

Location Systems

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Why is location important?

- After all you know where you are, right?
 - But do you always?
- How to get there?
 - Navigation assistance
- What is around me in this location?
 - Location-based search (Google-Local)
- Who else is around me?
 - Social awareness
- How can my devices/applications help me?
 - Get the information I need before I really need it



2

In-car Navigation

- Directions as you go



3

Google Local

- Pizza near NE 45th St and 15th Ave NE



4

BusView

- Busses near UW



5

Dodgeball

- Finding friends (and friends of friends) nearby

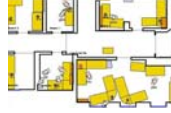


6

Some indoor applications



Video-conferencing



Active map



Virtual buttons



7

How is location computed?

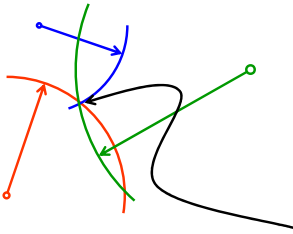
- The basic strategies
 - triangulation - measure distances
 - angulation - measure angles
 - proximity
 - fingerprint or scene analysis



8

Triangulation

- Distance to 3 reference points yield 2-D position (3 reference points for 3-D)



9

Measuring distance

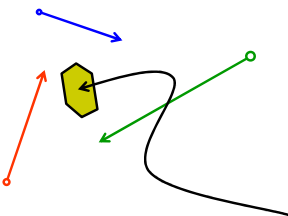
- Time of flight
 - $\Delta t \cdot c$ where c is the speed of light
 - measure as one-way or round-trip
 - fast measurements (3ns/meter)
- Strength of signal
 - stronger the signal, the closer we are
 - not a monotonic function due to the way radio signals propagate
- Inherent error
 - resolution of measurement
 - mapping of measurement to distance



10

Measuring distance in reality

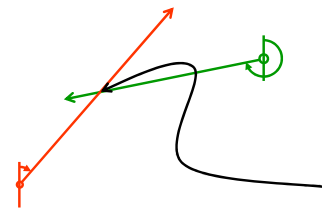
- Uncertainty in measurement



11

Angulation

- Use angles instead of distance
 - must agree on reference direction
- Same error issues as distance measurements



12

Proximity

- If something is close, then it is likely to be in the same place
- Use multiple reference points
- How close is close?



Highly inaccurate version of distance measuring

13

Fingerprint

- Does this look something I may have seen before?
 - keep track of properties of the environment
 - vision, radio signals, etc.



14

Axes of Location

- Indoor vs. outdoor
 - elevation/floor a particularly interesting issue
- Absolute vs. relative
 - 47N, 122E or 1 mi. N from where I am now
- Representation of uncertainty
 - distance or room-level
- Private vs. public
 - self-position vs. Big Brother
- Position vs. place
 - 47N, 122E vs. UW Campus

15

Some location technologies



16

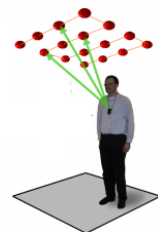
Some Examples

- Indoor
 - Active Badge/Bat
 - Cricket
- Outdoor
 - GPS
 - E911
- Both
 - Place Lab

17

Active Badge/Bat

- Centralized approach
- User carries badge that emits signal picked up by infrastructure
- System keeps track user's location
- Infrared – room-level location
 - one receiver per room
- Ultrasound – resolution of a few cms
 - more receivers the better



18

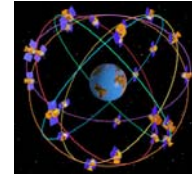
MIT Crickets

- Flips architecture of active bat system
- Infrastructure emits, user device listens
- Need synchronized clock
 - to measure time of flight
- Need to know where emitters are
- Use lightning/thunder approach
 - RF is lightning
 - ultrasound is thunder
 - measure time difference

19

Global Positioning System

- Developed by US/DoD
 - European Galileo now coming on-line
- How it works
 - Satellites emit signals on precise schedule
 - GPS unit triangulates based on time difference of arrival
 - 4 satellites needed for 3-D fix
- Problematic indoors, urban canyons, etc.



20

E-911/E-116

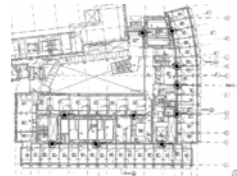
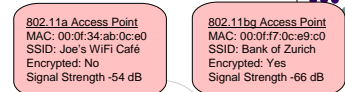
- FCC mandated in US (similarly in Europe)
- Localize emergency calls down to 100m
- Location computed by cell service provider
- Appended to emergency calls
- Also, sold back to user for commercial applications



21

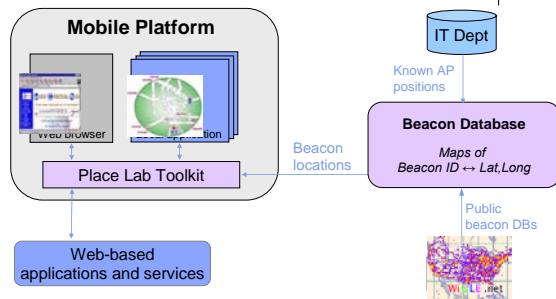
Place Lab

- Exploit proliferation of WiFi access points
 - Proximity-based
 - Fingerprint-based
- Need a database of access point locations



22

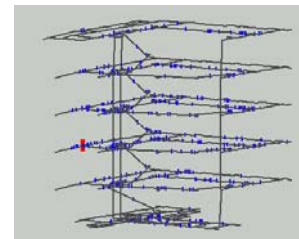
The Place Lab Architecture



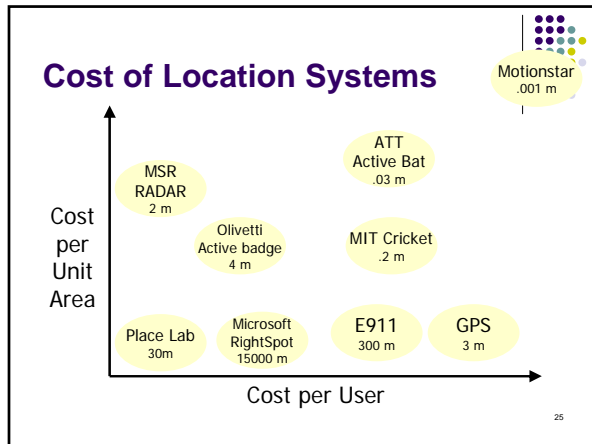
23

Demos

- Place Lab outdoors – proximity
- Place Lab indoors – fingerprint



24



- ## Some important trends
- Decrease infrastructure/calibration costs
 - Room-level localization
 - Movement in addition to location
 - Outdoor navigation
 - GPS as a model for other RF technologies
 - Wi-Fi, Bluetooth, GSM
 - Integration with information about physical world
 - Privacy awareness
 - Friend-finding applications (e.g., Dodgeball)

- ## Privacy and Location
- The following content was generously provided by *Sunny Consolvo* and *Ian Smith* of *Intel Research Seattle* (and their collaborators)
 - Moving from location technologies to communication practice
 - how will real people disclose/request/use location information?
 - what form will location information take?

Understanding Place

- Discovering and mapping boundaries of place
- Learning place labels
- Use the web
 - Mine place boundaries using GIS maps
 - Extract place labels from GIS, Yellow Pages, ...
- Use RF beacon data
 - Infer place boundaries from behavior and usage

- ## Location Disclosure
- Tracking
 - assets: packages, vehicles, etc.
 - people: security personnel, doctors/nurses
 - Job-related
 - Social

- ## Why social location disclosure?
- Social applications are a main driver of mobile telephony & SMS usage
 - Location-Based Services (LBS) are predicted to expand business opportunities for mobile devices
- Social location-based services on mobile devices are being implemented now*

Before designing ...

- How do people determine **when they will disclose** their location?

Who is making the request

What they're doing when they receive the request

Why they think the requester wants to know

Designers must account for the ways in which users make disclosure decisions

31

Before designing ...

- What would people disclose?

exact address

City

Lat/Lon Coordinates

ZIP Code

cross streets

neighborhood name

generic place name

State


Country

Designers need to know what level(s) of location detail people want to disclose

32

Evaluating social mobile apps


- Challenging because...
 - Difficult to follow people everywhere
 - Lab studies are out of context
 - Hard to predict how features will be used
- Need to carefully design a study



33

Participants, N=16

- 8 male / 8 female
- Aged 24-64, Seattle area
- Primary screening criteria:
 - Regular use of cell phone
 - Got out of house
 - Non-technical career
- 12 were employed full-time
- 14 had spouse / SO



34


Phase 1: In-lab exercises

- Participant background:
 - Demographics
 - Location "buddies"
 - Anticipated factors
- Consumer privacy classification
 - Westin/Harris Privacy Segmentation Index

Fundamentalists
 High privacy concern

Pragmatists
 Balance pros & cons

Unconcerned
 Little to no concern



35

Westin/Harris Privacy Segmentation Index

Strongly Agree	Somewhat Agree	Somewhat Disagree	Strongly Disagree
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S1: Consumers have lost all control over how personal information is collected and used by companies

S2: Most businesses handle the personal information they collect about consumers in a proper and confidential way

S3: Existing laws and organizational practices provide a reasonable level of protection for consumer privacy today

36

Thanks to Privacy & American Business for allowing us to reprint the Westin/Harris Privacy Segmentation Index

Scoring your responses

- (1) point for strongly/somewhat agreeing to S1
- (1) point for strongly/somewhat disagreeing to S2
- (1) point for strongly/somewhat disagreeing to S3

37

Thanks to Privacy & American Business for allowing us to reprint the Westin/Harris Privacy Segmentation Index

Privacy classifications

Fundamentalists (3 points)

- have "very high privacy concern" and are "passionate about what they [see] as business threats to their consumer privacy, and [favor] active government regulation of business and information practices"

Pragmatists (1-2 points)

- "ask what benefits they get as consumers in sharing their personal information to balance against risks to their privacy interests, and they usually favor a mixture of government and private solutions."

Unconcerned individuals (0 points)

- have "little to no concern about consumer privacy issues."

38

Thanks to Privacy & American Business for allowing us to reprint the Westin/Harris Privacy Segmentation Index

Phase 2: Experience sampling

- 2 weeks, *in situ*
- Randomly interrupted
 - 10 questionnaires/day
 - ~2-4 minutes to complete
- Asked about:
 - Current situation
 - Hypothetical location requests



39

Phase 2: Experience sampling

- Question types:
 - Context
 - Hypothetical requests
 - Follow-up
- Response rate: ~90%
 - ~126 questionnaires per participant



40

Single & Standing requests

- Single:
 - Assume **Anne** wants to know your location right now. Would you want the system to tell her "something" or "nothing" about your location?
- Standing:
 - You have received a request: whenever you arrive at your **home**, Ashley wants to know. Do you accept this request?
- Customized for each participant



41

Phase 3: In-lab exercises

- Interview about experiences
- Exercise revisions from Phase 1
 - Location "buddies"
 - Anticipated factors
- Equipment return and compensation
 - From \$60-250 USD (median = \$225)

42

Imagine...

- If someone wanted to know where you are right now, how would you reply?

777 NE Martin Luther King, Jr. Blvd
Portland, OR 97232, USA

Lat: 45:31:42N Lon: 122:39:42W

97232

NE MLK, Jr. Blvd & NE Oregon St.

Ballroom 202

CHI

Business trip

Portland

Something else?

43

It probably depends on...

- Who wants to know
- Why you think they want to know your location right now
- What level of detail you think would be most useful to the requester and
- Are you willing to disclose that to them?
- Might you even want to lie?

44

Who is requesting?

- What role does the requester play in the participant's social network?

Role	Responded with location to...
Spouse/SO	93% (of 670 requests)
Friends	85% (of 902)
Family	83% (of 1279)
Co-workers	53% (of 682)
Manager	34% (of 235)

He is being a butt

I'm mad at the person

- What is the *current state* of the relationship?

If you're mad at the person and they know you're at the park, guess who will probably show up...

45

Why do they want to know?

- Are they...

Sometimes I can't use the phone

- trying to figure out if I'm available?
- trying to find out if I'm okay?
 - 'okayness checking'
- just being nosy

Useful because people need to get a hold of me

My mother is nosy. It drives me crazy

Why do they need it? Are they just bugging me or do they have a real reason

46

What would help them?

- Would exact address be useful to...
 - my mother who lives in Dallas? probably not
 - my friend who I'm trying to meet for coffee/tea? maybe

47

Am I willing to disclose?

- Consequences of disclosing

When I go to babyGap, I don't want my husband to know

...if I told my wife I was taking the dogs out for exercise and I really didn't do it.

I wouldn't want people to ask me to pick stuff up.

Would I want to talk with or be in contact with this person right now?

48

Am I willing to disclose?

- Is the request appropriate?
 - When I was socializing with my friends, other people's requests seemed rude.
 - My parents never know my schedule, and this way, they could easily find out where I am if they can't get a hold of me.
 - Regarding my boss, all she needs to know is that I'm getting my work done, not where I am.
 - During work, it was okay when a co-worker or boss wanted to know where I was, but it was weird when I was at the coffee shop.

49

Participants' responses to co-workers & managers

- At work
 - Co-workers: 80%
 - Managers: 69%
- At home:
 - Co-workers: 47%
 - Managers: 24%
- At stores & restaurants:
 - Co-workers: 35%
 - Managers: 21%

50

Responses to spouse/SO, family & friends

- At work:
 - Spouse/SO: 91%
 - Family: 85%
 - Friends: 89%
- At home:
 - Spouse/SO: 92%
 - Family: 82%
 - Friends: 86%

51

Am I willing to disclose?

- Wanted to disclose *nothing* to 23% of requests:
 - I am busy (50%)
 - Request denied (37%)
 - System busy (12%)
 - Lie (1%)
 Listed in overall order of popularity

Various levels of denial are useful

52

Disclosing something

- Willing to disclose location to 77% of the 3,798 requests
- What they disclosed...

77%	Exact address, Generic place name, X streets
19%	City, Neighborhood, ZIP Code
5%	State, Country

Various levels of disclosure are also useful

53

Blurring location

- Being *purposely vague* when disclosing
- Often proposed as a way to protect privacy
- However, it was used for *clarity*, not *privacy*
- Once they chose to disclose, they disclosed the *most useful* level of detail

For someone in New York, "exact address" was not useful

54

Conclusions

- Social mobile applications for disclosing location are useful
- Our results show that people...
 - disclose what they think will be useful or don't disclose location
 - want various options for disclosing location and denying requests
 - will probably use this sort of app with a small number of trusted social relations

55

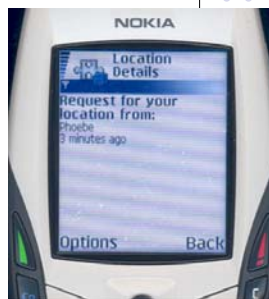
Reno Application

- "Where are you?"
- A mobile-phone application
 - Platform for doing research in the social mobile space
 - Answer the question: How can we directly support exchanging location information?
 - Input/output issues

56

Scenario (1)

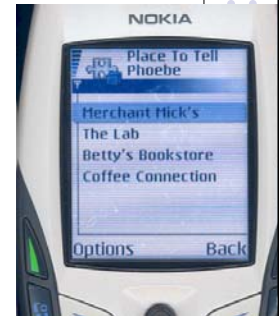
- Phoebe wants to see where Ross is
 - Worried about disturbing him
- Phoebe "renos" him to ask his location
- Message appears in his "location inbox"
- Ross decides to ignore the request for now...



57

Scenario (2)

- Ross answers a few minutes later
- He's at the bus stop near his office
- 4 nearby location options are presented
- "Merchant Mick's" is near the bus stop
- Assumes Phoebe will understand the context



58

Scenario (3)

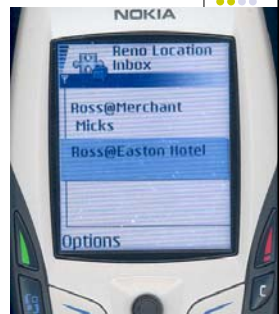
- Phoebe receives the disclosure at home
- She assumes Ross is on way home
- She assumes Ross is bringing Merchant Mick's dessert!



59

Scenario (4)

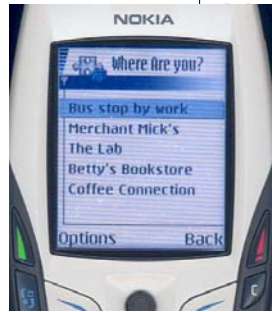
- Ross gets off the bus at the Easton hotel
- Reno detects his location
- Message is sent to Phoebe automatically
- She assumes he is 10 minutes from home
 - She knows the route!



60

Scenario (5)

- Ross arrives home 10 mins later
- Phoebe is angry because there is no tasty treat!
- Ross “teaches” his phone a new place name “Bus stop by work”



61

Reno Capability Summary

- Query another person's location
- Explicitly and manually push your location
 - Application is location-aware—prevents typing!
- Automatically “trigger” a disclosure from a location
 - Sent to a pre-defined person
 - Triggered on entry or exit
- Define a new place for use in future disclosures
- Built on SMS

62

Shared Context Makes Location (Place) Data Much More Powerful

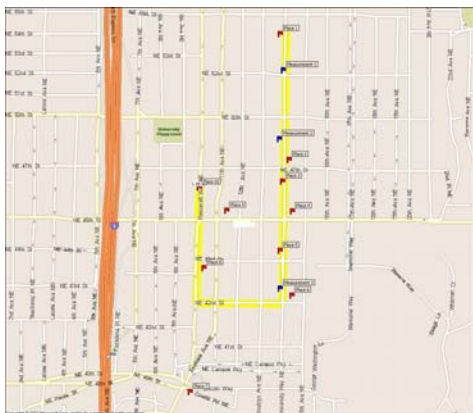
- Phoebe made a gigantic leap from the name of place to “he’s bringing dessert!”
 - Relationship's state and history
 - Physical state
 - Time of day (dinner)
 - Knowledge of route
- Shared context is key
 - Difficult to embody in automatic tool

63

Computing “Place”

- We used a very simple cell-based location scheme
 - Weak “fingerprinting” scheme
 - Consider the set of recently seen GSM cells
 - Match recent cells to stored sets to define a “place”
- Produces a list of places that are “near” the user
- Semantically meaningful places are not arbitrarily packed
- Need to understand exactly how accurate you need to be

64



65

Pilot Study

- One does a pilot because...
- 8 users for 5 days (wed-sun)
 - Pre-study questions, daily email diaries, all activities of the application were logged
- Members of the team and their families
 - What if things go horribly, horribly wrong... ?

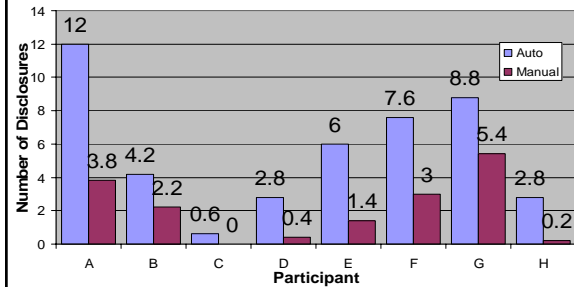
66

Phone Setup

- Supplied with ready-to-go Nokia 6600's
 - They kept their old phone number...
- Each participant was asked for a list of places, people and triggers for automatic disclosures
 - "Tell me when X gets to the store."
 - "Tell X when I leave the store."
 - All these lists coded into the phones

67

Total Disclosures By Participant



68

Qualitative Highlight

- We had mixed reactions to the automatic disclosure
 - Manual disclosure has humans on *both* ends

Late tonight, Phoebe pushed her location to me from SEA-TAC airport. That reminded me that ... I wanted get together with them socially when they arrived. I had forgotten it was this weekend.

Joey, Day 2 (Thurs)

69

Design Guidelines

- **Don't Start With Automation**
 - Automatic functions that communicate on behalf of the user should not be introduced by default, but only when a real need arises.
- **Flexibility in the Reply**
 - Users should be able to choose what the system discloses as a reply to a location request.
- **Support Denial**
 - Communication media should support the ability to ignore requests.
- **Support Deception**
 - Communication media should support the ability to deceive in the reply.
- **Support Simple Evasion**
 - Designs should include the ability of signaling "busy" as a baseline evasive reply.
- **Start with Person-to-Person Communication**
 - Social mobile applications should support person-to-person communication before attempting group communication.
- **Status/Away Messages**
 - Provide a way of signaling availability status.
- **Operators: Avoid Handling User Data**
 - Social location disclosure applications should not be provided by centralized services.

70

The Next Iteration . . .

- Place, not location
- Additional context/activity information
- Resolution
- Notification vs. awareness
- Automatic vs. explicit query/reply
- Group coordination
- Map-based interface

71