Input Devices

- Trackers
- Navigation
- Gesture Interfaces
Virtual Reality

“Virtual Reality is a high-end user interface that involves real-time simulation and interaction through multiple sensorial channels.” (vision, sound, touch, smell, taste)
Local Coordinate System for virtual objects: 6 degrees of freedom (D.O.Fs):

- three translations
- three rotations
Global Coordinate System for virtual space: embeds all local coordinate frames
Trackers measure motion of “objects” (e.g., user’s wrist or head) within a fixed system of coordinates

Technologies for tracking:

- Magnetic trackers (prevalent)
- Ultrasonic trackers (less used)
- Mechanical trackers (special cases)
- Inertial/ultrasonic trackers (new)
- Vision-based trackers (new)
Example: Head Tracking

• **How can left/right eye images be rendered to be consistent with the head position within a virtual space?**

• **What are the coordinate frames of reference?**
Classifying Tracker Technologies

What are some tracker parameters that characterize performance?

- Measurement rate – Readings/sec
- Sensing latency
- Sensor noise and drift
- Measurement accuracy (errors)
- Measurement repeatability
- Tethered or wireless
- Work envelope (working volume)
- Sensing degradation
Characteristics: Accuracy

Accuracy

Resolution

Real object position

Tracker position measurements
Characteristics: Drift

Tracker data
Real object fixed position

Sensor drift

Time
Characteristics: Latency

Real object position

Tracker data

Sensor latency

Time
Characteristics: Update Rate

Tracker A

Tracker B

Tracker Sampling Rate

150 updates/sec

120 updates/sec

90 updates/sec

60 updates/sec

30 updates/sec

1 2 3 4

Number of receivers
A mechanical tracker consists of a serial or parallel kinematic structure composed of links interconnected by sensorized joints.
Mechanical Trackers

• **Pros**
  – Sensors embedded in exoskeletons are very accurate and can be factory calibrated
  – **Very low latencies**
  – **Immune to external interference such as magnetic fields and large metal objects**

• **Cons**
  – **Range of motion (working volume) is limited**
  – **Ergonomics are challenging when worn on the body**
Push 1280 (Fakespace Inc)
Exoskeleton structure

Interface With computer
Faro
A magnetic tracker is a non-contact position measurement device that uses a magnetic field produced by a stationary **TRANSMITTER** to determine the real-time position of a moving **RECEIVER** element.
Magnetic Trackers

- Uses low-frequency magnetic fields to measure position
- Fields are produced by a fixed source
- Size of source must grow to support larger working volumes
- Receiver is attached to the tracked object
- Receiver has three perpendicular antennas
- Distance is inferred from the voltages induced in the antennas
- System needs calibration
Generating Magnetic Fields

- **Current-carrying coils generate a source magnetic field**
- **Circular coil carrying current I at a distance d and off-axis angle θ:**

\[
H_r = \frac{M}{2\pi d^3} \cos(\theta) \quad \text{(radial component)}
\]
\[
H_\phi = \frac{M}{4\pi d^3} \sin(\theta) \quad \text{(tangential component in \(\theta\) direction)}
\]
\[
H_\phi = 0 \quad \text{(tangential component in \(\phi\) direction)}
\]

where the H components are the radial and tangential components of the field, M is the magnetic moment of the loop, A and N are the area enclosed by the current loop and the number of turns of the loop/winding.
Magnetic Dipole

- **Time-varying magnetic field induces a measurable voltage in a coil**
- **Magnitude of the voltage is proportional to**
  - area of the coil
  - the rate of change of the field
  - the cosine of the angle $\theta$ (angle between the direction of the field lines and the axis of the coil)

Note that
- Signal strength falls off cubically with distance
- Induced field gives information about both distance and orientation

(Taken from SIGGRAPH 2001 Course 11 by Allen, Bishop and Welch)
Magnetic tracker with Data Glove
Fastrack magnetic tracker system

Electronic interface

Source

Stylus

Receiver

Fastrack magnetic tracker system
Fastrack *Long Ranger* source for the tracker system
Fastrack magnetic tracker electronics

Receivers

Source
Polhemus Long Ranger tracking system (Rutgers)
Magnitude of Error Vector / Moving Tripod

Tracking error as a function of tripod height
Flock of Birds magnetic tracker (Ascension Co.)
Motion Star wireless tracker (Ascension Technology)
Wireless suit (Ascension Technology)

Sensors: 20/suit
100 updates/sec
3 meters range from base unit
Resolution < 2 mm and < .2 degrees

Electronic unit (2 hours battery life)
1.7 kg (3.8 lb)
- Two opposite ERTs 3.6 × 3.6 m
- Two side-by-side ERTs 1.8 × 4.2 m
- Readings weighted to the closer ERTs
- Several Base Stations for several users
Liberty LATUS

- **A New Polhemus Wireless Tracker**
- Uses wireless sources, now called “markers”, each with a different frequency
- Each source position is measured by a receiver “receptor” within 8 ft. One receiver can track 4 markers
- The system can have up to 12 markers and up to 16 receptors
- Sampling rate is 188 Hz up to 8 markers and drops to 94 Hz from 9 to 12 markers
- Markers are battery powered up to 2.5 hours and weigh 2 ounces each
- For one marker and one receptor accuracy is 0.04 mm and 0.0012 degree at 1 ft range and drops afterwards
- Communication is through magnetic data link
Magnetic Tracker: Calibration

- **Use mechanical measurements to reduce errors**
- **Sensor noise** – variation in measurement with no real object motion – solved by over-sampling
- **Size of errors grow from source outwards**
- **Errors both in position and orientation**
Magnetic tracker accuracy degradation
Magnetic Tracker: Errors

Due to ambient noise:

\[ e_{\text{ambient}} = K_n (d_{\text{transmitter-receiver}})^4 \]

Due to metal:

\[ e_{\text{metal}} = \frac{K_r (d_{\text{transmitter-receiver}})^4}{(d_{\text{transmitter-metal}})^3 \times (d_{\text{metal-receiver}})^3} \]
<table>
<thead>
<tr>
<th>AC and DC Magnetic Trackers</th>
</tr>
</thead>
<tbody>
<tr>
<td>• DC trackers are immune to non-ferromagnetic metals (brass, aluminum and stainless steel)</td>
</tr>
<tr>
<td>• Both DC and AC trackers are affected by the presence of Ferromagnetic metals (mild steel and ferrite)</td>
</tr>
<tr>
<td>• Both are affected by copper</td>
</tr>
<tr>
<td>• AC trackers have better resolution and accuracy</td>
</tr>
<tr>
<td>• AC trackers have slightly shorter range</td>
</tr>
</tbody>
</table>
**Table 2.1** Performance comparison: Fastrack vs. Flock of Birds

<table>
<thead>
<tr>
<th>SPECIFICATION</th>
<th>FASTRACK</th>
<th>FLOCK OF BIRDS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operation radius</td>
<td></td>
<td></td>
</tr>
<tr>
<td>normal</td>
<td>0.75 m (30&quot;)</td>
<td>1.2 m (48&quot;)</td>
</tr>
<tr>
<td>extended</td>
<td>2.25 m (90&quot;)</td>
<td>3 m (120&quot;)</td>
</tr>
<tr>
<td>Angular range</td>
<td>all-attitudes</td>
<td>±180°Azimuth &amp; Roll ±90°Elevation</td>
</tr>
<tr>
<td>Transl. accuracy</td>
<td>0.03° RMS</td>
<td>0.1° RMS</td>
</tr>
<tr>
<td>Transl. resolution</td>
<td>0.0002°/inch range</td>
<td>0.03° RMS</td>
</tr>
<tr>
<td>Angular accuracy</td>
<td>0.15° RMS</td>
<td>0.5° RMS</td>
</tr>
<tr>
<td>Angular resolution</td>
<td>0.025° RMS</td>
<td>0.1° RMS at 12&quot;</td>
</tr>
<tr>
<td>Update rate (measurements/sec)</td>
<td>120 (one receiver)</td>
<td>144</td>
</tr>
<tr>
<td></td>
<td>60 (two receivers)</td>
<td>(up to 30 receivers)</td>
</tr>
<tr>
<td></td>
<td>30 (four receivers)</td>
<td></td>
</tr>
<tr>
<td>Latency (msec) (single receiver)</td>
<td>8.5 (no filtering)</td>
<td>7.5 (no filtering)</td>
</tr>
<tr>
<td>Metal Interference</td>
<td>Ferrite</td>
<td>Ferrite</td>
</tr>
<tr>
<td></td>
<td>Mild Steel</td>
<td>Mild Steel</td>
</tr>
<tr>
<td></td>
<td>Copper</td>
<td>Copper</td>
</tr>
<tr>
<td></td>
<td>Stainless steel</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Brass</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Aluminum</td>
<td></td>
</tr>
<tr>
<td>Interface</td>
<td>RS-232 (select. baud rates to 115,200 or IEEE-488 up tp 100 kbaud/sec)</td>
<td>RS-232 (select. baud rates to 115,200 or RS-422/485 (select. baud rate to 500,000)</td>
</tr>
<tr>
<td>Data format</td>
<td>ASCII or Binary</td>
<td>Binary</td>
</tr>
<tr>
<td>Modes</td>
<td>Point or stream</td>
<td>Point or stream</td>
</tr>
</tbody>
</table>
Videos