**Lecture 2 -- 2/8/16**
**Positioning ("Localization")**

What is the goal of positioning?

"Where am I"

- latitude / longitude
- address
- indoor location

Why do we care?

- Outdoor positioning / mapping / route planning
- Indoor positioning (directions, finding equipment, etc)
- Inertial tracking, etc, in robotic surgery or augmented reality

(Different applications have vastly different needs / use cases)

<u>What is lat / lon?</u>

Angle north (above) / south (below) equator; angle east (right of) / west (left of) prime meridian.

diagram:

What is equator / prime meridian? How do we measure?

How do we define elevation? How is that measured?

Different "datums" define parameters used to measure these things

WGS84 -- current standard that is used -- defines size/shape of earth, as well as mean sea level for purpose of measurements of latitude / longitude

<u>How do we measure distance on Earth?</u>

Can't just measure straight line distance, since Earth is spherical (actually and "ovoid" -- slightly squished on top and bottom.

Simple approximation -- assume Earth is a sphere, then measure using law of haversine's.

haversine = "half versine"; versine = 1-cos(a) ; haversine = (1-cos(a))/2
(show slides)

How do we figure out where we are?

- proximity to well know point of reference (POR)
- lateration ("trilateration")
- angulation ("triangulation")

Proxmitiy

RFID, WiFi AP, or dedicated infrastructure

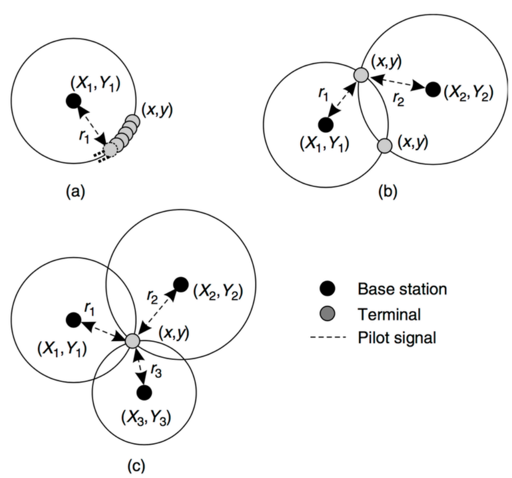
Ex:  Assume I am in the location of the current (or strongest) WiFi AP

How do I know where APs are?  I can bootstrap by measuring their location using some highly accurate method (i.e., a survey, or GPS) -- Show wigle.net

Can see that I can employ a more complex technique than just looking at a single AP -- I can look all the APs around me, and try to use them to constrain where I might be -- this is "fingerprinting", maybe based on the strength of their connection (RSSI).

Trilateration

Given signals from 3 or more base-stations at well-known locations (which may be in some database we look up, or in an advertisement sent by the base station), we can compute our position relative to each of them and set up constraints to solve for our location.  From the reading:




Can set up a system of equations based on pythagorean theorem, i.e.

r1 = sqrt((x1-x)^2 + (y1-y)^2), etc

How do we measure how far we are from POR?

- Signal Strength (RSSI) -- distance is proportional to signal strength -- this is a gross approximation since signals are attenuated by some materials much more than others, etc.

- Radio -- transmitted message contains the time when the message was sent. Need to be very carefully time-synced with sender for good accuracy, since even a few milliseconds of error will result in positional estimates that are off by a long way (3x10^8 m/sec --> 1msec 3x10^5 m = 300 km!) Will discuss how GPS achieves this.
10 m / 3x10^8 = 3.3*10^-8 = 3 nsec!

- Acoustic (ultrasound) -- travels much slower, so time sync requirements are a lot less stringent. Typically send a radio message and acoustic message at the same time, with radio message telling us time the message was sent.

Both radio and acoustic signals are subject to *multi-path* effects -- reflections off of surfaces. Both are attenuated by various materials (to differing extents).

<u>What can I do if I don't want to estimate the range?</u> Suppose we are a cellular provider and we want to estimate the position of a device but don't want to require it to send a special packet with the time or time sync with it? If we control 3 basestations that can hear the handset, we can measure the *difference of arrival* of a packet from the handset. This sets up a system of hyperbolas that constrain the location of the device, as in the reading.

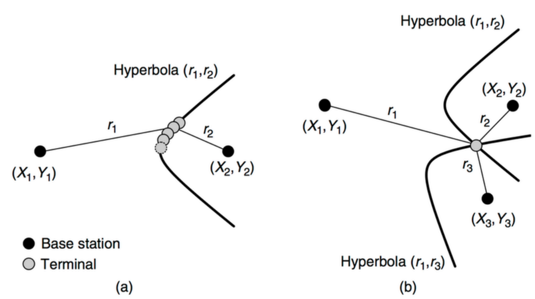



Figure 6.7 Hyperbolic lateration.

<u>Triangulation</u> -- instead of estimating ranges, I can estimate the angle of arrival of a signal. How do I do that? Imagine I have an array of antennas arranged in a circular pattern -- strongest signal will arrive on antenna closest to the transmitter. Angles (in theory) allow me to figure out my location with just two transmitters.

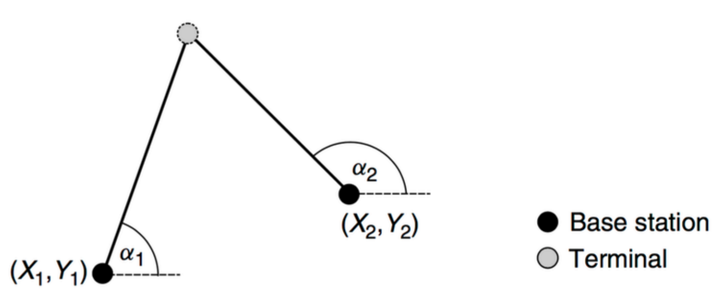



Figure 6.9 Angulation.

Can set up a system of equations as before, i.e.,
tan(sigma_1) = (Y_1 - y) / (X_1 - x)
tan(sigma_2) = (Y_2 - y) / (X_2 - x)

These methods can be enhanced via "dead reckoning", i.e., estimating that the heading and velocity will remain constant. GPS Receiver does this.

Breakdown of existing technologies by approach

| technology | | power | time to fix | accuracy |
|---|---|---|---|---|
| GPS | satellite triangluation<br>line of sight | high | high | high(*) |
| cell triangulation | cellular/RSSI trilateration | low | low | low |
| wifi triangulation | cellular/RSSI trilateration | medium | low | medium |

All three can be augmented w/ dead reckoning and inertial sensing

"terminal based" vs "network based"

Most of these technologies are "terminal based" -- i.e., the network is not involved. some network-based approaches do occur -- i.e., your cell provider knows where your phone is for call routing and E911 purposes.

iOS apis

- position (different granularities)

- BTLE ranging?

- ranging --

addresses / geocoding ?

- ios API
- how does this work?