Image-Guided Procedures
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Disclosure

Bob Galloway is a founder, chief technical officer and president of Pathfinder Therapeutics Inc, of Nashville, TN
Presentations

1:10 - 1:45 - Basics of Image-Guided Procedures
   Bob Galloway
1:45-2:20 - Medical Images
   Ken Wong
2:20-2:55 - Advances in Localization
   Kevin Cleary
2:55-3:10 - Break
3:10-3:45 - Interventional Radiology application
   Filip Banovac
3:45-4:20 - Dealing with intraprocedural deformation
   Mike Miga
4:20-5:00 - Panel discussion - What is the future of IGP

Introduction to Image-Guided Procedures

• History
• Terminology
• Components
  – Images
  – Localization
  – Registration
  – Display
• Applications
• Validation
History of Image-Guided Therapy

• 1896 J.H. Clayton. X-Ray use in surgery
• 1904 Horsley and Clarke. Stereotactic frame
• 1946 Spiegel and Wycis. Stereotactic frame using xrays.
• 1940’s~1950s: Leksell, Riechert-Mundinger, Talairach, Cooper...

Technology-Guided Therapy Timeline

• 1986
Terminology

- “Frameless Stereotaxy”
- Image-Guided Surgery
- Image-Guided Procedures
- Image-Guided Interventions
- Technology-Guided Therapy
Technology-Guided Therapy

The central tenet of technology-guided therapy (TGT), is that a significant number of disease or disorder processes have a restricted spatial extent and that knowledge of the location and extent of that disease or disorder will allow more specific therapy. Specific therapy implies complete treatment of the disease or disorder with no therapy damage to the surrounding healthy tissue.

IGS or TGT Requires

• Image Information
  – Image size and resolution
  – Understanding of Spatial Distortion
  – Image Contrast
  – Dealing with Multi-modal image information
• Physical Space Localizer
  – Range (Work volume)
  – Resolution
  – Update Speed
  – Sensitivities.
IGS or TGT Requires

• Image-Space to Physical Space Registration
  – Intrinsic or Extrinsic Features
  – Speed to solution
  – Reliability and robustness of method

• Display of Information
  – N-dimensional information on a three dimensional (2 spatial 1 time) display
  – Role of rendering & transparency

IGS or TGT Requires

• Dealing with changes
  – Changes between imaging and surgery
  – Intraoperative changes
    • Deformations due to pharmacological effects
    • Deformations due to tractions
When the mathematical relationship between a point in one space and the homologous point in another space is known, the spaces are considered registered. If that relationship can be reduced to a single common translation and rotation, the registration is considered rigid.
Transformation Matrix

\[
\begin{bmatrix}
X^P \\
Y^P \\
Z^P
\end{bmatrix} =
\begin{bmatrix}
X^I \\
Y^I \\
Z^I
\end{bmatrix}
\begin{bmatrix}
R_{11} & R_{12} & R_{13} \\
R_{21} & R_{22} & R_{23} \\
R_{31} & R_{32} & R_{33}
\end{bmatrix} +
\begin{bmatrix}
T^X \\
T^Y \\
T^Z
\end{bmatrix}
\]

Registration References

- Handbook of Medical Imaging, Vol 2, Chapter 8, Fitzpatrick, Hill and Maurer SPIE Press.
Articulated Arms

- All are revolute (only angular change)
- All use optical encoders for angle sensing
- Mark I and II – Vanderbilt
- Aachen
- Oolu
- Guthrie/Radionics
- Zamorano/Fischer

Localizer References


Applications of TGT

• Intracranial Neurosurgery
  – Tumor resection
  – Implantation of Neuroprostheses
• Spinal Surgery
• Liver Surgery
• Orthopedic Surgery
• Colorectal Cancer Staging and Surgery
• Ophthalmologic Surgery
• Cochlear Implants

Applications of TGT

• Lung Therapy
  – Tumor resection/ablation/brachytherapy
• Prostate Therapy
  – Open or robotic surgery
  – Brachytherapy
• Direct injection Chemotherapy/ Gene Therapy
Image-Guided Neurosurgery
Display Types

Cortical Surface Mapping
Display of function on brain images:
Image-Guided Liver Surgery (IGLS)

- Primary liver cancer is second most common cancer world-wide.
- Metastatic disease to the liver is common from colorectal & breast primaries
- Less than 50% of surgical candidates for liver metastatic tumors get surgery
OR Results

Bitmap from Range Scanner

Point Cloud

Tessellated Surface
Spinal Surgery

• >250,000 lumbar spine operations per year (US)
• Back-Pain Patient Outcomes Assessment Team (HS 06344): Cost of back pain: $50 billion (US)
• Traditional posterior approaches are “suboptimal”
Alternatives to IG – Colorectal staging and therapy

• Standard Endorectal US
  – 3-D anatomy not visualized
  – Very difficulty to take biopsy sample near US-identified structure.

• MR Imaging
  – Requires specialized coils
  – Postural changes between MR and procedure rooms make registration very difficult.

Applications of TGT
Colorectal Cancer Staging and Surgery

One of the most prevalent cancers in the US

Visualization of the layered structure of the rectum is important for staging and therapy
New Therapeutic Applications
Cochlear Implantation
• Only available therapy for the profoundly deaf
• Outcome tends to be binary
• 1% morbidity (Facial nerve)

Applications of TGT
• Cochlear Implants
Other TGT

• Prostate
  – Aaron Fenster – Robarts
  – Intuitive Surgical – DaVinci
    • Radical versus targeted
• Lung
  – Bill Higgins at Penn State – 7th level branching
• Cardiac
  – Interventional applications of stents, balloons and RF ablation

Validation

• System Performance in Phantoms
• System Performance in Animal Models
• Patient Outcome
• Device Accuracy
• Registration Accuracy
• System Information Transfer
Thessalonians 5:21

Prove all things; hold fast that which is good.

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