Image-Guided Interventions
Technology and Applications

Organizers: Emad Doctor, Pascal Fallavollita, Ali Kamen, Ziv Yaniv
Welcome

8:30am: Introduction, and overview [Ziv Yaniv]
8:45am: Imaging [Pascal Fallavollita]
9:15am: Segmentation [Wiro Niessen]
9:45am: Registration [Stefan Klein]
10:15am: Q/A and Break
10:30am: Tracking systems [Kevin Cleary]
11:00am: Image based tracking technologies [Terrence Chen]
11:30am: Visualization and augmented reality [Nassir Navab]
12:00pm: Robots in image-guided interventions [Peter Kazanzides]

12:30pm: Lunch, on your own

1:15pm: Liver Interventions [Russ Taylor]
1:45pm: Ultrasound guided procedures [Wolfgang Wein]
2:30pm: Cardiac Interventions [Terry Peters]
3:00pm: Catheter Based Interventions [Razvan Ionasec]
3:30pm: Q/A and Break
3:45pm: Hemodynamic modeling and simulation [Puneet Sharma]
4:15pm: Prostate Interventions [Gabor Fichtinger]
4:45pm: Orthopedic Applications [Rob Rohling, Purang Abolmasumi]
5:15pm: Panel discussion
If You Don't Know Where You're Going, Any Road Will Get You There  (Lewis Carroll)

Where are we going:
1. Patient specific.
2. Treat the medical condition without damaging healthy tissue.

Where no man has gone before: Star Trek IV, The Voyage Home

Are we there yet? Insightec’s ExAblate Neuro System
The Process
(Lung Biopsy Example)

- Diagnosis
- Pre/Intra-operative Planning
- Intra-operative Plan Execution And Modification
- Post-operative Evaluation
Elements of Image-Guided Interventions

1. Imaging.
2. Segmentation.
3. Registration.
4. Tracking.
5. Visualization.

The devil is in the details:
- Image characteristics and content
- Algorithm parameters
- Physical constraints, or lack thereof
- Computational complexity
- System integration
A journey of a thousand miles begins with a single step (Lao-tzu)

December 22\textsuperscript{nd} 1895, Wilhelm Conrad Röntgen acquires the first x-ray image:
Imaging

Look inside the body with minimal damage to healthy tissue.

1. Does the modality have detrimental effects?
   - Ionizing radiation

2. What does the image convey?
   - Structure, Function

3. What is the image dimensionality?
   - 2D tomographic, 2D projective, 3D, 2D+time, 3D+time (time is not commensurate with space)

4. Does the image exhibit artifacts?
   - Geometry, Intensity

5. What are the characteristics of the image element?
   - Number of channels, Range of values

6. What is the data storage format?
Segmentation

Delineating objects in medical images.

1. Why do we want to segment the data?
   - Planning, Registration

2. What do we want to segment?
   - Man made objects - designed for detection, Anatomical structures – context specific.

3. What is the degree of automation and what is the computational complexity?
   - Manual    Semi-automatic    Automatic

4. What approach to use?
   - Low level process – only use information obtained from the image (threshold, region growing, clustering, edge detection).
   - High level process – incorporate prior knowledge (active contours/snakes, level sets, active appearance and shape models).
Registration

Establish a common geometric reference frame between data sets.

1. Why do we want to register the data?
   • Transfer plan to physical space, Merge multiple sources of information, Construct anatomical atlas

2. Which transformation?
   - rigid          affine                    deformable+constraints

3. What type of data does the method use?
   - points, contours, surfaces, intensities, gradients

4. Is the solution closed form or iterative?
   • Iterative – how is it initialized?
     what is the computational complexity?

Hawkes et al. IGI book
Tracking

Determine the position and orientation of tools and anatomical structures relative to a fixed coordinate system – mostly commercial systems.

1. How does the system work?
   - optical IR, optical visible light, electromagnetic, mechanical

2. What are the system characteristics?
   - refresh rate and lag, number of objects tracked simultaneously, working volume, wired or wireless tools.

3. Is the system performance effected by the environment?
   - ferromagnetic materials, specific constraints on placement

4. Does the system effect the environment?
   - introduce imaging artifacts, constraints on physical location

5. Does the system have additional capabilities?
   - Optical visible light systems provide the video stream.

Mountney et al. IEEE Signal Processing
Visualization/Augmented Reality

Provide visual information to plan, guide and assess the intervention.

1. Which method is appropriate:
   - direct volume rendering, surface rendering, re-slice/re-format + overlay, video stream + overlay (AR)

2. What is the computational complexity of the method?
   - introduce latency between action in physical world and its representation in the virtual one.

3. What is the effect of visualization on task performance?
   - Improves the perception of relationships between underlying anatomical structures and tools?

Bullitt and Aylward TMI 2002
Fichtinger et al.
Navab et al.
Birkfellner et al.
Fichtinger et al.
Robotic Devices

Augment the physician’s abilities, both to perform interventions through small incisions, external or internal, and the ability to operate on smaller structures.

1. What is the impact of the system on the working environment?

2. Do parts of the procedure become more invasive?

3. Is there a loss of information?
   - tactile feedback
Human Computer Interface

Grad-Student Interface Syndrome (GSIS):
Ethics

• Animal Experiments (IACUC - Institutional Animal Care And Use Committee).

• Human Experiments (IRB - Institutional Review Board).

• Patient Privacy (Health Insurance Portability and Accountability Act - HIPAA).

• No Equivalent to Hippocratic Oath.

Picture Courtesy Nation Library of Medicine (NIH)
Postdoctoral Positions at SZI

- Three/Four positions available immediately.

- Academic Supervisors: Kevin Cleary, Marius Linguraru, Raj Shekhar, Ziv Yaniv.

- Required qualifications include:
  1. PhD in engineering (electrical, computer or biomedical) or computer science
  2. Demonstrated expertise through doctoral work in one or more of the following areas: image registration, surgical navigation and visualization, medical image analysis, minimally invasive interventions, etc.
  3. Strong C/C++ programming and good communication skills
  4. Peer-reviewed publications

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