Trans-rectal MR-guided prostate biopsy
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:


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
Materials

• Build **Slicer3 (Slicer 3.x)**, instructions can be found at:

• 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
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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

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Systems overview

3D Slicer

Flexible Shafts
Endorectal Coil
Positioning Stage
Biopsy Needle
Mount

Targeting Parameters

Physician's Interface

Physician

Physician's position

MRI Images

Robot position

MRI Scanner Computer

Real-time Tracking System

Patient

Robot

Closed MRI scanner

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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
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

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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

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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”
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
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 (TRPBTutorialDataset\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

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**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
Pick biopsy targets
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)
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
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

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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.

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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