Tuesday, February 16, 2016

Indoor Location Systems

Outline

- Goals & objectives of indoor location
  - What space (room, part of room, …)
  - Coordinates (why? navigation)
  - Orientation/direction (why? navigation, augmented reality, …)
- Recap of different approaches to (indoor) positioning
  - Proximity sensing (which cell)
  - Lateration
  - Angulation
  - Dead reckoning
  - Pattern matching
- Today
  - Wi-Fi positioning: RADAR paper
  - RF+ultrasound: Cricket
  - But before these, historical context…

Historical context

- First research system I know of was Active Badge from the Cambridge Computer Lab in the UK between 1989-92. It was developed by a team that included Andy Hopper, Roy Want, and others.
- Active badges on mobile assets
- Passive sensors ceiling at known locations
- Each badge periodically broadcasts its ID on an infra-red channel. A subset of sensors with line-of-sight receive it and figure out which room/space the badge is in.
- Periodicity of transmission determines tracking accuracy, but more periodic transmissions are less scalable.

- Infra-red does not provide a ready way to estimate distance, so this system is well-suited for space determination.
- But unfortunately IR has deadspots, doesn't function so well in bright light. And it also does bounce off walls (cf. your TV remote).
- A research success — pioneering work!

Then, in the mid-1990s, mobile computing started taking off!

The first big consumer laptops, the first big handhelds, and wireless cards all started happening!

Researchers started looking at this problem once again. Several early systems:

RADAR —> Wireless LAN radios by Microsoft Research —> the paper is more of a study of approaches than a complete system

Active Bat —> By the active badge group @Cambridge, but using ultrasound

Cricket —> RF+ultrasound, from MIT

We will talk about RADAR and Cricket

RADAR

- What's the fundamental idea in 3 sentences?
    - Use commodity wireless radios with infrastructure access points (base stations at known positions) and gather signal strength measurements in an offline "mapping" phase to build a "fingerprint map" of known positions to observed signal strengths at the known access points
    - Here, a fingerprint is the signal strengths observed at the known access points from a transmission made at some location
    - Online, use the fingerprint map and a fingerprint observed from an unknown location to estimate the transmitter's position
- There are a number of details to work out to get this approach to succeed:
    - (Note: what paper calls signal strength, SS, is typically called RSSI, the received signal strength indicator, today)

    - (Note: Paper initially started with SNR, signal to noise ratio, but they discovered it didn't work well; today this is not a surprising thing, and probably shouldn't have been surprising in 1999 either! But they showed empirically it didn't work well.)
    - Mapping phase used direction. That's because of signal obstruction/ occlusion by a human user. 2.4 Ghz is especially susceptible here.
    - (Note: this work was done before Wi-Fi became popular — Lucent's WaveLAN inspired the development of the Wi-Fi standard.)
    - The key is how to use the signal-strength fingerprints
    - Distance in signal space: treating the signal strengths observed at each access point as a point in an orthogonal coordinate space, one can define the Euclidean distance between these signal fingerprints.

- Empirical: look at k nearest neighbors (taking the max of different orientations) and combine those, say, by averaging.
- Signal propagation: use knowledge of path loss, building plans, etc. to infer

- Pros
    - Uses existing infrastructure
    - No extra hardware
- Cons
    - In practice requires training and isn't easy to work across buildings
    - A bigger problem is robustness with time
    - Need automatic maintenance and "zero config"
        - Work has been happening here
- Impact
    - RADAR was first proposal to use "Wi-Fi" (before Wi-Fi)
    - Large amount of follow-on work

- Broadly in three areas
    - Better fingerprinting and learning
    - MIMO — using Angle of Arrival for angulation rather than alteration
    - Combining with inertial sensors
- In good conditions and in papers, accuracy is impressive!
- But robustness is still lacking
    - Come back to the same building in a month and it doesn't work so well!

Cricket — see slides

SUMMARY

- Exciting area and has had enormous impact
- But indoor location is a tricky thing
    - Is it useful if it works only 60% of the time? 80% of the time? Or does it have to work 99% of the time for it to be useful?
    - Outdoors, there was massive investment to get GPS to work
    - But there is 100x more indoor built-up space, perhaps more