Context Aware
Indoor & Outdoor Location Sensing

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The main parts of this talk:

1- Techniques used in location sensing

2- Properties of location sensing

3- Location awareness systems
1- Techniques used in location sensing

1.1.1 Triangulation (Lateration / Angulation)

Lateration: measuring distance

- Direct: realizing physical movement, Robot hard estimating coordination.

- TOF: Velocity, Movement
  fix object, difference between transmission & arrival time of emitted signal.
GPS, hard measuring time of space to the object; use local time

- Attenuation: signal becomes weaker, measure attenuation. SpotOn

1.1.2 Angulation: measuring two angles. Cisco’s VOR system
1.2 Proximity

- Detecting physical contact
e.g. pressure, touch sensors

- Monitoring wireless cellular access points
e.g. mobile device in range of one or more AP

- Observing automatic ID systems
e.g. Credit cards, land line telephone records
1.3 Scene analysis

- Uses analyzing method to estimate object
- Observing particular point
- Different in the scene is the movement
  - + getting result without angels or distances
  - - The observer need to have access
# 1.4 RFID

- Includes chips and antenna

<table>
<thead>
<tr>
<th></th>
<th>Active RFID</th>
<th>Passive RFID</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Communication Range</strong></td>
<td>Long range (100m or more)</td>
<td>Short or very short range (3m or less)</td>
</tr>
</tbody>
</table>
| **Multi-Tag Collection** | • Collects 1000s of tags over a 7 acre region from a single reader  
  • Collects 20 tags moving at more than 100 mph | • Collect's hundreds of tags within 3 meters from a single reader  
  • Collects 20 tags moving at 3 mph or slower. |
| **Sensor Capability**    | Ability to continuously monitor and record sensor input; data/time stamp for sensor events | Ability to read and transfer sensor values only when tag is powered by reader; no date/time stamp |
| **Data Storage**         | Large read/write data storage (128KB) with sophisticated data search and access capabilities available | Small read/write data storage (e.g. 128 bytes) |

*Table taken from: Active and Passive RFID: Two Distinct, But Complementary, Technologies for Real Time Supply Chain Visibility*
## Continue RFID

<table>
<thead>
<tr>
<th></th>
<th>Active RFID</th>
<th>Passive RFID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tag Power Source</td>
<td>Internal to tag</td>
<td>Energy transferred from the reader via RF</td>
</tr>
<tr>
<td>Tag Battery</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Availability of Tag Power</td>
<td>Continuous</td>
<td>Only within field of reader</td>
</tr>
<tr>
<td>Required Signal Strength from Reader to Tag</td>
<td>Low</td>
<td>High (must power the tag)</td>
</tr>
<tr>
<td>Available Signal Strength from Tag to Reader</td>
<td>High</td>
<td>Low</td>
</tr>
</tbody>
</table>

*Table taken from:* Active and Passive RFID: Two Distinct, But Complementary, Technologies for Real Time Supply Chain Visibility
1.5 Infrared (IR)

- Connect wirelessly between tags
- Antenna detect by receivers close tag
- Higher RF, shorter range, more waves propagate in a straight line

+ good accuracy

- can’t emit through walls
- Lower availability (pocket)
1.6 WLAN 802.11b

- Popular technology
- Easy, reliable using WLAN infrastructure
- Additionally using location server
- Bit rate 11Mbps, range 50-100m
- Accuracy 2m

- Power supplier after each short time period
1.7 Bluetooth

- New in the market of location sensors
- Bit rate 1Mbps
- Range short 10-15m

Details later on section 3
Graphic taken from Hazas, M., Scott, J., and Krumm, J. Location-aware computing
2- Properties of location sensing

2.1 Absolute & Relative:

- Uses coordinating system for locating
- 2 GPS receivers responds to the same position using Latitude, Longitude, Altitude

- Relative uses other object references
- Emergency call, two teams, two different positioning.
2.2 Accuracy & Precision requirements:
- Important concept of positioning
- Military & Civil applications

2.3 Scale:
- Evaluating the scale depends on the coverage area, number of objects, time.
- GPS serves huge number of receivers
- Some tags can't read more than one in the same area.
2.4 Cost & Limitation
- **Time**: install the process, administration needs
- **Range of work**

2.5 Recognition
- GUID, tag, label of an object
- External database (name, type, semantic info)
- GUID and contextual information e.g. museum retrieve of description in a specified language
3 Location awareness systems

- Indoor location systems:
  + Active Badge
  + Active Bat
  + Cricket
  + Radar
  + Bluetooth

- Outdoor location systems
  + GPS
  + GLONASS
  + Galileo
Active Badge

- Current version offers bidirectional communication, 48 bit address
- Badge transmits each ten seconds
- Control device collects information after each emitting from the sensors

- Telephone receptionist scenario, below 100% moving, not sighted 5 minutes last info, away means absence more than week.
- FIND, WITH, LOOK, HISTORY
55*7mm package, weighted 40g
Graph taken from http://ei.cs.vt.edu/~wwwbtb/fall.96/Presentations/badges.gif
Active Bat

+ 3D Ultrasonic location system
+ Low power, wirelessly & inexpensive
+ Useful for limited range tracking

- Bat carried by users, receivers fixed on the ceiling, based on triangulation positioning
- Calculate the distance TOF, when the pulse is emitted, speed of sound is known
Active Bat has 95% accuracy of Triangulation within 3cm.

Graphs taken from http://www.cl.cam.ac.uk/research/dtg/attarchive/bat/flatBatInside.jpg
Cricket

- Has both RF & Ultrasonic techniques
- Beacons listen and send signals, and find distance by measuring the time difference
  (ability of positioning without central server for query)

+ decentralizing decreases the cost of management.
+ increases the privacy of each user
Cricket V2:
Improved and simplified hardware component
Auto configuring (Beacon, Listener, or both)
RADAR

- RF based system
- Uses signal strength from wireless equipment
- RF transceivers called the base station (connector between the wireless & wired networks)
- Generally laptops or computers with WLAN 802.11 ars used as base station
- Stable & continuously connected
  - Location consist of multi floors
  - Tracking might be hard, when the device is limited in power
<table>
<thead>
<tr>
<th>System</th>
<th>Bat</th>
<th>Active Badge</th>
<th>RADAR</th>
<th>Cricket</th>
</tr>
</thead>
<tbody>
<tr>
<td>User privacy</td>
<td>No</td>
<td>No</td>
<td>Possible, with user computation</td>
<td>Yes</td>
</tr>
<tr>
<td>Decentralized</td>
<td>No</td>
<td>No</td>
<td>Centralized RF signal database</td>
<td>Yes</td>
</tr>
<tr>
<td>Heterogeneity of networks</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Cost</td>
<td>High</td>
<td>High</td>
<td>No extra component cost, but only works with one network</td>
<td>Low (U.S. $10) component cost</td>
</tr>
<tr>
<td>Ease of deployment</td>
<td>Difficult; requires matrix of sensors</td>
<td>Difficult; requires matrix of sensors</td>
<td>RF mapping</td>
<td>Easy</td>
</tr>
</tbody>
</table>

**Table taken from:** Nissanka B. Priyantha, Anit Chakraborty, and Hari Balakrishnan. The Cricket Location Support System
Bluetooth

- Access point act as Master, connected with seven other devices called Slaves
- The group of 8 devices called piconet
- Divides the band into 79 channels & hops
- Can fit the radius up to 10m

+ low cost, low power query
* Binary location: a room-oriented approach. An access point is installed in every room.
* Analog location – an X-Y oriented approach, AP’s are installed more sparsely (typically, 10-15 m apart).

Graph taken: http://www.cl.cam.ac.uk/research/dtg/attarchive/bat
GPS

- United States Global Positioning System consists of 29 Satellites
- Every satellite has its own atomic clock for time measuring in an accurate way

Civil GPS receivers positioning
Selective availability (SA) deactivated on may 2, 2000.

WAAS, wide area augmentation system has been opened since 99 in USA, and it’s available as portable GPS since 2001.

In Europe a similar technique used, it’s called EGNOS (European Geostationary Navigation Overlay Service).

<table>
<thead>
<tr>
<th>Accuracy of GPS system with SA activated</th>
<th>± 100 Meter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical accuracy with SA deactivated</td>
<td>± 15 Meter</td>
</tr>
<tr>
<td>Typical accuracy of differential GPS (DGPS)</td>
<td>± 3 - 5 Meter</td>
</tr>
<tr>
<td>Typical accuracy with WAAS/EGNOS</td>
<td>± 1 - 3 Meter</td>
</tr>
</tbody>
</table>

Table taken from: http://www.kowoma.de/en/gps/accuracy.htm
<table>
<thead>
<tr>
<th>Technique</th>
<th>Attributes</th>
<th>Accuracy (Precision)</th>
<th>Scale</th>
<th>Cost</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPS</td>
<td>Radio time-of-flight lateration</td>
<td>Physical Absolute Use exposes location</td>
<td>1-5 m (95-99%)</td>
<td>24 satellites worldwide</td>
<td>Expensive infrastructure $100 receivers</td>
</tr>
<tr>
<td>Active Badges</td>
<td>Diffuse infrared cellular proximity</td>
<td>Symbolic Absolute Use exposes location</td>
<td>Room size</td>
<td>One base per room, badge per base per 10 sec</td>
<td>Administration costs, cheap tags and bases</td>
</tr>
<tr>
<td>Active Bats</td>
<td>Ultrasound time-of-flight lateration</td>
<td>Physical Absolute Use exposes location</td>
<td>9 cm (95%)</td>
<td>One base per 10 sq m, 25 computations per room per sec</td>
<td>Administration costs, cheap tags and sensors</td>
</tr>
<tr>
<td>Cricket</td>
<td>Proximity lateration</td>
<td>Symbolic Absolute/relative</td>
<td>4 x 4 ft regions (≈100%)</td>
<td>≈1 beacon per 16 sq ft</td>
<td>$10 beacons and receivers</td>
</tr>
<tr>
<td>MSR RADAR</td>
<td>802.11 RF scene analysis and triangulation</td>
<td>Physical Absolute Use exposes location</td>
<td>3-4.3 m (50%)</td>
<td>Three bases per floor</td>
<td>802.11 network installation, ≈$100 wireless NICs</td>
</tr>
</tbody>
</table>

Source: Adapted from Table 1 of Hightower and Borriello (2001)
GLONASS

- The former Soviet Union GLObal NAvigation Satellite System
- It’s a radio based navigation system
- Now GLONASS use the third generation Uragan-K
- with a life time of 10-12 years
- will enter the Uragan-M next year.
- The availability of this satellite is 45% in Russia, 25% significant areas, and less than 30% for the whole earth
- But the problem is that among GLONASS 19 satellites only 12 are operating, the spacecraft life time of some are going to expire by the end of 2008. However this means GLONASS needs to launch 17 new satellites if the deadline kept 2009.
GALILEO

- The European Union positioning system. It would be operational on 2012, having 30 spacecrafts, with 12 years lifetime.
- The number of countries wishing to participate actively in Galileo is growing. The European Commission is holding discussions with Ukraine, India, Brazil, South Korea, Mexico and Australia. Some countries like China, and Israel has also indicated its aim of investing soon in Galileo by joining the Galileo Joint Undertaking.
- Problems need to fix before the deadline. Still the companies didn’t decide the way to go forward.
- Galileo will be free of charge, the security conditions are satisfactory.
Conclusion

- Why do we need many systems?
- Which system is better?
- Systems improved everyday
- New techniques arrived
- Non-stop competition
Thank You!

Any questions …