Slide 1

Who are we?

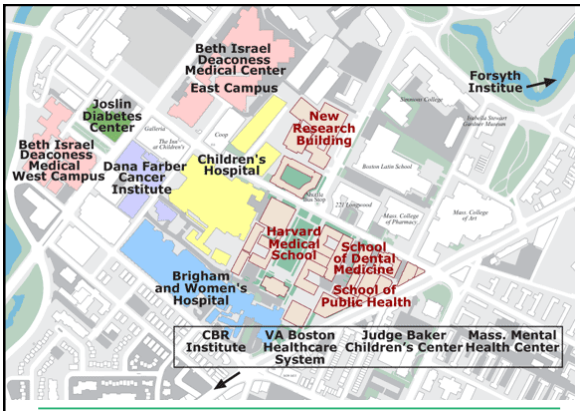
- National Center for Image Guided Therapy (NCIGT)
- Multi-disciplinary research laboratories in Brigham and Women's Hospital.
- Strong emphasis on real clinical applications of advanced medical robots and medical image processing

Slide 2

Brigham and Women's Hospital

One of 17 teaching hospitals of Harvard Medical School

Slide 3



Slide 4

NCIGT and AMIGO

- Advanced multi-modality image guided operating room
- PET/CT, OR, 3T MRI
- NIH- and hospital-funded research-oriented operation theater
- Designed and used by multi-disciplinary clinical teams (including me!)
- Open in mid Dec 2010, First case in Feb 2011

Who am I?

- Pre-doctoral fellowship at BWH in ’95
- Post-doc, then Junior Faculty at BWH/Harvard Medical School, ‘98-’01
- Univ. Tokyo Mech. Engineering faculty ‘01-’05
- Back to BWH ‘05
  - Technical Director, IGT Program at BWH ‘05
  - Founded Surgical Navigation and Robotics Laboratory ’07
  - Leader, Navigation and Robotics Core, NCIGT, ’10
- Continuing research interest in Image Guided Therapy and Medical Robotics

Advanced science and technology in a hospital

Silverman, Tuncali, Tatli

Scientists fully funded by competitive research funds

Clinicians partially funded by research funds, and strongly encouraged to establish clinical and scientific research program

My/Our Value

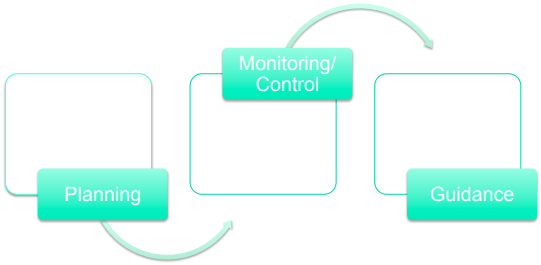
Science

Application ⟷ Engineering

Part 1/4
Close-bore MRI-guided biopsy

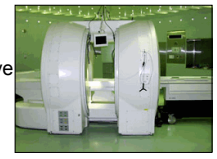
Boston City View from Charles River

Engineering methods in IGT



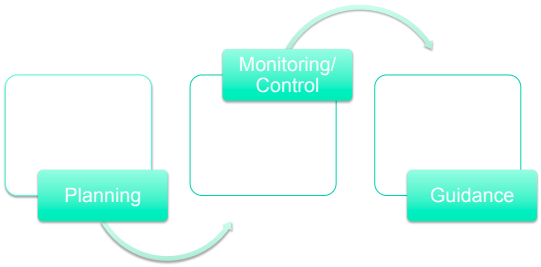
MRI-guided prostate biopsy

- Prostate cancer
- Alternative to TRUS guided biopsy after repeated negative biopsy with rising PSA level [D'Amico 2001]
- MRI for imaging, planning, target localization, guidance
- Challenge
  - Use of contemporary wide-bore 3T MRI scanner, and pre-operative diagnostic MRI

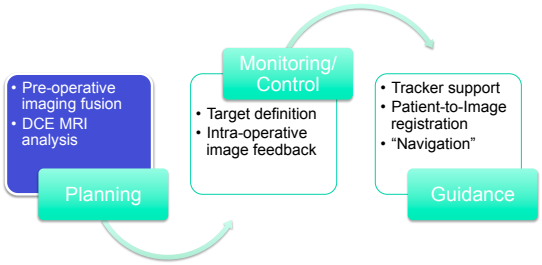


Hata et al, Interventional MRI 2010

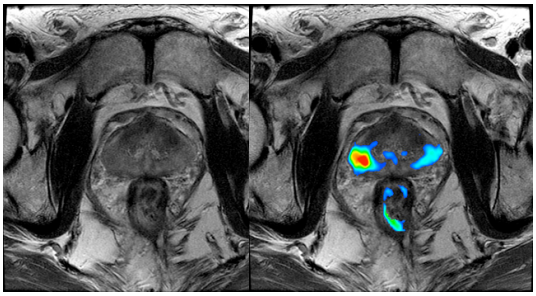
Engineering methods in IGT



MRI-guided prostate biopsy

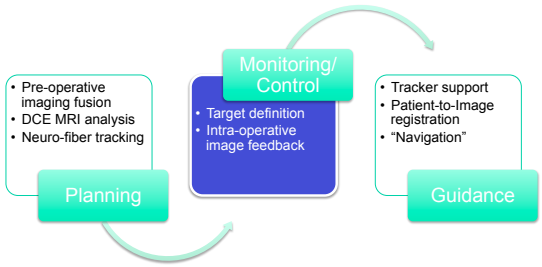


Pharmaco-kinetic analysis of dynamic contrast enhanced images

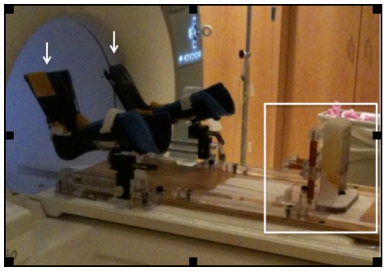


Tempany, Tuncali, Tokuda, Hata (BWH), and Iordachita (JHU)

Role of Slicer in IGT research



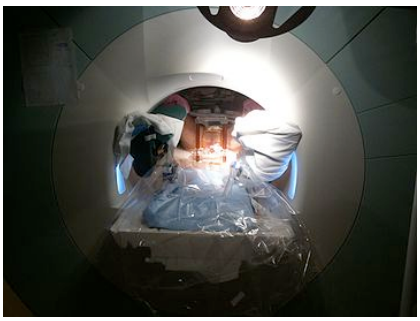
Building apparatus



Tokuda, Hata, Tempany, Tatli, et al

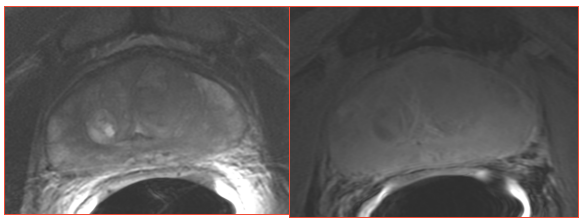
Slide 17

MRI-guided biopsy at 3T



Slide 18

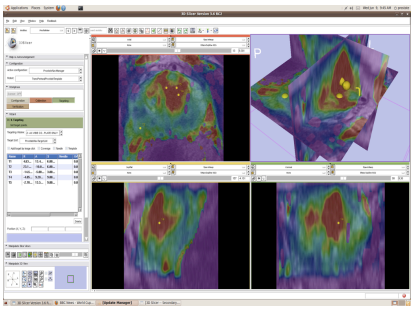
Deformable Registration of Pre- and Intra-procedural Images



BrainsFit Module in 3D Slicer
Rigid, Affine, B-spline deformable registration
Federov et al, ISMRM 2011

Slide 19

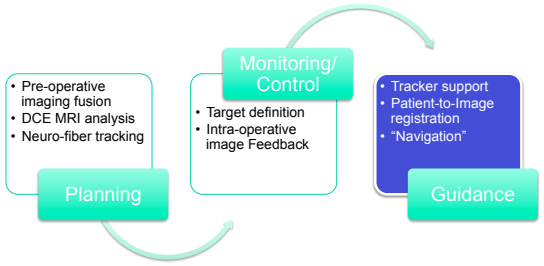
Biopsy Targets



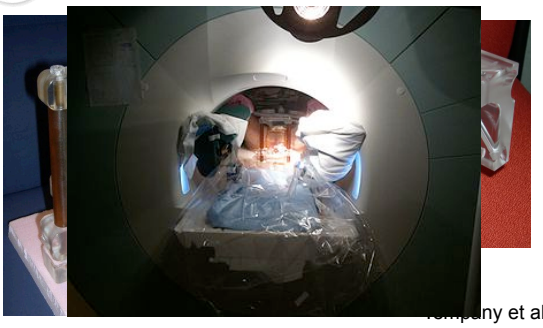
Tempany et al

Slide 20

Role of Slicer in IGT research



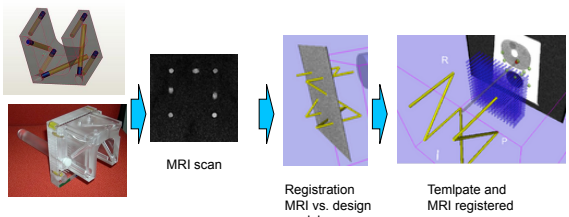
Integrated needle guidance template and z-frame



Tempany et al

Z-frame calibration

Method to register the template to the MRI



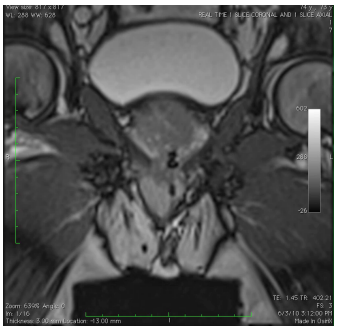
MRI scan

Registration MRI vs. design model

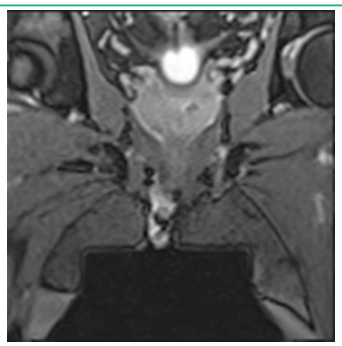
Templpate and MRI registered

DiMaio et al

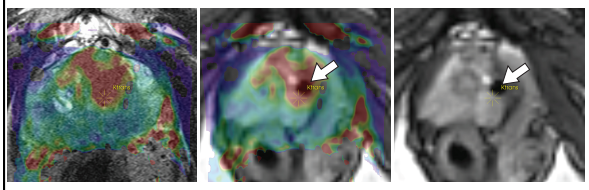
Biopsy under MRI guidance



Tempany et al



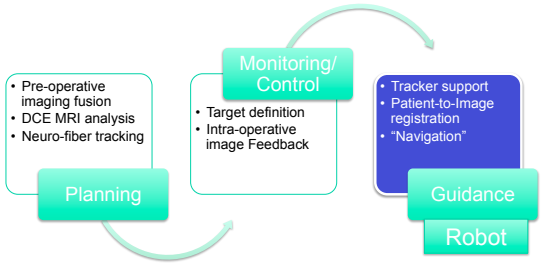
Accuracy assessment



Part 2/4
MRI-guided robotic surgery

Harvard Medical School

Guidance by robot



Medical Robotics

[Taylor, Stoianovici 2003]

- Surgical assistance
  - To enhance the ability of human surgeons to perform surgical procedures
  - Product-level developments by Intuitive and Hanson Medical, etc
- Surgical CAD/CAM
  - A computer model of a patient from medical images
  - Plan an intervention, registering the computer model/ plan to the actual patient
  - Using robots to help carry out the plan
  - [BWH contribution] Use intra-operative images to update medical images and plans
  - [BWH contribution] Use intra-operative images to control robots

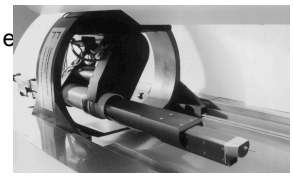
Innomotion

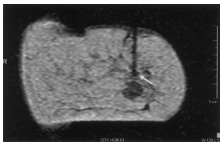
- [Gutmann,2002],,,,**[Melzer IEEE EMBS Magazine 2008]**
- The MR-compatible, servo-pneumatically driven, robotic device
  - Highly redundant safety features meeting EU standard
  - Custom made actuators and sensors
- Percutaneous biopsies [Moche et al, JMRI, 2010]
  - Femur and sacral bone, lesser pelvis, iliac lymph node, lumbar spine abscess, liver
  - 1.0T

[Moche et at 2010]

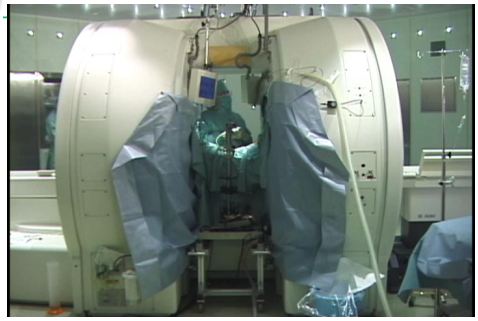
ROBITOM, University of Jena

- Kaiser Fischer e al 2000
- Pfleiderer et al 2008
- Breast biopsy
- 1.5T scanner
- 14 cases tested



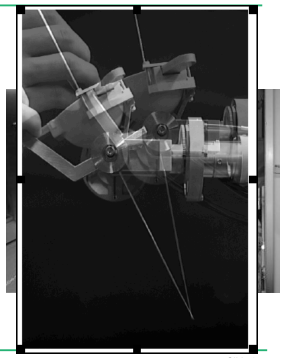


Pfleiderer et al 2008



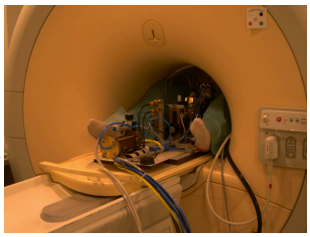
MRI Robot

- Designed for 0.5T open scanner
- Synergistic control
  - Needle holder controlled manually
  - Robot keeps the selected target at the remote-center-of-motion
  - [Hata et al JMRI 2008]
- Clinical feasibility study
  - [Morikawa Am J Surg. 2009]



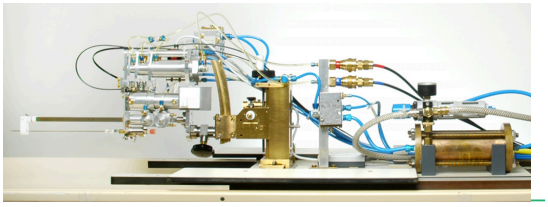
Utrecht Prostate Robot

- 1.5T
- van den Bosch 2010
- Deliver fiducial gold markers inside prostates patients eligible external beam radiotherapy treatment (EBRT)



Utrecht Prostate Robot

- "The robot *tapped* the needle stepwise towards this position while controlling the step size (typically 5 mm) and the needle depth."
- "During the tapping fast 2D MR scans were acquired to track the needle trajectory on-line and to independently monitor the needle depth"

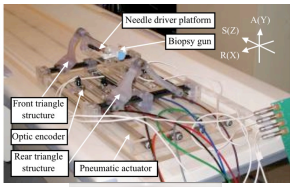


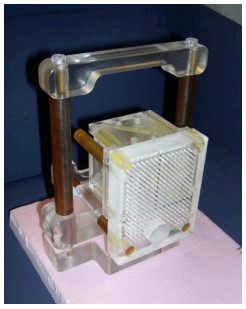
Balanced steady state free precession

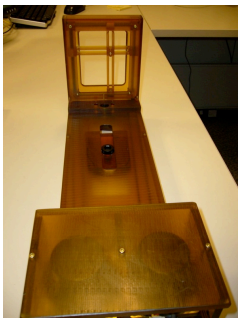
JHU/BWH 3T Robot

- Scanner independent
  - Tested in GE 3T, Siemens 3T wide bore
- Prostate Intervention
- Pneumatic motor
- Integrated scanner and robot control

Fischer, Tempany,Iordachita







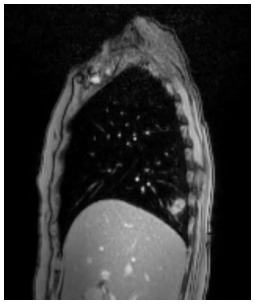
P01 Robotics core. Hata

Leveraging software from established clinical methods

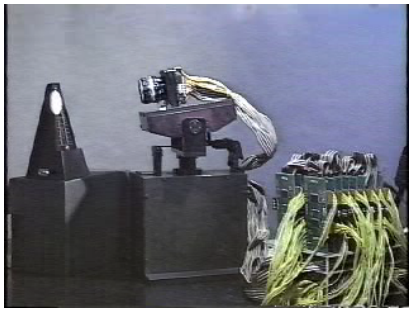
Part 3/4
Vision: Image-driven robots

Harvard College

Organ motion



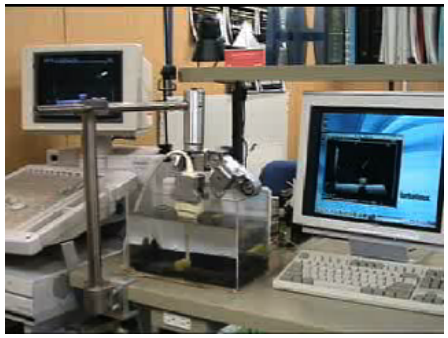
Motion Compensation



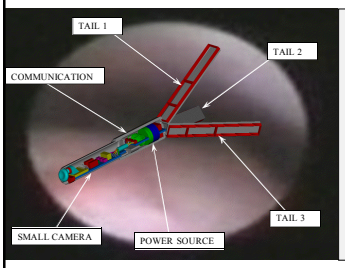
Ishikawa, Univ. Tokyo

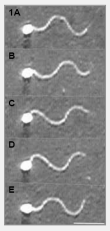
Motion Compensation

[Lesniak, Hata et al Phy Med Bio 2007]



Swimming Endoscope

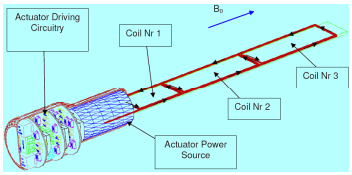




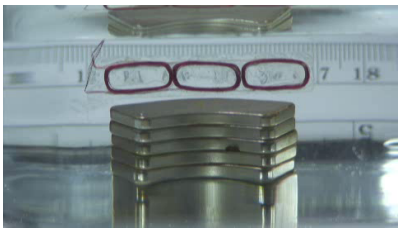
Spermatozoa Swimming from the Lugworm Arenicola marina A. A. PACEY, J. C. COSSON AND M. G. BENTLEY (1994).

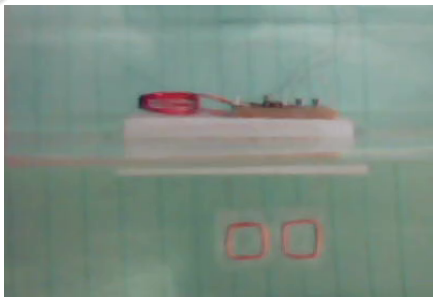
[Kosa, Hata 07,08]

MRI swimming robot

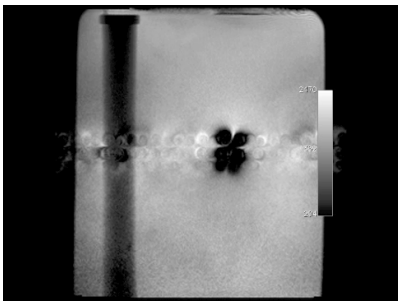


2cm swimming tail, in 3T MRI
Kosa Hata et al, IEEE ICRA 2010

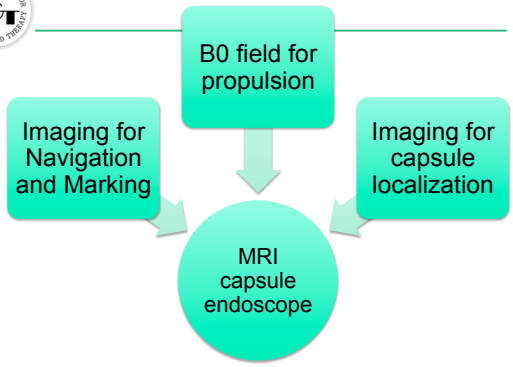




Slide 49



Slide 50



Slide 51

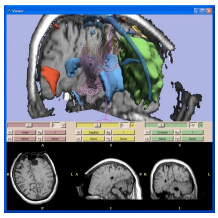
Research Impact
Dissemination
Industry Collaboration

NA-MIC Programming Week

Slide 52

What is 3D Slicer?

- 3D Slicer is…
  - Free, Open-software
  - An end-user application for 3D medical image computing research and Image Guided Therapy
  - A platform for research
  - A freely-downloadable program with source and binaries for Windows, Linux, Mac OSX

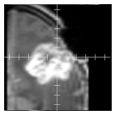


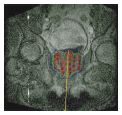
Slide courtesy of Drs. Kikinis and Pieper

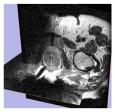
Slicer Download Statistics
Total downloads: 18576
Total Slicer2 downloads: 1150
Total Slicer3 downloads: 11520

Software Design

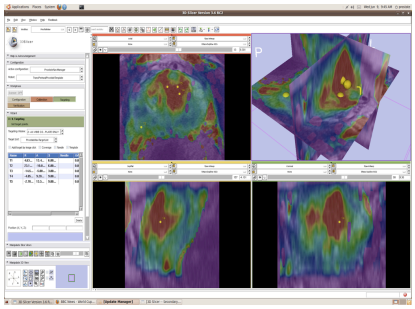
- To maximize function commonalities among applications
  - Brain (biopsy, craniotomy, NdYAG laser ablation)
  - Prostate (brachytherapy, biopsy)
  - Liver and kidney (Microwave, Cryo, laser ablation)
  - Endoscopy (broncho-, neuro-, feto-scopy)





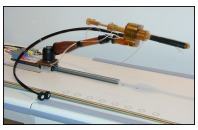


BWH MRI-guided Biopsy



Tempany et al

Queens Trans-Rectal Robotic Prostate Biopsy (Fichtinger et al.)



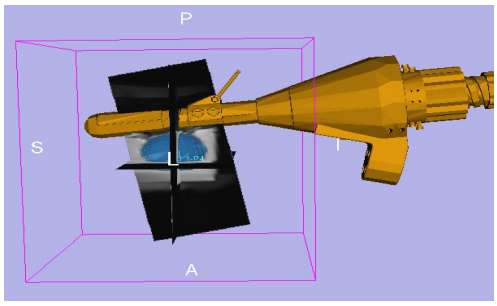
Objective: Develop and integrate end-to-end application module inside 3D Slicer to perform robotic prostate biopsy intervention

[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

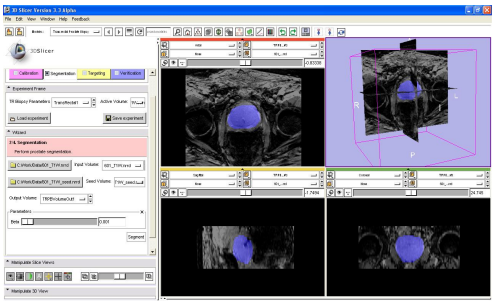
Fichtinger

Navigate



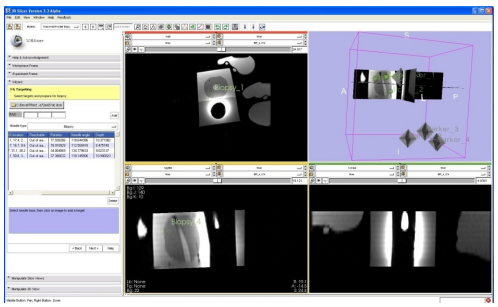
Fichtinger

Segment

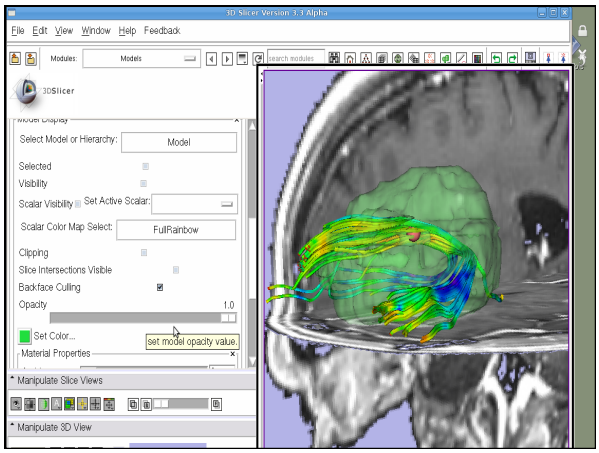


Fichtinger

Target

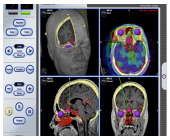


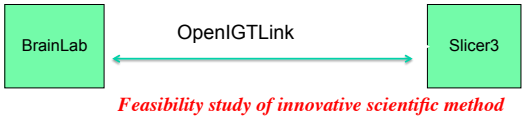
Fichtinger
Slide 61



Interfacing commercial navigation to Slicer

- BrainLab
  - Commercial navigation
  - Everyday use, stable
- 3D Slicer
  - Science/innovation





Feasibility study of innovative scientific method with minimum disruption to clinical work flow

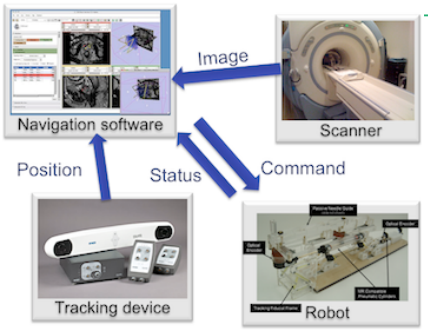
Slide 63

Realtime Fiducial Seeding

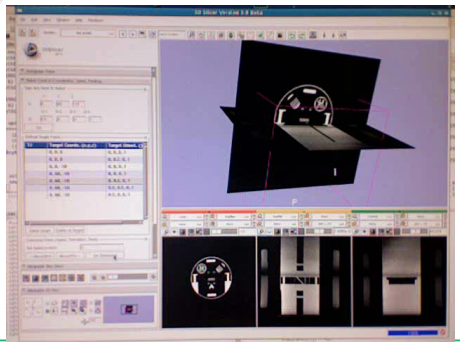
Intra-operative Real-time Querying of White Matter Tracts During Frameless Stereotactic Navigation

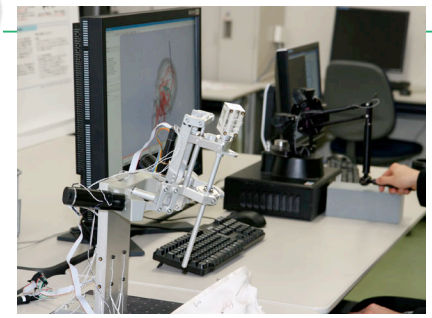
Elhawary H., Norton I., Liu H., Patel P., Rigolo L., Papademetris X., Hata N., Golby AJ

Video Supplement



Integration to MRI scanners



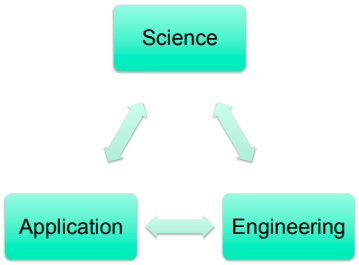


Nagoya Institute of Tech

Conclusion

Group Photo, New OR construction

My value



Conclusion

- Image Guided Therapy
- Intra-operative Image Guided Therapy
- Robots as guidance tool
- Added value of robots in image-guided therapy
  - Needle detection
  - Motion compensation
- This presentation is posted at wiki.na-mic.org
- Visit the following sites for the material and the papers related to this talk
  - www.snrlab.org
  - www.ncigt.org
  - www.slicer.org
  - www.na-mic.org

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