3D Localizers for Surgical Navigation
600.445

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3D localizers

- Determine 3D positions in space relative to some coordinate system
- Also called “3D digitizers”, “3D navigation systems”, “localizers”, etc.
- Many uses
- Many technologies

Localizer technologies

- Instrumented passive manipulator
- Active manipulator
- Ultrasound
- Electromagnetic
- Optical active
- Optical passive
- Miscellaneous – e.g., fiber optic
Passive mechanical linkages

- Encoders & linkage
Figure 23.3 Mechanical principle of ET-01.
Figure 23.4 The ET-01 measuring arm with 4.5 degrees of freedom.

Figure 23.7 Four and one-half degrees of freedom in ET-02.
Passive mechanical linkages

• Encoders & linkage

• Advantages:
  – simple
  – no line-of-sight problems
Passive mechanical linkages

- Encoders & linkage

- Advantages:
  - simple
  - no line-of-sight problems

- Drawbacks
  - clumsy
  - single frame
  - reference base

Some commercially used examples
Active mechanical linkages

- Robot + hand guiding
- E.g., Robodoc

Advantages
Active mechanical linkages

• Robot + hand guiding
• E.g., Robodoc
• Advantages
  – accurate
  – registered to robot
  – can combine with search, actions
• Drawbacks
  – clumsy
  – expensive
  – single tool, referencing
Ultrasound

- “Clickers”+microphones
- time delays give distances
- multiple distances give pos.
Ultrasound

- “Clickers”+microphones
- time delays give distances
- multiple distances give pos.

Advantages

- Cheap, unobtrusive
- multiple rigid bodies
Ultrasound

- “Clickers”+microphones
- time delays give distances
- multiple distances give pos.

- Advantages
  - Cheap, unobtrusive
  - multiple rigid bodies
- Drawbacks
  - Accuracy drifts (e.g., temperature)
  - Lack of self-evident warning

Electromagnetic

- Originally developed for fighter pilot head tracking
- Reasonably accurate 6 dof
- E.g., Polhemus, Ascension, NDI Aurora

- Advantages

- Drawbacks
How Does An EM System Work?

Credit: Paul McDonald, NDI

How a Magnetic System Works

Credit: Paul McDonald, NDI
Current Electromagnetic Products

- NDI Aurora
- SNT Axiem
- Ascension Flock of Birds
- Polhemus Patriot

Example: NDI Aurora™

Transmitter | 5 DOF Sensors | 6 DOF Sensors

Example: ATI medSAFE™ (Sensors)

http://www.ascension-tech.com/medical/medSAFE.php

Example: ATI medSAFE™ (Transmitters)

http://www.ascension-tech.com/medical/medSAFE.php
Electromagnetic

Pros
• No line of sight required
• Tools can be populated with small sensors
• Generally less expensive than optical

Cons
• Metal Interference
• Less stable than optical
• Smaller measurement volume
• Incapable of tracking more than 4 6DOF tools

Credit: Paul McDonald, NDI

Optical active

• Track LED markers
• Triangulate to locate 3D
• E.g.: Optotrak, Pixsys
• Current “gold standard”

Advantages

Disadvantages
PixSYS system

Optical Active

NDI Optotrak

Flashpoint
Optical active

- Track LED markers
- Triangulate to locate 3D
- E.g.: Optotrak, Pixsys
- Current “gold standard”

- Advantages
Optical active

- Track LED markers
- Triangulate to locate 3D
- E.g.: Optotrak, Pixsys
- Current “gold standard”

- Advantages
  - very accurate
  - multiple rigid bodies
  - versatile
  - reasonably fail-safe

- Disadvantages
  - line-of-sight restrictions
  - large, expensive
Optical passive

- Triangulate markers in standard video images or specialized IR cameras
- E.g.,
  - Heilbrun, Colchester, Mathelin, …
  - Polaris, Claron

Commercial Example (Reflective Markers): NDI Polaris
How does the Polaris system work?

The illuminators flood the area with infrared light.

The infrared light is reflected back to the Position Sensor by the passive markers, while active markers emit infrared light.

By calculating the position of each individual marker on a tool, the System is able to determine the exact location of the tip of the tool using a pre-determined algorithm.
Commercial Example (Ordinary Video): Claron Technology

http://www.clarontech.com

JHU research examples: tool tracking

Track video of tools in mono or stereo images

In-place 2D overlay
Optical passive

- Triangulate markers in standard video images or specialized IR cameras
  - E.g., Heilbrun, Colchester, Mathelin, …
  - Polaris, Claron
- Advantages
  - Inherent alignment for overlay
  - Same method thru microscope
  - Standard components
  - Fairly fail-safe
- Drawbacks
  - Lots more computing needed (but special hardware possible)
  - Line-of-sight
  - Video resolution

Optical Summary

**Pros**
- Industry Standard
- Well known and defined performance characteristics
- Ability to track large multiple of tools simultaneously
- Accuracy typically below 0.35 mm RMS
- Large measurement volume
- Variety of targets can be affixed to the tool (IRED, sphere)
- Video self alignment [rht]

**Cons**
- Line-of-sight required
- Extraneous IR (sunlight)
- Rigid body tracking is most accurate, unable to track flexible devices
- Historically more costly when compared to other technologies
- Larger tools

Credit: Paul McDonald, NDI