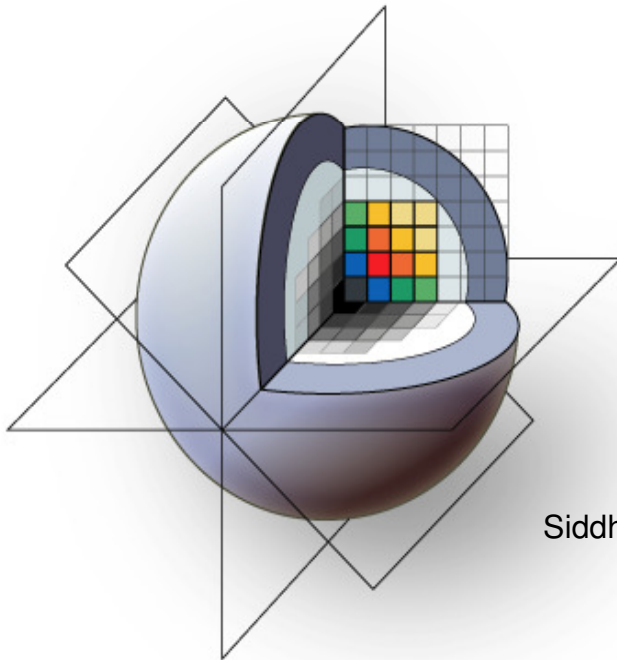




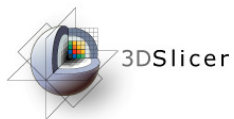
Slicer3 Training Compendium

Slicer3 Training Tutorial Trans-rectal MR-guided prostate biopsy



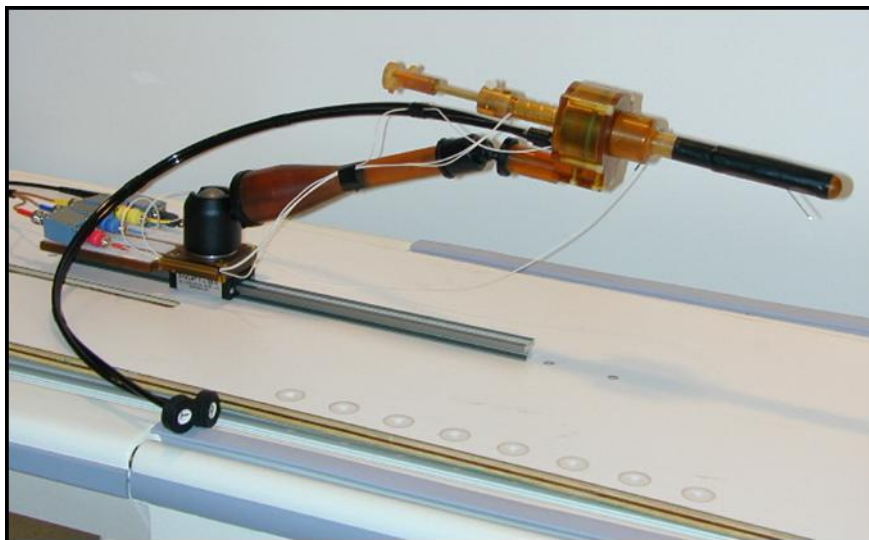
Queens School of Computing
Johns Hopkins University
Georgia Tech University

Siddharth Vikal, Axel Krieger, Iulian Iordachita, Yi Gao, Andras Lasso,
Allen Tannenbaum,
Gabor Fichtinger
Contact: gabor@cs.queensu.ca



Learning Objective

This tutorial will teach you how to perform MR-guided prostate biopsy using MR-compatible trans-rectal robot with SLICER





Prerequisites

MR-compatible trans-rectal robot: Detailed information can be found here:

[1] Krieger A, Susil RC, Menard C, Coleman JA, Fichtinger G, Atalar E, Whitcomb LL, Design of A Novel MRI Compatible Manipulator for Image Guided Prostate Intervention, IEEE Trans. Biomed. Eng. 2005; 52(2):306-313

[2] Susil RC, Ménard C, Krieger A, Coleman JA, Camphausen K, Choyke P, Ullman K, Smith S, Fichtinger G, Whitcomb LL, Coleman NC, Atalar E, Transrectal Prostate Biopsy and Fiducial Marker Placement in a Standard 1.5T MRI Scanner, J Urol. 2006 Jan;175(1):113-20



Prerequisites

This tutorial assumes that you have already completed the tutorial **Data Loading and Visualization**. Tutorials for **Slicer3** are available at the following location:

- **Slicer3** tutorials

<http://www.na-mic.org/Wiki/index.php/Slicer3.2:Training>



Materials

- Build **Slicer3** (***Slicer 3.x***), instructions can be found at:
http://www.slicer.org/slicerWiki/index.php/Slicer3:Build_Instructions
- Build ***TRProstateBiopsy*** module, source code
<http://svn.na-mic.org/NAMICSandBox/trunk/Queens/TRProstateBiopsy/>
Set the output path of build to be Slicer's \\lib\\Slicer3\\Modules

Now, when you run Slicer3-real.exe from the release/debug directory, *TRProstateBiopsy* shows up in modules drop down list



Materials

- Tutorial dataset (< TRPBTutorialDataset .zip>)
- Unzip the folder
- Will create the directories within top level directory (TRPBTutorialDataset): Calibration, Segmentation, Targeting, Verification

Disclaimer: *It is the responsibility of the user of Slicer to comply with both the terms of the license and with the applicable laws, regulations, and rules.*



Overview

1. Clinical background and motivation
 2. Systems overview
 3. Workflow
 4. Demonstration with SLICER
 1. Robot calibration
 2. Prostate segmentation
 3. Biopsy targeting
 4. Verification
-



-
- 1. Clinical background and motivation**
 2. Systems overview
 3. Workflow
 4. Demonstration with SLICER
 1. Robot calibration
 2. Prostate segmentation
 3. Biopsy targeting
 4. Verification
-



MRI-guided prostate biopsy: clinical background

- Prostate cancer, most common cancer in men
- Core needle biopsy definitive diagnostic for prostate cancer
- TRUS has been “Gold standard” for guiding biopsy
- MRI/MRS offers high sensitivity for localizing tumor
- Robotic access required inside scanner^{1,2}

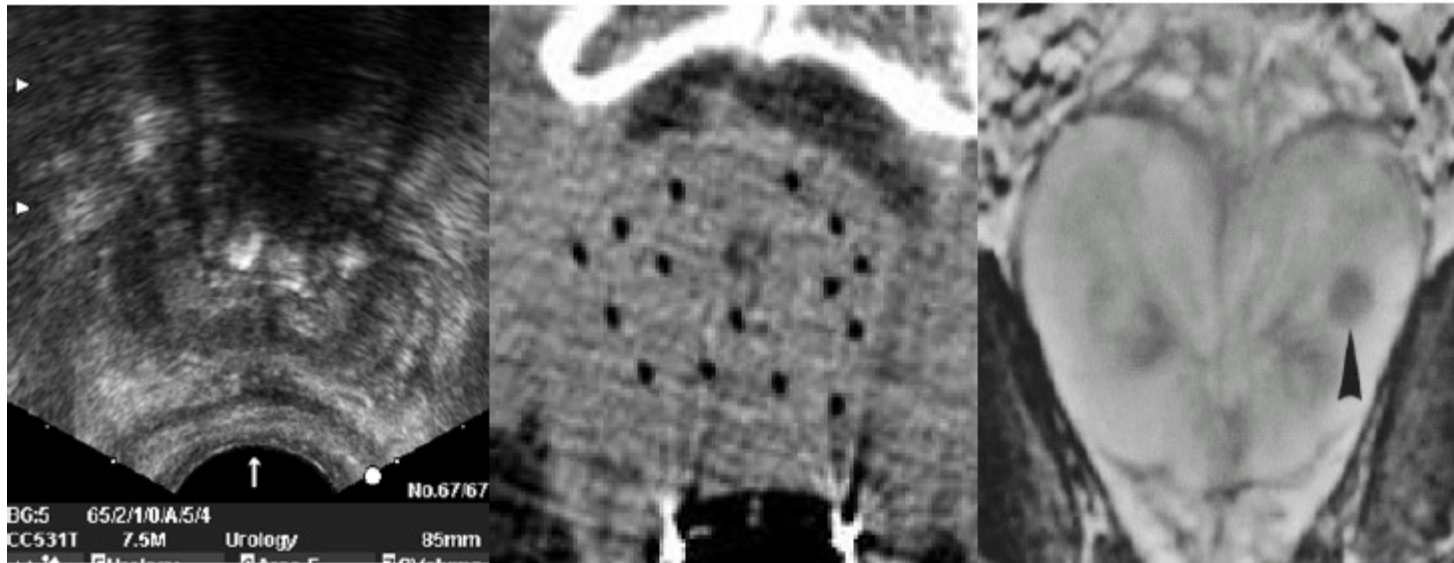


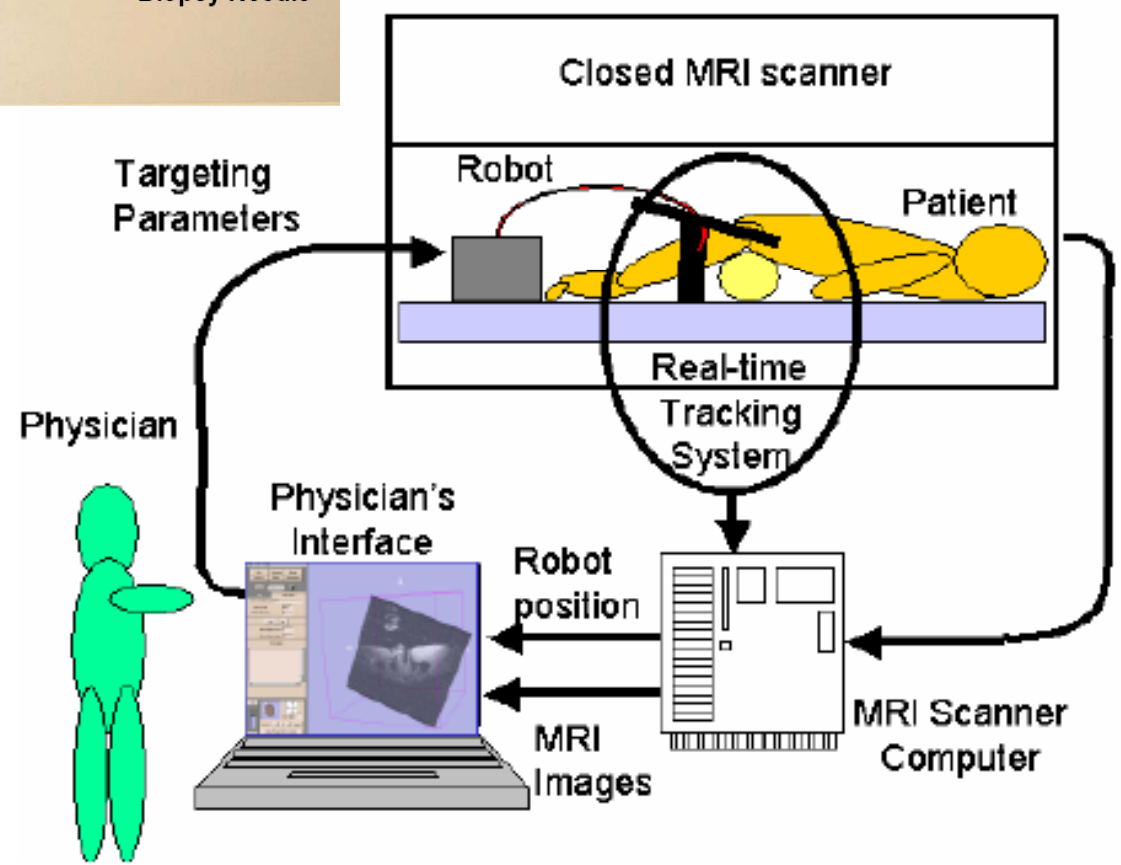
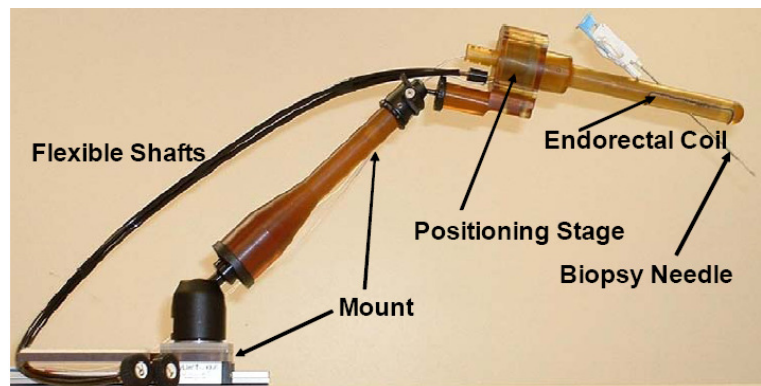
Figure 1.1: Prostate images from ultrasound, CT, and MRI



-
1. Clinical background and motivation
 - 2. Systems overview**
 3. Workflow
 4. Demonstration with SLICER
 1. Robot calibration
 2. Prostate segmentation
 3. Biopsy targeting
 4. Verification
-



Systems overview





-
1. Clinical background and motivation
 2. Systems overview
 - 3. Workflow**
 4. Demonstration with SLICER
 1. Robot calibration
 2. Prostate segmentation
 3. Biopsy targeting
 4. Verification
-



Workflow

1. Acquire a calibration volume, calibrate/register robot to MR coordinate system
 2. Acquire targeting volume, pick/mark biopsy(or seed) targets
 3. Perform biopsy
 4. Acquire validation volume, with needle still in
 5. Perform validation analysis
-

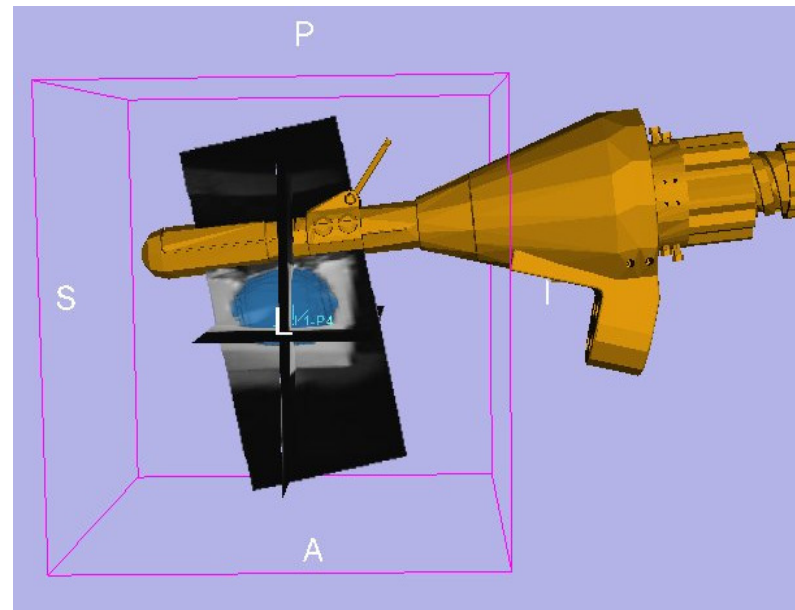


-
1. Clinical background and motivation
 2. Systems overview
 3. Workflow
 - 4. Demonstration with SLICER**
 1. Robot calibration
 2. Prostate segmentation
 3. Biopsy targeting
 4. Verification
-



Demonstration with SLICER

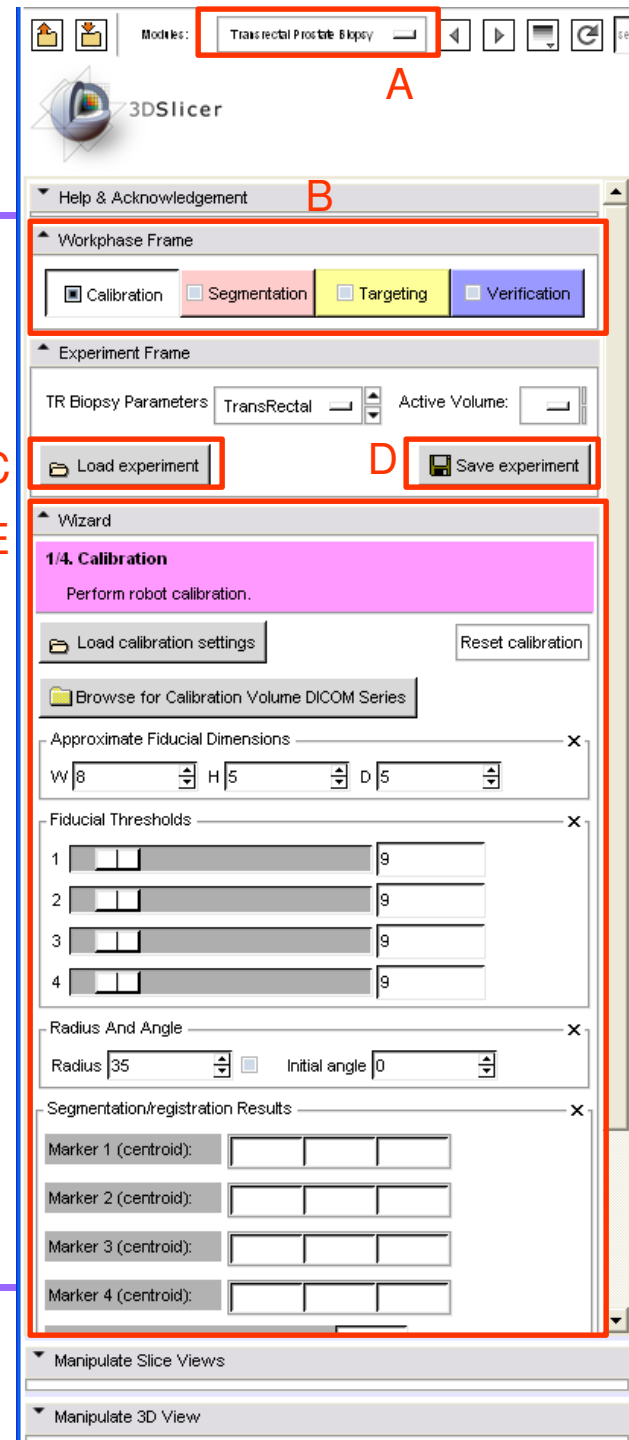
1. Robot calibration (registration)
2. Prostate segmentation
3. Biopsy targeting
4. Verification





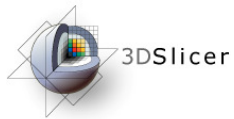
Transrectal Prostate Biopsy GUI

- A** - Select << Transrectal Prostate Biopsy >> from modules list, GUI loads up with “Experiment” frame and “Wizard workflow GUI” frame
- B** - Workphase frame depicts which step you are currently in, can also be for navigation a particular step directly
- C** - “Load experiment” to load any previously saved intervention
- D** - “Save experiment” to save the experiment
- E** - Wizard workflow GUI, as an intuitive interface to perform the intervention step-by-step; here, it illustrates the first step of calibration; each step’s wizard GUI is explained in the following slides





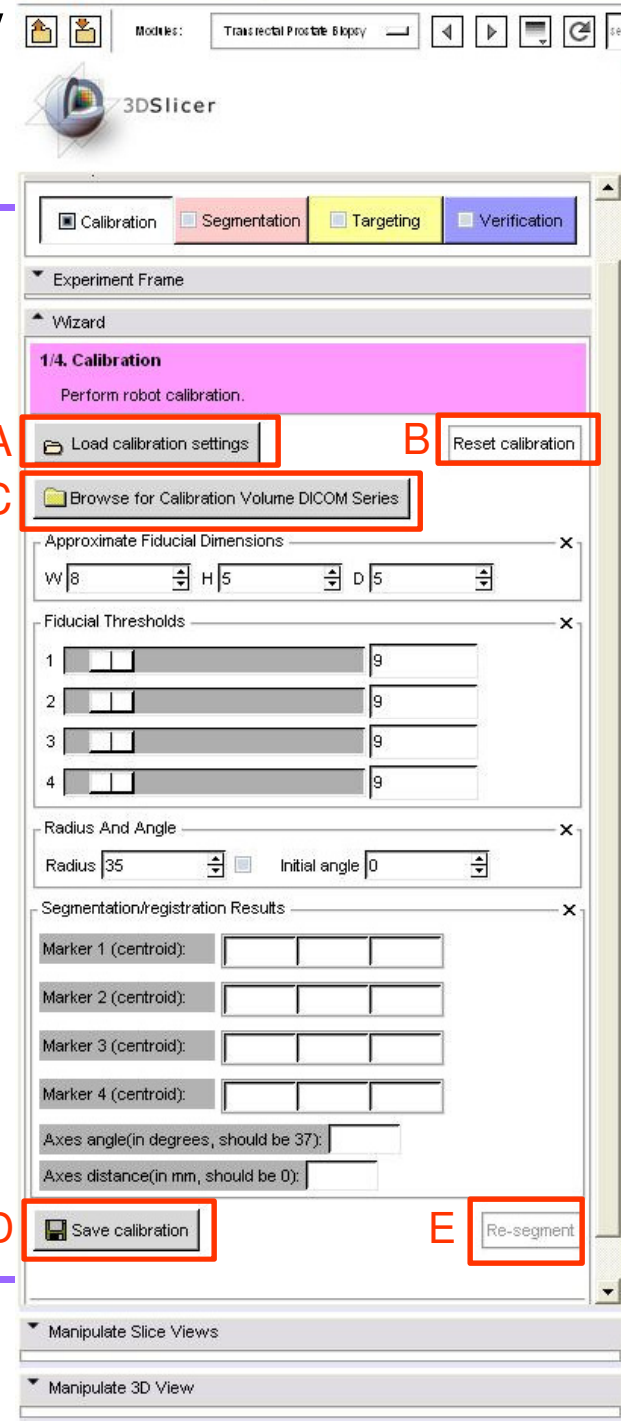
Calibration



Calibrate step wizard GUI

Load/save/reset

- A - Click to load a previous saved calibration
- B - Reset calibration completely, new marker guesses
- C - Click to load calibration volume dicom series
- D - Save the current achieved calibration
- E - Re-segment markers with new set of segmentation parameters, not giving new guesses; this button becomes active if calibration has been done at least once

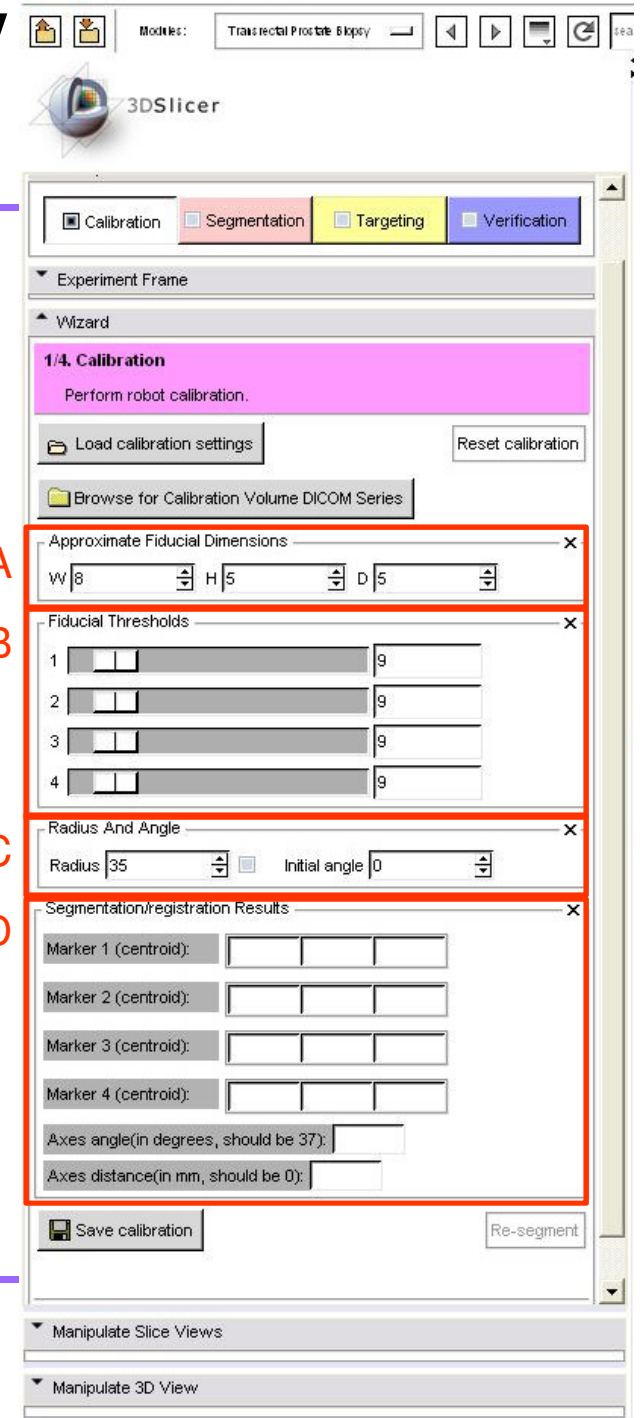




Calibrate step wizard GUI

Marker segmentation parameters

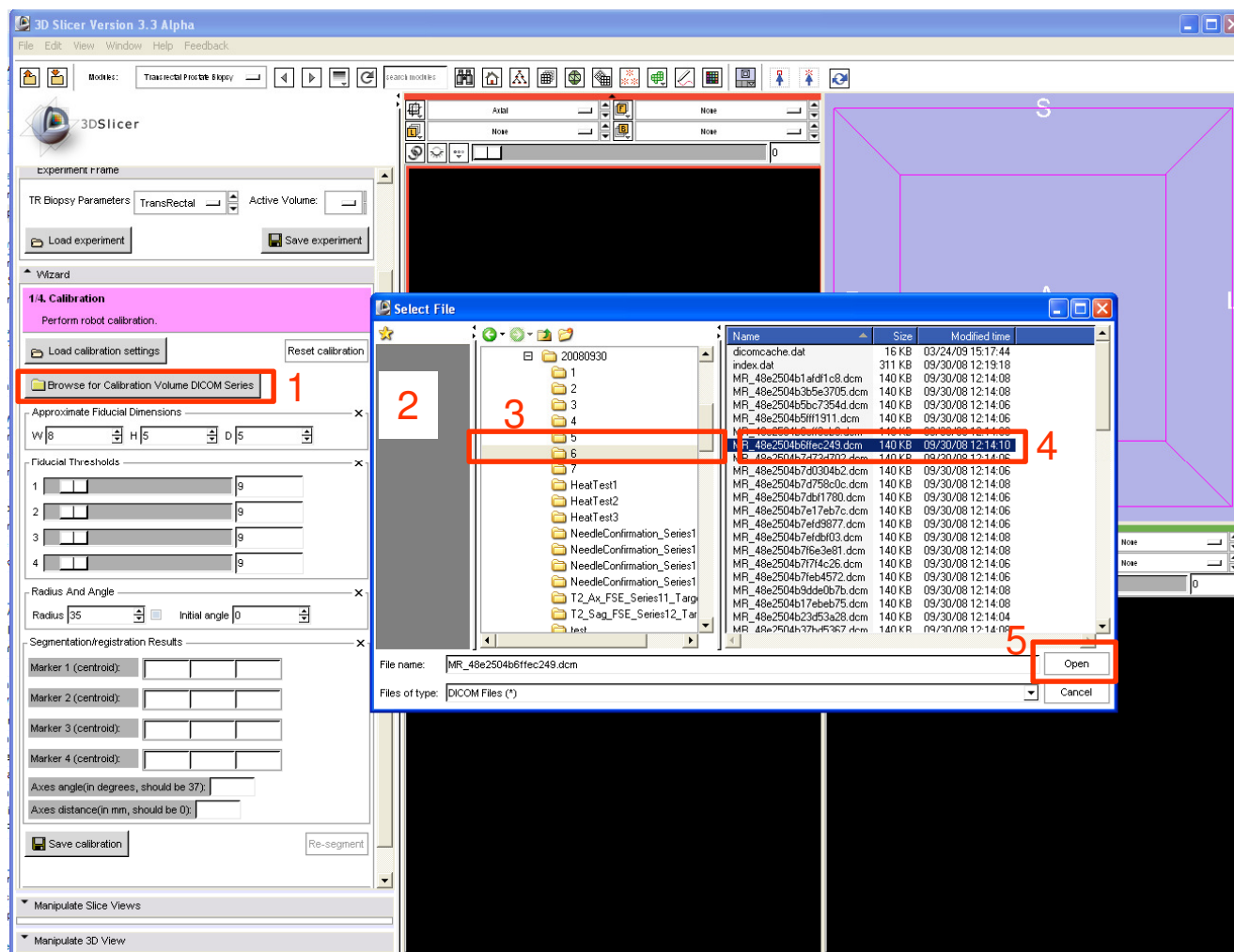
- A - Approximate fiducial dimensions for morphological filtering
- B - Threshold for each of the four markers on robot to aid segmentation
- C - Readings on the robot
- D - Segmentation/Registration results displayed here

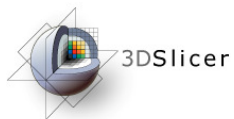




Load calibration dicom series

- 1 - Click “Browse for calibration dicom...”
- 2 - Dialog box appears
- 3 - Navigate to desired directory (TRPBTutorialDataset \Calibration\)
- 4 - Select any one file in the directory
- 5 - Click “Open”





Calibrate step

1 - Select the parameters

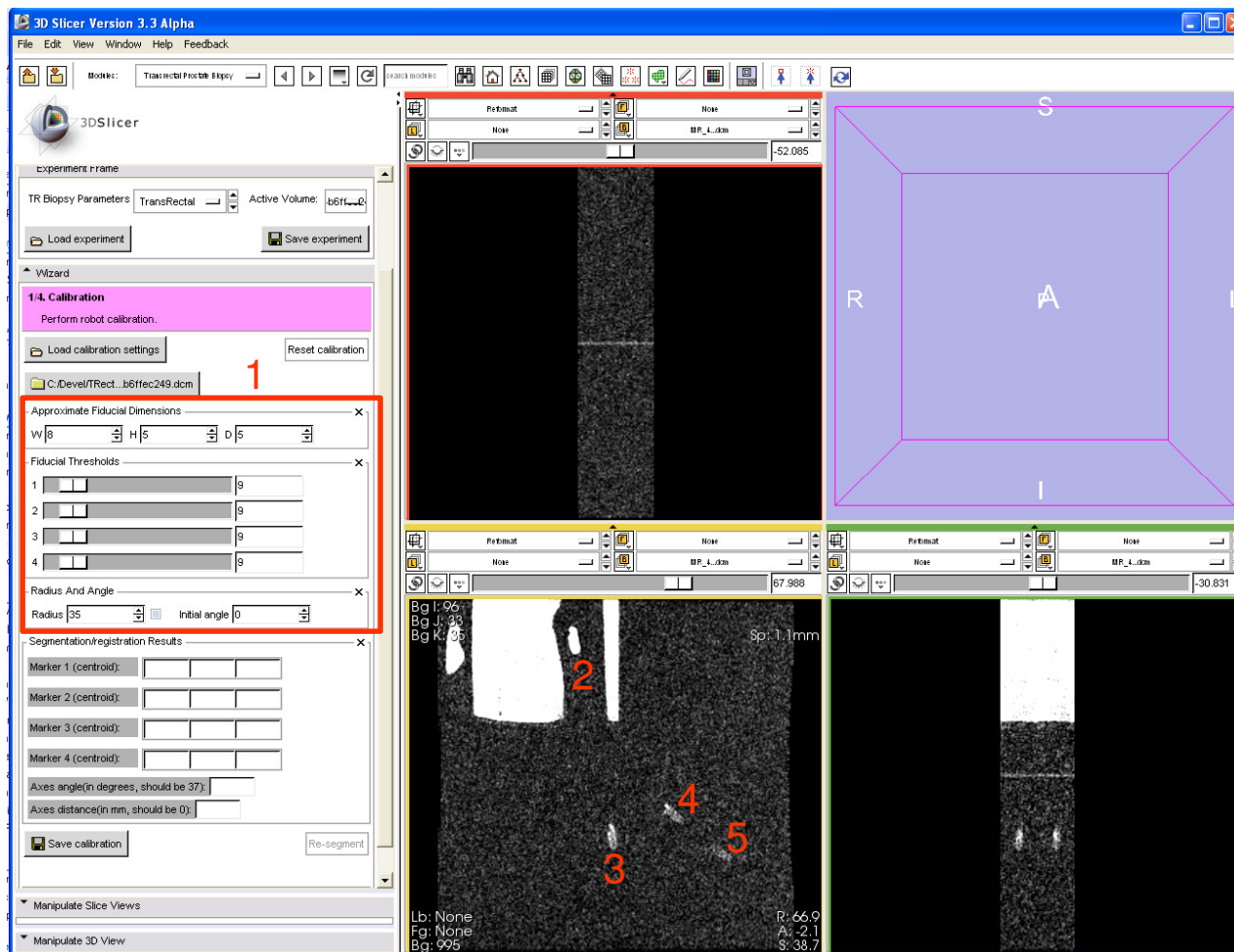
In any of three views, wherever the marker is best visible:

2 - Click first marker roughly at center

3 - Click second marker roughly at center

4 - Click third marker roughly at center

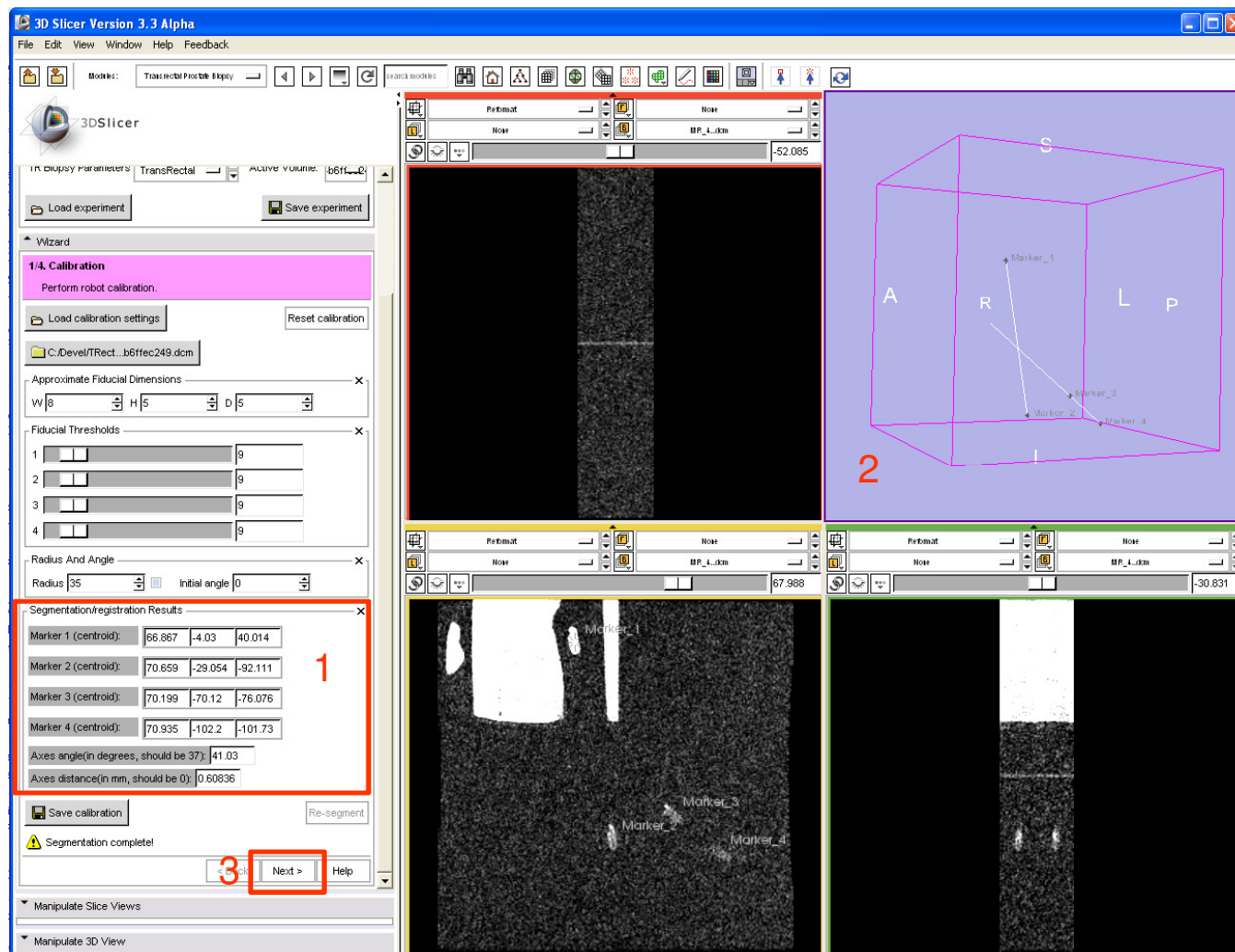
5 - Click fourth marker roughly at center





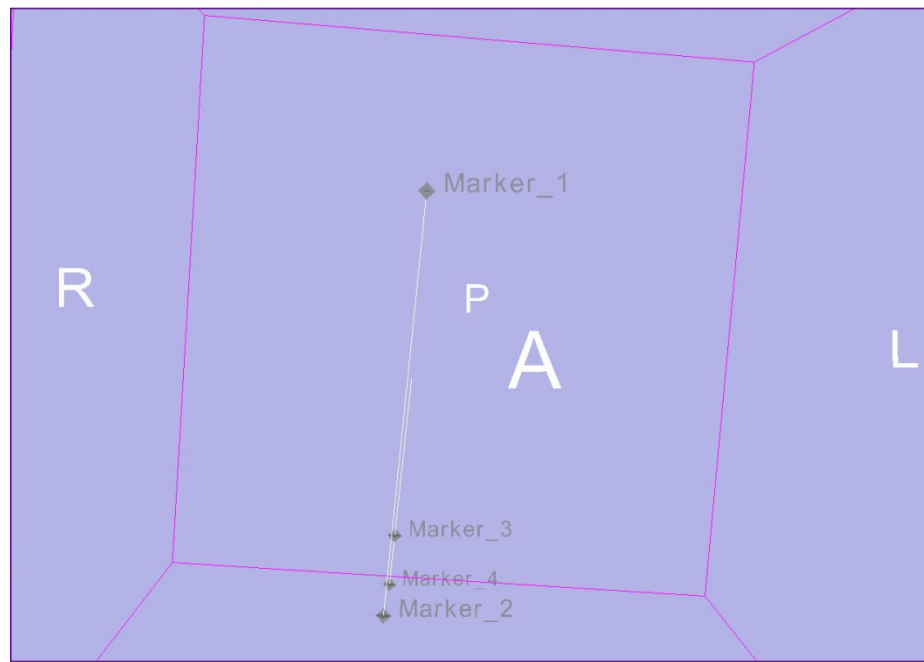
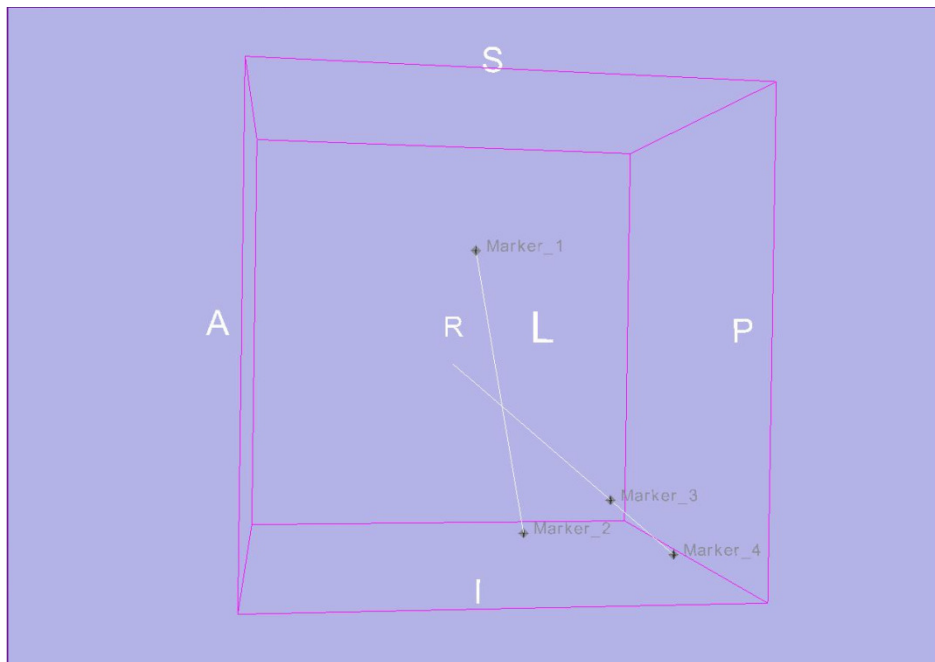
Calibrate step -- results

- 1 - Results displayed
- 2 - 3D visualization of registration, depicting two axes of robot (probe and needle); gives an idea of coverage
- 3 - Click "Next" if satisfied with results



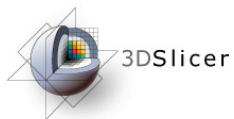


Calibrate step -- results



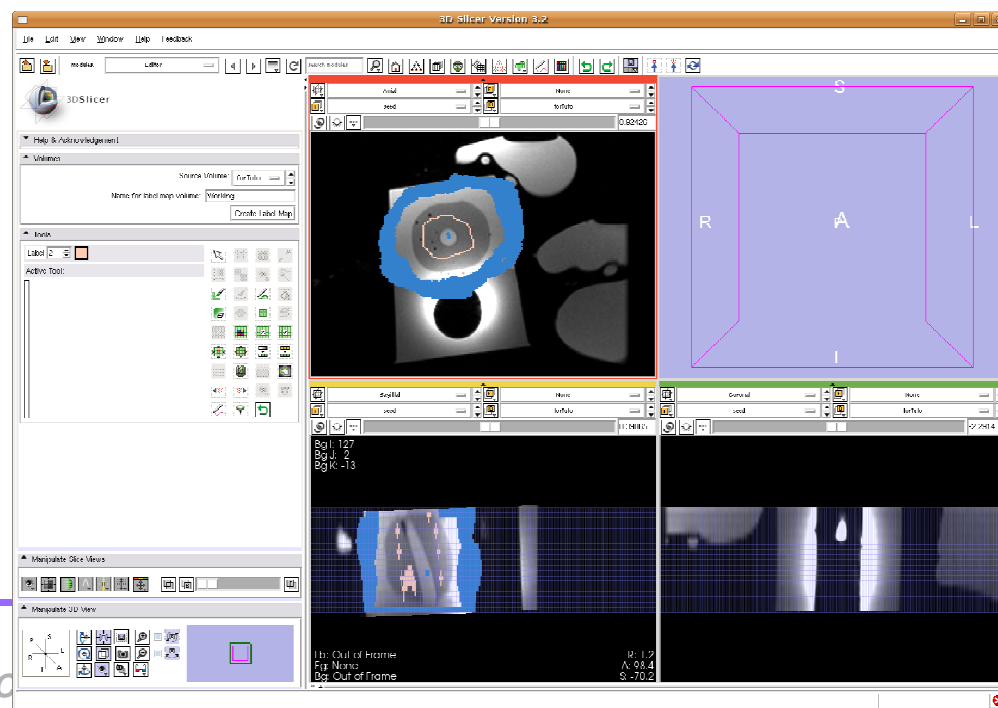


Prostate Segmentation



Generate the seed image

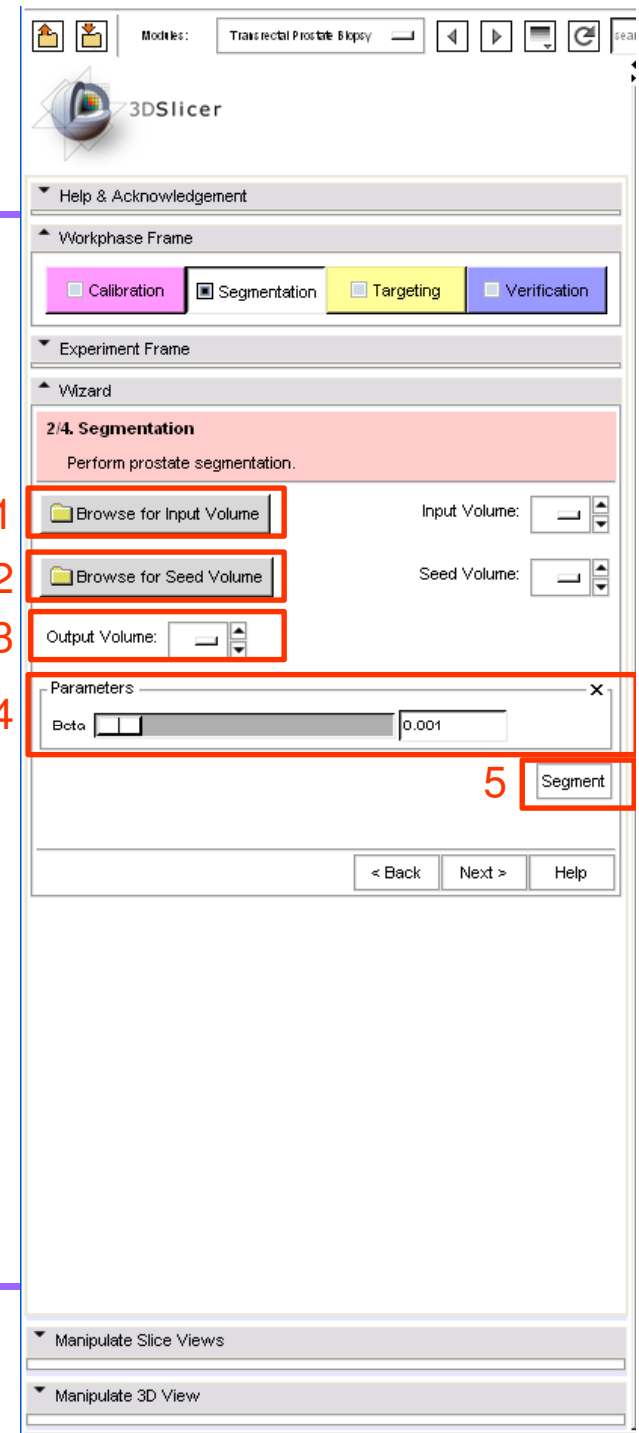
- Use the Slicer3 Editor:
 - Load the volume
(TRPBTTutorialDataset\ToSegment.nhdr)
 - Label 1: background seed, **blue**
 - Label 2: object seed, **orange**





Segmentation step wizard GUI

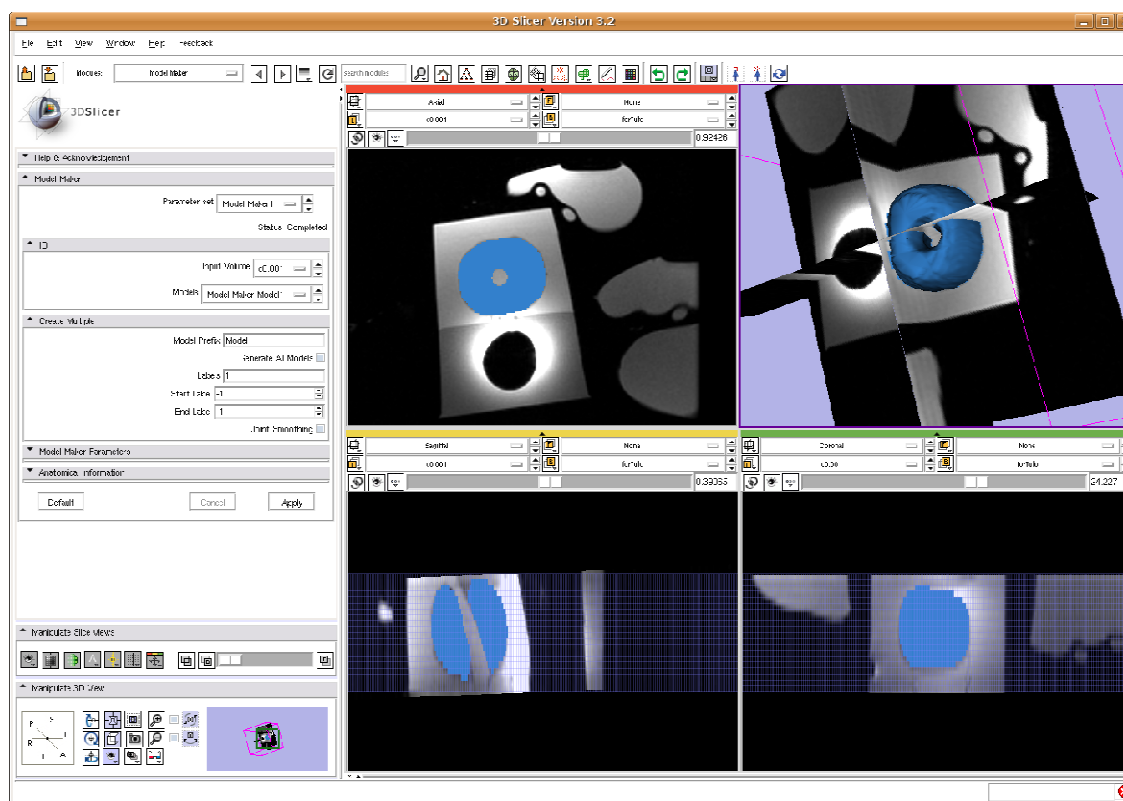
- 1 - Click to load the input volume (Load from directory: TRPBTutorialDataset\ToSegment.nhdr)
- 2 - Click to load the seed volume (Use the seed volume generate in previous step or load from directory TRPBTutorialDataset\seed.nhdr)
- 3 - Set output volume (Set “Create new one”)
- 4 - Segmentation parameter “Beta” to 0.001
- 5 - Press to start the segmentation





Generate model

- Use the Slicer3 Model maker module:
- Use the volume generated from previous step as input



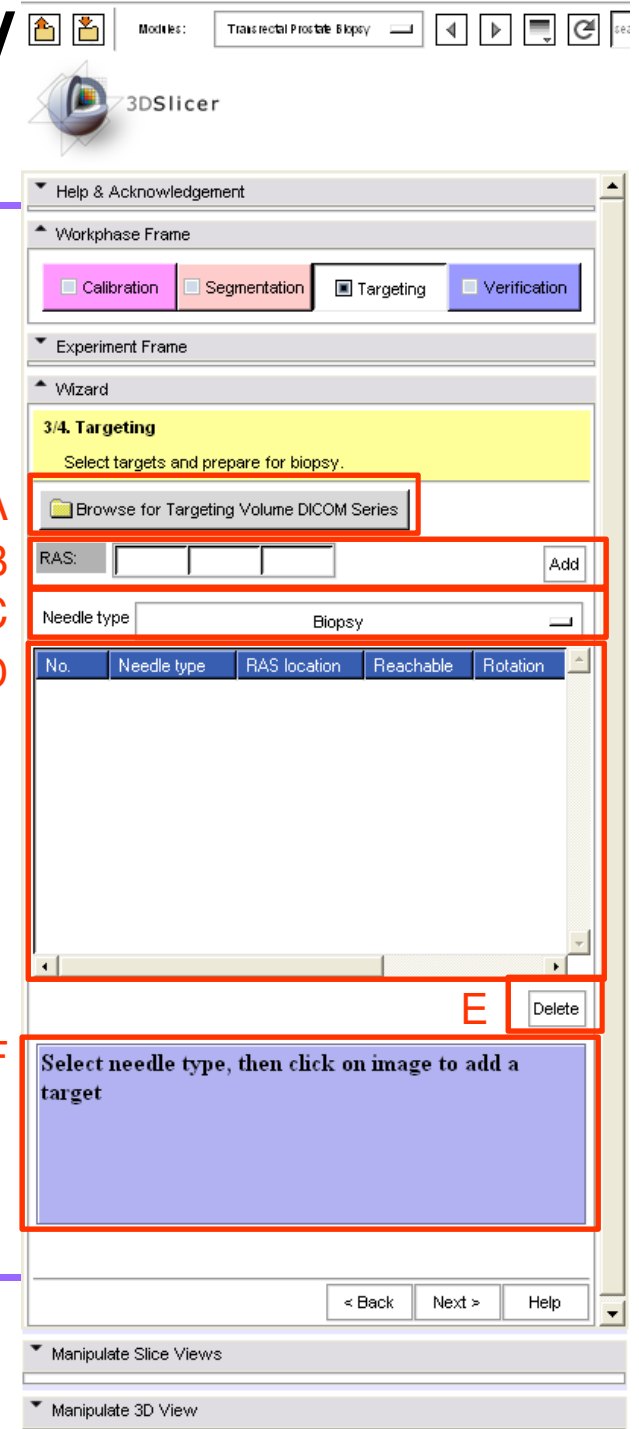


Targeting



Targeting step wizard GUI

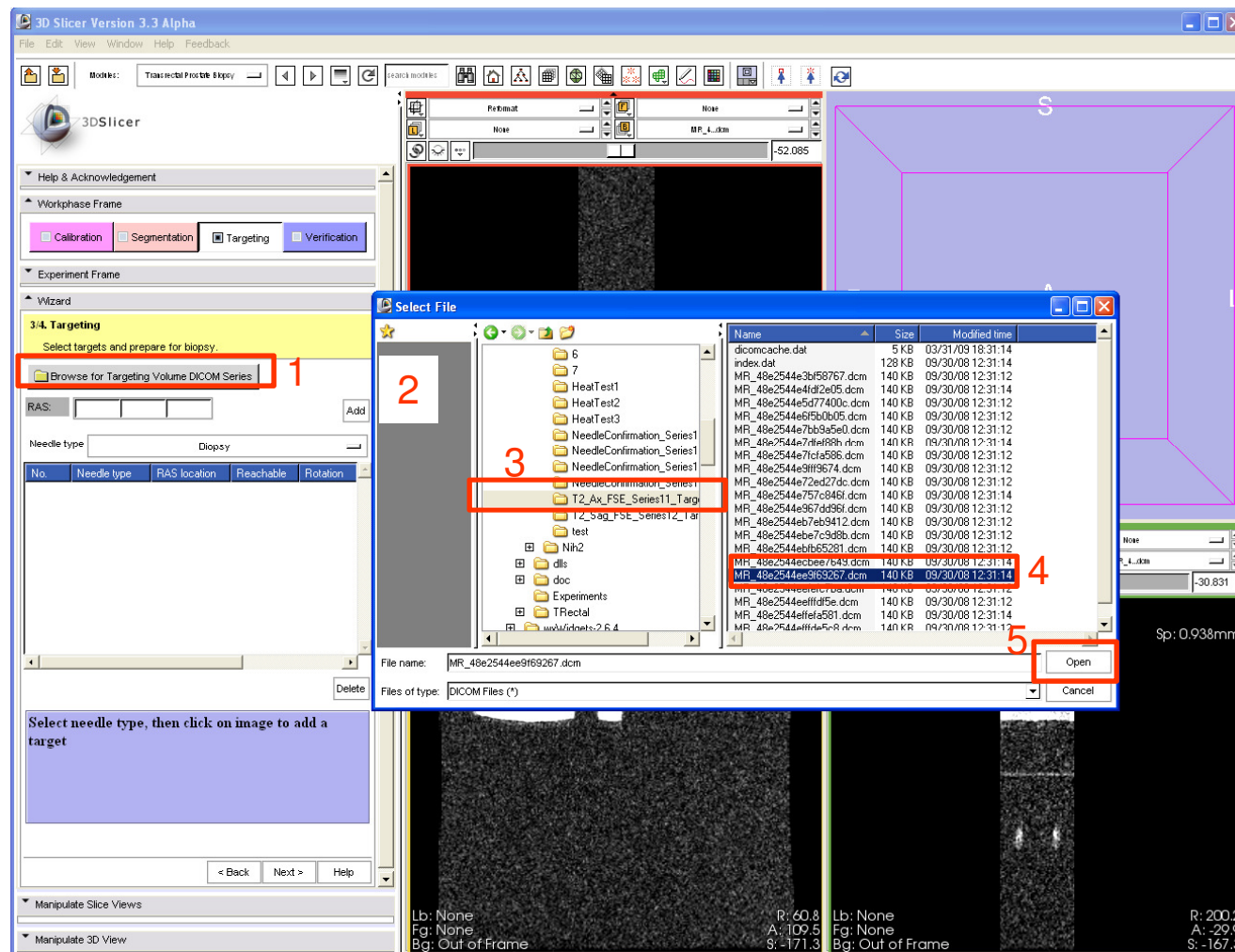
- A - Click to load the targeting volume dicom series
- B - Controls to key-in the target RAS coordinates (conventional method is to just click using mouse)
- C - Drop-down list to choose from available needle types
- D - Multi-column scrollable list, that would display each target, along with all the relevant information about targeting parameters of the robot to reach that target location
- E - One can delete a certain target, by first selecting the target from the list and then clicking 'Delete'
- F - Message/instruction display area





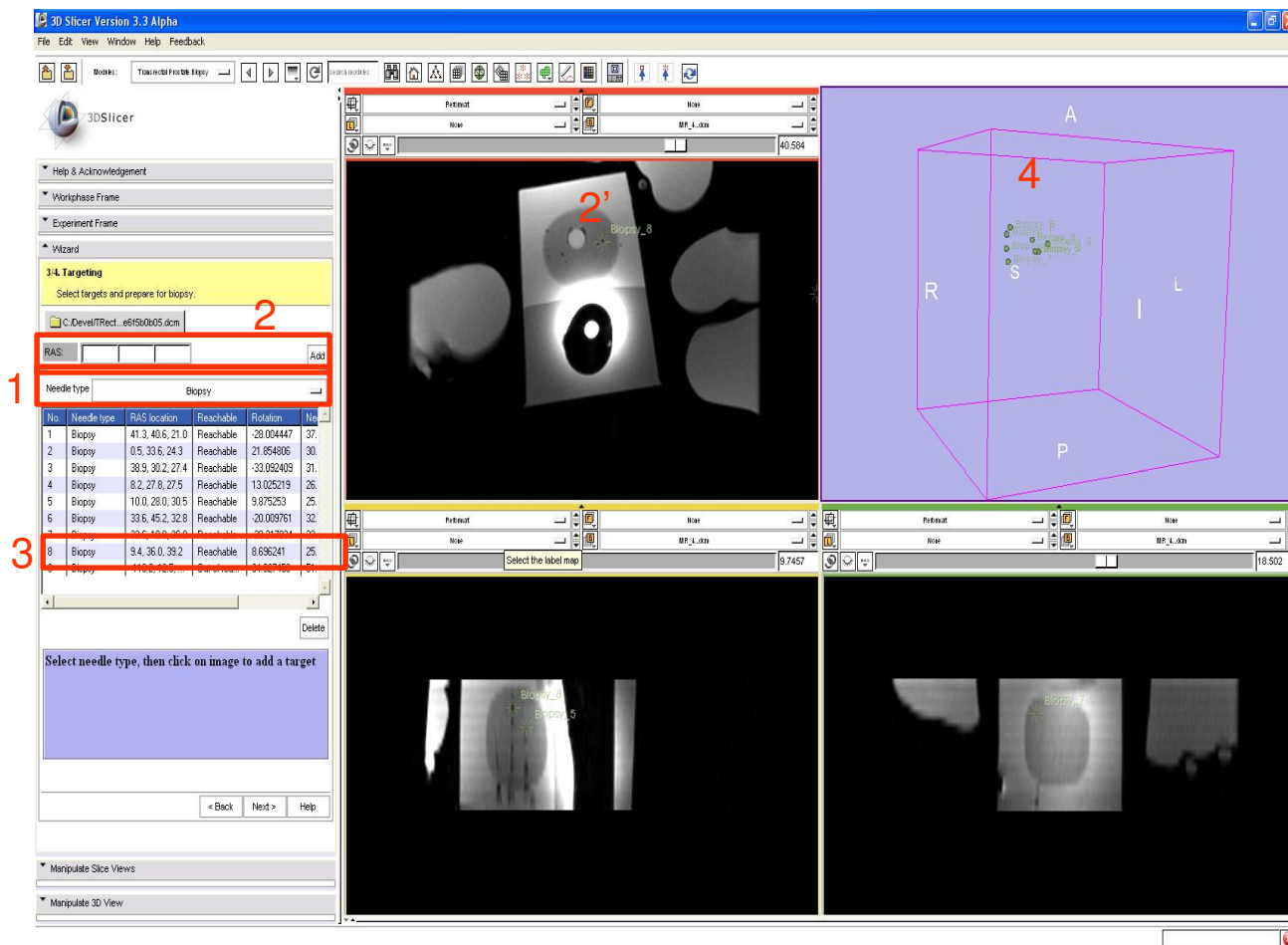
Load targeting dicom series

- 1 - Click “Browse for targeting dicom...”
- 2 - Dialog box appears
- 3 - Navigate to desired directory (TRPBTutorialDataset \Targeting\)
- 4 - Select any one file in the directory
- 5 - Click “Open”



Pick biopsy targets

- 1 - Select the needle type from drop-down list
- 2 - Key-in 'RAS' coordinates
or
- 2' - Navigate to desired slice in any of three views, and pick a target by clicking
- 3 - Target and its targeting parameters populated in the list
- 4 - Target shows up in the 3D view



The screenshot shows the 3D Slicer interface with the following elements:

- Top Panel:** Shows the current slice (Axial) and the selected needle type, 'Biopsy'.
- Left Panel (3.4. Targeting):** Contains a table of biopsy targets. A red box highlights the 'Needle type' dropdown menu (labeled '1') and the 'RAS' input field (labeled '2').
- Table of Biopsy Targets:**

No.	Needle type	RAS location	Reachable	Rotation	No.
1	Biopsy	41.3, 40.6, 21.0	Reachable	-28.004447	37.
2	Biopsy	0.5, 33.6, 24.3	Reachable	21.854806	30.
3	Biopsy	38.9, 30.2, 27.4	Reachable	-33.092409	31.
4	Biopsy	8.2, 27.8, 27.5	Reachable	13.025219	26.
5	Biopsy	10.0, 28.0, 30.5	Reachable	9.875253	25.
6	Biopsy	33.6, 45.2, 32.8	Reachable	-20.009761	32.
7	Biopsy	20.0, 28.0, 30.5	Reachable	9.875253	25.
8	Biopsy	9.4, 36.0, 39.2	Reachable	8.636241	25.
- Right Panel (3D View):** Shows a 3D model of the patient's head with a purple wireframe box representing the biopsy target. A red box highlights this 3D view (labeled '4').



Pick biopsy targets

3D Slicer Version 3.3 Alpha

File Edit View Window Help Feedback

Monitors: Transrectal Prostate Biopsy

3DSlicer

Help & Acknowledgement

Workphase Frame

Experiment Frame

Wizard

3.4. Targeting

Select targets and prepare for biopsy.

C:\Devel\TRect...e619b0b05.dcm

RAS: Add

Needle type: Biopsy

No	Needle type	RAS location	Reachable	Rotation	Ne...
1	Biopsy	41.3, 40.6, 21.0	Reachable	-28.004447	37.
2	Biopsy	0.5, 33.6, 24.3	Reachable	21.854806	30.
3	Biopsy	38.9, 30.2, 27.4	Reachable	-33.092409	31.
4	Biopsy	8.2, 27.8, 27.5	Reachable	13.025219	26.
5	Biopsy	10.0, 28.0, 30.5	Reachable	9.875253	25.
6	Biopsy	33.6, 45.2, 32.8	Reachable	-20.009761	32.
7	Biopsy	33.6, 19.9, 36.8	Reachable	-38.217034	23.
8	Biopsy	9.4, 36.0, 39.2	Reachable	8.696241	25.
9	Biopsy	-110.2, 12.5, ...	Out of rea...	84.627450	51.

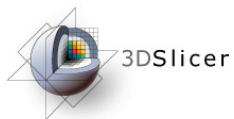
Select needle type, then click on image to add a target

< Back Next > Help

Manipulate Slice Views

Manipulate 3D View

3D only layout



Select a specific target, and perform biopsy with robot

- 1 - Scroll, and select from the list, the target which you want to biopsy
- 2 - The target is marked red and is brought to view in all three orthogonal views
- 3 - In 3D view, target selected and the 3D needle trajectory visualized (very useful feedback for clinician)

3D Slicer Version 3.3 Alpha

File Edit View Window Help Feedback

Workbench: Targeted Prostate Biopsy

3DSlicer

Help & Acknowledgement

Workbench Frame

Calibration Segmentation Targeting Verification

Experiment Frame

Wizard

3.4. Targeting

Select targets and prepare for biopsy.

C:\Devel\Rect...e6r5b0b05.dcm

RAS: [] [] [] Add

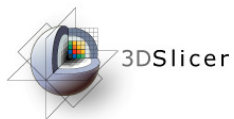
Needle type: Biopsy

Needle type	RAS location	Reachable	Distance (mm)
1 Biopsy	40.7, 41.1, 2	Reachable	27.490483
2 Biopsy	36.8, 20.4, 2	Reachable	33.753118
3 Biopsy	9.3, 27.7, 30.5	Reachable	10.805347
4 Biopsy	34.1, 45.4, 3...	Reachable	20.708035
5 Biopsy	9.8, 48.3, 35.7	Reachable	6.142423

Needle type: Biopsy
RAS location: R 40.7, A 41.1, S 21.0
Reachable: Yes
Depth (cm): 12.7
Device rotation (degrees): -27.5
Needle angle (degrees): 37.5

3D View: Sp: 3mm, Bg I: 198, Bg J: 175, Bg K: 9, R: -34.8, A: 41.4, S: 24.2

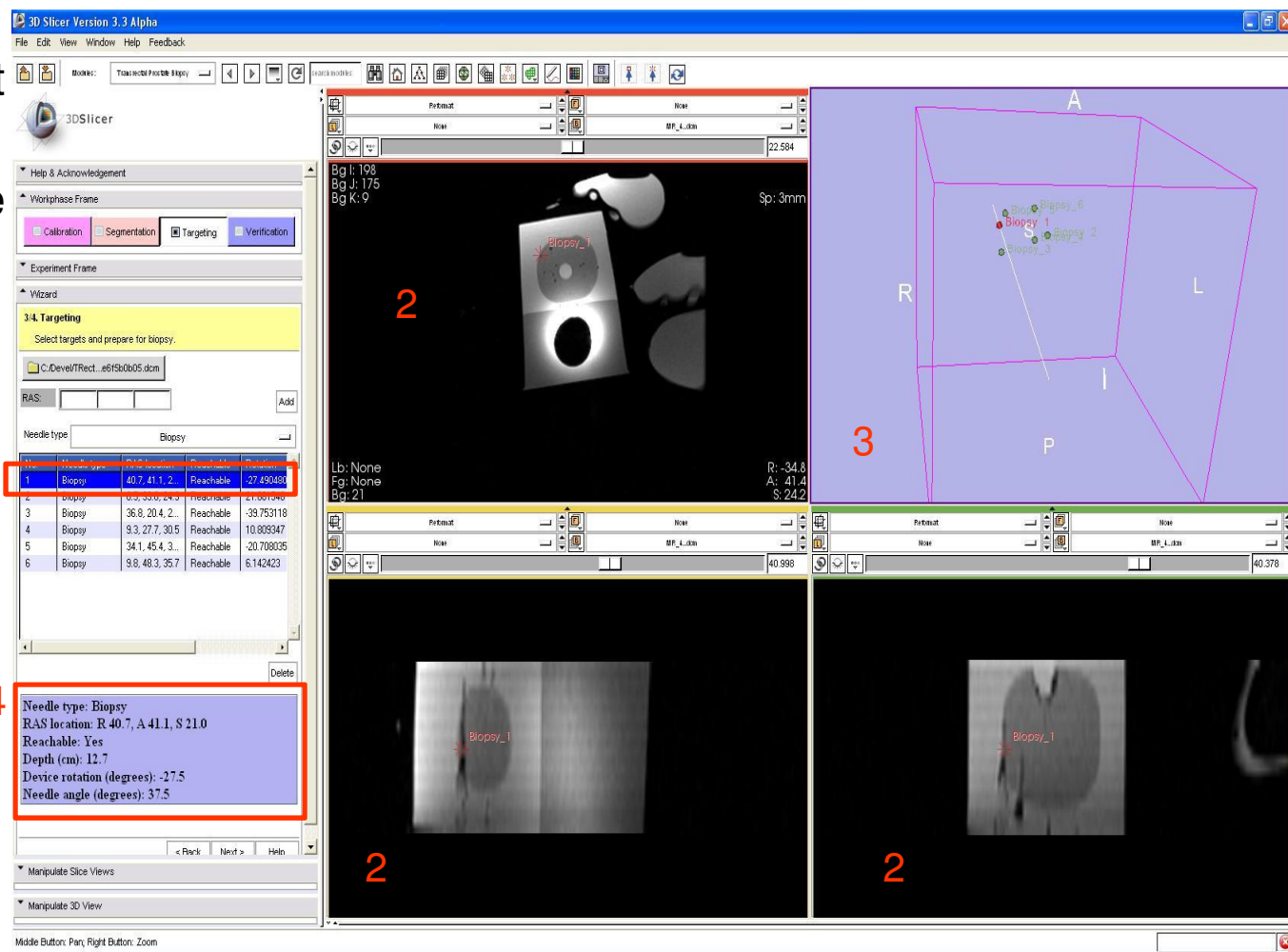
2D Views: Bg I: 198, Bg J: 175, Bg K: 9, R: -34.8, A: 41.4, S: 24.2



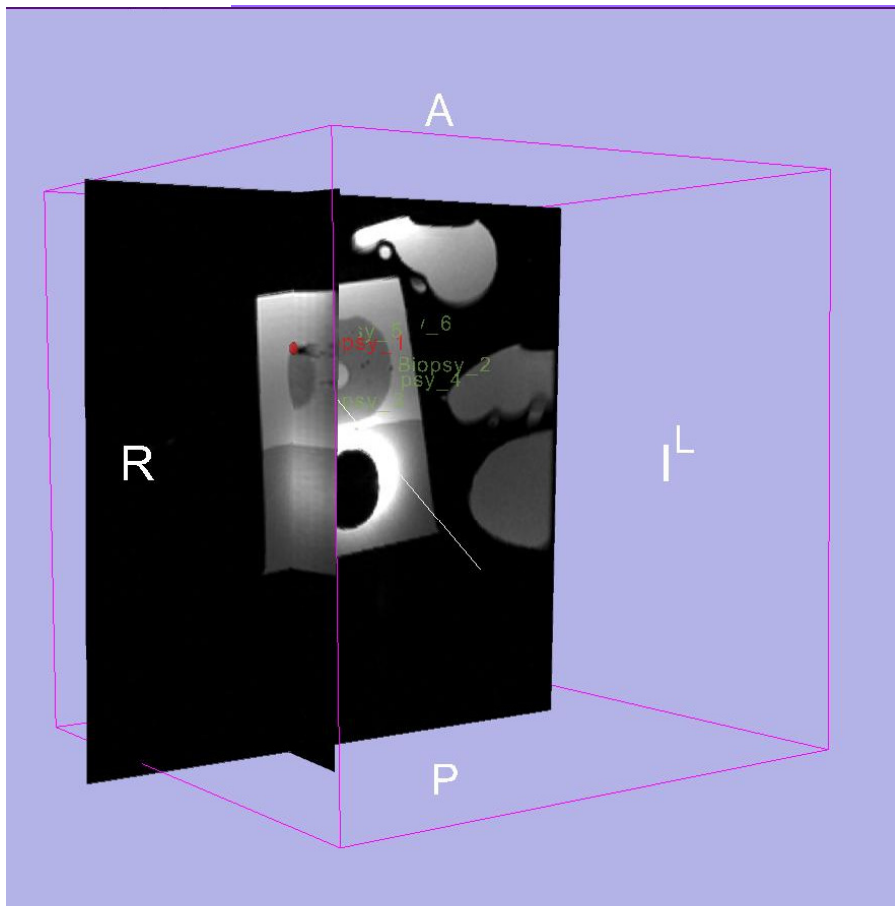
Select a specific target, and perform biopsy with robot

- 4 - Targeting parameters for robot displayed
- 5 - On the robot, set the device rotation, and needle angle values to as computed and displayed for that specific target; fire the needle to perform the biopsy!

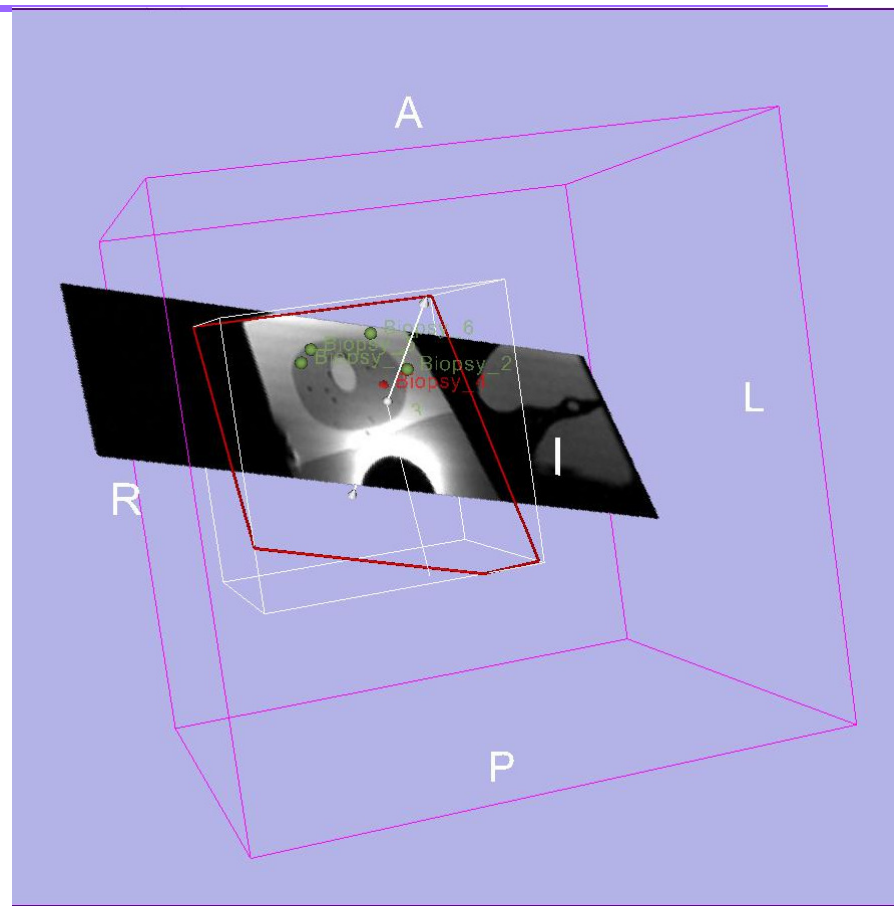
PS: Robot is not software actuated, one has to manually set the parameters and perform biopsy



Visualization capabilities



Turn slice visibility 'on' for better visualization of target within anatomy



Use Slicer's re-format widget to re-slice in arbitrary orientation e.g. along plane of needle trajectory

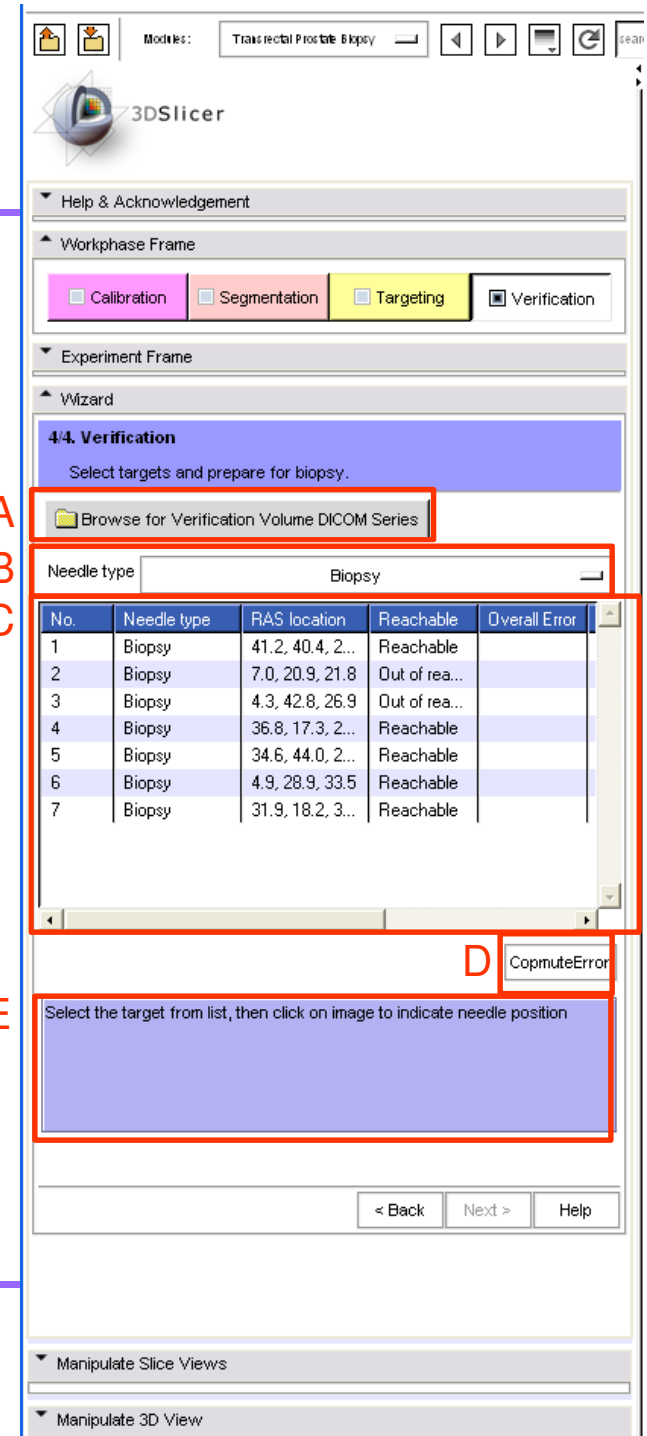


Verification



Verification step wizard GUI

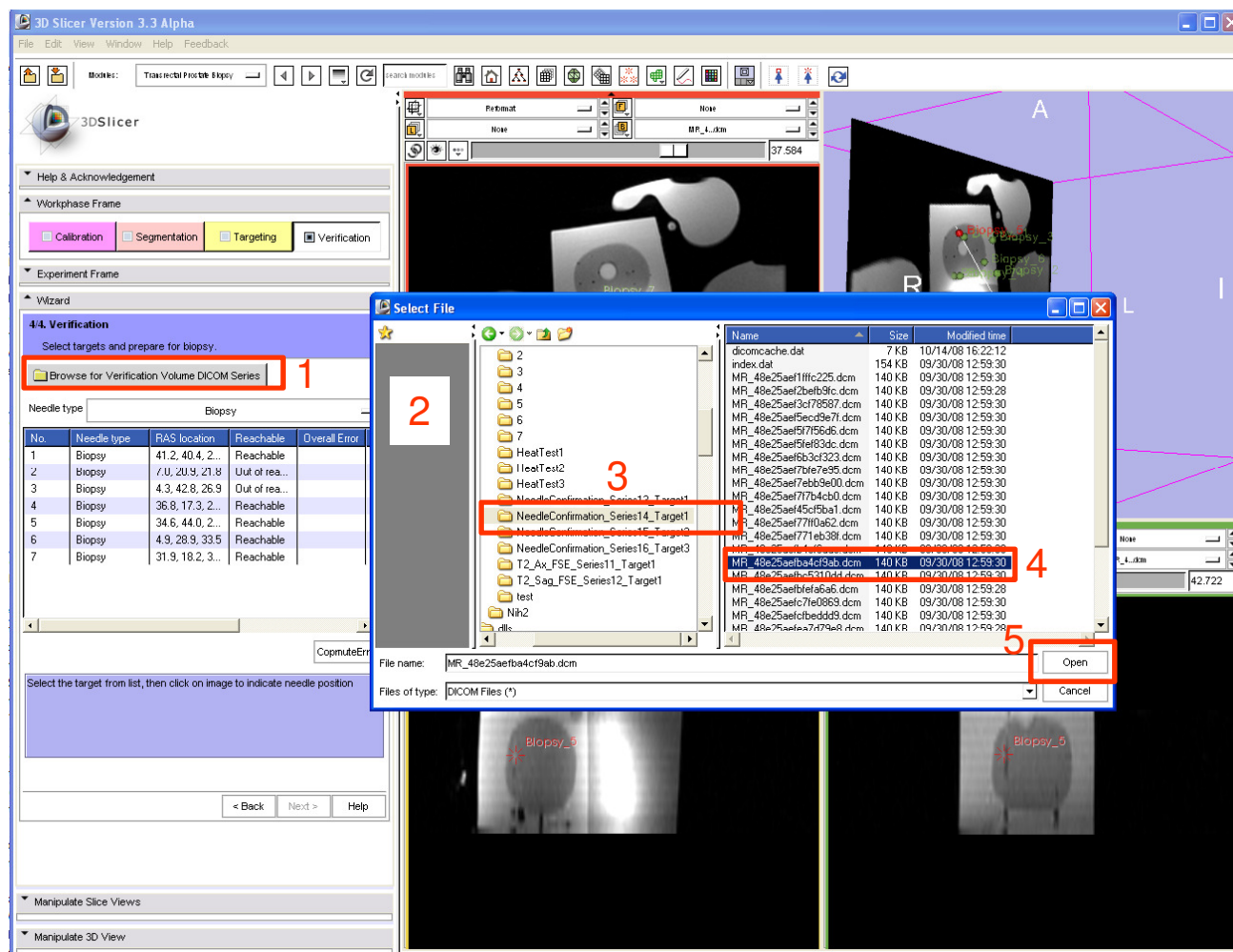
- A - Click to load the verification volume dicom series
- B - Drop-down list to choose from available needle types
- C - Multi-column scrollable list, that would display each target, along with the error calculations if the target was validated
- D - Click 'Compute Error' to initiate verification process
- E - Message/instruction display area





Load verification dicom series

- 1 - Click “Browse for targeting dicom...”
- 2 - Dialog box appears
- 3 - Navigate to desired directory (TRPBTutorialDataset \Verification\)
- 4 - Select any one file in the directory
- 5 - Click “Open”





Verify a target

- 1 - Select the target from the list to validate
- 2 - Click 'Compute Error'
- 3 - Click to give needle end
- 4 - Click to give the other end of needle
- 5 - Needle placement error calculated and displayed

3D Slicer Version 3.3 Alpha

4.4. Verification

Select targets and prepare for biopsy.

C:\Devel\TRect...f7bfe7e95.dcm

Idx	Structure type	RAS location	Reachable	Minimum Error
1	Biopsy	41.7, 40.8, 1...	Reachable	0.5
2	Biopsy	4.3, 23.3, 16.7	Out of Fra...	
3	Biopsy	33.6, 43.8, 2...	Reachable	
4	Biopsy	7.6, 28.9, 33.5	Reachable	
5	Biopsy	33.0, 44.6, 3...	Reachable	

Compute Error

Needle type: Biopsy
RAS location: R 41.7, A 40.8, S 18.0
Reachable: Yes
Overall error (mm): 0.5
IS axis error (mm): 0.0
AP axis error (mm): 0.0

Clicked 1st marker at 41.8 41.4 12.0

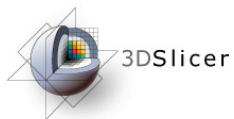
3 4

5



Conclusion

- End-to-end application for performing a MR-guided prostate intervention using SLICER is presented
- Intuitive graphical user interface to interact with the data
- The NAMIC kit's open-source environment allows clinicians and researchers to share data and solutions to common problems



Acknowledgements



National Alliance for Medical Image Computing

NIH Roadmap for Medical Research, Grant U54 EB005149



National Institutes of Health

1 R01 CA118371-01A2