计算机辅助手术讲座（13）

Image Guided Surgery (13)

计算机辅助手术的历史和关键技术

IGST History and Key technologies

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Why IGST?

Derives of IGST

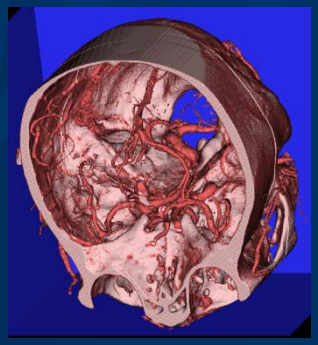
- **Image-guided surgery was first proposed in 1994 by Grimson from AI Laboratory, MIT, USA although the similar idea was given by other people including**
  - **Stereotactic neurosurgery (Galloway, Vanderbilt University, USA, 1990)**
  - **Image-guidance for neurosurgery (Peters, McGill University, Montreal, Canada, 1994)**

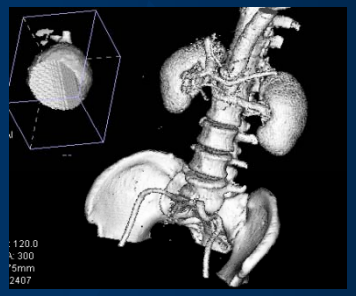
The trend of the modern surgery development

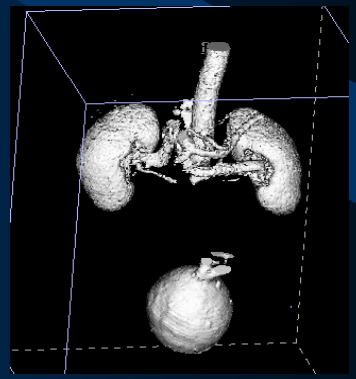
- **Minimal Invasive surgery**
  - ✓ Reduce the hurt
  - ✓ Reduce the surgical time
  - ✓ Reduce costs (blood etc.)
  - ✓ Reduce the recovery time
- **IGST**
  - ✓ Localize the target
  - ✓ Visualize the tumor and the surrounding organs
  - ✓ Increase the accuracy and success rates

IGST in Clinic

- Based on CT / MRI
- Tracking the surgical instrument and define the coordinates with patient.
- During the surgery, the computer can help to trace the position of the tool related to the body structure.







IGST General Tasks

1. Gather preoperative image data: CT/MRI/US etc;
2. Localize and track the position of the surgical tool or therapeutic device;
3. Register the localizer volume with the preoperative data;
4. Display the position of the tool with regard to medically important structures visible in the preoperative data;
5. Account for differences between the preoperative data and the intraoperative reality

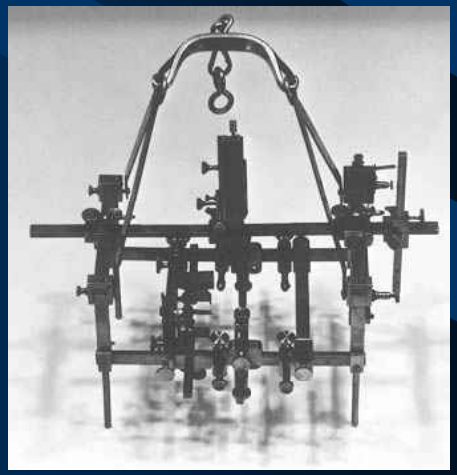
IGST History

History

- Quite young: 20 years history
- However, the concept and subprocesses has been developed, tested and refined for 100 years.
  - In 1895: first X-ray reported
  - In 1896: removed sewing needle guided by X-ray (J.H. Clayton, Birmingham, England)
  - In 1896: removed a bullet from a leg (John Cox, McGill University, Montreal, Canada)

Stereotaxy

- Horsley and Clark frame
  - In 1908, they proposed a frame affixed to a subject's head (in this case, monkey)
  - The frame can help to guided electrodes to be introduced into the skull and moved to locations within a Cartesian space.
  - Auditory canals, orbital rims
  - Spatial brain atlases
  - Assume the inner structure stable

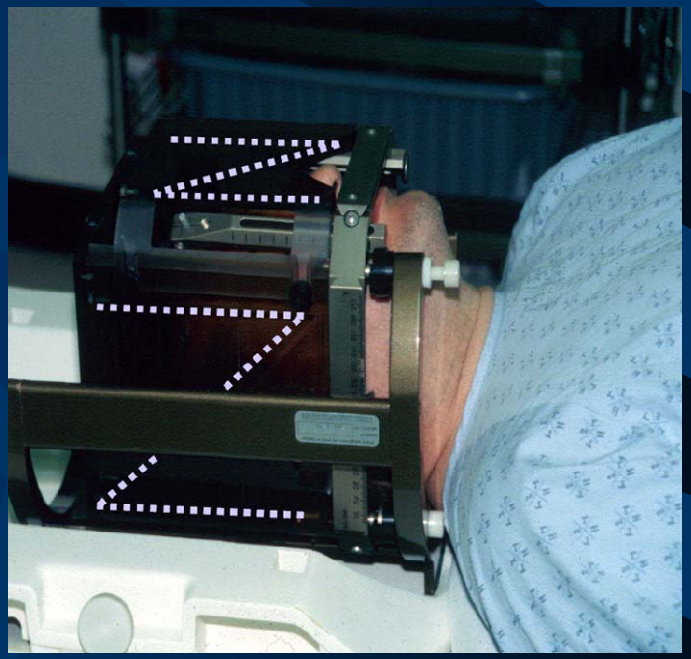


Stereotaxy

- Leksell Frame (modern)
  - In 1951, 1980, Leksell and Jernberg introduced a frame on polar coordinates.
  - Isocenter could be aligned with the target center
  - Gamma Knife
- Other frames:
  - BRW, CRW
  - Compass system

The arrival of CT

- Invention of CT:
  - In 1973, Hounsfield EMI announced CT scanner
  - 3D image of internal structures of body
- CT based stereotactic frames
  - In 1976: Bergstrom and Greitz described the first case
  - In 1979: Brown introduced “N” bar system
  - Integration of localization and registration.



Computer systems come of age

- In August 1981: IBM PC released;
- In 1987: T. Peters introduced the first PC-based IGST system for Nuero-surgery
- Frameless stereotactic system:
  - The first system came from Roberts' lab (in 1986 and 1989)
  - The second published system was from Tokyo Police Hospital (Watanabe, 1987)

Challenges

- After 20 years development, the IGS system has been commercialized quickly into different area:
  - Neurosurgery, Orthopedic Surgery, Dental surgery, ENT and Cardiac surgery
- Existing problems:
  1. Cost and complexity;
  2. Deformation of organ (organ is moving)
  3. Reality and applicability

Tracking Device

Tracking Device

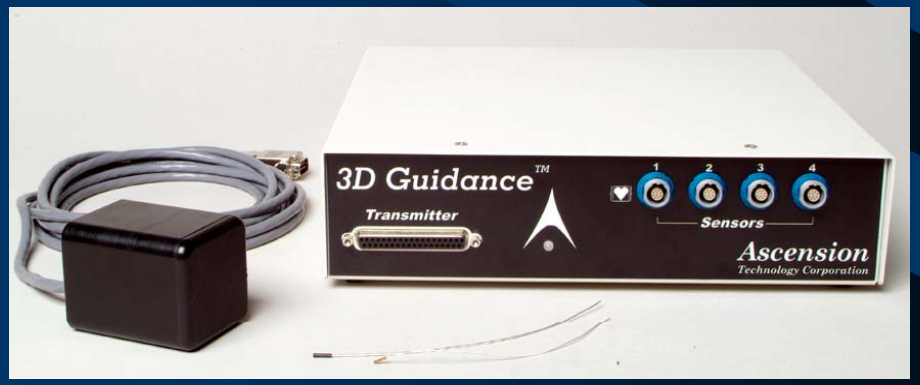
- Tracking devices are an essential component of an IGST system, which are used to track the position of instruments related to the patient's anatomy
- Mechanical digitizer -> optical tracking system (OTS) -> electromagnetic tracking system (EMTS)
- Varity tracking devices are chosen highly application dependent.

Principle of OTS

- OTS features:
  - Videometric tracking systems: identify markers on video image sequence. (one or more video cameras) Claron Technology inc.
  - IR-based tracking systems: optical band-pass filter eliminates all ambient lights. More stable. two types IR trackers: active and positive. (NDI Technology Inc.)

Principle of EMTS

- The features of EMTS:
  - AC-driven tracking: the systems are driven by alternating current. NDI Aurora system;
  - DC-driven tracking: the systems are driven by quasistatic direct current. Ascension Technology.
  - Passive / transponder tracking: track position by localizing permanent magnets or implanted transponders.



Other Tracking Technologies

- Shape tape: use optical sensor linkages to measure torsion and flexion of fiber optic cables to determine position and pose alone the entire length of the device.
- Inertial sensors: measure the acceleration and angular velocity, low accuracy, not be tolerated for medical use.
- Hybrid tracking: EMTS and OTS, but costly.

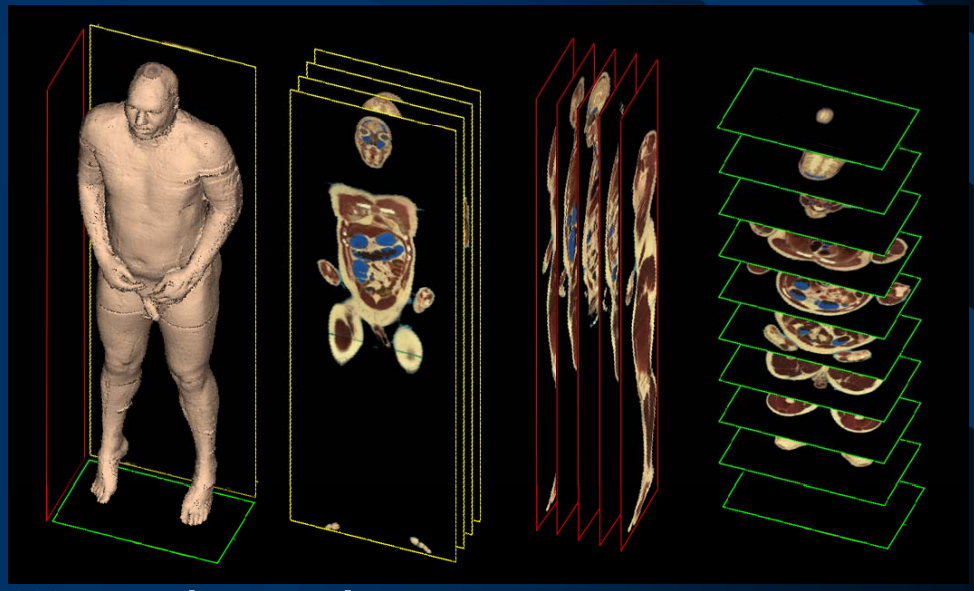
Accuracy

- Accuracy in IGST is a critical issue. The next items are well concerned:
  - Tracker accuracy: a crucial component of the overall target registration error (TRE).
  - Evaluation of the IGST system should take place with the specific intended clinical application in mind.
    - Can therapeutic outcome be improved by deploy a IGST system?
    - Can this improvement be optimized by other tracking technique?

Visualization in IGST

Visualization

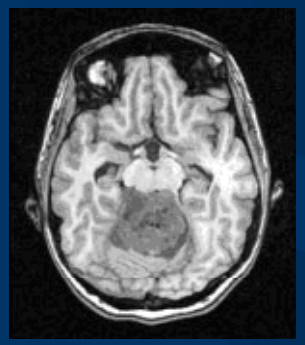
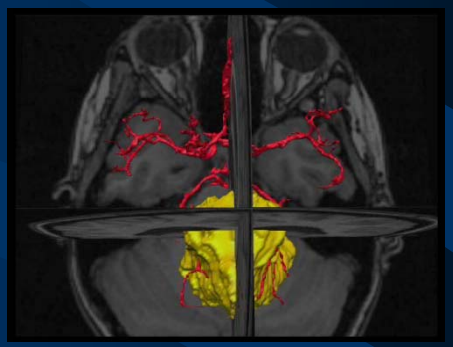
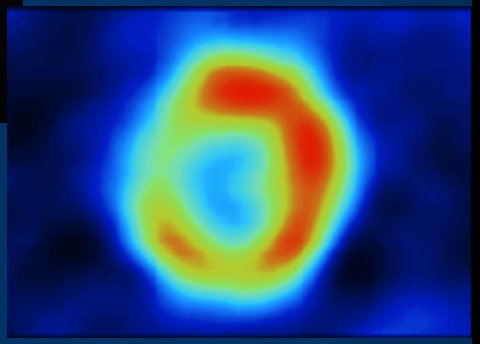
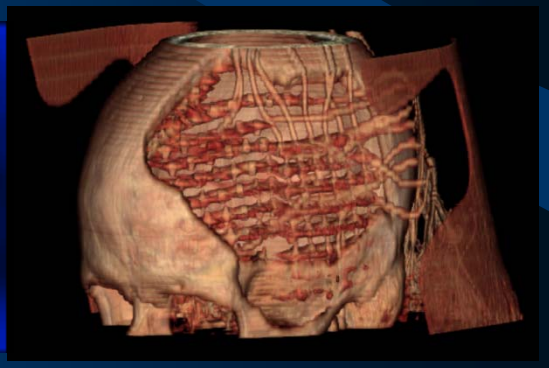
- Visualization is one of the primary interfaces between a surgeon and his patient;
- The purpose of visualization in IGST is to faithfully represent the patient and surgical environment, and to accurately guided the surgeon to localize the treatment target during a surgery.
- Common anatomical orientation of 3D image data are:
  - Axial (transverse),
  - sagittal,
  - Coronal.



Images in IGST

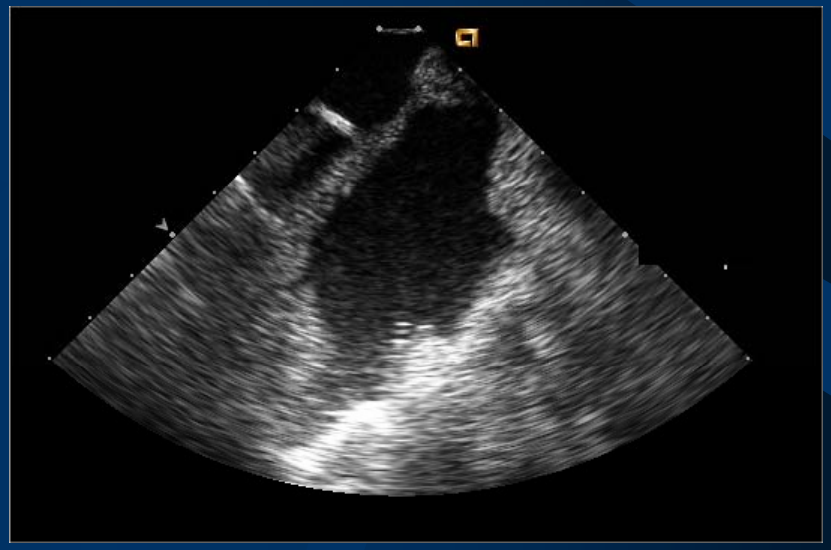
- Preoperative images
  - CT, MRI
  - Nuclear Image Scans and Functional Dada (PET, SPECT)



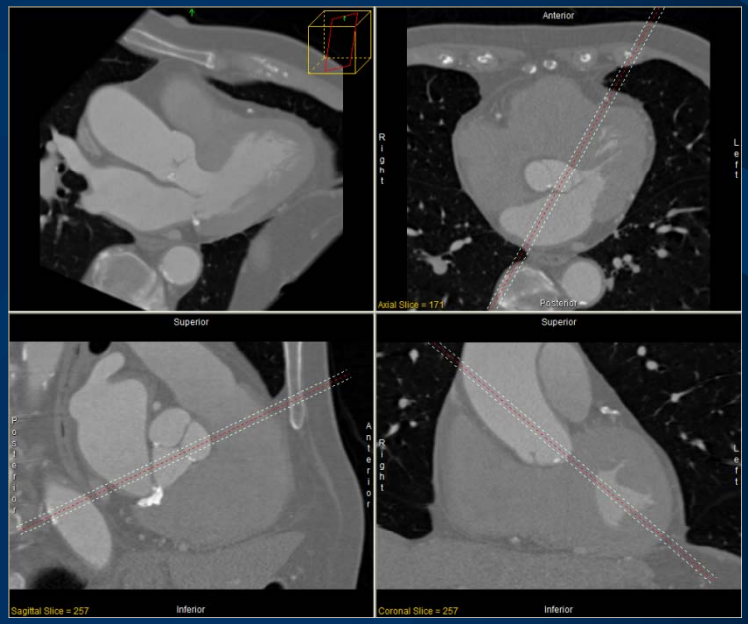
Images in IGST

- Intra-operative images
  - X-Ray Fluoroscopy and Rotational Angiography
  - Intra-operative Ultrasound
  - Intra-operative CT and MRI: iCT / iMR



Visualization

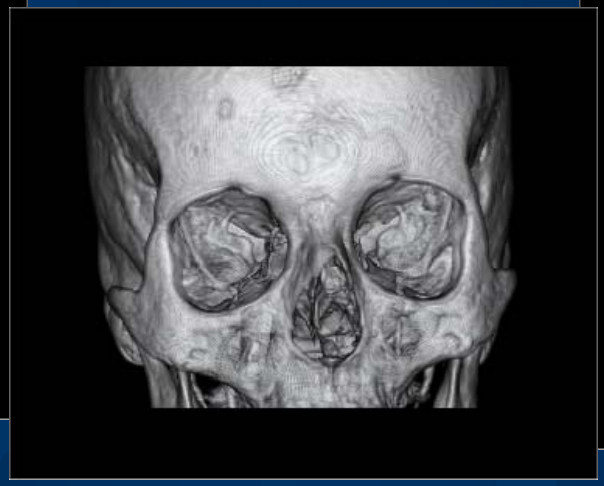
- 2D-Multi-Planar and Oblique
  - 2D-Multi-Planar: an uncomplicated method for displaying medical image data (2D slices)
  - Oblique Image Display: providing 2D slices of the data that are not orthogonal to the acquisition orientation.



Visualization

- 3D Surface Rendering and 3D Volume Rendering
  - 3D display on a 2D screen involves the mapping of a 3D object into a 2D image.

surface

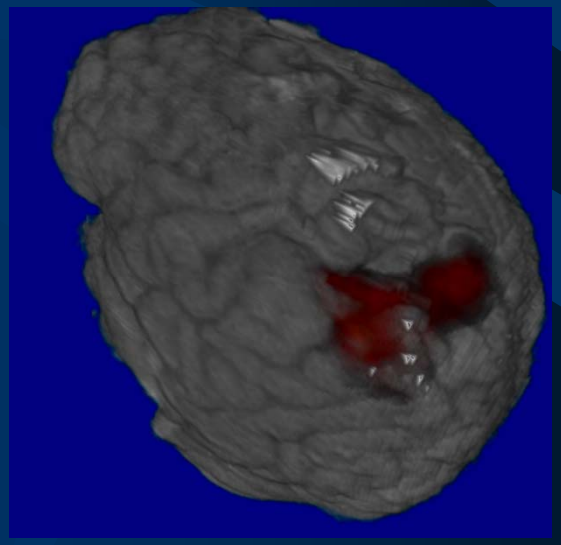


Volume (Ray casting)

Volume (threshold)

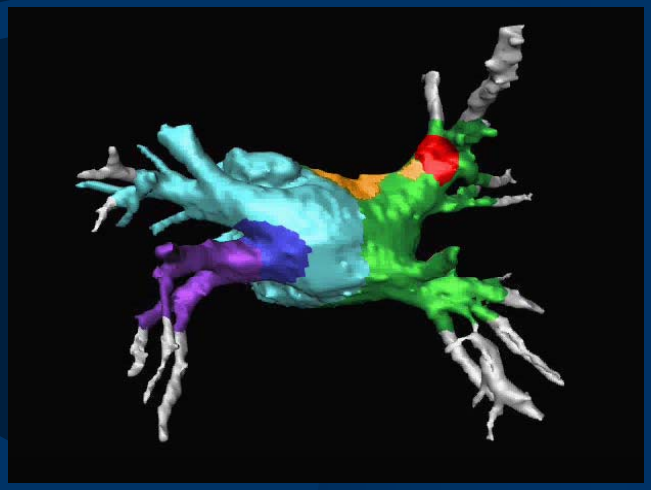
Image Fusion

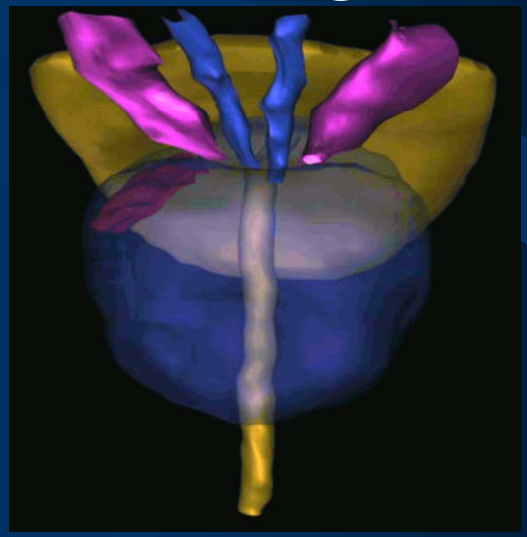
- Diverse imaging modalities provides different anatomical, pathological and /or functional information
  - Data fusion play an important role in IGST
  - Multiple volumes of data can be combined into a single volume using a variety of blending functions
    - Grayscale blending
    - Color blending
    - Hybrid blending



Multi-object Rendering

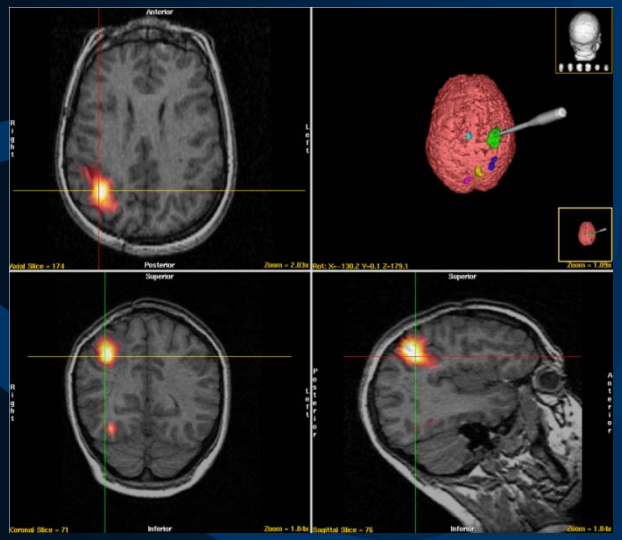
- Parametric Mapping: a specific mapping of color onto an atomic data.
- Multi-object Rendering: multiple related anatomical objects are all relevant to an IGST procedure and should be visualized together.

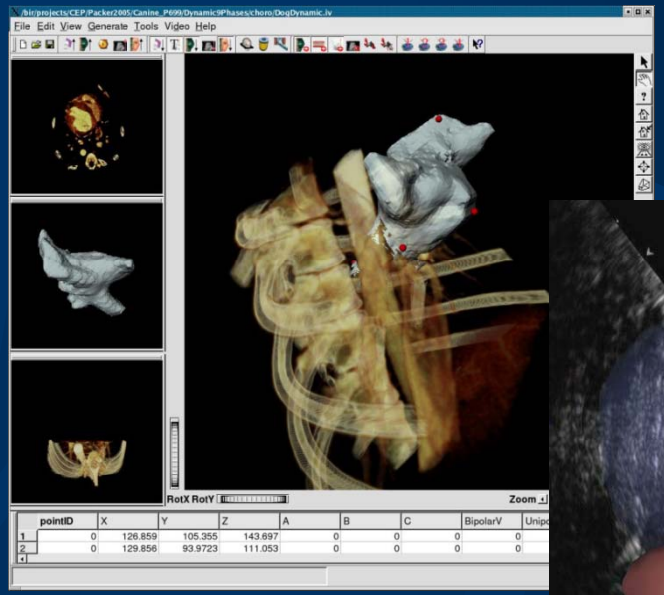


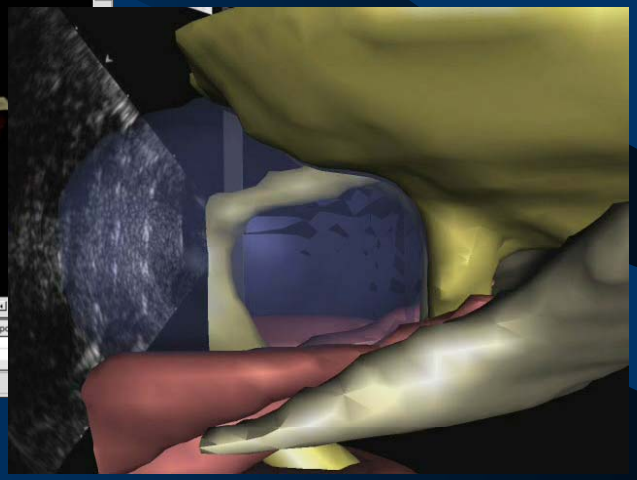


Applications

- Epilepsy (癲痫) Foci Removal
- Left Atrium Cardiac Ablation
- Permanent Prostate Brachytherapy

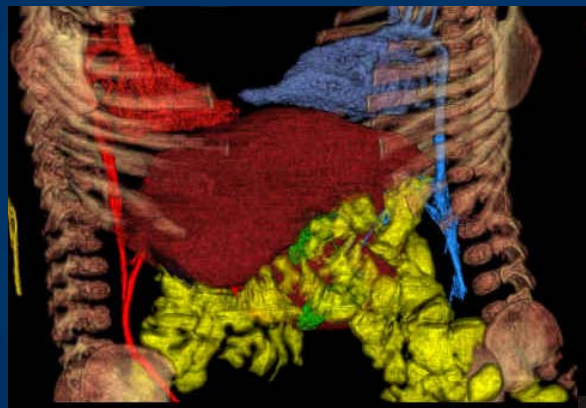


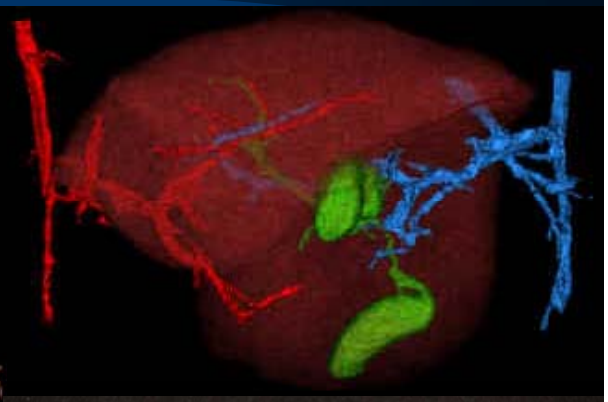


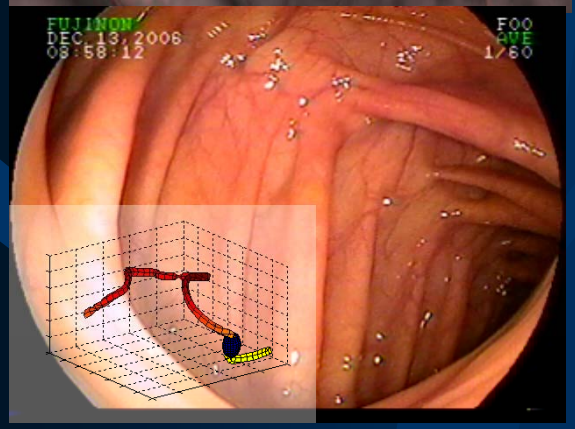


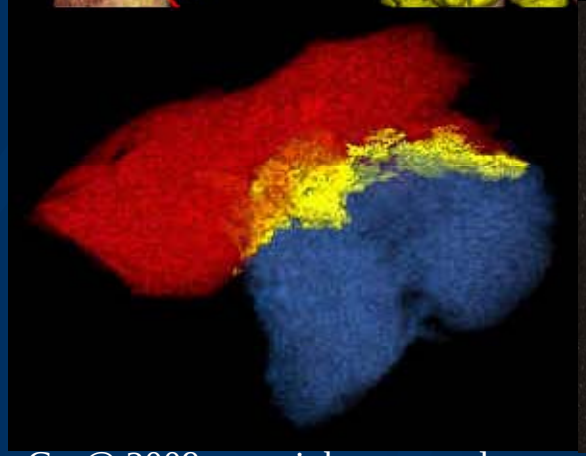
Applications

- Virtual and Enhanced Colonoscopy
- Surgical Separation of Conjoined Twins









Discussion