
Amsterdam
Weesp
Huizen
Elburg
Location-Enhanced Computing

Today's Outline

- Applications
  - Lots of different apps out there
  - Stepping back, big picture
- Ways of Determining Location
- Location Privacy

Location-Enhanced Applications

- Provide useful services by leveraging knowledge about the location of people, places, & things
  - Examples: AT&T's Find Friends service, Tour Guide
  - Also driven by emergency response (E911)

AT&T Find Friends

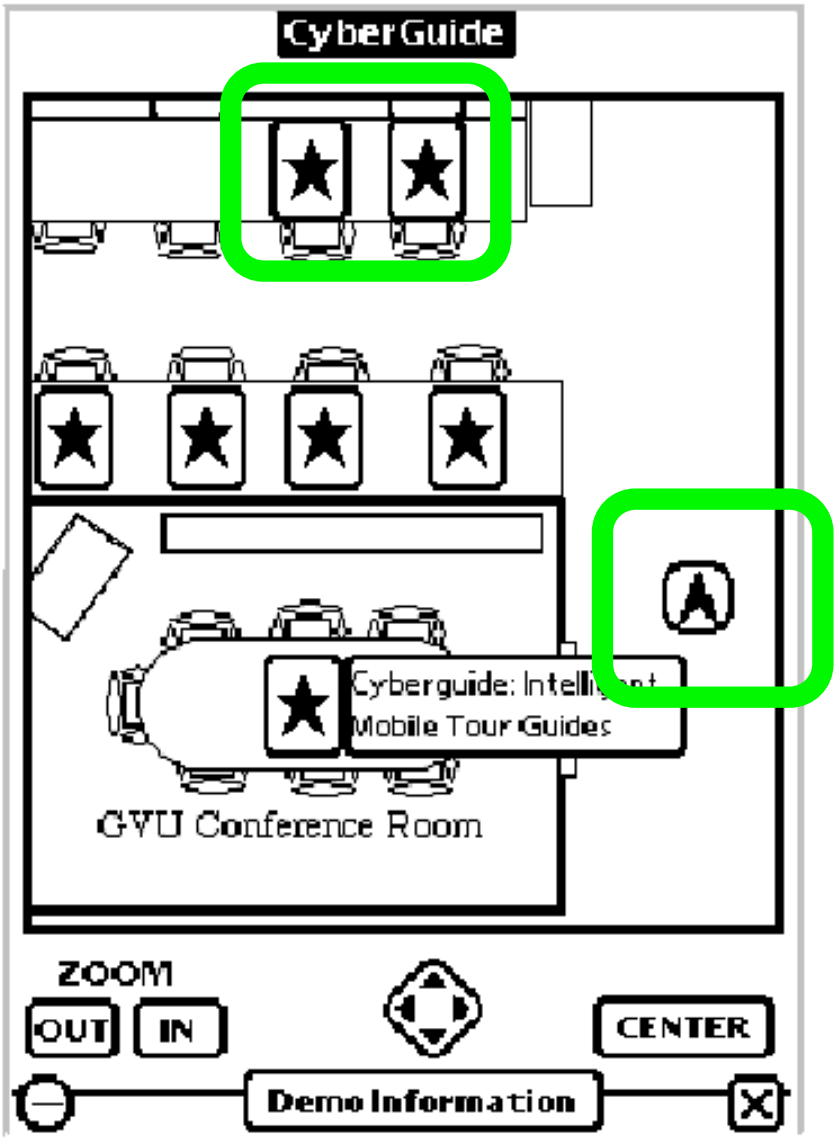
Ekahau

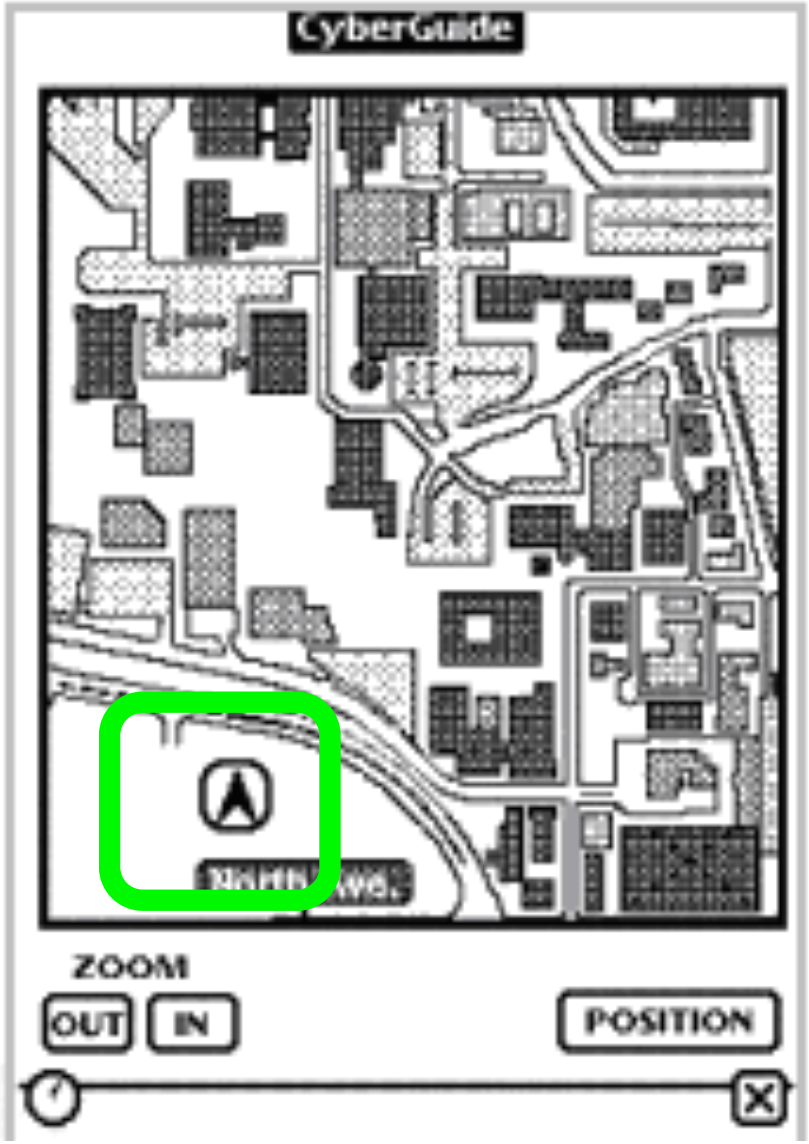
Tour Guides

- Provide information about locale

- Cyberguide
- GPS or infrared tracking
  - Fairly precise location
- Display location on screen
- Predefined points of interest
  - Automatically pop up if nearby
- Travel journal
  - Keep log of places seen and photographs taken

Tour Guides


CyberGuide
Cyberguide: Intelligent Mobile Tour Guides
GVU Conference Room
ZOOM
OUT
IN
CENTER
Demo Information


CyberGuide
ZOOM
OUT
IN
POSITION

GeoNotes

- Attach digital notes to physical places
  - Can actively query for notes
  - Or get them pushed to you

- Other examples of push:
  - Speed trap ahead?
  - Friend nearby?
  - Leave voice notes for friends

Games

- Pirates!
  - Physical space is oceans + islands
  - Find “virtual islands”
  - Search for treasure
  - Fight other pirates
- Geocaching
  - People hide things
  - Publish the lat-lon to web site
  - Other people find them

Address, City, State, Postal Code | Search by Address

Click on Cache to view Details...

10 Geocaches Found in search area*...				
	Cache Name	O	F	B
1.	Uneven Pavement			
2.	O.O.P.S.			
3.	tree of life			
4.	(Ladies and Gentlemen) The Bridge and the Groom			
5.	Foreign Finance Fund 1			
6.	Height Matters to the Flyer			
7.	Schenley!			
8.	See the Strip			
9.	Amazingly Evil			
10.	Walk the Block			

Showing 10 Cache(s).

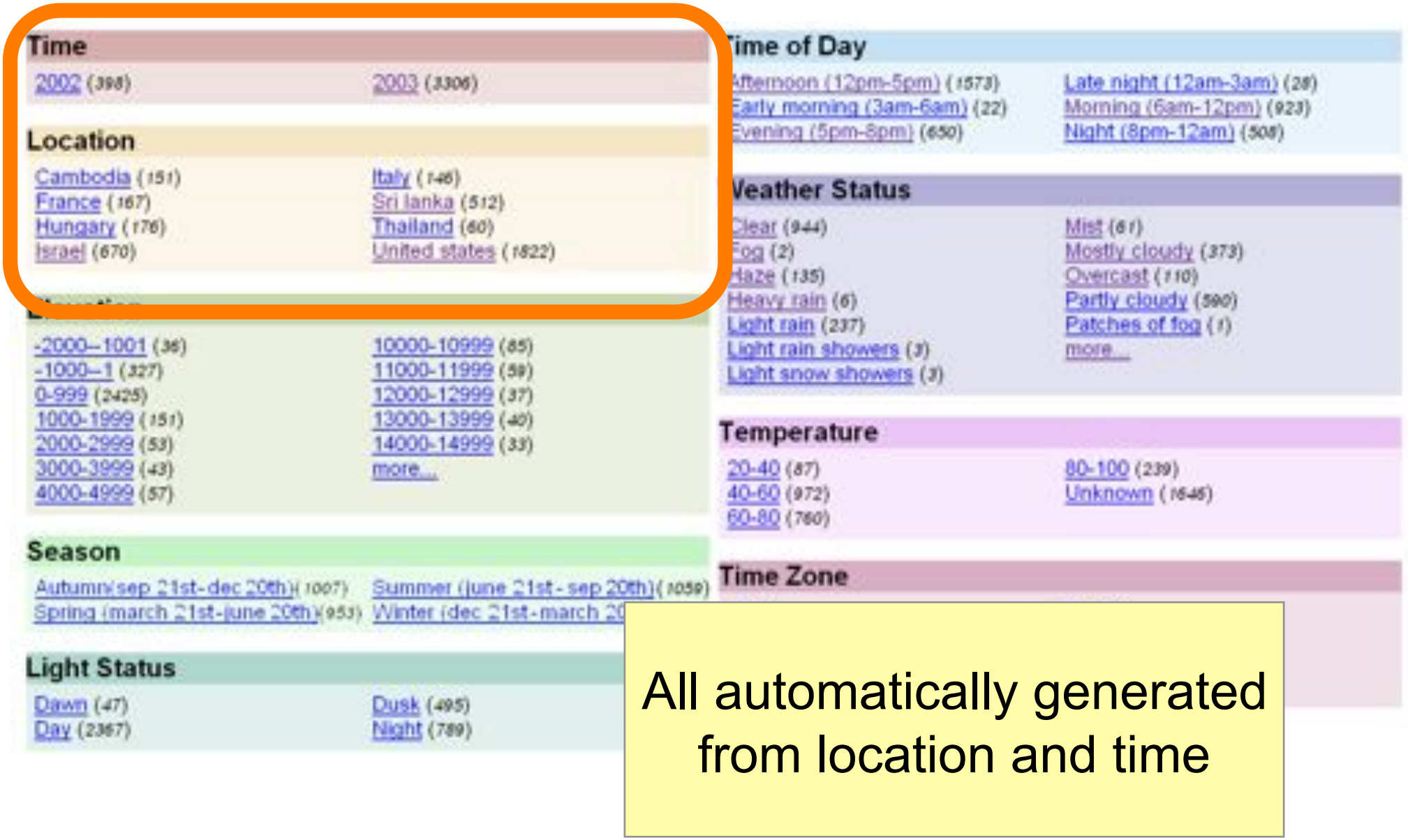
Tagging

- Tag digital content with location information
  - Example: Mobile Media Metadata

Tagging

- Tag digital content with location information
  - Example: Mobile Media Metadata
- Good area: digital photos
  - Cameras already coming out with GPS and WiFi
  - Work on adding location data
  - Given location + time, can also add weather, season, etc
  - Can also automatically organize your photos!

Tagging



All automatically generated from location and time

Tagging

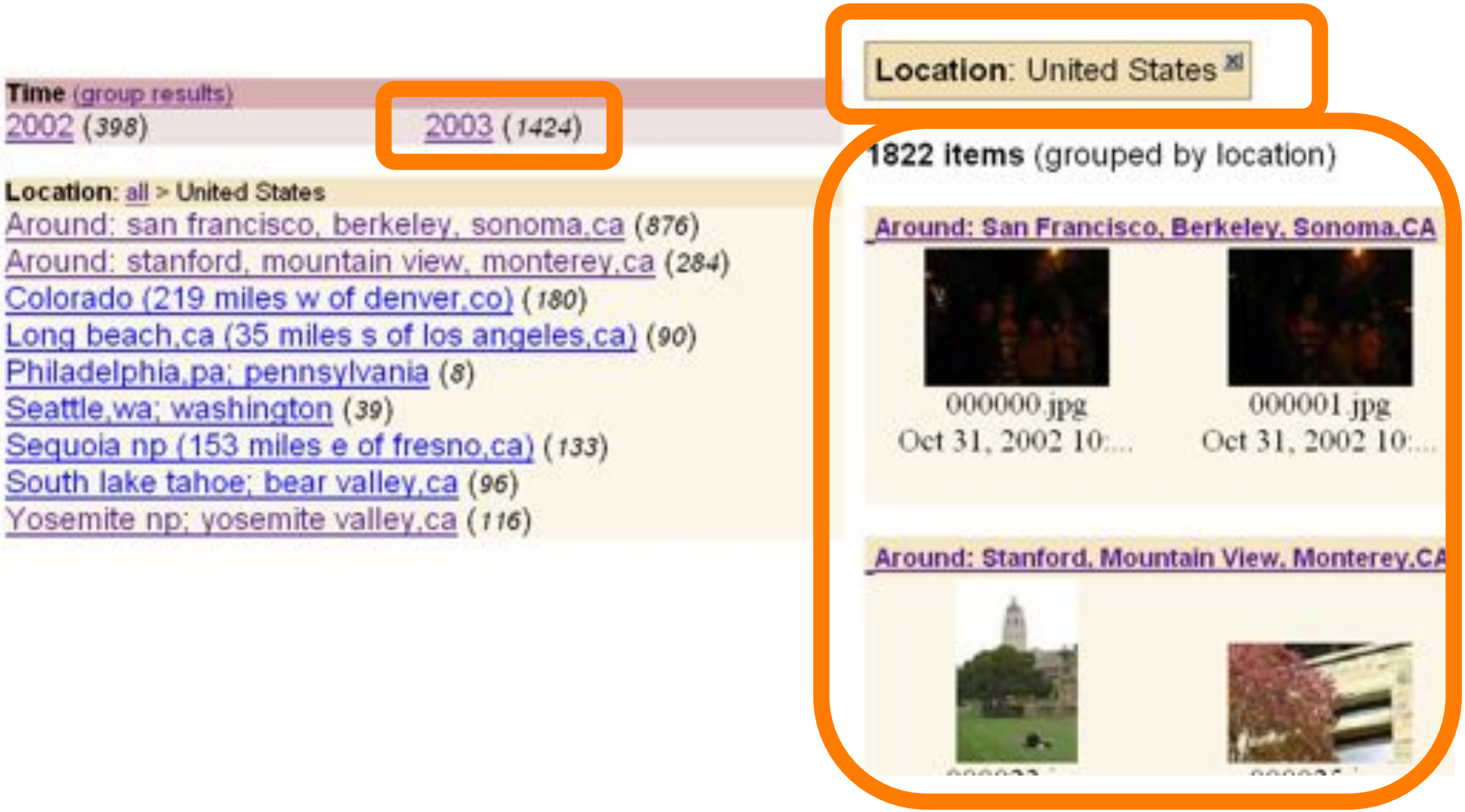
Time

2002 (*398*)
2003 (*3306*)

Location

Cambodia (*151*)
France (*167*)
Hungary (*176*)
Israel (*670*)
Italy (*146*)
Sri lanka (*512*)
Thailand (*60*)
United states (*1822*)

Tagging


Time (group results)
2002 (398)
2003 (1424)
Location: all > United States
Around: san francisco, berkeley, sonoma,ca (876)
Around: stanford, mountain view, monterey,ca (284)
Colorado (219 miles w of denver,co) (180)
Long beach,ca (35 miles s of los angeles,ca) (90)
Philadelphia,pa; pennsylvania (8)
Seattle,wa; washington (39)
Sequoia np (153 miles e of fresno,ca) (133)
South lake tahoe; bear valley,ca (96)
Yosemite np; yosemite valley,ca (116)
Location: United States
1822 items (grouped by location)
Around: San Francisco, Berkeley, Sonoma,CA
000000.jpg
Oct 31, 2002 10:...
000001.jpg
Oct 31, 2002 10:...
Around: Stanford, Mountain View, Monterey,CA

Tagging

Time: all > 2003
2003-01-18: san francisco,ca (1 hours) (5)
2003-01-18: san francisco,ca (2 hours) (64)
2003-02-01: berkeley,ca (6 hours) (14)
2003-02-15: san francisco,ca (1 hours) (7)
2003-02-15: san francisco,ca (2 hours) (68)
2003-02-17: san francisco,ca (1 hours) (5)
2003-03-09: muir beach,ca (4 hours) (34)
2003-03-15: san francisco,ca (1 hours) (18)
2003-04-17: san francisco,ca (1 hours) (10)
2003-04-19: san francisco,ca (1 hours) (25)
more...

Location: all > United States > Around: San Francisco, Berkeley, Sonoma,CA (group results)
Berkeley; oakland,ca (188)
San francisco,ca; golden gate nra (379)

Time: 2003

Location: United States > Around: San

567 items (grouped by time)

2003-01-18: San Francisco,CA (1 hours) 5


000535.jpg
Jan 18, 2003 2:1...


000536.jpg
Jan 18, 2003 2:1.

2003-01-18: San Francisco,CA (2 hours) 64

Tagging: Other Possibilities

- Location-enhanced blogging
  - Tag each entry with your current location
  - Find other blog entries at same time and place
- Automatic diary creation

Messaging


NOKIA
Location details
Request for your location from:
Options
Back

Messaging

Place names entered in previously

Uses cell towers to see if you have been there before (“fingerprinting”)

Messaging

Messaging

- DeDe system by Nokia allows contextual messaging
  - Send this to Alice when she is at the mall
- Active Campus at UCSD

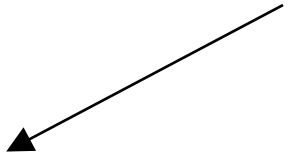
Other Location Apps

- Reminders
  - “Buy milk next time I am at store”
  - Like calendar reminder, except by location
  - Where did I park?
- Recommenders
  - Real-world recommender system
  - Like Tivo’s thumbs up / thumbs down
- Tracking and notification
  - GPS boxes
  - Fleet tracking
  - Kids (Wherify)

Stepping Back, Big Picture

- Lots of apps out there
  - Better awareness, coordination, messaging, memory support, information retrieval
- Location as primary input or as supporting input
  - Ex. Tour guide vs photo retrieval
- Real-time location or historical
  - Ex. Friend Finder vs photo retrieval

Today's Outline



- Applications
- Ways of Determining Location
  - Describe various systems
  - Step back, look at design space and tradeoffs
- Privacy

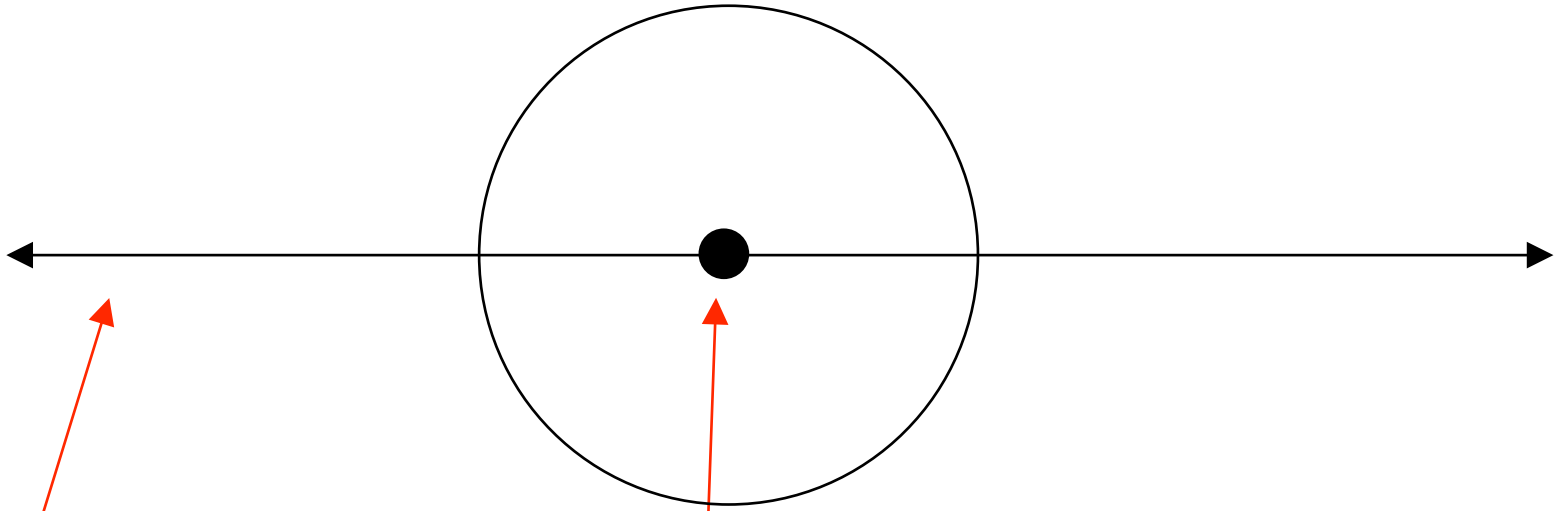
Global Positioning System (GPS)

- Best known and most pervasive
- Works with geosynchronous satellites
  - ~28 up in space now, needs min 24

- How does GPS work?

GPS in 1-Dimension

You receive a signal and you calculate it took N seconds to get to you. Given that you know signal speed…

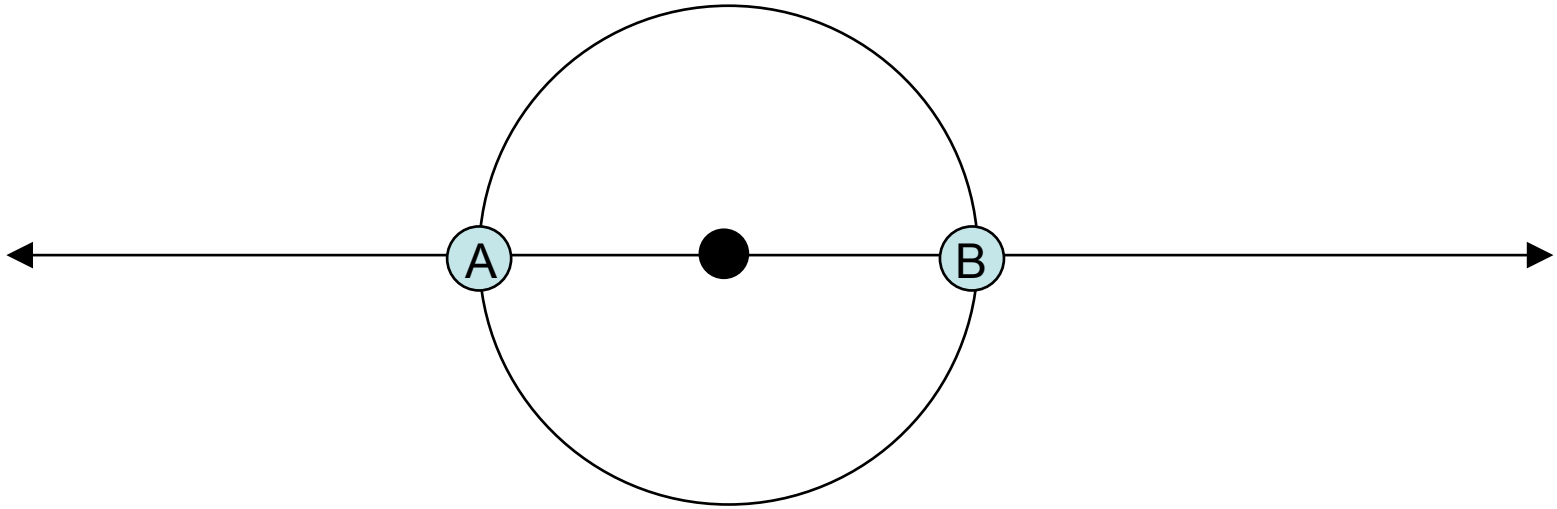


The World

You know a satellite is located here

GPS in 1-Dimension

You receive a signal and you calculate it took N seconds to get to you. Given that you know signal speed…

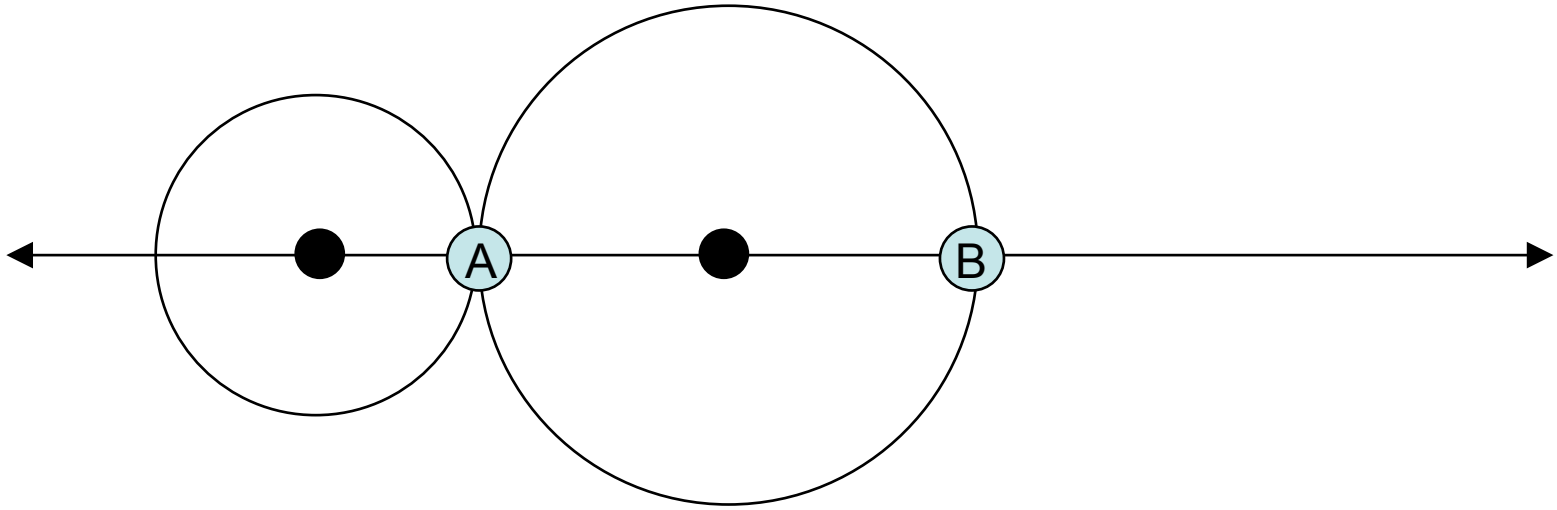


…you know you are either at point A or B

How to disambiguate A and B?

GPS in 1-Dimension

Solution: Add another satellite!



- For 1D, need at least 2 satellites
- For 2D, need at least 3 satellites
- For 3D, need at least 4 satellites
  - GPS signal doesn't go thru earth, thus multiple satellites
  - Can also use geometric constraints too

Two Questions:

- How do we know where the satellites are?
- How do we calculate distance?

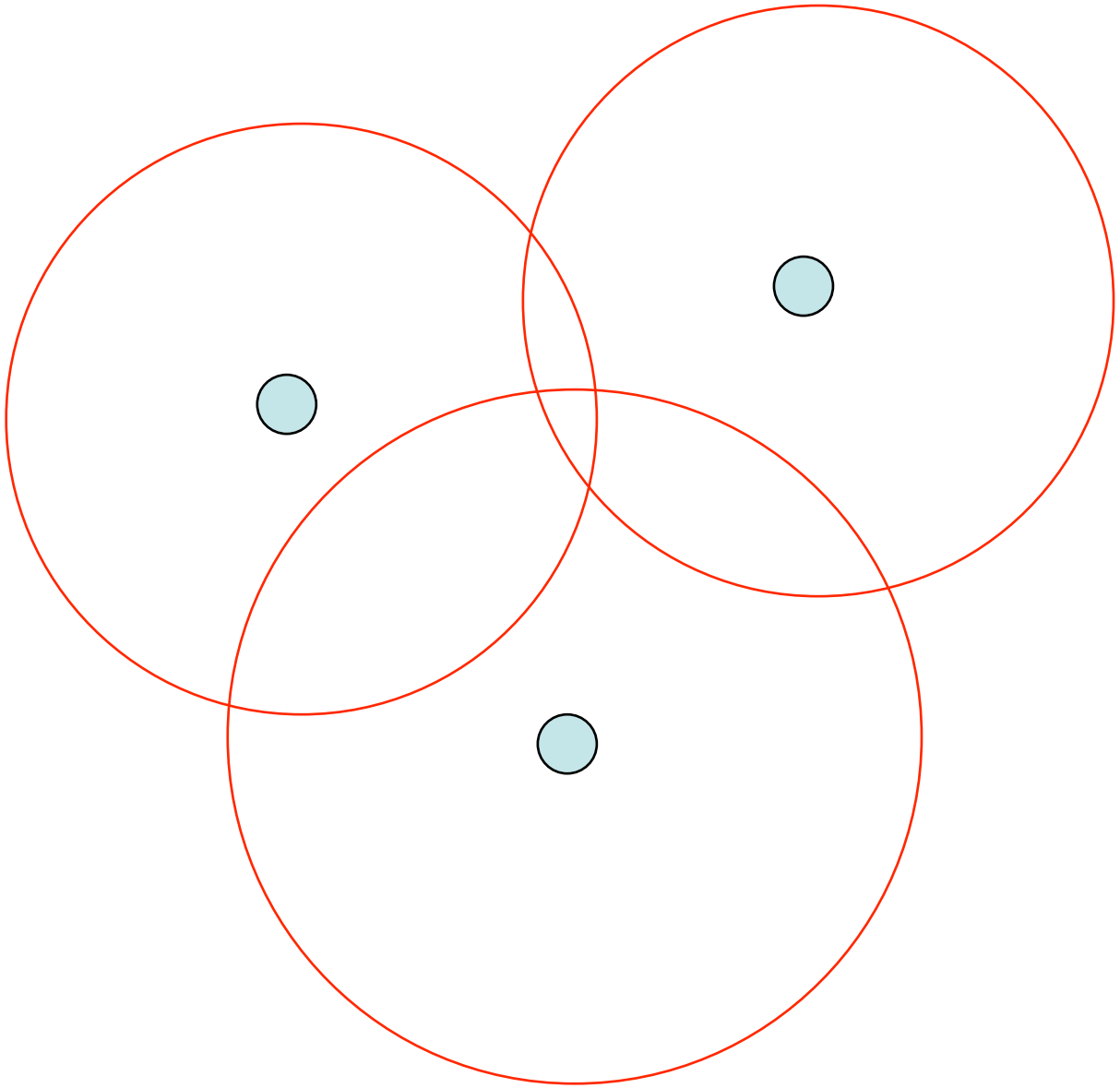
How do we know where GPS Satellites are?

- Each satellite:
  - Has well-known ID
  - Has well-known orbit
  - Broadcasts well-known 1024 bit pseudo-random code
  - Broadcasts satellite correction info (ie where satellite is)
  - Broadcasts current time

When your GPS receiver gets a signal

- To calculate GPS satellite location:
  - Checks what satellite ID it can see
  - Reads broadcasted corrections to orbital data
  - Given correct time, can calculate satellite location
- To calculate own location:
  - Looks up satellite's 1024 bit pseudo-random code
  - Compares the offset (to determine time of flight)
  - Given correct time, knows when code started
  - Given time of flight and *c*, calculates distance

Tri-Lateration / Calculating Location



Global Positioning System (GPS)

- Pros
  - ~5 meters precision
  - Differential GPS even better
  - A few cell phones have GPS now
  - Receivers relatively cheap
  - Coverage is very good
- Cons:
  - Doesn’t work indoors
  - Doesn’t work well urban canyons (New York)
- First GPS2 satellite recently launched
- Competitors: Galileo, Glonass

Cell Tower Triangulation

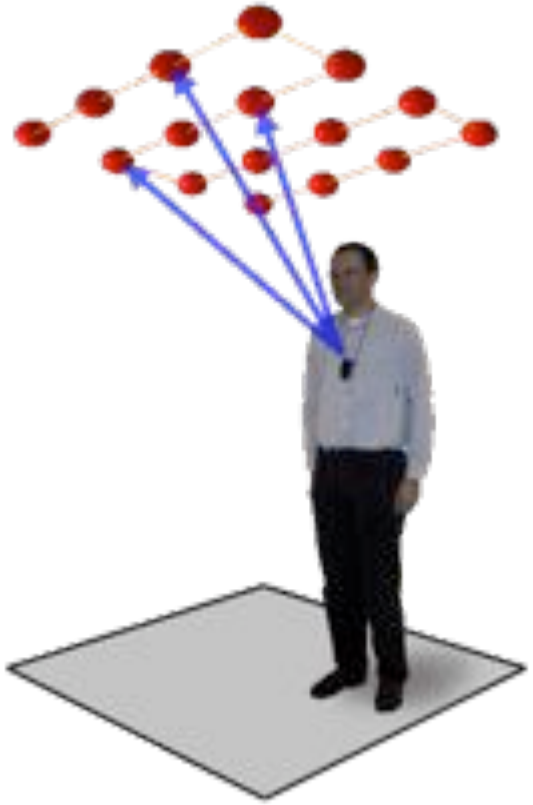
- Primarily driven by Emergency services
- Relatively expensive to instrument phones with GPS
  - Even $1 USD is expensive to cell phone manufacturers
- Can use existing cell towers to triangulate location
  - Typically assisted, phone company activates special chip on your phone to calculate timing info from towers
  - A: Phone can calculate location itself
  - B: Phone can send data to cell carrier to calculate location
  - ~100 meters, up to 1km in rural, more towers is better
- Cell tower fingerprinting is a variation

Active Badge

- Active Badge
  - Badges emit infrared signals
    - Gives rough location + ID
    - Signals ~15 seconds
  - Room-size granularity
  - Light sensor added to help conserve battery life
- Pros
  - Good room-sized location info
  - Good mental model (wear badge → tracked)
- Cons
  - Overhead for setting up receivers (high incremental cost)
  - Limited coverage

Active Bat

- Device sends out ultrasound
  - ~few centimeters precision
  - Lots of receivers in ceiling
  - Uses trilateration to calculate
- Pros
  - Very good precision
- Cons
  - Even higher setup + maintenance
  - Limited coverage

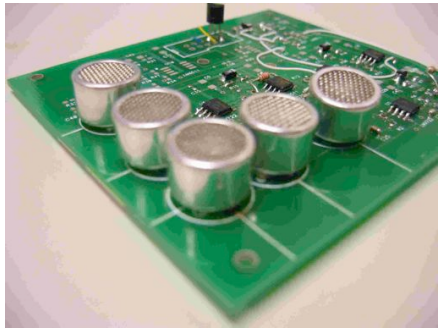


Microsoft RADAR

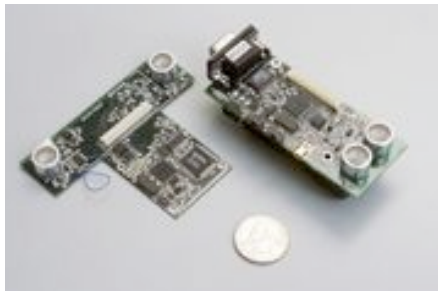
- Uses WiFi to estimate location
  - Setup – Store tuple of (WiFi IDs, signal strengths)
  - Runtime – Get all WiFi IDs and signal strengths, find nearest neighbor, interpolate if needed
  - 5-20 meters (depending on walls, phase of moon, etc)
- Pros
  - Cheap hardware installation
- Cons
  - “Can you hear me now?” setup
  - Lack of coverage
  - Privacy?!

MIT Cricket

- Custom hardware for *location support*
  - Rather than you tell building where you are, building tells you
  - Uses RF and ultrasound
  - Mount beacons on walls and ceilings (must be well-known)
  - Calculates Time Difference of Arrival (TDOA)

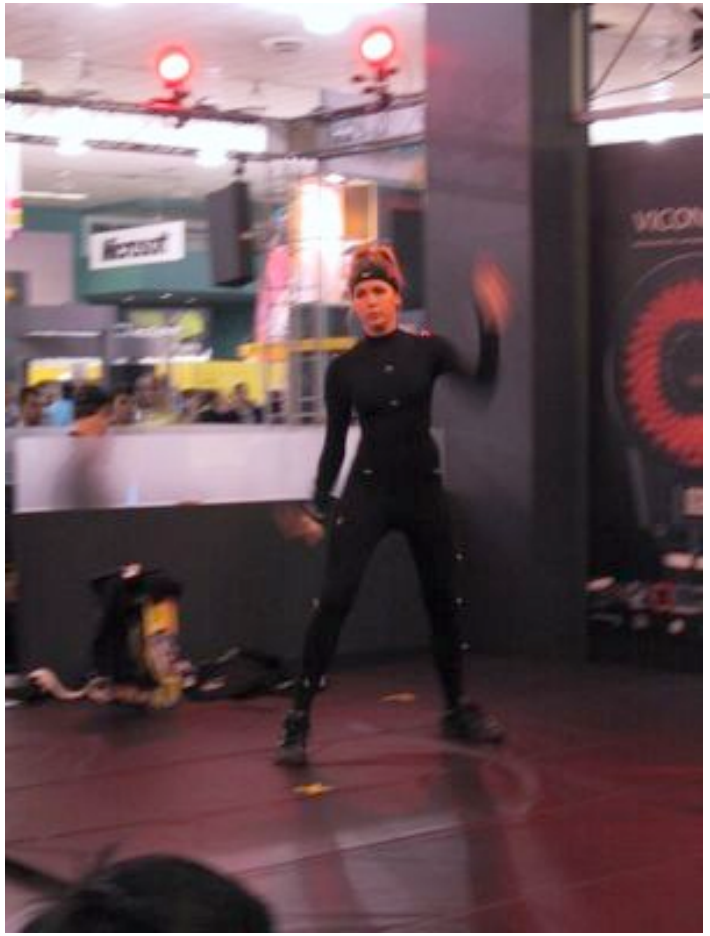


- Pros
  - Orientation + location
  - Privacy
- Cons
  - Same as before (setup, coverage)



Motion Trackers

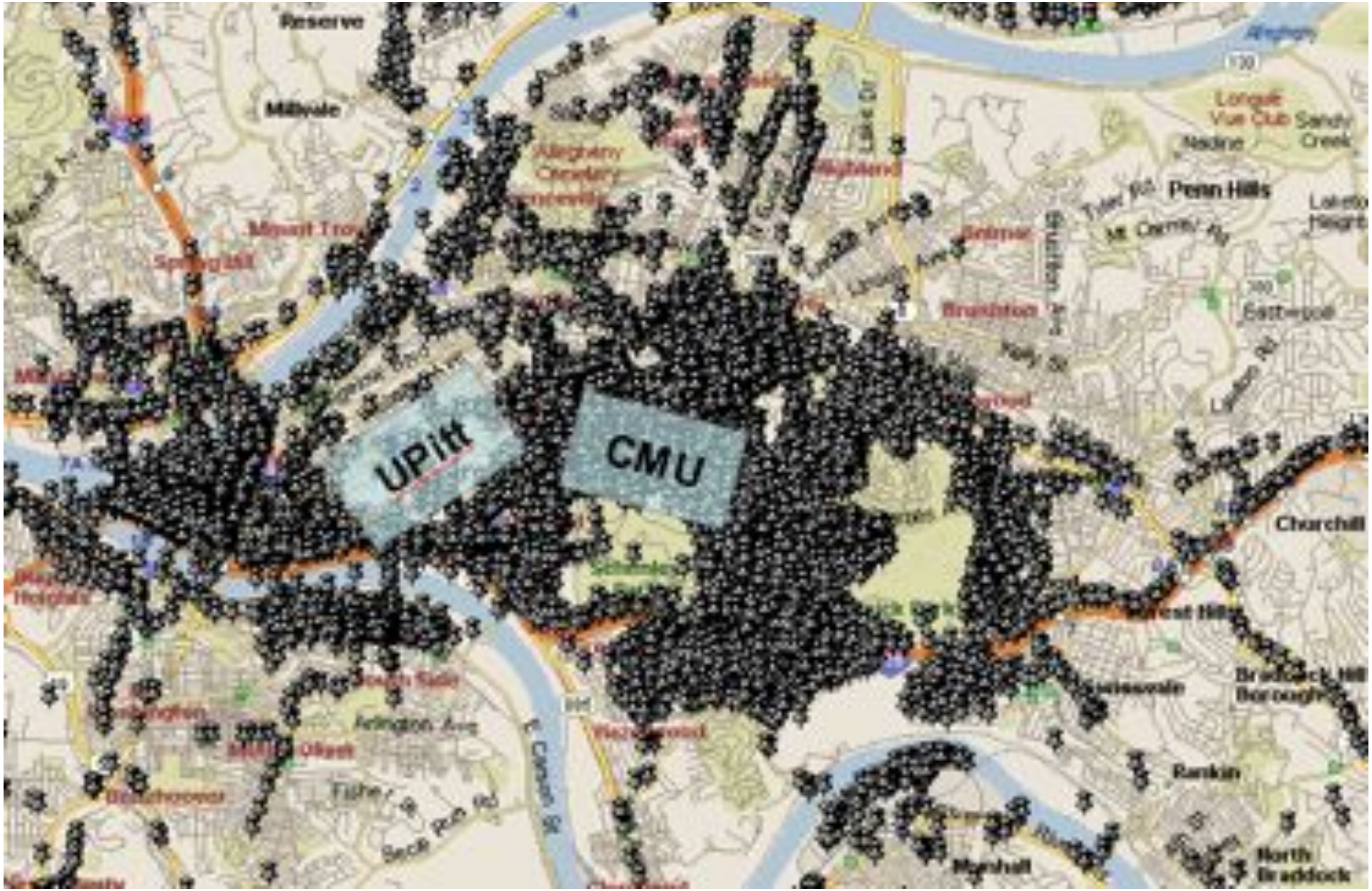
- Useful, but not our focus here
  - Camera-based
  - Motion-based



Intel Place Lab

- Place Lab WiFi positioning system calculates location
  - Unique WiFi MAC Address → Latitude, Longitude

- Works indoors and in urban canyons
- Works with encrypted nodes
- No special equipment
- Privacy-sensitive
- Rides the WiFi wave


UPitt
CMU
Reserve
Millvale
Penn Hills
Churchill
Rankin
North Braddock


Carnegie Mellon
University

Intel Place Lab

- Place Lab WiFi positioning system calculates location
  - Unique WiFi MAC Address → Latitude, Longitude
  - ~25-50 meters
  - Cell tower version too (all cell towers, not just one provider)
- Pros
  - Very good coverage
  - Easily accessible to laptops and PDAs
  - Privacy
  - War drivers keep database mostly up to date
- Cons
  - Relatively poor precision
  - Poor coverage in rural areas

Web-based Versions of WiFi

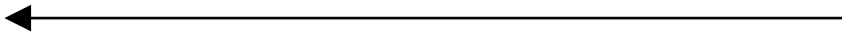
- Microsoft Live Search
  - http://preview.local.live.com/
- Loki
  - http://loki.com/

Stepping Back, Big Picture

- Physical / Symbolic location
  - GPS vs Active Badge
- Relative / Absolute
- Local / Remote
  - World tells user where she is, or user tells world?
- Precision and Accuracy
  - Plus orientation, activity, velocity, etc
- Cost (initial, incremental)
- Coverage

Scale	Technology	Applications
1000 meters / zip	IP Address	Location-based ads
100 meters / building	Place Lab Cell Tower Positioning	Emergencies Find Friend Tagging
10 meters / room	Active Badge WiFi Positioning	Find Friend GPS Box Tourguides Navigation Geonotes Reminders
1 meter	GPS	Glacier tracking Fleet tracking
0.1 meter	Active Bats RFIDs	Where are my keys? Direct input

Today's Outline

- Applications
- Ways of Determining Location
- Privacy 

Location Privacy?

- Unfortunately, not a lot of work done here (yet)
  - An active research area
- Roughly, five (semi-)technical areas:
  - Algorithmic
  - Structural
  - Policy
  - Interaction
  - Analysis and Design
- Lots of legal or market issues too

Algorithms for Privacy

- Blurring
  - “in UMA” vs “in Madeira”
  - Useful in certain cases
- K-Anonymity
  - Degrade before releasing
  - Everyone uses trusted proxy
  - Proxy only reveals location info mixed with k-1 others

Structural Approaches

- Hardware and software architectures
  - Ex. MIT Cricket and Place Lab, calculate location locally
- Locally stored data, locally run services
- Every morning, Alice downloads content for Funchal
  - Community events like talks, concerts, book signings
  - Restaurant guides (download and geocode entire site)
  - Locally filter and examine
- Can also block-fetch info
  - Ex. Travel to Lisbon, download all info for that week
  - Service knows you are in Lisbon, that's it
  - If linked with calendar, can do this when you're in Funchal

Structural Approaches

- Different update rates for data
  - Every day - events
  - Every month - bus schedules
  - Every year - maps
- Tradeoffs:
  - Freshness of data, cpu, disk storage, bandwidth
  - Availability and privacy

Policy

- Not too much work here
- P3P – Platform for Privacy Preferences Project
  - Machine readable privacy policy of web site
  - Well-known location, so your browser can just download it
  - If you have privacy prefs specified, browser can compare
  - Typically used for e-commerce, email addresses, etc
  - Also has field for location information
- GeoPriv
  - IETF working committee
  - Rule-based specification of when and who to disclose to
  - Ex. Ok to reveal timezone, not ok to reveal city

What Lies Ahead?

- Need better models and user interfaces for privacy
- Need to make it easier to program
  - Hard to program for phones
  - App might work for Nokia phones, but not for others
- Need to make it easier to create content
  - Web took off because anyone could create content
- Useful to have a general Place Database
  - You are at “Café de Teatro”

What Lies Ahead?

- One huge non-technical barrier is business model
  - Phone carriers want to make a profit off of everything
- Observation:
  - Location technologies available for 15+ years now
  - But no widely used apps beyond navigation, why?
- Some companies in this area:
  - WaveMarket,
  - Ekahau, Skyhook
  - Motorola, Qualcomm, Nokia

Summary

- Applications
  - Tour guides, tagging, messaging
- Ways of Determining Location
  - GPS, WiFi positioning, RF, Ultrasound, trilateration
  - Physical / Symbolic, Absolute / Relative, Cost
- Privacy
  - Algorithmic, structural, policy, interaction, analysis & design