


Role of Image Processing, Navigation and Robots in Image-guided Intervention
 Nobuhiko Hata
 Associate Professor of Radiology
 Harvard Medical School

Who are we?

- Multi-disciplinary research laboratory in Brigham and Women's Hospital.
 - Engineers in a hospital
- Part of National Resource Center for Image Guided Therapy.
 - Liaison to other NIH-sponsored research teams
 - Liaison to industry (SBIR/ STTR)
- Strong emphasis on real clinical applications of advanced medical robots and medical image processing

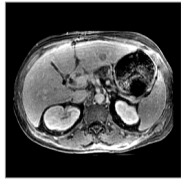


What are we good at?

- Auxiliary robot with high dexterity surgical tools
 - Master - Slave
 - Commercial example - Intuitive, Cardiorobotics, Corindus, Hansen, and more.
- → CAD/CAM robot
 - Precision targeting tools
 - Commercial example - Mako, Robodc, and more.
 - Combination with Imaging
 - Combination with Image processing
 - Combination with Navigation

PRE-PROCEDURAL CE MRI

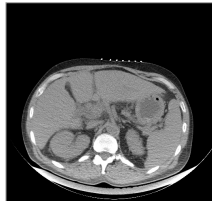
--MRI Pre



BWH Ablation Case
 50yo M, 2cm primary liver tumor (HCC) in segment 2
 Slide courtesy of Dr. Silberman

INTRA-PROCEDURAL CT

--CT Intra



Registration Method in 3D Slicer


Non Rigid Registration Method

- Global motion of the liver modeled with Affine Registration
- B-Spline interpolation model for local deformation of the tissue
- Capable of registration between multiple modalities (MR - CT, CT - CT)
- Requires manual segmentation of the organ for higher accuracy
- Applied to liver and kidney

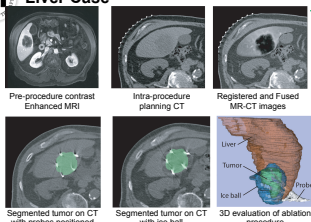
Elhawary, Oguro

REGISTERED IMAGES

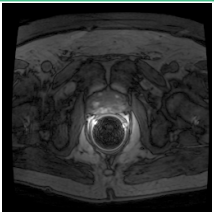
Example:
 Registered Data
 --Merged MRI & CT



Liver Case



Diffusion Contrast Enhanced MRI



3T Pre-procedural MRI

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

©2010 MDCT, Inc. Slide 10

SLICER PRESENTATION

©2010 MDCT, Inc. Slide 11

©2010 MDCT, Inc. Slide 12

©2010 MDCT, Inc. Slide 13

MRI-guided biopsy at 3T

©2010 MDCT, Inc. Slide 14

©2010 MDCT, Inc. Slide 15

©2010 MDCT, Inc. Slide 16

3T Close-bore MRI

- Diagnosis and therapy in multi-modality image setting, incl. high-field closed-bore scanner (3T)
 - High-quality imaging,
 - More prevalent in clinics and hospitals.
- Challenges
 - Access to lesions
 - Motion compensation
 - Close-loop Therapy.

©2010 MDCT, Inc. Slide 17

UK Prostate Biopsy Robot

Ethvariy et al., A Modular Approach to MRI Compatible Robotics: Interconvertible One DOF stages, IEEE Engineering in Medicine and Biology Magazine, vol.27(1), pp.35-41, 2008

©2010 MDCT, Inc. Slide 18

In-bore Needle Placement

GE 3T Excite bore

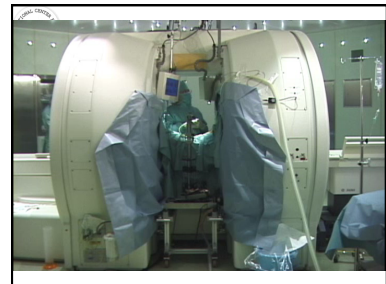
Optical Encoder

Pneumatic Cylinder

Vertical Motion Mechanisms

Joint Project with Drs. Fichtinger and Fischer.

Slide 19



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 JMIR 2008]
- Clinical feasibility study
 - [Morikawa Am J Surg. 2009]

Slide 22

Actively swimming capsule endoscope using MRI for energy delivery, imaging, and navigation

- The capsule endoscope today is purely diagnostic
 - Cannot be used to take biopsies, apply therapy, or mark abnormalities for surgery.
 - Cannot be controlled once it has been ingested
 - Once it has passed a suspicious abnormality, its progress cannot be slowed to better visualize the area.
- The proposed swimming capsule: A patient merely swallows the capsule, and the gastroenterologist maneuvers it using MRI along with guidance and monitoring mapping

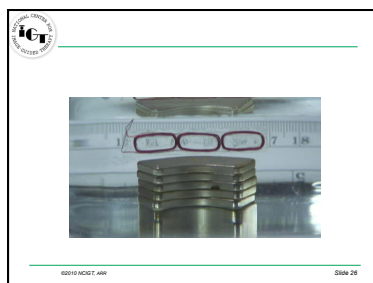
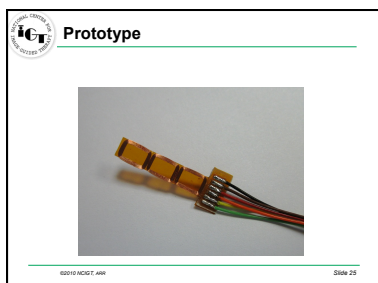
Slide 23

Swimming Endoscope

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

[Kosa, Hata 07.08]

Slide 24

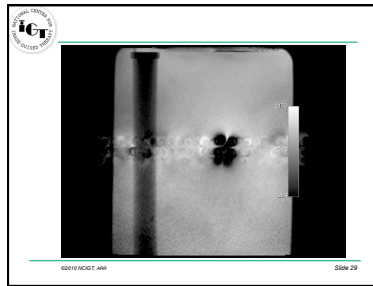
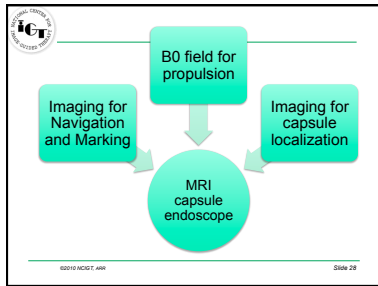


MRI swimming robot

2cm swimming tail, in 3T MRI

Kosa Hata et al, IEEE ICRA 2010

Slide 27



BWH Image Guided Therapy Program

- Individual research programs (e.g. R01 grants)
- Three NIH-funded national centers
 - National Center for Image Guided Therapy
 - Neuro Analysis Center
 - National Alliance for Medical Image Computing

©2010 MDCT, LLC Slide 31

NIH-funded Center

- Complementary to traditional R01-type research
- Resource center
 - Conduct state-of-art IGT translational research collectively with R01-type program
 - Provide methods, software, tools, and know-how to facilitate cutting edge IGT research in other US investigators
 - Nurture clinical and translational researchers
- Service, Dissemination, Training
 - See www.nccu.edu, www.fda.gov, www.slicer.org for the materials
- Vendor independent methods
 - with vendor supported translational studies, reflecting the nature of cotemporary IGT research

©2010 MDCT, LLC Slide 32

Highlighted Center Activity #1: 3D Slicer

- A platform for image analysis and visualization
- A freely-downloadable program
 - Source code and executables available for Windows, Linux, and Mac OS X
 - All Code Reusable
- Slicer is a research platform:
 - NOT an FDA approved medical device
 - NOT finished – some parts will work better than others

©2010 MDCT, LLC Slide 33

NA-MIC collaboration Trans-Rectal Robotic Prostate Biopsy (Fichtinger, Queens Univ)

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

© Hrago A. Sadiq, Robert C. Coleman, J.A. Fichtinger, G. Abad, D. Whitcomb, L.L. Design of A Novel MRI Compatible Manipulator for Image Guided Prostate Intervention, IEEE Trans. Biomed. Eng. 2005; 52(2):295-312
© Sadiq, R.C., Hrago, A., Coleman, J.A., Campbell, R., Cheng, H., Srinivas, S., Smith, S., Fichtinger, G., Whitcomb, L.L., Coleman, R.C., Abad, E., Transrectal Prostate Biopsy and Fiducial Marker Placement in a Standard 1.5T MRI Scanner, J. Urol. 2009; Jan; 179(1):115-20

©2010 MDCT, LLC Fichtinger Slide 34

Segment

©2010 MDCT, LLC Fichtinger Slide 35

Target

©2010 MDCT, LLC Fichtinger Slide 36

Navigate

©2010 MDCT, Inc. Fichtinger Slide 37

Software Design

- Software design to maximize function commonalities among applications
 - Brain (biopsy, craniotomy, NdYAG laser ablation)
 - Prostate (brachytherapy, biopsy)
 - Liver and kidney (Microwave, Cryo, laser ablation)

©2010 MDCT, Inc. Slide 38

3D Slicer in MRI-guided therapy

- Our recent study* has shown that a new therapy software can be developed in as little as 120 man-hours
- The paper has been downloaded over 700 times from SPL DB in the last half year
- Making it the most downloaded paper related to Slicer in SPL

*Hata N, Pizer S, Joleau F, Tempany C, Black P, Morikawa S, Inoki H, Hashizume M, Kikinis R. Application of Open Source Image Guided Therapy Software in MRI-guided Therapy. Med Image Comput Comput Assist Surg 94 (2010) 1187-1191. doi:10.1016/j.micpro.2010.11.001

©2010 MDCT, Inc. Slide 39

National Center for Image Guided Therapy
Brigham and Women's Hospital
Boston, Massachusetts USA

a teaching affiliate of
Harvard Medical School

Value proposition to industrial partners

©2010 MDCT, Inc. Slide 40

Access to research resource

- Open source software for public use.
- BSD-style (liberal) open source license
- 590K lines of code and extensive documentation
- Worth 160 person years, \$16-20 Mil
- ITK 20Mil, VTK 39 Mil
- State-of-art methods for prototyping

©2010 MDCT, Inc. Slide 41

Clinical feasibility studies with minimum resource investment

- Enables high-risk high-return research
 - Using FDA-approved commercial system
 - Experimenting advanced methods and tools in Slicer
 - In IRB-approved clinical research program at collaborating clinical sites

©2010 MDCT, Inc. Slide 42

Complementary roles

- Slicer3
 - cross-platform and user application for analyzing and visualizing medical images.
 - Not regulated by FDA
 - Constantly updated to incorporate state-of-art medical image processing tools
- BrainLab
 - offers a set of integrated OR solutions, for instance neurosurgery, orthopedic, and RT oncology.
 - Tracking, registration
 - Stability, Support
 - FDA approved

©2010 MDCT, Inc. Slide 43

Integrating Slicer and BrainLab navigation

- Rationale
 - Well tested and proven methods performed by BrainLab system
 - State-of-art research by 3D Slicer
- Exemplary clinical applications
 - Needs – Interactive DTI tractography in OR using tracking tool to examine tumor/critical fiber tract relationship
 - Benefit – minimizing neurological complication

©2010 MDCT, Inc. Slide 44

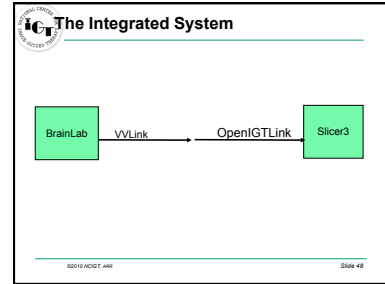
©2010 MDCT, Inc. Slide 45



iCT

- **BiImage Suite**
 - An integrated image analysis software suite developed at Yale University.
- **VectorVision Link (VVLink)**
 - A custom designed client/server tool
 - Enables bi-directional data transfer such as image data sets, visualizations and tool positions in real time.
- **OpenIGTLink**
 - a simple network protocol intended for trackers, robots and other devices to send data to the main application.

©2010 MDCT, LLC Slide 47



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

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

Video Supplement

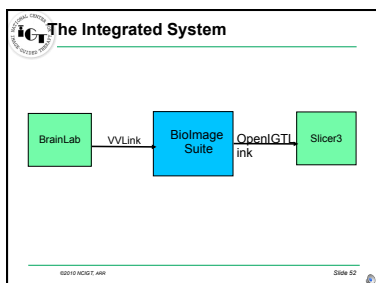
©2010 MDCT, LLC Slide 49




iCT

- **VectorVision Link (VVLink)**
 - A custom designed client/server tool
 - Available for purchase from BrainLab as an optional package to their navigation system
 - Enables bi-directional data transfer such as image data sets, visualizations and tool positions in real time.
- **OpenIGTLink**
 - a simple network protocol intended for trackers, robots and other devices to send data to the main application.

©2010 MDCT, LLC Slide 51






Partnership with Industry

- Providing advanced medical image processing, visualization, navigation, robotics technology
- Exploring new clinical methods in 3D Slicer
- Transitioning to more sustainable clinical program, or dissemination by commercialization

©2010 NCST, LLC Slide 43



Acknowledgement

- Support: NIH Grant (5U41RR019703, 5P01CA067165, 1R01CA111288, 1R01CA124377, 5P41RR013218, 5U54EB005149, 5R01CA109246), NSF (9731748), CIMIT, METI, GE.
- Junichi Tokuda, Hiroto Hatabu
- Ferenc Jolesz, Clare Tempny, Ron Kikinis
- The contents of the slides in the presentation has been published elsewhere as of Nov 4, 2010.
- This presentation has been posted at wiki.na-mic.org and made public as of Nov 3, 2010.

©2010 NCST, LLC Slide 44