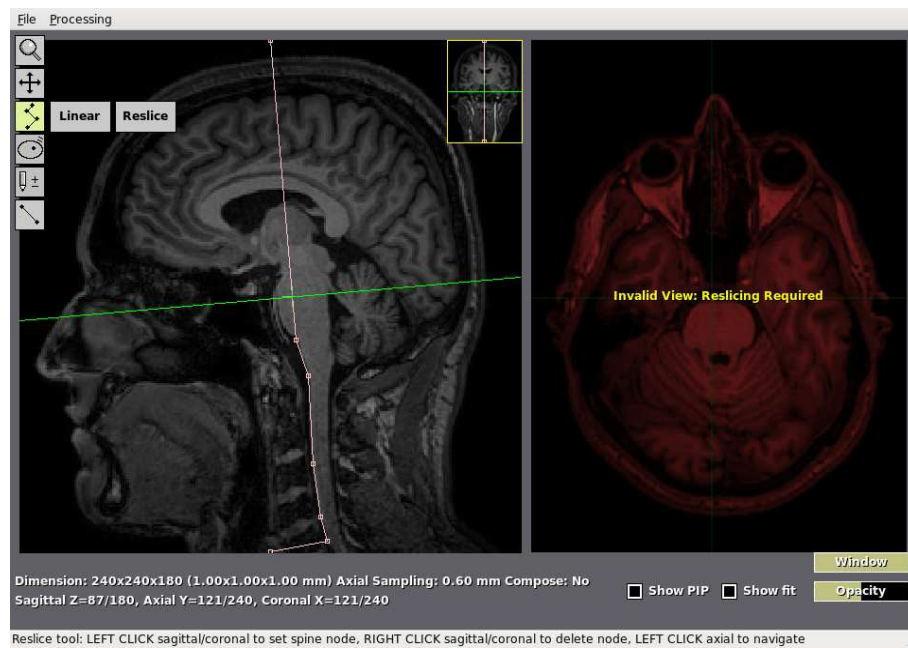automatic segmentation tool. Click on the PIP to switch back the left pane to sagittal

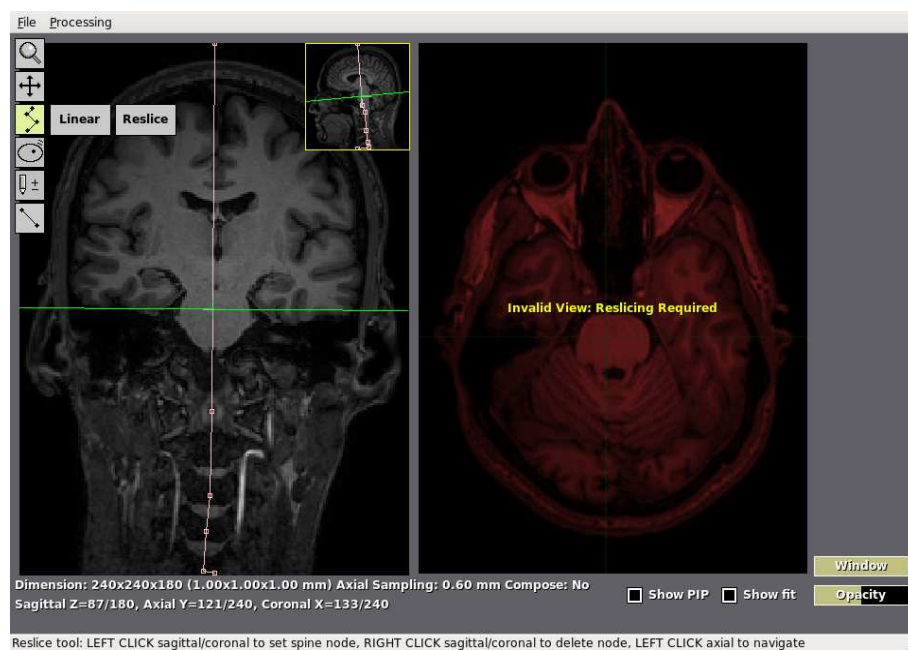Figure 3.1: Sagittal reslicing guide.

Figure 3.2: Coronal reslicing guide.

slices. Use the up/down keyboard arrow keys to locate a slice on the desired level for study. In this example, we will measure the spinal cord at the top of the C3 vertebra,

on the topomost slice where the disk between C2 and C3 no longer appears. Press Z on the keyboard twice to select 4X axial zoom mode, and right click at the center of the spinal cord on the right pane to segment it (Figure 3.3).
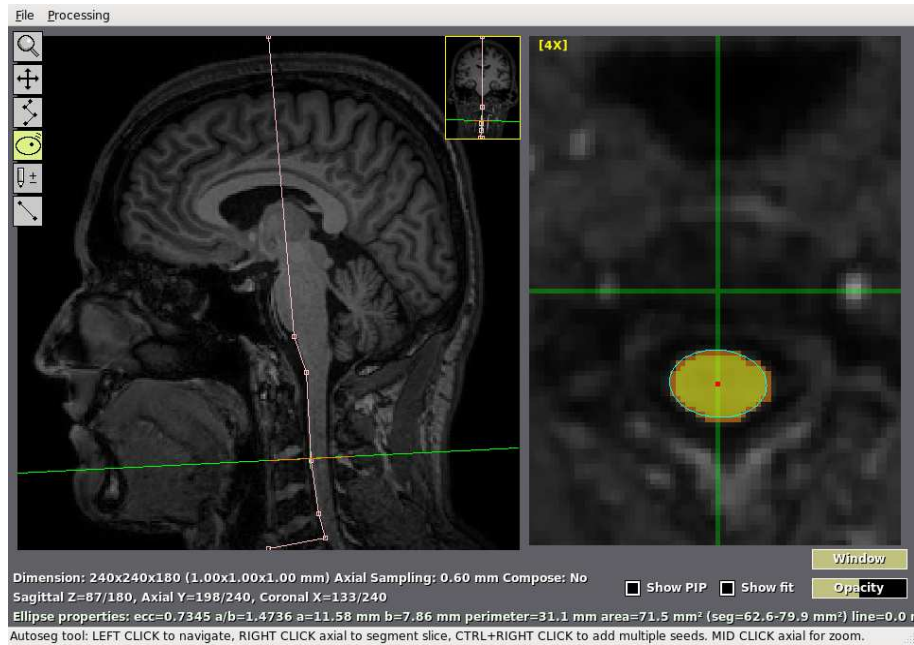
Figure 3.3: Spinal cord segmented.

If any distance measurement is desired, select the Distance measurement tool and left-click both endpoints on the right pane. If you want to segment the spinal cord at other slices, select the semi-automatic segmentation tool, navigate to the desired slice with the keyboard arrow keys and repeat the procedure.

Once you are satisfied with the measurements, select *File* ▶*Save State* to save the results.

Saved States

When the current state is saved with the *File ▶ Save state* command, SpineSeg splits state information into 8 files, written to the same directory where the loaded volume file is located. The file names are generated automatically based on the original file name. The naming and format of each of these files is described below.

4.1 Interpolated original volume

When a volume without a saved state is first loaded by SpineSeg, it is interpolated to make its resolution isometric, using the highest resolution among the 3 axes. E.g., a volume with voxel size $1.0 \times 1.0 \times 3.0$ mm is interpolated to $1.0 \times 1.0 \times 1.0$ mm.

When the state is saved, this interpolated volume is written to

```
zzz_BASENAME_vol.scn
```

where `BASENAME` is the original volume's filename stripped of the .scn extension, if it is present. Despite the .scn extension, this file is saved compressed by bzip2. This file is a 16-bit depth SCN file compressed with bzip2.

4.2 Resliced volume

The sequence of axial slices, interpolated to the enhanced axial resolution and reformatted according to the guiding curves of the reslice tool, is written to

```
zzz_BASENAME_rsd.scn
```

This volume is also written as a 16-bit depth SCN file compressed with bzip2.

4.3 Segmentation volume

A segmentation volume is written to

```
zzz_BASENAME_seg.scn
```

This is an 8-bit label volume with the same dimension and resolution of the resliced volume. Voxels with no segmentation are labeled with 0, internal voxels in segmented objects are labeled with 1, and border voxels in segmented objects are labeled with 2. This volume is written as an 8-bit depth SCN file compressed with bzip2. Within SpineSeg, the voxels labeled with 2 are the ones used to fit the ellipses.

4.4 Seeds volume

A seeds volume is written to

```
zzz_BASENAME_see.scn
```

This is an 8-bit label volume with the same dimension and resolution of the resliced volume. Seed voxels are labeled with 1, the remaining are labeled with 0.This volume is written as an 8-bit depth SCN file compressed with bzip2.

4.5 Interface State

The state of various interface controls is written to

```
zzz_BASENAME_cfg.txt
```

This is a text file with 3 lines. The first line contains 13 numeric values separated by spaces, lines 2 and 3 are comments. The values in the first line are, respectively: current tool, cursor coordinate (Y), cursor coordinate (Z), overall zoom level, pan coordinate (X), pan coordinate (Y), window saturation level, opacity, show fit checkbox, show pip checkbox, cursor coordinate (X), sagittal/coronal view state, stack composition state.

4.6 Distance Measurement Locations

The state of distance measurements is written to

<div style="border:1px solid">

zzz_BASENAME_lin.txt

</div>

This is a text file with one measurement per line. Each line has the form `y x1 z1 x2 z2`. Coordinates are given in the domain of the resliced volume, and each line represents a line segment $(x1, y, z1) - (x2, y, z2)$.

4.7 Measurements

The segmentation and distance measurement properties are written to

<div style="border:1px solid">

zzz_BASENAME_fit.txt

</div>

This is a text file. The first line, starting with `0file`, is a comment. The rest of the file is one line for each slice with any measurements. Properties are comma-separated and presented in this order: original volume file basename, Y coordinate of the slice, ellipse eccentricity, major/minor semi-axis ratio, major semi-axis (in mm), minor semi-axis (in mm), ellipse perimeter in mm, ellipse area in mm^2, segmentation area without the border (mm^2), segmentation area with the border (mm^2), distance measurement length (mm).

4.8 Reslicing Curves

The reslicing guiding curves are written to

```
zzz_BASENAME_rsv.txt
```

This is a text file with one line per control point. Sagittal control points are in the form x X Y, where (X, Y) is the coordinate of the control point, and coronal control points are in the form z Z Y, where (Z, Y) is the coordinate of the control point. A line with the word spline indicates spline interpolation mode for the reslicing guides. Absence of this line indicates linear mode.