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Mobile and Ubiquitous Computing

Location Sensing

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Session Overview

- What is location sensing
- How do we use location
- Location sensing techniques
  - Triangulation
  - Proximity
  - Scene analysis
- System examples

Location sensing

- Use computing and digital communications to find location
- How did we do it before?
  - used landmarks in the environment
  - used proximity to landmarks
  - used the positions of starts
  - somebody else told us where we are
- Why do we need location?
  - to navigate
  - to know how to behave

Uses of location

- Mapping systems
- Locating people and objects
- Wireless routing (geo-casting)
- Supporting smart spaces and location-based applications
- Location is just one type of context

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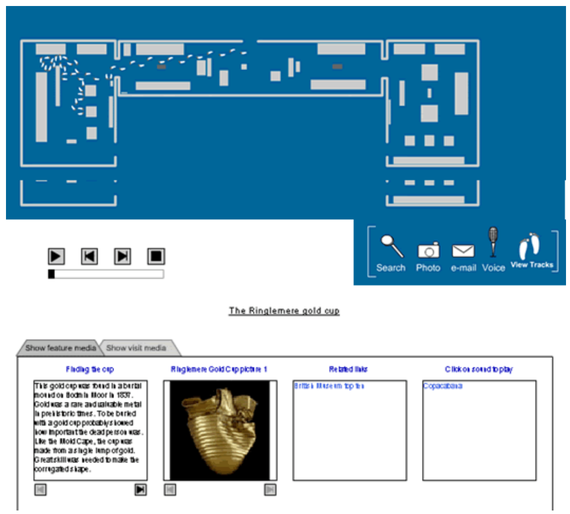
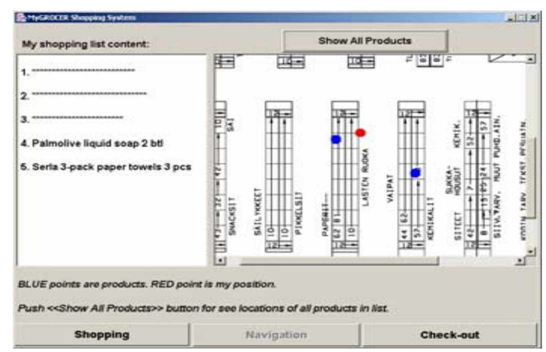
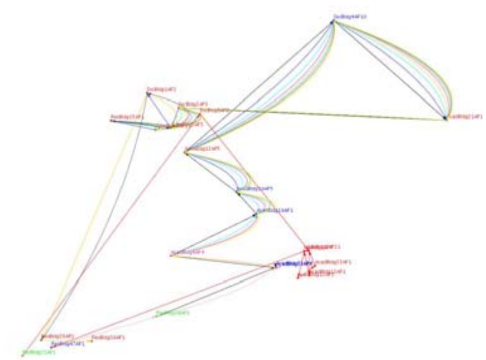
Examples of location use

- Car navigation systems
- Tourist guides
- Indoor guides
- Tracking
- Context







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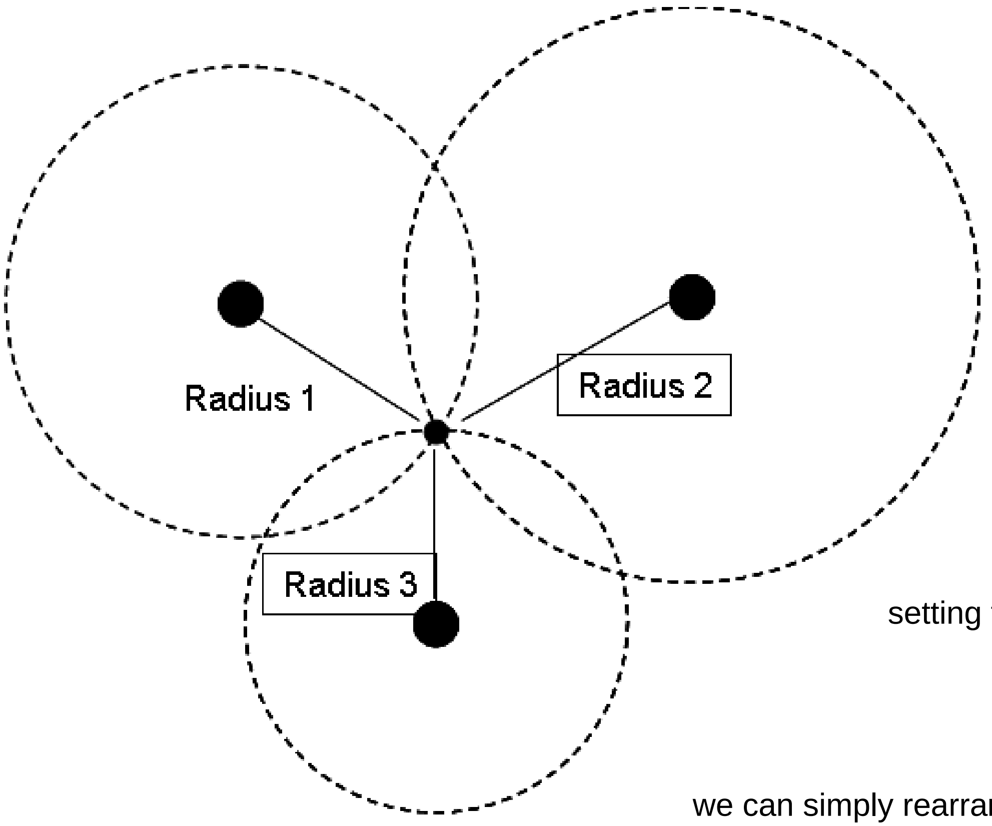
Location Sensing Techniques

- Triangulation
  - Lateration (using distance)
  - Angulation (using angles)
- Proximity
  - Contact
  - Contactless
- Scene analysis

Triangulation

- Compute object locations using the properties of triangles (e.g law of sines, Pythagorean theorem etc)
- Several combinations of distance/angle measurements would work
- Generalization into 3 dimensional objects
- E.g. 3 non-collinear points are needed in 2D and 4 non-collinear points are needed in 3D

Lateration



$$r_1^2 = x^2 + y^2 + z^2$$
$$r_2^2 = (x-d)^2 + y^2 + z^2,$$
$$r_3^2 = (x-i)^2 + (y-j)^2 + z^2$$

subtract the second from the first and solve for *x*

$$x = \frac{r_1^2 - r_2^2 + d^2}{2d}$$

substituting back into the formula for the first sphere produces the formula for a circle, the solution to the intersection of the first two spheres:

$$y^2 + z^2 = r_1^2 - \frac{(r_1^2 - r_2^2 + d^2)^2}{4d^2}$$

setting this formula equal to the formula for the third sphere finds

$$y = \frac{r_1^2 - r_3^2 + (x-i)^2}{2j} + \frac{j}{2} - \frac{(r_1^2 - r_2^2 + d^2)^2}{8d^2 j}$$

we can simply rearrange the formula for the first sphere to find the z-coordinate

$$z = \sqrt{r_1^2 - x^2 - y^2}$$

Lateration Measurements

Types of measurements

- Direct touch
  - Measure distance directly
- Time-of-flight of the radio signal between transmitter and receiver
  - Measure time and then calculate the distance using the speed of the signal
- Signal attenuation ie. drop in the strength of a signal as it propagates in space
  - Measure the signal at the receiving end and then calculate the distance as the drop to what the signal was at the source

Lateration Measurements

- Time-of-flight example
  - sound waves
  - speed 344m/s at 21^{o}C
  - distance = time x speed
  - speed depends on environmental conditions
  - depends on accurate timings
- Signal attenuation
  - calculate based on send and receive strength
    - Absorption, scattering, interference
    - Free space loss = 32.4 + 20xLog F(MHz) + 20xLog R(Km)
  - attenuation varies based on environment

Time-of-Flight Problems

- Often requires high time resolution (for accurate light or radio propagation measurements)
  - a light pulse which travels at 299,792,458m/s will cover 5m in 16.7ns
  - a 0.001 sec error leads to 200 miles error!
- Clock synchronization critical
  - Accurate synchronization between reference beacons and receivers
  - Beacons could use atomic clocks (100k cost)
  - Could improve using extra measurements

Global Positioning System

- 27 satellite constellation
- More than 50 launched since 1978
- Powered by solar energy
- Each carries a 4 rubidium atomic clocks
  - locally averaged to maintain accuracy
  - updated daily by US Air Force Ground control
- Satellites are precisely synchronized with each other
- 400 M USD per year

Global Positioning System

- Receiver is not synchronized with the satellite transmitter
- Satellites transmit their local time in the signal
- Receivers compute their difference in time-of-arrival
- Receivers estimate their position (longitude, latitude, elevation) using (at least) 4 satellites
- Accuracy is about 5 meters (20 meters until recently when random error was introduced)
- Differential GPS provides extra accuracy approx. 2 meters

- European solution: Galileo

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GPS data with NMEA

```
$GPGGA,123519,4807.038,N,01131.000,E,1,08,0.9,545.4,M,46.9,M,,*47
```

GGA	Global Positioning System Fix Data
123519	Fix taken at 12:35:19 UTC
4807.038,N	Latitude 48 deg 07.038' N
01131.000,E	Longitude 11 deg 31.000' E
1	Fix quality: 0 = invalid 1 = GPS fix (SPS) 2 = DGPS fix 3 = PPS fix 4 = Real Time Kinematic 5 = Float RTK 6 = estimated (dead reckoning) (2.3 feature) 7 = Manual input mode 8 = Simulation mode
08	Number of satellites being tracked
0.9	Horizontal dilution of position
545.4,M	Altitude, Meters, above mean sea level
46.9,M	Height of geoid (mean sea level) above WGS84 ellipsoid
(empty field)	time in seconds since last DGPS update
(empty field)	DGPS station ID number
*47	the checksum data, always begins with *

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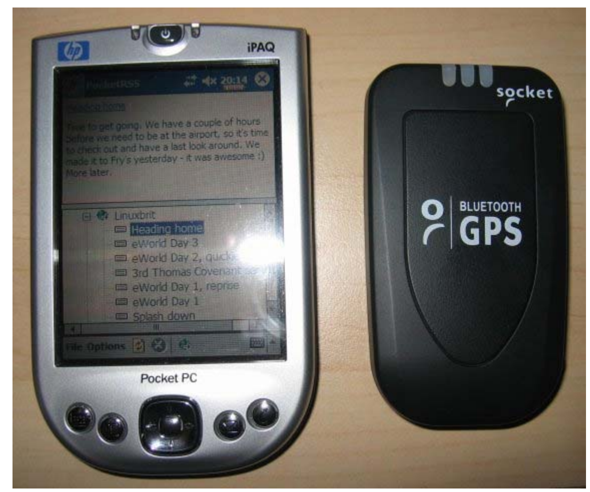
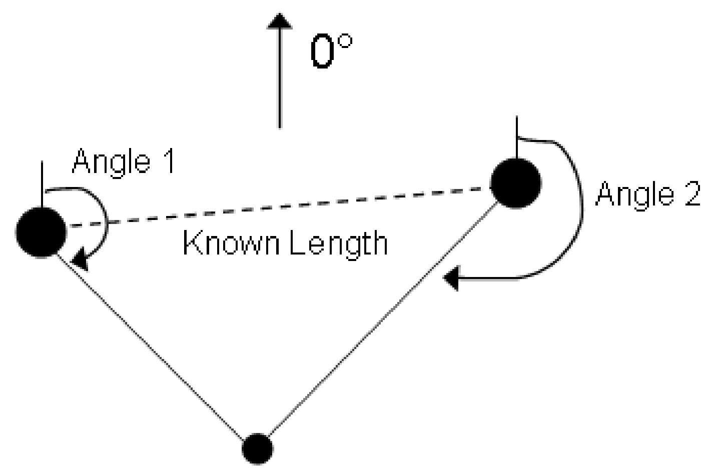
Using GPS

- GPS terminals require significant battery resource and computational power
- Signal strength measurements are low cost
- Computation can be unloaded to a more powerful device on the network e.g. assisted GPS



Angulation

- Location sensing in 2D requires
  - 2 angle measurements from known location
  - 1 distance measurement (between the 2 locations above
- Example system: phased antenna array

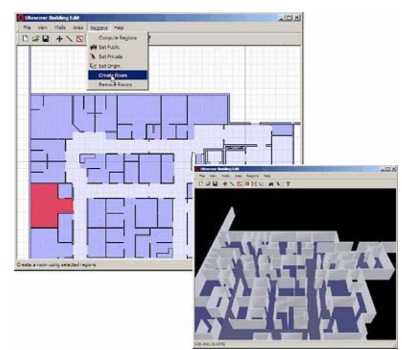


Phased Antenna Array

- Multiple antennas with known separation (i.e. distance) – the military is very fond of this!
- Each measures time-of-flight of signal
- Using the difference in times and the (known) geometry of the receiving array, we can calculate the required angle
- If there are enough elements in the array and large separation, angulation can be performed accurately

Ubisense

- Uses phased array antennas on the tag
- Tags relay location back to the network
- Real time tracking
- Uses ultra wide band technology



Proximity

- Physical contact
  - pressure, touch sensors or capacitive detectors
  - computer login
  - credit card sale
- Within range of an access point
  - GSM, wi-fi, Bluetooth
  - RFID
  - visual

BBC Mobile Location Tag

Location tags

- Affix tags at locations
- Tags transmit location identifiers thus allowing locations sensing
- Extensive installation at Shinjuku in Tokyo
- Same idea used indoors at the Exploratorium to create an interactive museum guide

Use of proximity tags in museum exhibits

- Tags in the floor read by displays on wheels at the Okayama City Digital Museum
- PDA recognizes specific exhibits at Granite State MetalWorks
- San Francisco MOMA installation than displays live social networking information

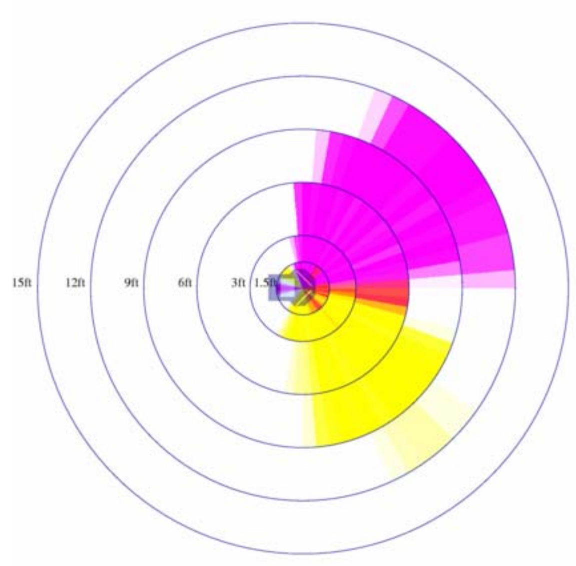
Scene Analysis

- Compares scenes to reference scenes
  - Image, electromagnetic spectrum
- Construct a signature of a position and apply pattern matching techniques with this signature
- Differential scene analysis
  - Tracks differences in scenes

RFID and vision

- Dumbo at Intel Labs Seattle
- Uses vision to navigate the environment
- Uses RFID reader to create a map of proximity to RFID
- Can subsequently use the model to sense location with RFID only

http://seattleweb.intel-research.net/projects/guide/projects/dumbo/



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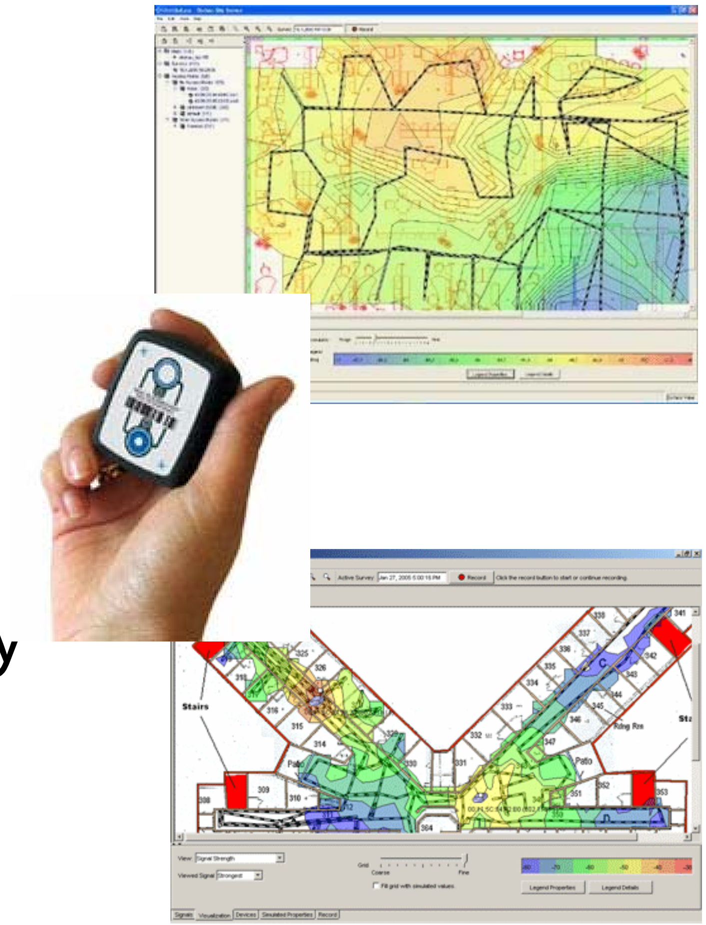
Ekahau

- Signal strength from wi-fi access points
- Has to do a site survey to build model
- Uses Bayesian statistics to improve prediction of location (ie. Uses previously known location to find new)
- Real time data using tag



Scene Analysis Challenges

- Issues
  - the observer needs access to the features of the environment against which it will compare its observed scenes
  - changes of the environment that affects these features may require their reconstruction

Summary

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