

# Image-Guided Interventions Technology and Applications

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**Children's National**

SHEIKH ZAYED INSTITUTE *for* Pediatric Surgical Innovation

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# 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.

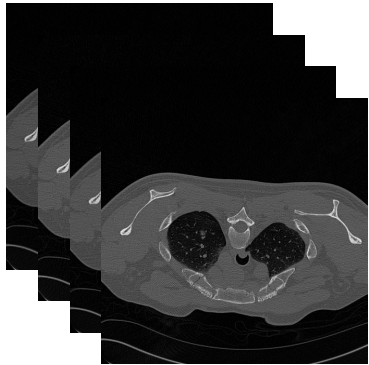


Where no man has gone before:  
Star Trek IV, The Voyage Home



Are we there yet?  
Insightec's ExAblate Neuro System

# The Process (Lung Biopsy Example)

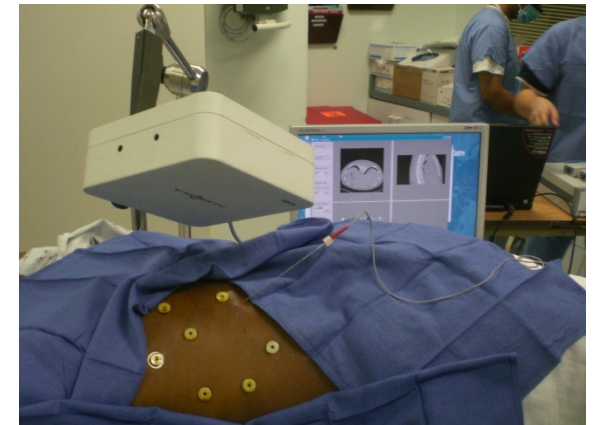
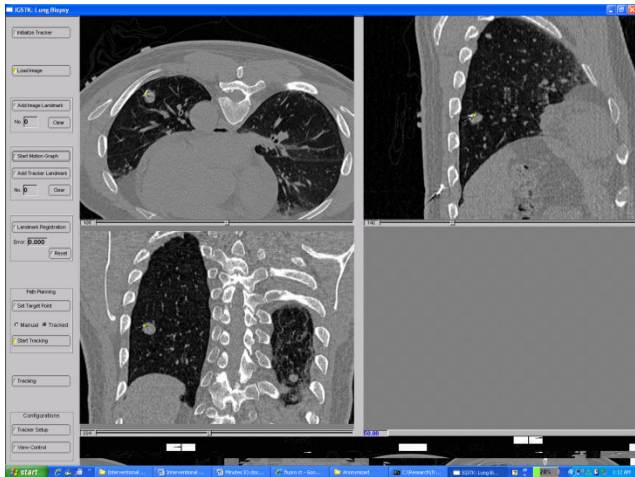
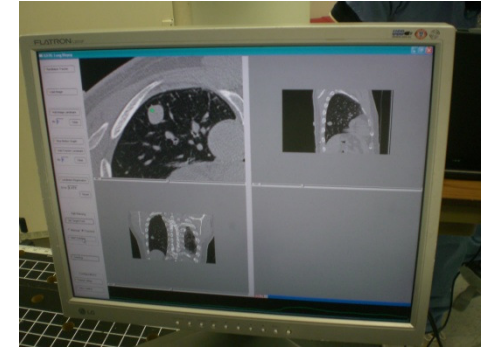


Diagnosis

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.
6. Robotics.

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<sup>nd</sup> 1895, Wilhelm  
Conrad Röntgen acquires the  
first x-ray image:

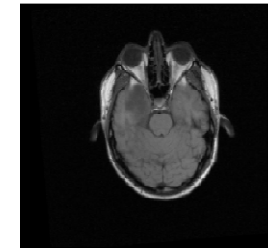
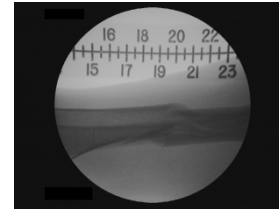


# Imaging

Look inside the body with minimal damage to healthy tissue.

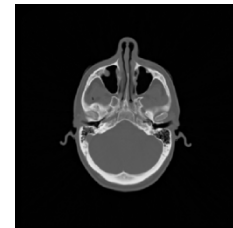
1. Does the modality have detrimental effects?

- Ionizing radiation



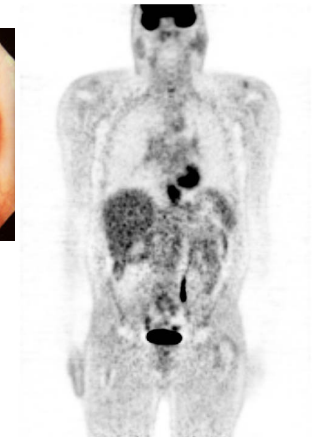
2. What does the image convey?

- 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?

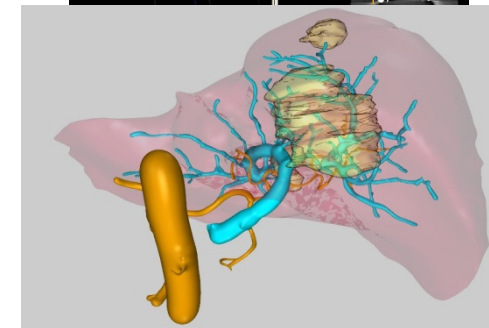
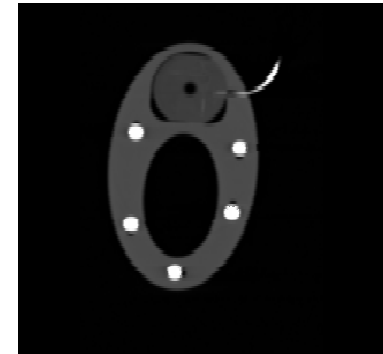
- Man made objects - designed for detection, Anatomical structures – context specific.

3. What is the degree of automation and what is the computational complexity?



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).



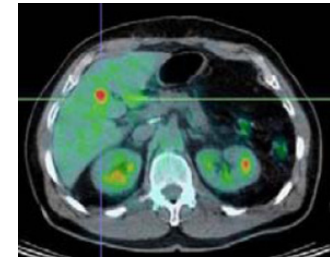


# Registration

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

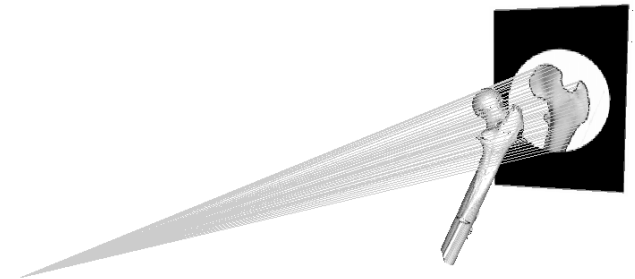


## 2. Which transformation?



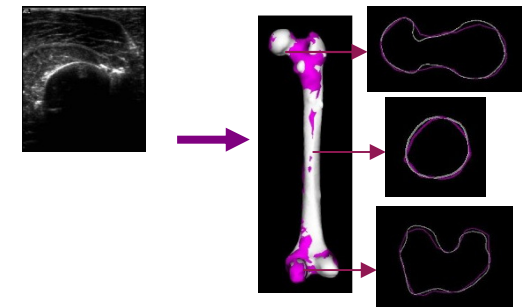
## 3. What type of data does the method use?

points, contours, surfaces, intensities, gradients



## 4. Is the solution closed form or iterative?

- Iterative – how is it initialized?  
what is the computational complexity?

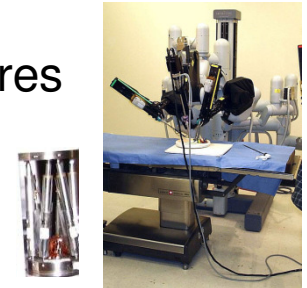


# Tracking

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



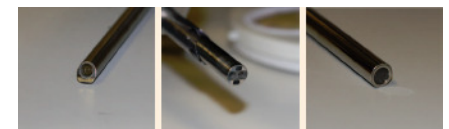
## 4. Does the system effect the environment?

- introduce imaging artifacts, constraints on physical location



## 5. Does the system have additional capabilities?

- Optical visible light systems provide the video stream.

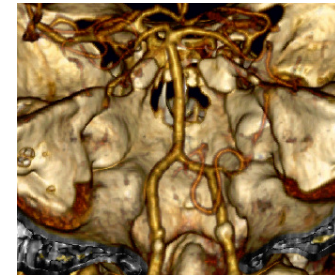


# Visualization/Augmented Reality

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

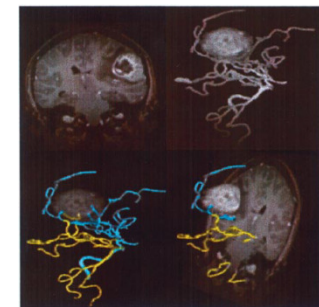
## 1. Which method is appropriate:

- 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?

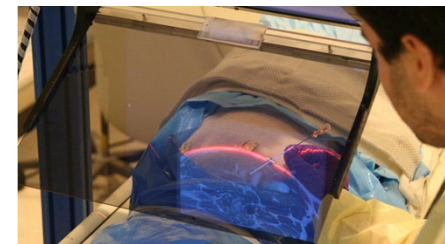
Bullitt and Aylward TMI 2002



Navab et al.



Birkfellner et al.



Fichtinger et al.

# Robotic Devices

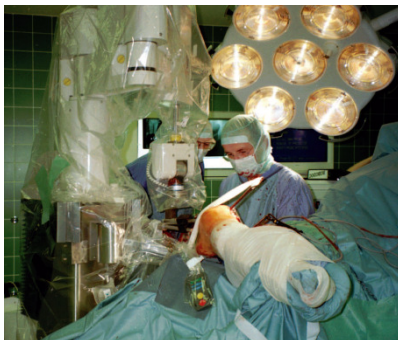
Augment the physician's abilities, both to perform interventions through small incisions, external or internal, and the ability to operate on smaller structures.

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

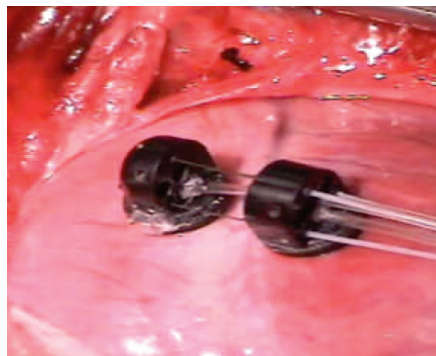
2. Do parts of the procedure become more invasive?

3. Is there a loss of information?

- tactile feedback



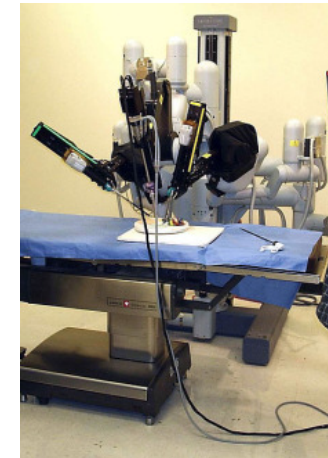
ROBODOC



Riviere et al.



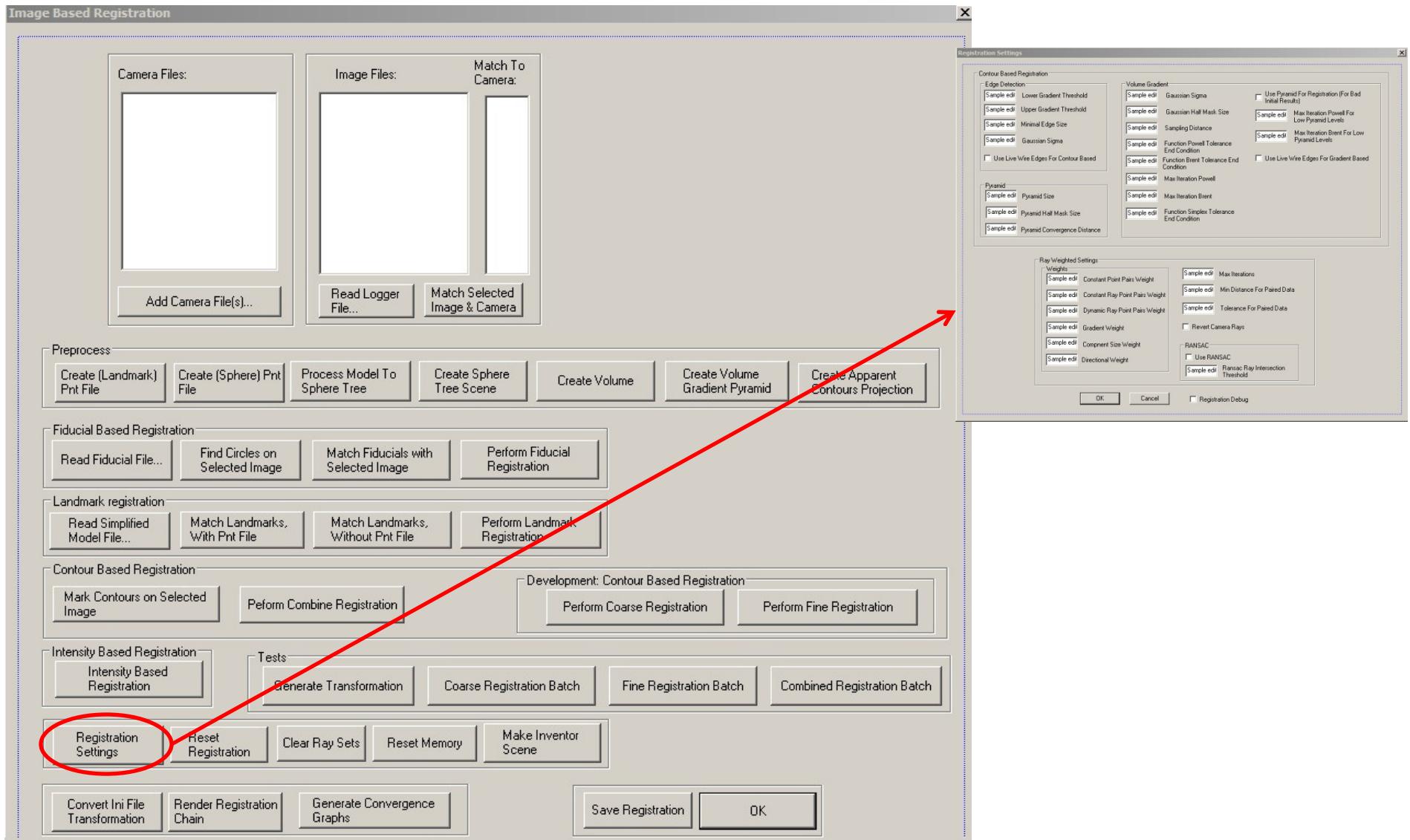
Mazor Robotics



Intuitive Surgical

# Human Computer Interface

## Grad-Student Interface Syndrome (GSIS):



The screenshot displays the 'Image Based Registration' software interface. The main window contains several sections for different registration methods:

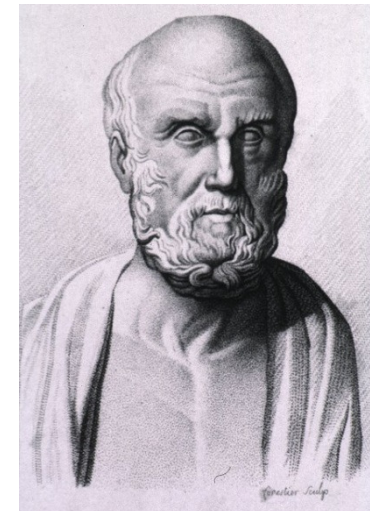
- Camera Files:** Includes an empty list box and an 'Add Camera File(s)...' button.
- Image Files:** Includes an empty list box, a 'Read Logger File...' button, and a 'Match Selected Image & Camera' button.
- Match To Camera:** An empty list box.
- Preprocess:** A row of buttons including 'Create (Landmark) Pnt File', 'Create (Sphere) Pnt File', 'Process Model To Sphere Tree', 'Create Sphere Tree Scene', 'Create Volume', 'Create Volume Gradient Pyramid', and 'Create Apparent Contours Projection'.
- Fiducial Based Registration:** Buttons for 'Read Fiducial File...', 'Find Circles on Selected Image', 'Match Fiducials with Selected Image', and 'Perform Fiducial Registration'.
- Landmark registration:** Buttons for 'Read Simplified Model File...', 'Match Landmarks, With Pnt File', 'Match Landmarks, Without Pnt File', and 'Perform Landmark Registration'.
- Contour Based Registration:** Buttons for 'Mark Contours on Selected Image', 'Perform Combine Registration', 'Perform Coarse Registration', and 'Perform Fine Registration'. A sub-section 'Development: Contour Based Registration' is also visible.
- Intensity Based Registration:** A button for 'Intensity Based Registration'.
- Tests:** Buttons for 'Generate Transformation', 'Coarse Registration Batch', 'Fine Registration Batch', and 'Combined Registration Batch'.
- Registration Settings:** A button circled in red, which is highlighted by a red arrow pointing to a separate 'Registration Settings' dialog box.
- Other buttons:** 'Reset Registration', 'Clear Ray Sets', 'Reset Memory', 'Make Inventor Scene', 'Convert Ini File Transformation', 'Render Registration Chain', 'Generate Convergence Graphs', 'Save Registration', and 'OK'.

The 'Registration Settings' dialog box is open, showing various parameters for registration:

- Contour Based Registration:** Includes 'Edge Detection' (Lower Gradient Threshold, Upper Gradient Threshold, Minimal Edge Size, Gaussian Sigma, Use Live Wire Edges For Contour Based) and 'Pyramid' (Pyramid Size, Pyramid Half Mask Size, Pyramid Convergence Distance).
- Volume Gradient:** Includes 'Gaussian Sigma', 'Gaussian Half Mask Size', 'Sampling Distance', 'Function Powell Tolerance End Condition', 'Function Brent Tolerance End Condition', 'Max Iteration Powell', 'Max Iteration Brent', and 'Function Simplex Tolerance End Condition'.
- Ray Weighted Settings:** Includes 'Weights' (Constant Point Pairs Weight, Constant Ray Point Pairs Weight, Dynamic Ray Point Pairs Weight, Gradient Weight, Component Size Weight, Directional Weight), 'Max Iterations', 'Min Distance For Paired Data', 'Tolerance For Paired Data', and 'Revert Camera Rays'.
- RANSAC:** Includes 'Use RANSAC' and 'RANSAC Ray Intersection Threshold'.

# 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

Kevin Cleary – [KCleary@childrensnational.org](mailto:KCleary@childrensnational.org)