Tracking Systems

• Track (locate) objects in space
  – 3 degrees of freedom for position
  – 3 degrees of freedom for orientation
  – 6 degrees of freedom for a rigid body
  – Most can track multiple objects

• Tracker types
  – Mechanical (early systems)
  – Optical (standard of care)
  – Electromagnetic (hot topic)
Early Mechanical Localizers: Mark I and Mark II Articulated Arms

Localizer Slides Courtesy of Robert Galloway, PhD, Vanderbilt University, Technology Guided Therapy Program

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Slide 3

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Pros and Cons of Articulated Arms

• Pros
  – Highly reliable
  – Highly accurate
  – Highly stable

• Cons
  – Cumbersome to use
  – Can easily interfere with surgical field
  – Cannot track multiple devices
Optical Localizers: Principle of Triangulation
Optical Localizer Classification

• Infrared-based (IR) tracking systems
  – Active optical systems
    • Optotrak Certus (Northern Digital Inc.)
  – Passive / active optical systems
    • Polaris Spectra and Vicra (Northern Digital Inc.)

• Videometric tracking systems
  – Micron Tracker (Claron Technology)

• Laser tracking systems
  – laserBird2 (Ascension Technology)
Infrared-based: Optotrak Certus

- Three-camera system
- Accuracy: very high
  - 0.15 mm maximum
- Field of view: large
  - Greater than 1 cubic meter
- Physical size: large
  - 1126 mm x 200 mm x 161 mm
- Tool tracking: active sensors

Specifications from: http://www.ndigital.com/research/certus.php

Figure courtesy of Northern Digital Inc.
Multiface Tool

- > 60 degree visibility
- Requires high speed location of sources.
Optical Tracking System and Display
Polaris Optical Localizer
Northern Digital Inc.

- Two 2-D sensors
- Operate with active or passive tools
- 60 Hz max
- USB interface

Working Volume (Field of View)

Polaris Spectra

Polaris Vicra

Figures courtesy of Northern Digital Inc.
Active Tools

- Infrared-emitting markers that are activated by an electrical current
- Tool geometries can be small since the same geometry can be used multiple times
- Markers can be cleaned easily
- Tool description file can be programmed into tool

Description from Northern Digital Inc.
Passive Tools

- Spherical, retro-reflective markers that reflect infrared light emitted by the illuminators on the position sensor
- Wireless
- Track numerous tools without reducing sample rate
- Need unique geometry for each tool – tools can be large
Choosing an Optical Tracking System
(courtesy Northern Digital)

- Size of measurement volume needed
- Update rate required for tracking
- Number of tools to be tracked
- Space restrictions and mounting location of system
- Integration/compatibility with current Polaris system
Setting Up Your Tracker (practical advice)

• Hardware
  – Need something to mount the tracker on
    • Tripod is a good solution
    • Buy a good one
  – Need some way to attach the tools to the object to be tracked
    • Can bolt directly or use clamp from Northern Digital

• Software
  – Trackers now come with a USB interface
  – They also have an application programming interface
    • More on this later
Another Optical System
Claron MicronTracker

- Use real-time stereoscopic vision to detect and track the pose of specially marked objects
- Objects are marked using small checkered target regions
- Firewire interface
  - Video: http://www.clarontech.com/measurement_demos.php

Claron Technology
Georgetown University
Electromagnetic versus Optical Tracking

• Tracking for image-guided surgery has been dominated by optical trackers
  – Advantages
    • Relatively large field of view
    • Highly accurate
  – Disadvantages
    • Require maintaining a line of sight
    • Therefore cannot track instruments inside the body

• Electromagnetic tracking
  – Does not require a line of sight
  – Therefore can track inside the body
Electromagnetic Tracking
Principle of Operation

Courtesy of Northern Digital Inc.
Footnote for Panel Discussion

• The term “electromagnetic” tracking has historically been used to describe systems that are based on magnetic fields.
• Some researchers may argue that these systems should be called “magnetic” spatial measurement systems since they do not depend on the electric field component of the electromagnetic wave.
• However, we will use the term electromagnetic here to reflect common usage and the fact that a varying magnetic field has an associated electric component.
Electromagnetic Tracker Characterization

- **AC driven systems**
  - FASTRAK (Polhemus Inc.)
  - Aurora (Northern Digital Inc.)

- **DC driven systems**
  - 3D Guidance (Ascension Technology)

- **Passive or transponder systems**
  - Calypso 4D system (Calypso Inc.)
Polhemus AC Driven Tracking

• From their website
  – Polhemus pioneered AC motion tracking
  – Unlike products based on pulsed DC technology, Polhemus trackers are not negatively affected by the earth’s magnetic field, power outlets or electric motors

• Not currently used in image-guided systems though since small tools are not available

Figure courtesy of Polhemus Inc.
Aurora

- Enables non-line of sight tracking
- Tracks up to 8 tools using miniature sensor coils
- Maximum rate of 40 Hz
- Measurement volume
  - 500 mm cubed
  - Starting 50 mm from field generator

Figures courtesy of Northern Digital
Electromagnetically Tracked Biopsy Needles

MagTrax Needle, Traxtal Inc

Courtesy of Northern Digital Inc.

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Vertebroplasty

EM Navigation system

Aurora
3D Guidance (Ascension)

- Track up to eight miniaturized 6 DOF sensors or twenty-four 5 DOF sensors simultaneously
- Driven by quasistatic direct current (DC)
  - Can be more immune to eddy current distortions caused by common conductive metals, such as stainless steel (300 series), titanium, and aluminium

Figures courtesy of Ascension
“Metal Immune” Flat Transmitter

- Placed beneath a patient to negate any possible distortion of measurements by ferrous metal in an OR or procedural table
- ±20 cm X, Y, 10--46 cm Z coverage
- Radio-translucent and radio-opaque models available

Figures courtesy of Ascension
Calypso System for Prostate External Beam Radiation

- System components
  - 1) Beacon electromagnetic transponder (implanted in patient)
  - 2) 4D console (in room monitoring for setup)
  - 3) 4D electromagnetic array
  - 4) 4D tracking system (out of room monitoring)
  - 5) Optical system (for initial positioning)

Figures courtesy of Calypso Medical
IGSTK Open Source Software
(image-guided surgical toolkit: igstk.org)
How to Choose a Tracker

- Must be based on clinical application
- First, do you need to track inside the body?
  - Choice of electromagnetic versus optical
- Second, what is the tracking volume required?
- Third what are the tools required?
- Good topic for panel discussion
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