Robot-assisted MRI-guided prostate biopsy using 3D Slicer

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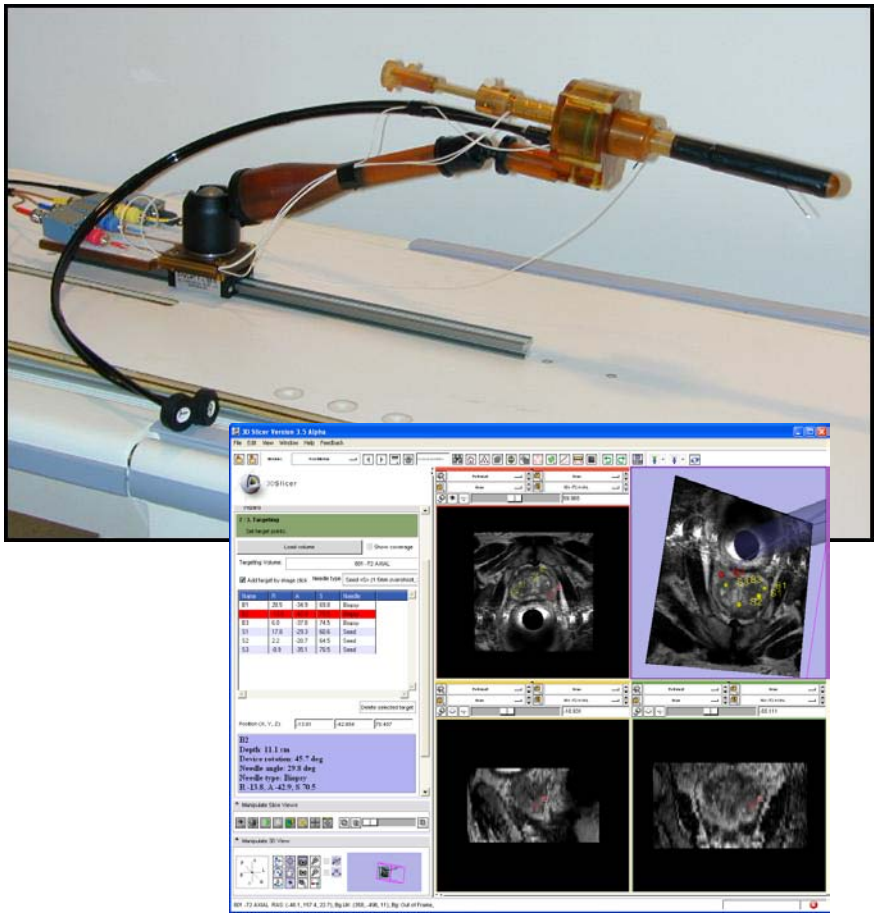
Learning Objective

This tutorial demonstrates how to perform a MRI-guided robot-assisted prostate biopsy and seed placement using 3D Slicer.

It is not necessary to have access to a robotic device or an MRI scanner to complete the tutorial.



Pre-requisite

This tutorial assumes that you have already completed the **Slicer3Visualization Tutorial** (by Sonia Pujol)

The tutorial is available at:
http://www.slicer.org/slicerWiki/index.php/Slicer3.6:Training

Material

- This tutorial requires the installation of the **Slicer3.6 release** and the tutorial dataset.

They are available at the following locations:

- **Slicer3.6** download page
  http://www.slicer.org/pages/Downloads/
- **Tutorial dataset**:
  ProstateNavData_TutorialContestSummer2010
  http://wiki.na-mic.org/Wiki/index.php/File:Fiducials_TutorialContestSummer2010.zip

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.*

Platform

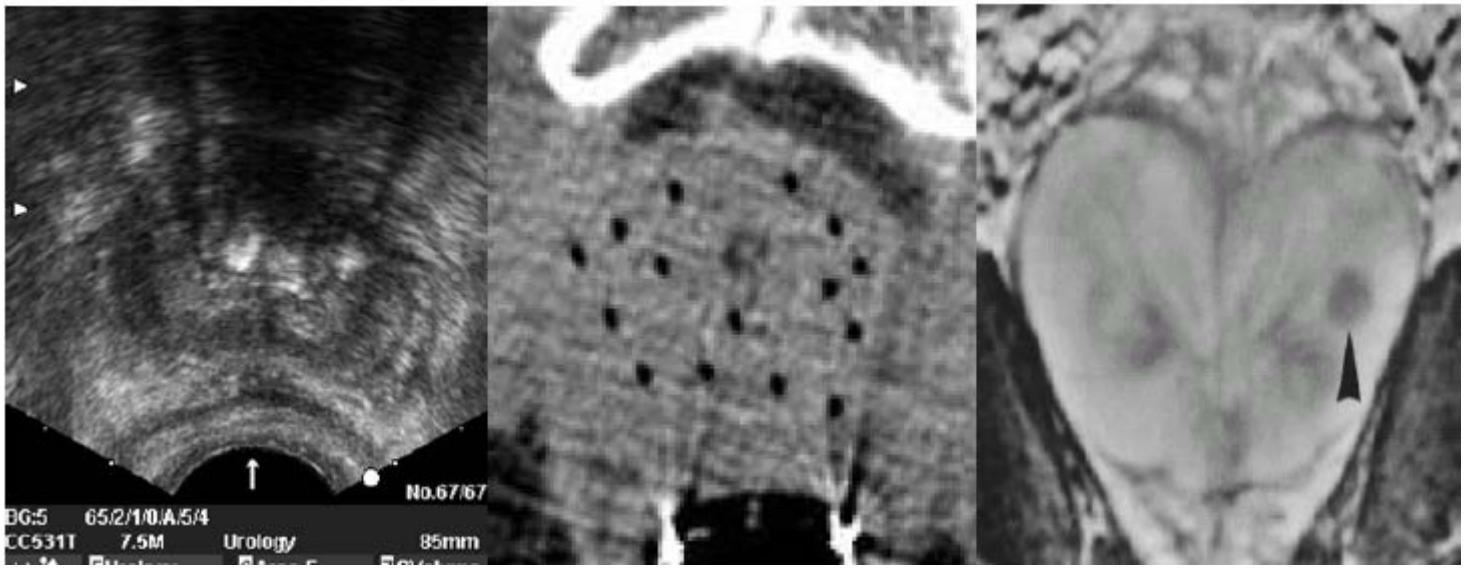
- The tutorial has been developed and tested on Windows XP and Windows 7 platforms.

Overview

- MRI-guided prostate biopsy: clinical background
- Systems overview
- Clinical workflow
  - Set up and calibration
  - Target planning and needle insertion
  - Verification
- Conclusion

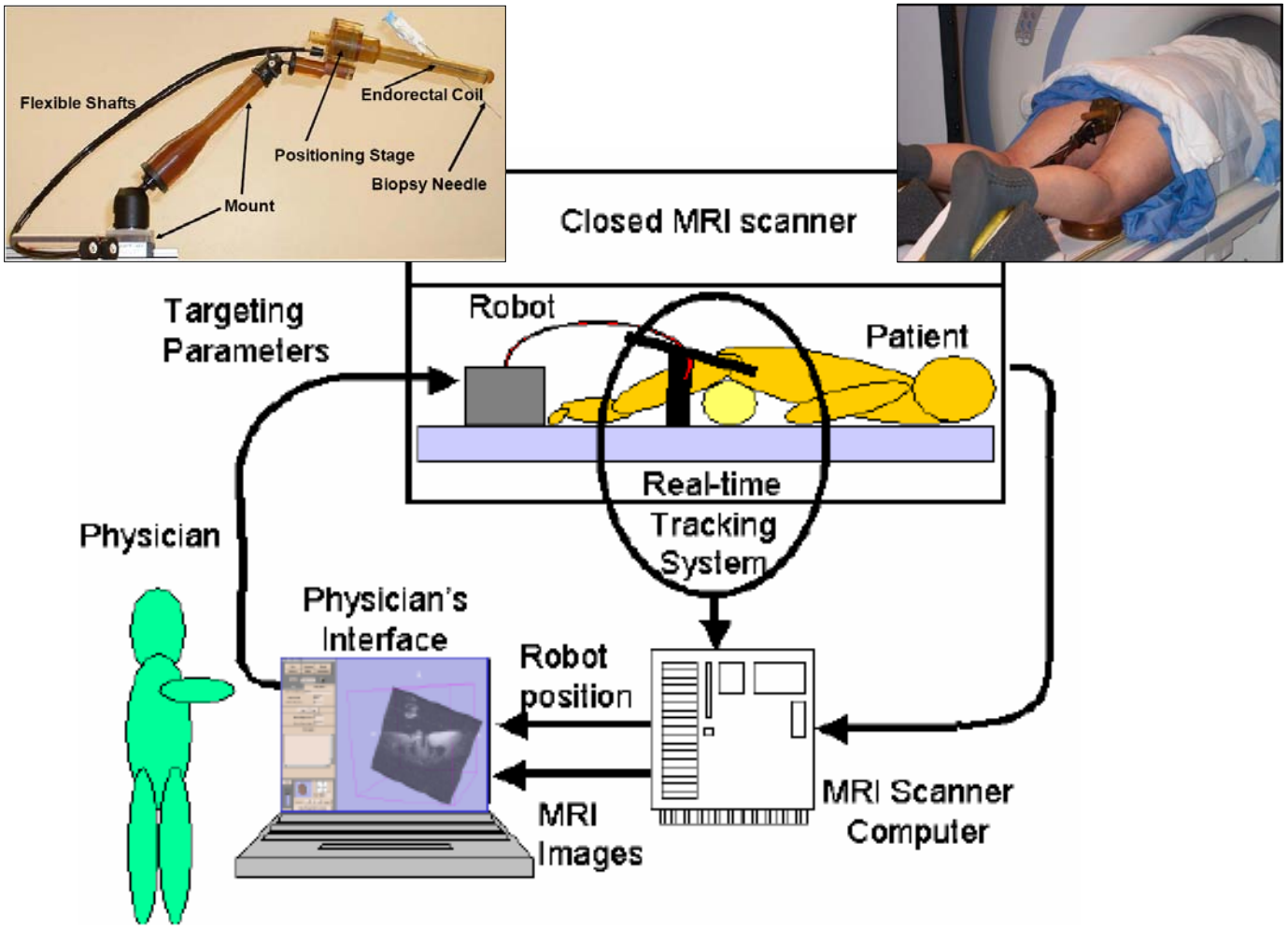
MRI-guided prostate biopsy: clinical background

- 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]



Prostate images from ultrasound, CT, and MRI

Systems overview



More information

Detailed information about the transrectal procedure:

[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

Clinical workflow

- Acquire a calibration volume (high resolution image of the calibration object)
- Calibrate/register robot to MR coordinate system
- Acquire targeting volume (high-resolution image of the patient anatomy)
- Pick/mark biopsy or seed targets
- Perform needle insertion
- Acquire verification volume (quick, low-resolution image with needle still in place)
- Verify the needle position

Set up and calibration

Start the ProstateNav module

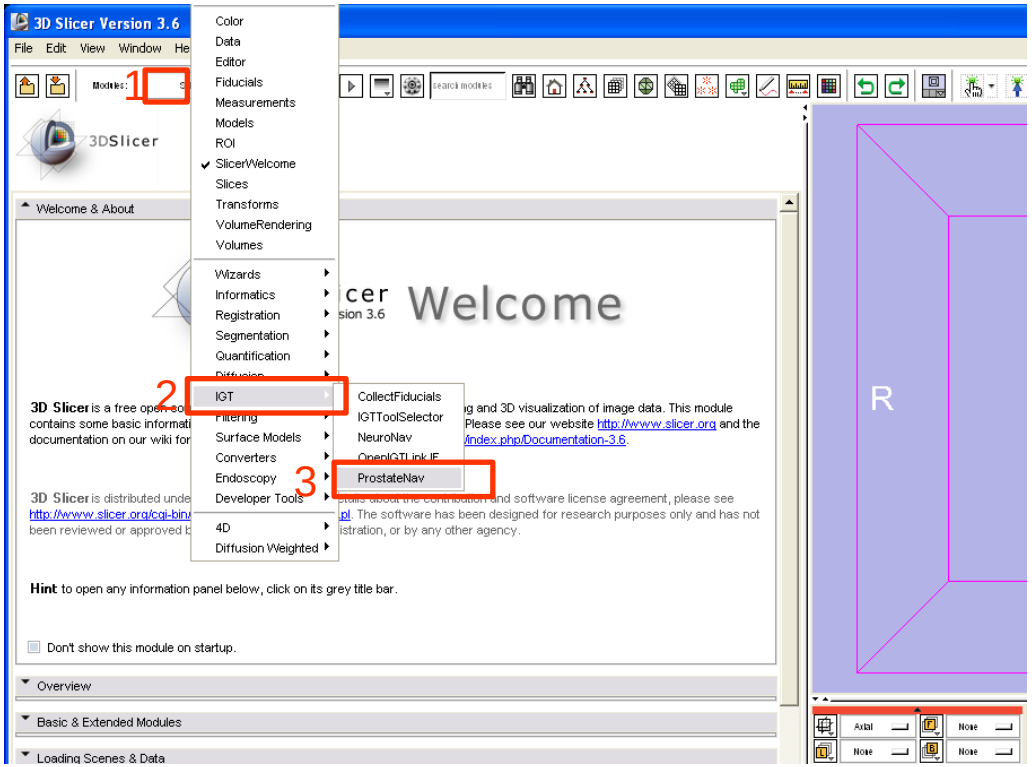
When 3D Slicer is started it shows the Welcome window on the left.

To see the user interface of the prostate biopsy navigation module:

1 – Click on the “Modules” list

2 – Click on the “IGT”

3 – Click on the “ProstateNav”

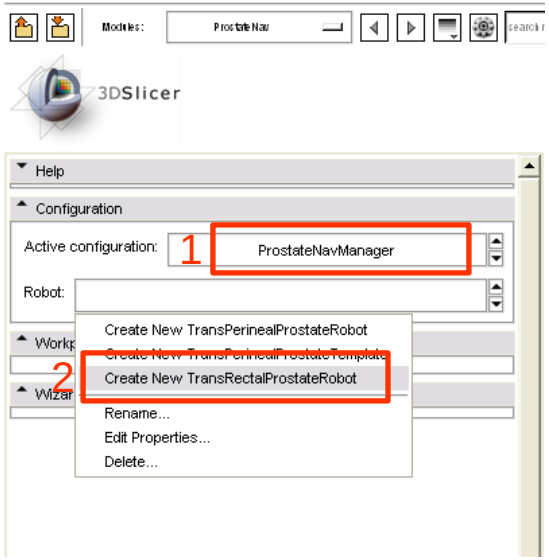


Select a robot device

Before starting the procedure the needle guidance device has to be set up.

1 – Click on the “Active configuration” list and select “Create New ProstateNavManager” to create a new ProstateNavManager node. All the calibration, planning, targeting, and verification information will be saved into this node.

2 – Click on the “Robot” list and select the device that will be used for the needle insertion. This tutorial presents the workflow for the transrectal robotic device, so choose the “Create New TransRectalProstateRobot” item



When the robotic device is selected then the Workphase and Wizard windows are updated to show the transrectal procedure workflow steps.

Load calibration image

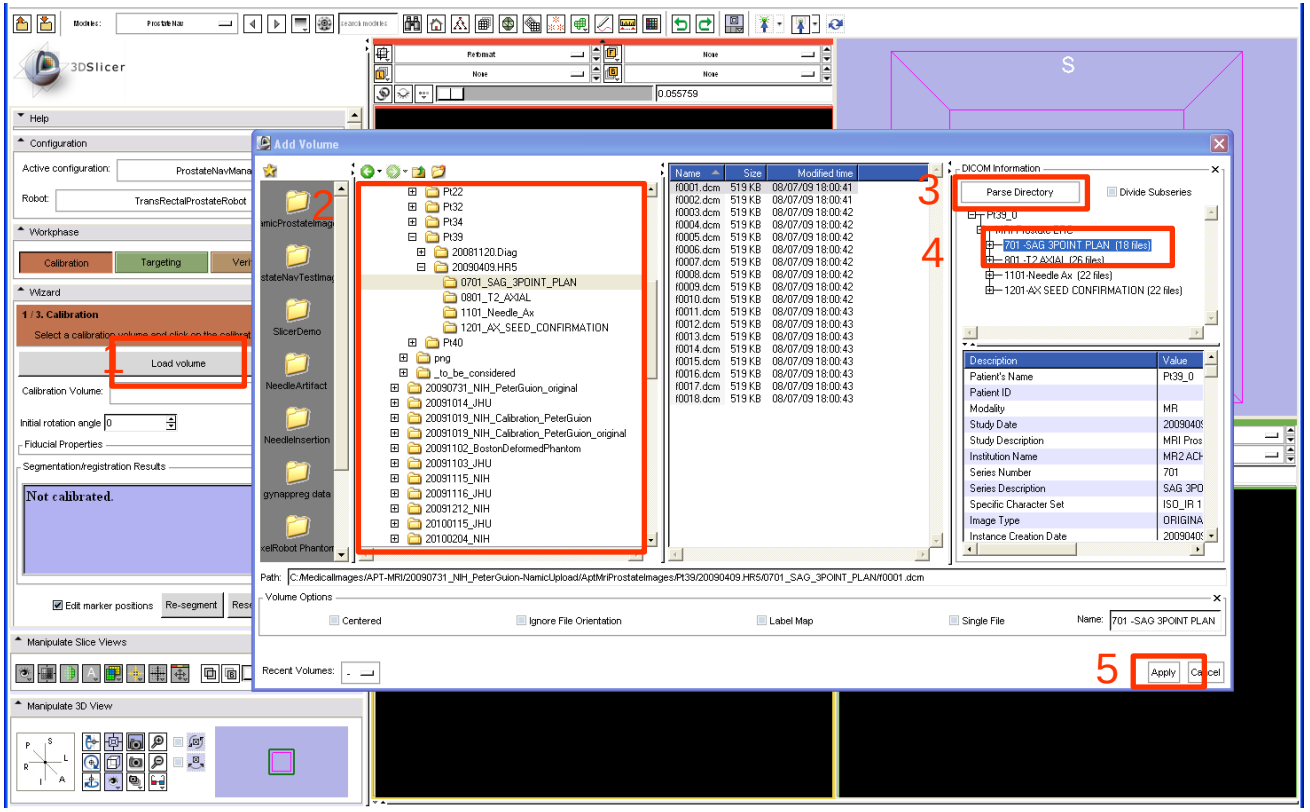
1 – Click on the “Load volume” button

2 – Select the image folder in the folder tree

3 – Click on “Parse directory”

4 - Select the calibration image:
“**701 Sag 3Pt Plan**”

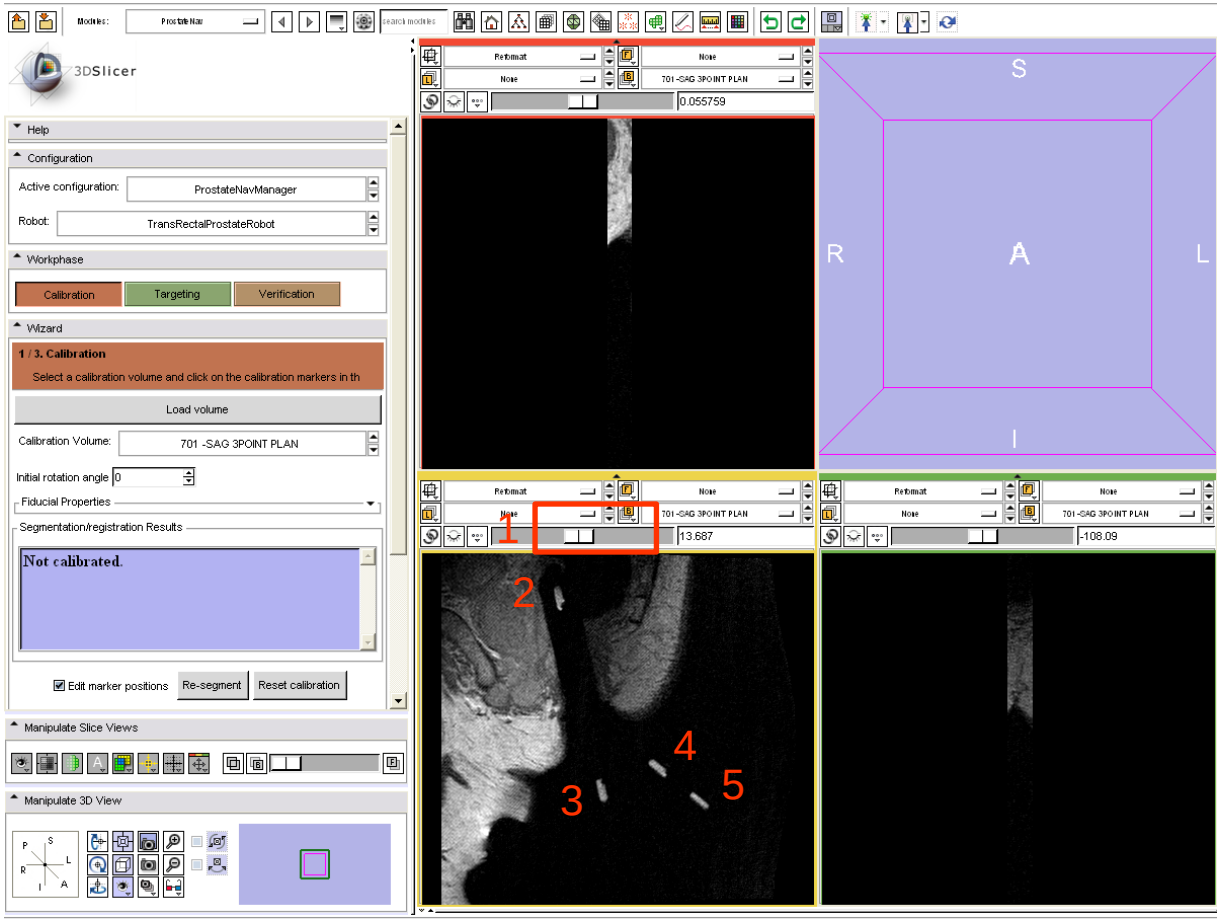
5 - Click “Apply”



Mark calibration fiducials

1 – Select a slice where the fiducials are visible by using the slider above the image and/or using the mouse wheel

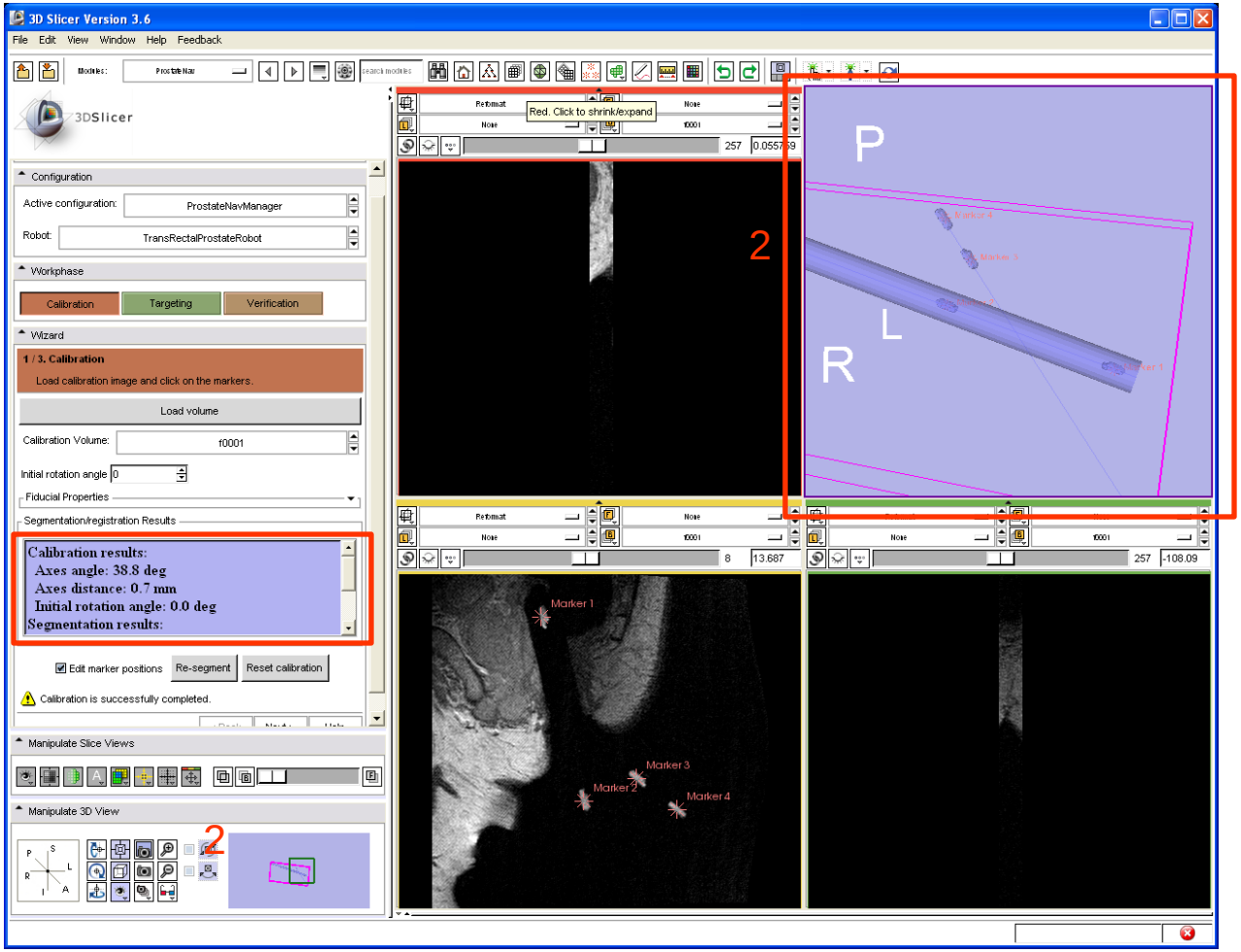
2..5 – In any of slice views, click near the center of each marker



Review calibration results

1 – Numerical results displayed (axes angle, distance)

2 – The segmented fiducials are shown in the 3D viewer window.



Refine calibration results

If either the numerical results or the displayed marker segmentation indicates that the calibration might be inaccurate (large axes distance, axes angle different from 37 deg, marker contours are uneven or incomplete), then calibration can be refined:

A – Click on the small arrow next to “Fiducial Properties” to show the segmentation parameters

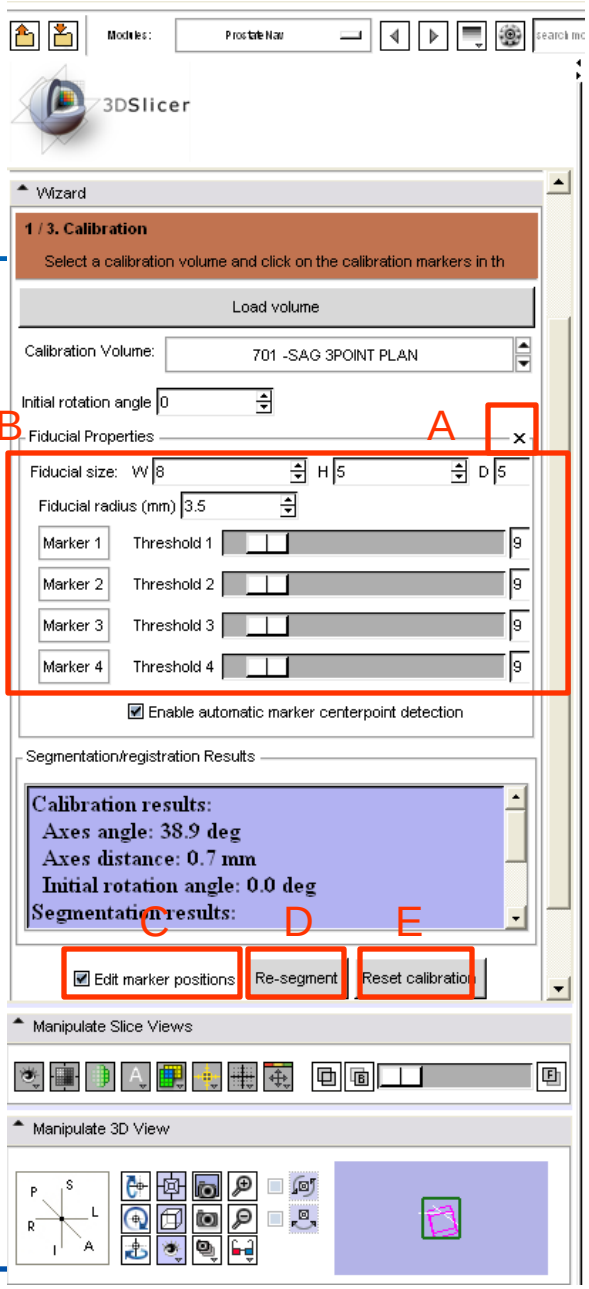
B – Segmentation parameters

Fiducial size: W/H/D = width/height/depth of the region around the clicked point where automatic marker detection is performed.
Fiducial radius: only voxels that are closer to the axis than this radius will be included in the automatic marker detection region.
Threshold: marker segmentation threshold
Enable automatic marker centerpoint detection: If enabled, then marker center will be automatically detected, near the clicked position, using the fiducial size, radius, and threshold parameters. If disabled then the clicked positions will be used as marker centerpoint positions.

C – Edit marker positions: enable this checkbox to set the mouse mode so that clicks on the image places fiducial markers

D – Re-segment: click to re-run automatic marker detection algorithm after changing segmentation parameters

E – Reset calibration: removes calibration markers



Target planning and needle insertion

Load targeting image

1 – Click on the “Targeting” button to move to the planning and targeting workflow step

1 – Click on the “Load volume” button

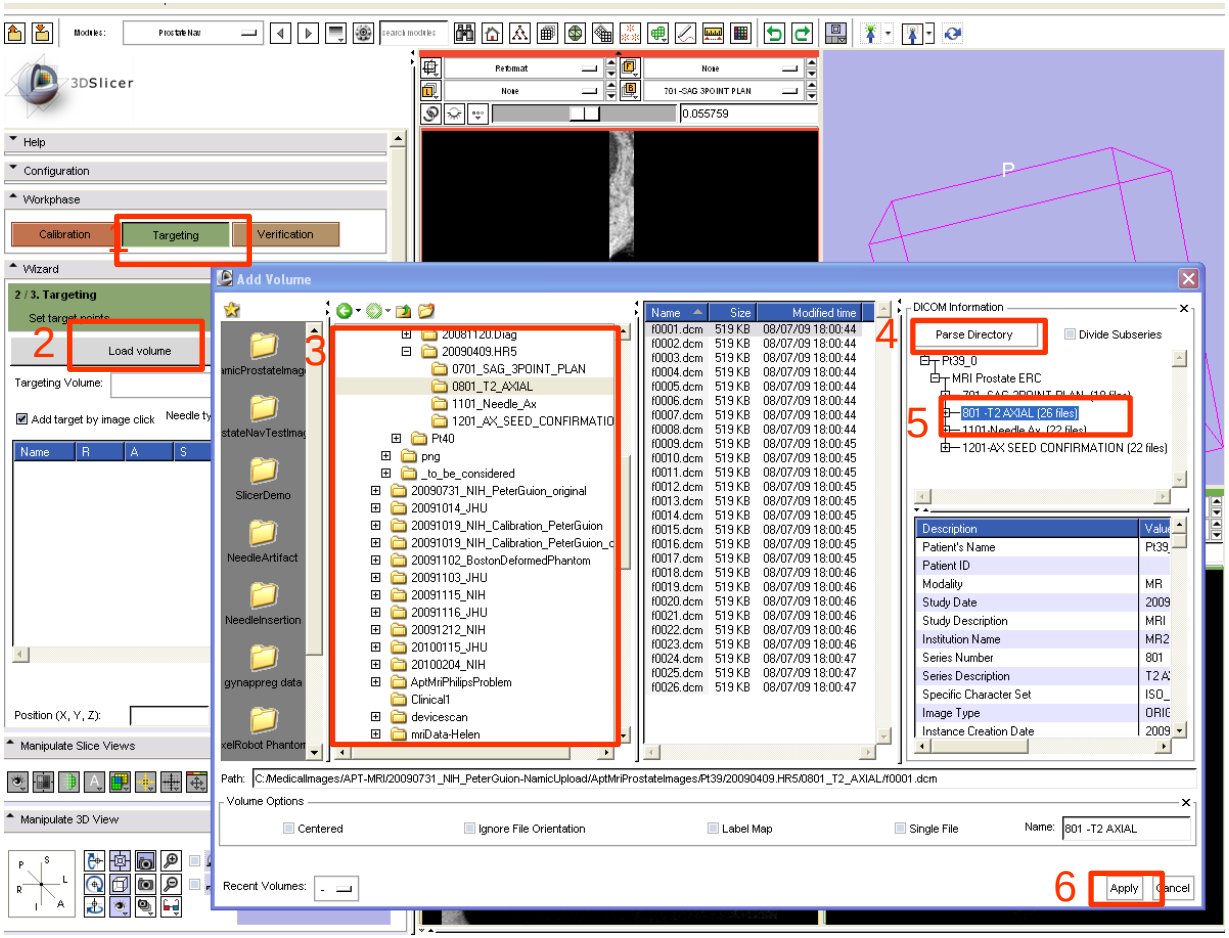
2 – Select the image folder in the folder tree

3 – Click on “Parse directory”

4 - Select the targeting image:

“**801 - T2 AXIAL Plan**”

5 - Click “Apply”



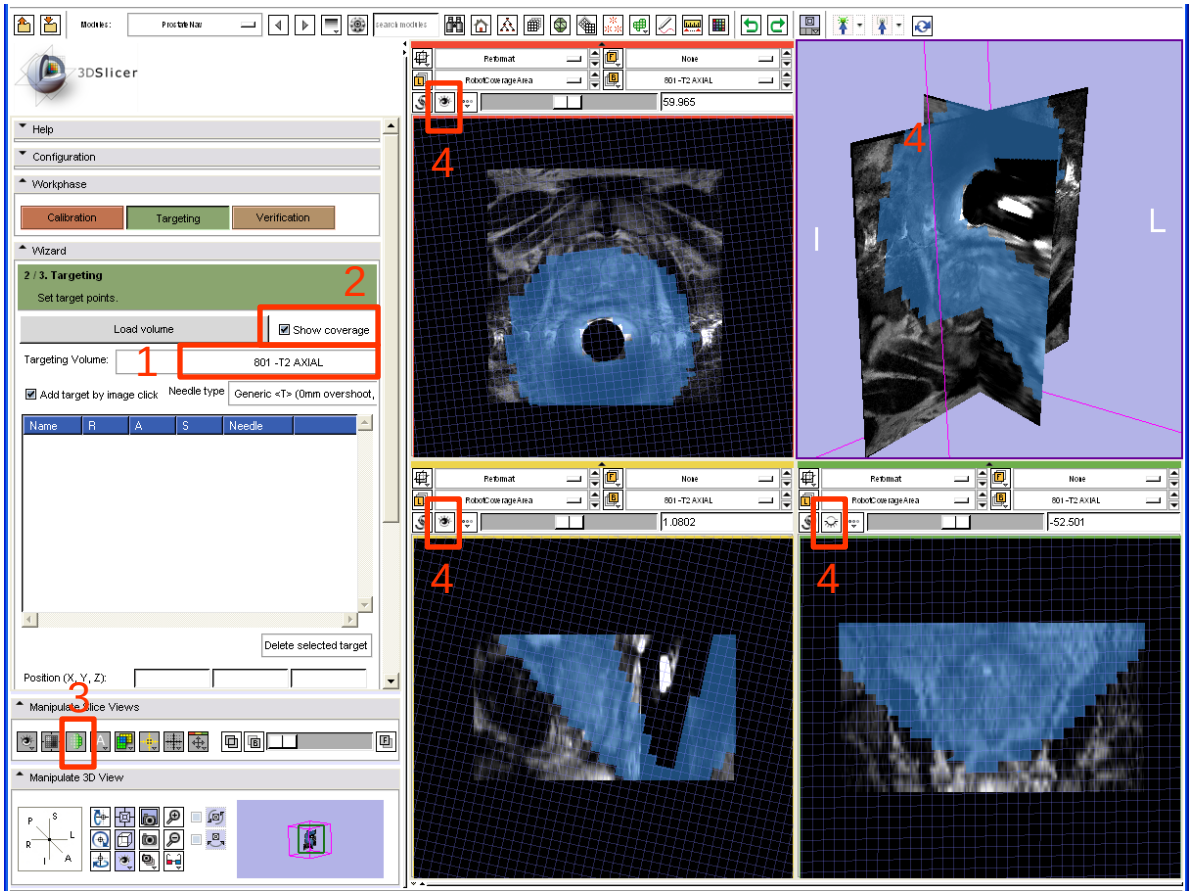
Prepare target planning

1 – Select the targeting volume: “**801 – T2 AXIAL**”

2 – Click “Show coverage” and browse through the slices to verify that the device can reach all the desired target areas (displayed as a blue overlay)

3 – Click on the label layer opacity icon and move the slider to adjust coverage area display opacity

4 – Click the “eye” icons to show/hide a slice in the 3D viewer



Define targets

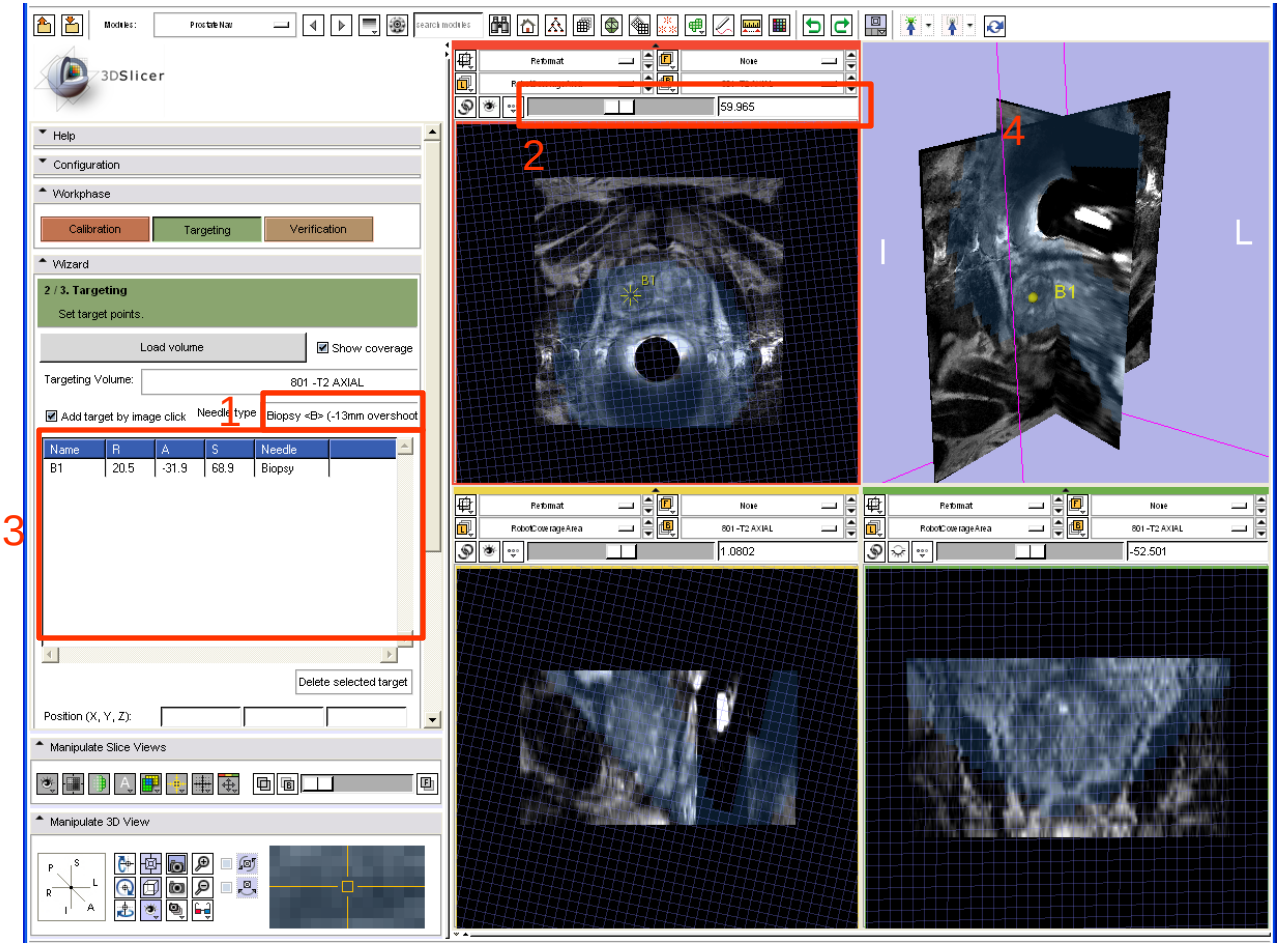
Perform the following steps for each target:

1 – Select the needle type

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 (double-click on any of the position value to enter a specific R/A/S coordinate value)

4 - Target point is displayed in the 3D view



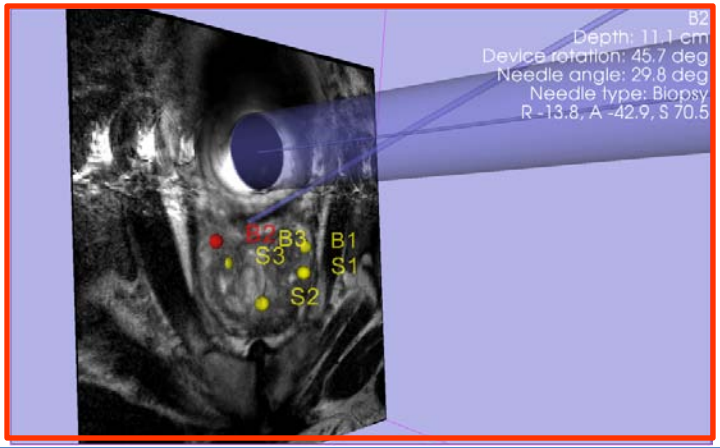
Needle insertion

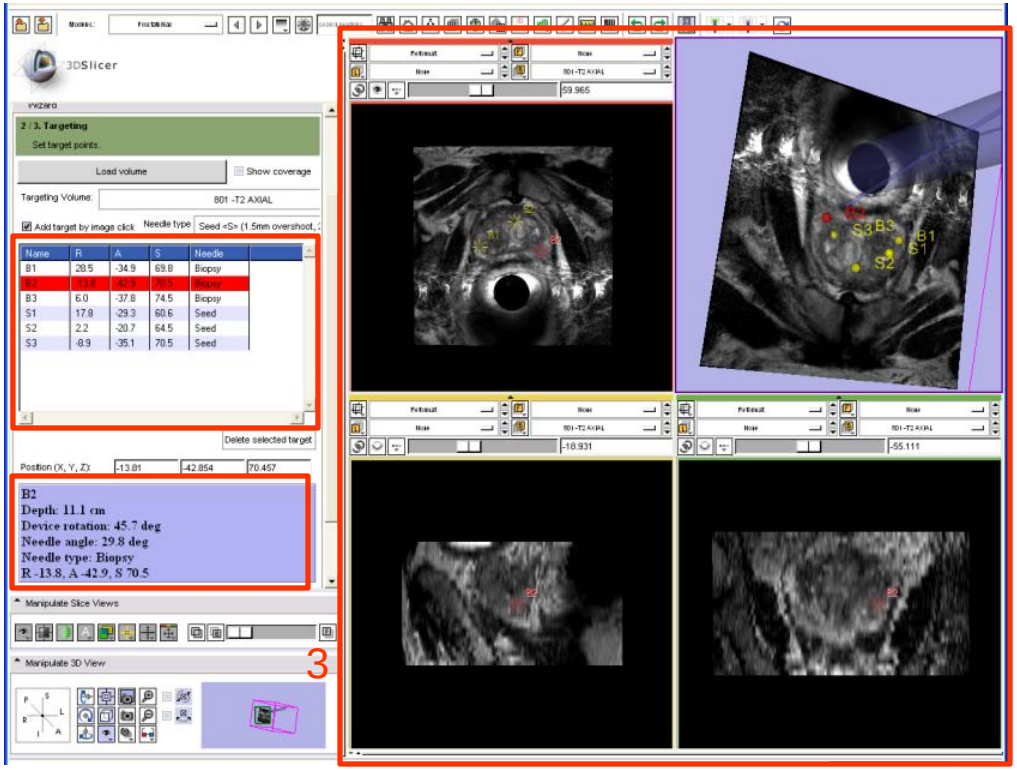
1 – Click on a target in the target list

2 – Targeting parameters are shown below the target list

3 – The target and needle trajectory is displayed in all the slice views and in the 3D view

4 – 3D view and targeting parameters are displayed in the secondary (procedure room) monitor





The robot is motorized, one has to manually set the displayed targeting parameters on the robot manipulator and insert the needle.

Verification

Load verification image

1 – Click on the “Verification” button to move to the verification workflow step

1 – Click on the “Load volume” button

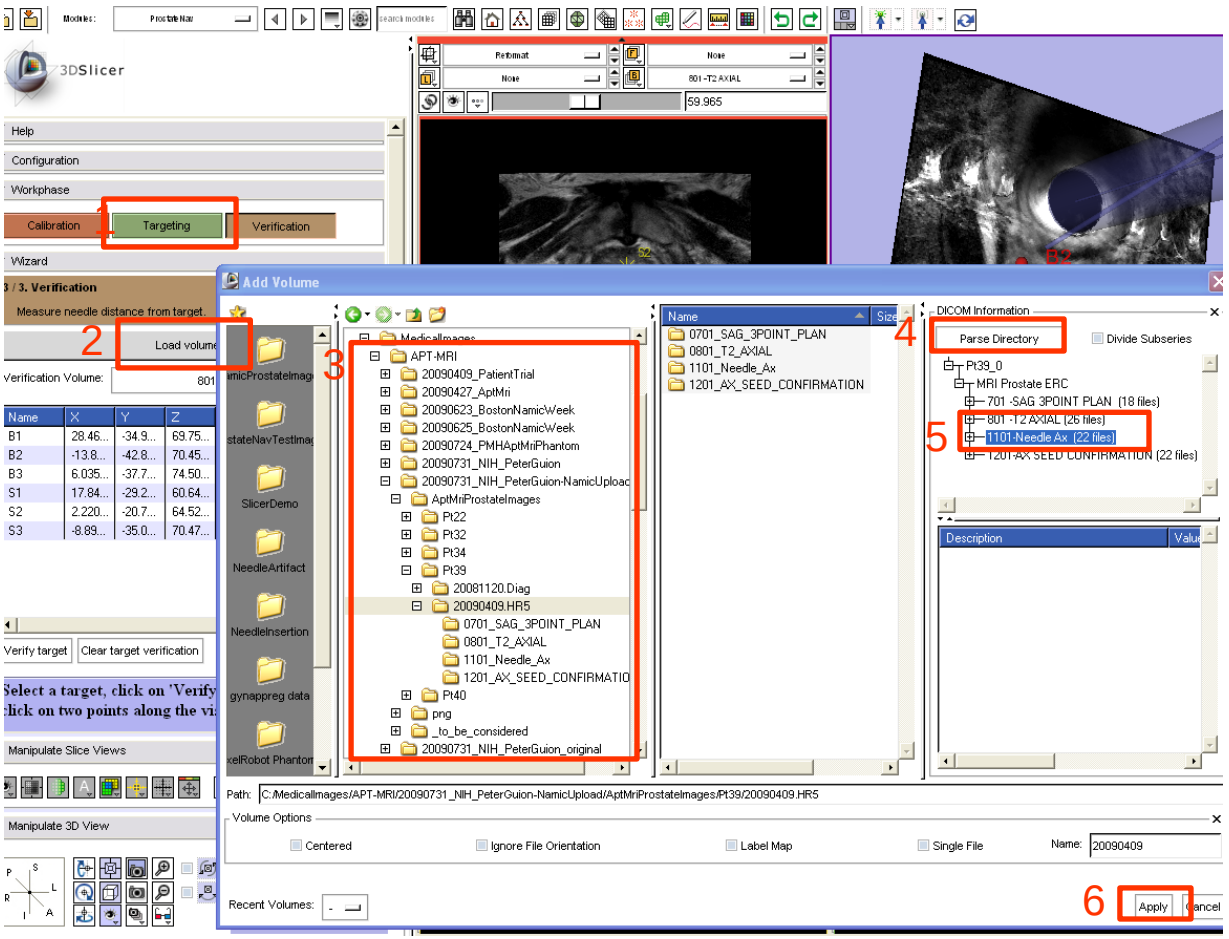
2 – Select the image folder in the folder tree

3 – Click on “Parse directory”

4 - Select the verification image:

“**1101-Needle Ax**”

5 - Click “Apply”

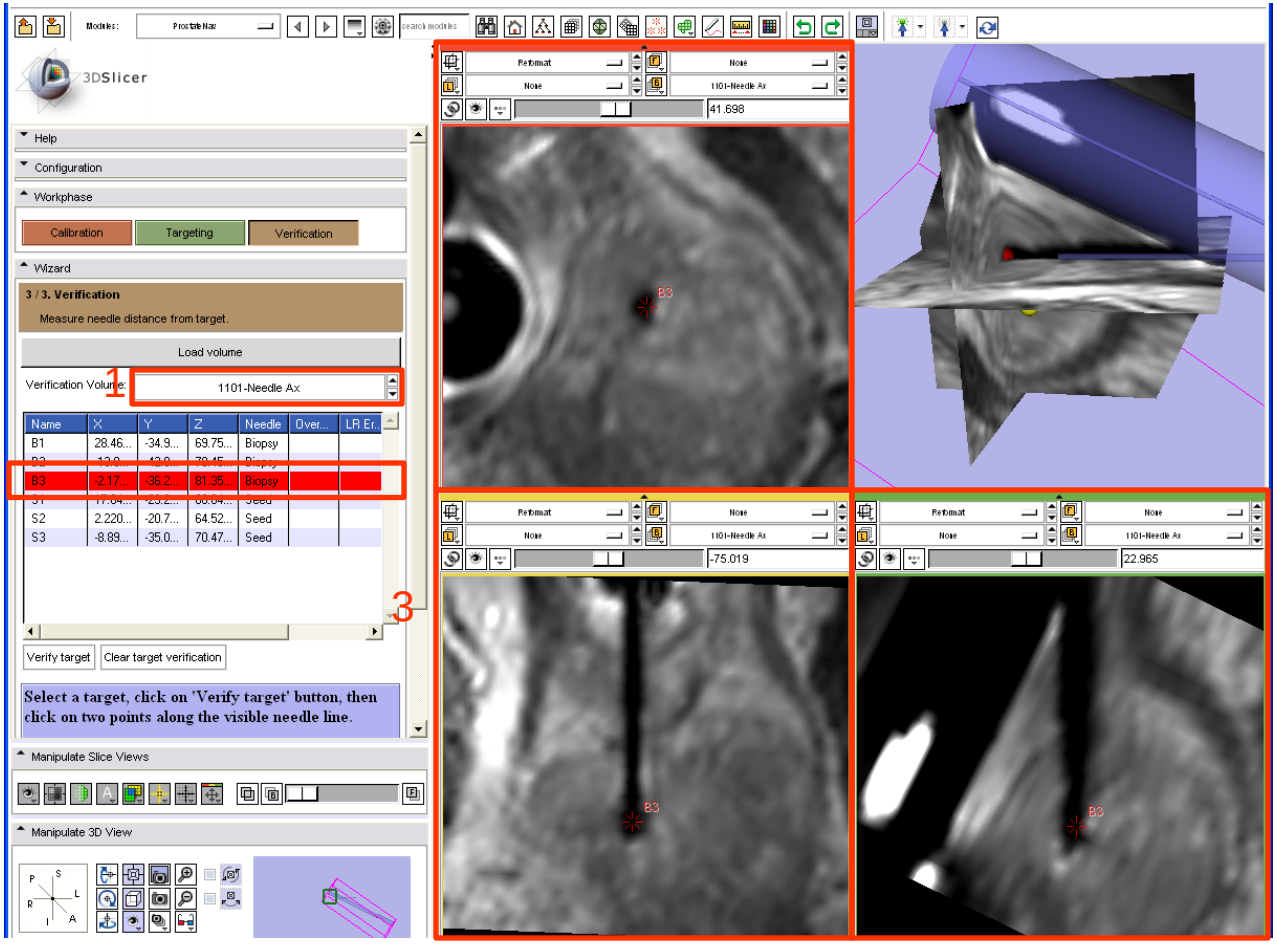


Verify target visually

1 – Select the verification image (where the needle is visible)

2 – Click on the target in the target list that corresponds to the needle in the image

3 – Three orthogonal slices are shown in the slice viewers, reformatted to be aligned with the planned needle trajectory



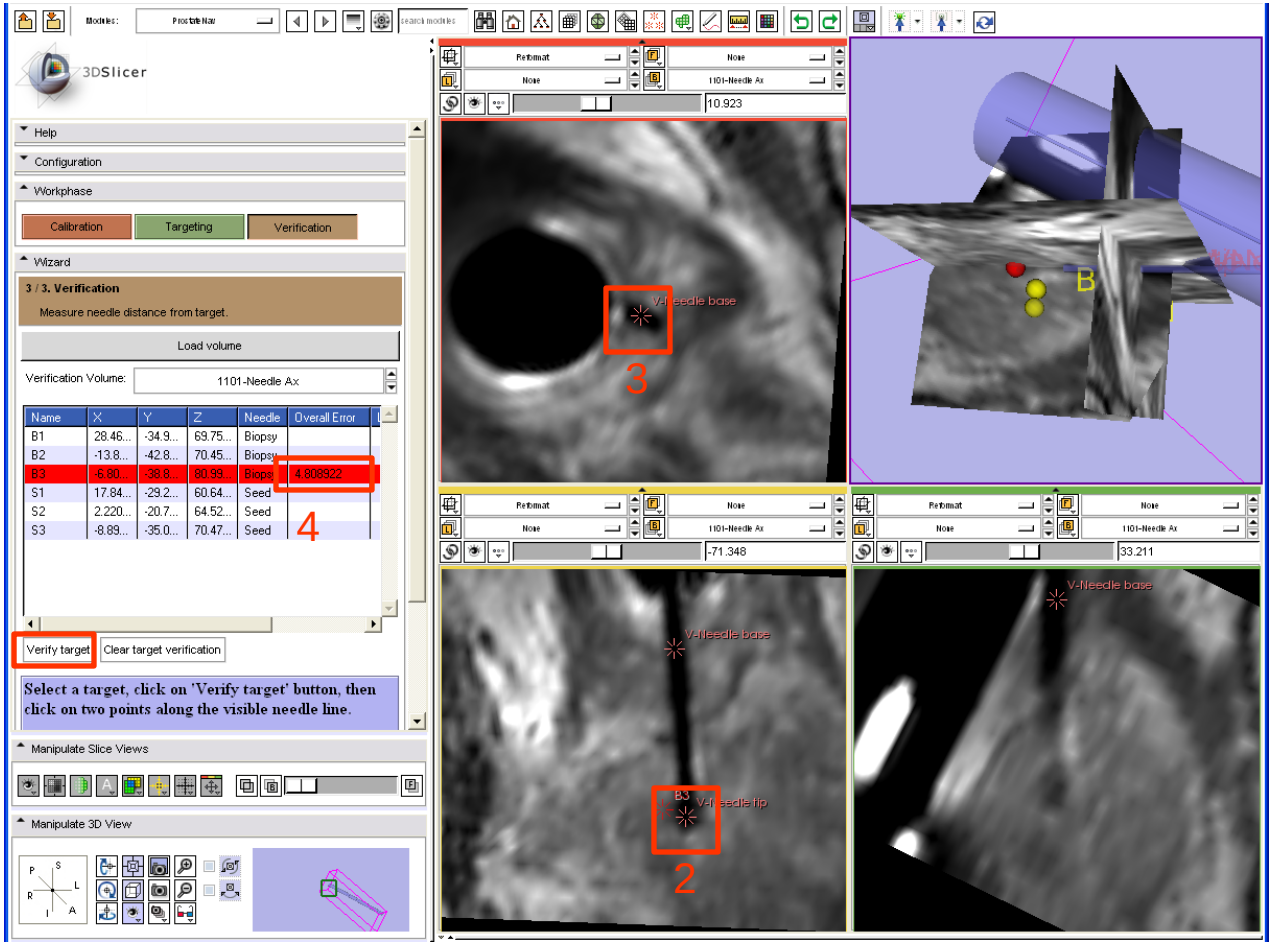
Verify a target quantitatively

To quantitatively evaluate the targeting error:

1 – Click on “Verify target”

2, 3 – Click on the centerline of the needle at two different positions (anywhere along the needle, as far as possible from each other)

4 – The distance of the needle centerline from the target point is displayed in the target list



Evaluate patient motion

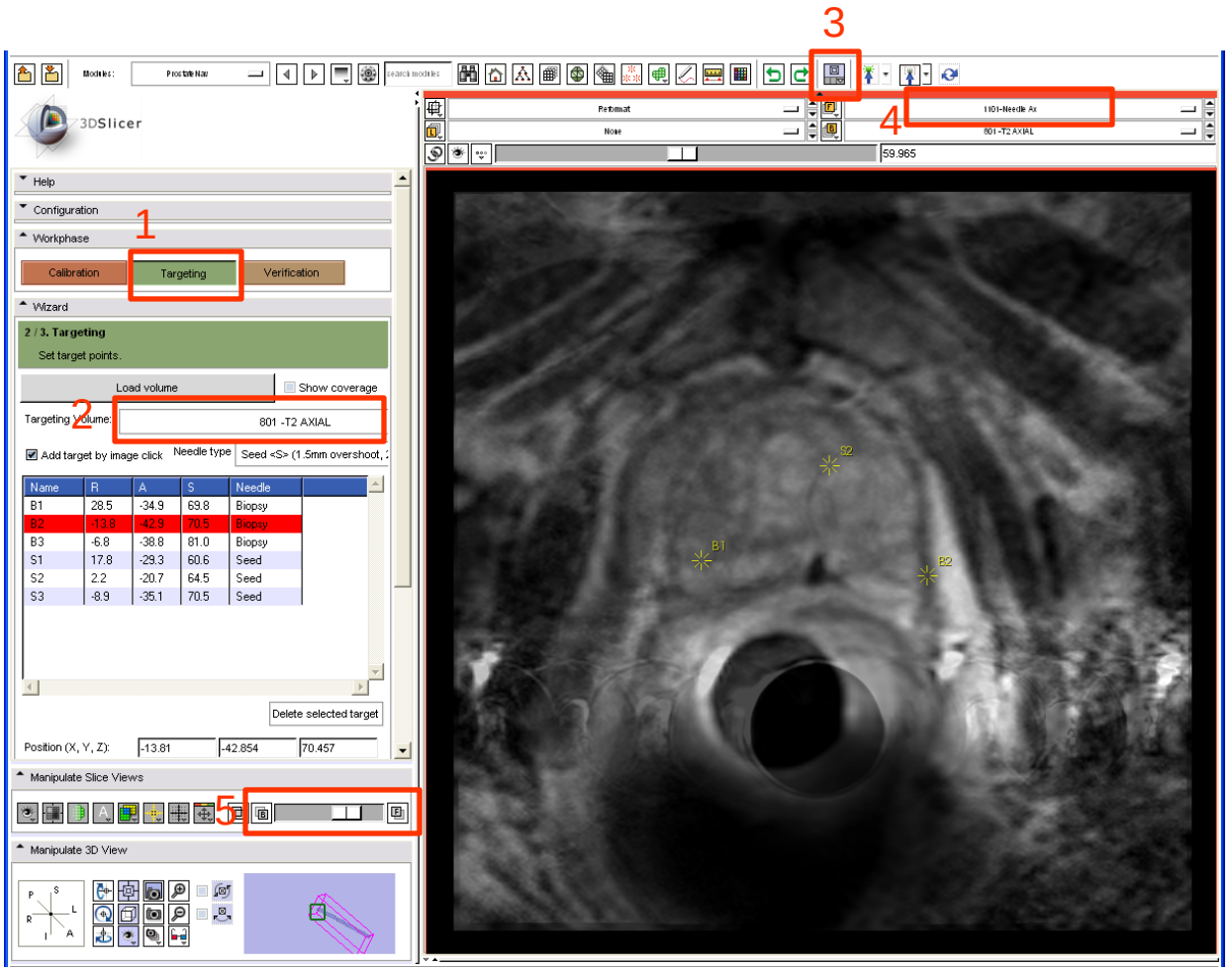
1 – Click on “Targeting”

2 – Re-select the targeting image to show it in the slice viewers

3 – Select the “Red slice only layout” to see a maximized view of the axial slice

4 – Select the latest acquired image to be in the foreground

5 – Use the slider to fade between the targeting and the latest image to see if there was any significant patient motion



Conclusion

- 3D Slicer with ProstateNav allows planning, performing, and evaluating MRI-guided prostate intervention.
- ProstateNav relies on Slicer core features for volume, model, and fiducial visualization and applies them to fulfill application-specific needs.
- Slicer core features and extensions can be used to interactively explore, understand the data, and troubleshoot the image-guided intervention system (proved to work very well in preliminary clinical testing).

Acknowledgements

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