CS 525M: Mobile and Ubiquitous Computing
Did You See Bob? Human Localization using Mobile Phones

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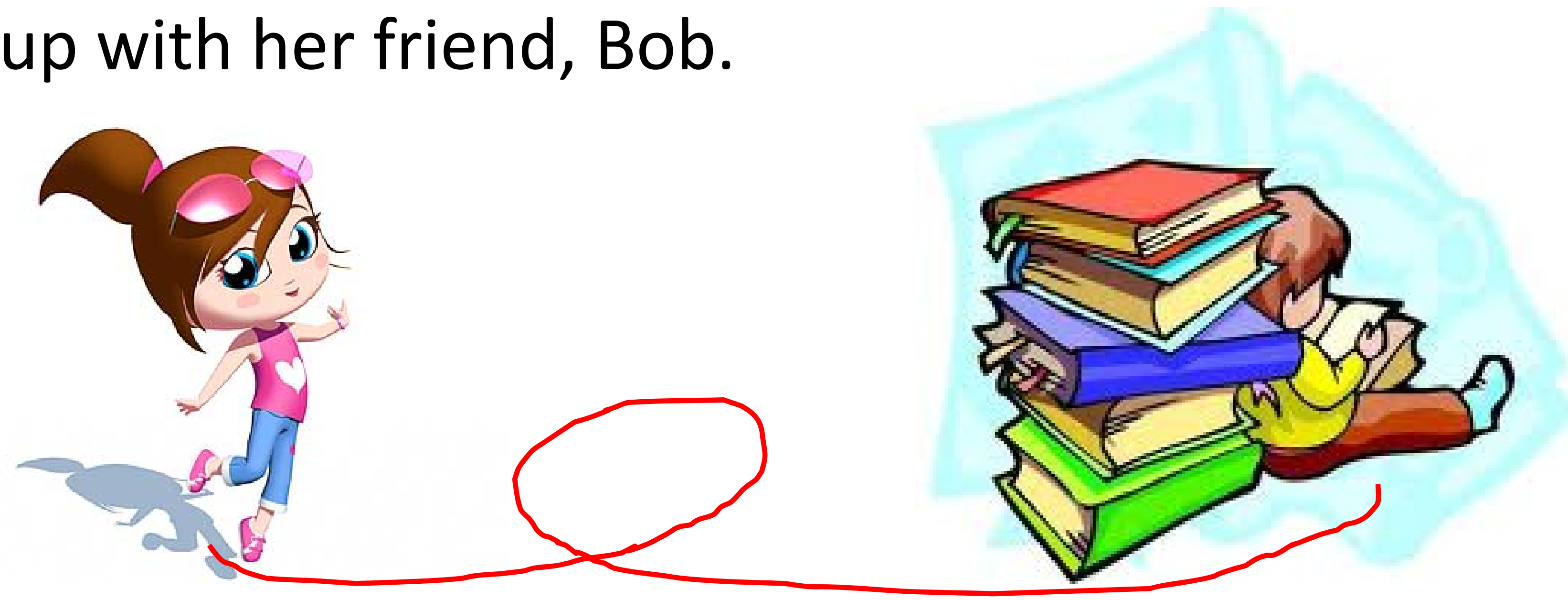
Introduction: motivation

- Finding Bob: a hypothetical scenario.

At MobiCom 2010 is in progress in a big hotel in Chicago, and as Alice arrives, she intends to meet up with her friend, Bob.



Introduction: motivation

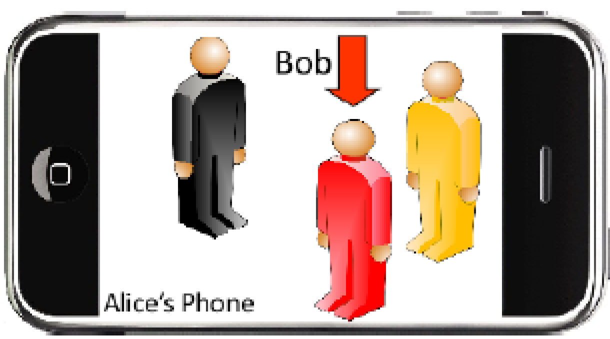
- Probable Solutions: Difficult!

Random walk? Make a phone call? No answer, have to wait and find. GPS? Ask other people?

- An smart phone APP: Escort!
- Problem: in a human populated public place, develop an App that can localize and route a person A to a specified person B.

Introduction: solution

- Electronic Escort Service: A system guides a user to the vicinity of a desired person in a public place.
- Display an **arrow** and **visual identification**



Introduction: methodology

- Do not rely on: GPS, Wi-Fi, War-driving, cellular base stations, floor map.
- They only use: an **audio beacon** randomly placed in the building, **accelerometer** and **compass**, **microphone**, **speaker** on the phone.
- Reason: battery life, Wi-Fi exists, latitude/longitude are not important

Introduction: methodology

1. Capture users’ “movement traces”
2. records “encounters” between users and beacon
3. uploaded <movement trace, encounter> to a remote server
4. A global view of the users’ positions and paths on remote server.
5. Create a route

Introduction: methodology

- Example: Route A to B by movement and intersections (Assumption: No one way traffic)

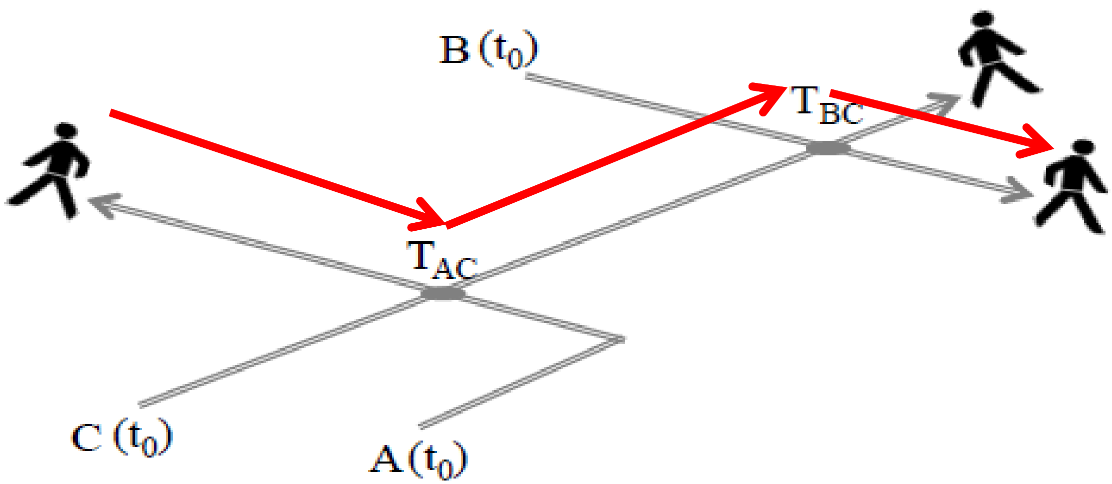


Figure 1: The Escort server assimilates a global view of users' movement and intersection patterns. The human icons show the current location of the user U, while $U(t_0)$ denotes user U's first recorded location. T_{UV} denotes the intersection time of users U and V.

Introduction: system overview

- Detect **path**: Accelerometers and compasses
- Detect **encounter**: Listen inaudible tones.
- global reference for **error correction**: A beacon.

Introduction: system overview

- Detect **path**

walking trail: <*displacement, direction, time*>

displacement = number of steps * user's steps size

Accelerometer and compass provide number of steps

Introduction: system overview

- Detect **encounter**

(Bluetooth doesn’t work: people move too fast)

Each phone Periodically,

1. playing a unique tone (inaudible)
2. listening for other device(Phone or Beacon)

Introduction: system overview

- Detect **encounter:** noise scenarios

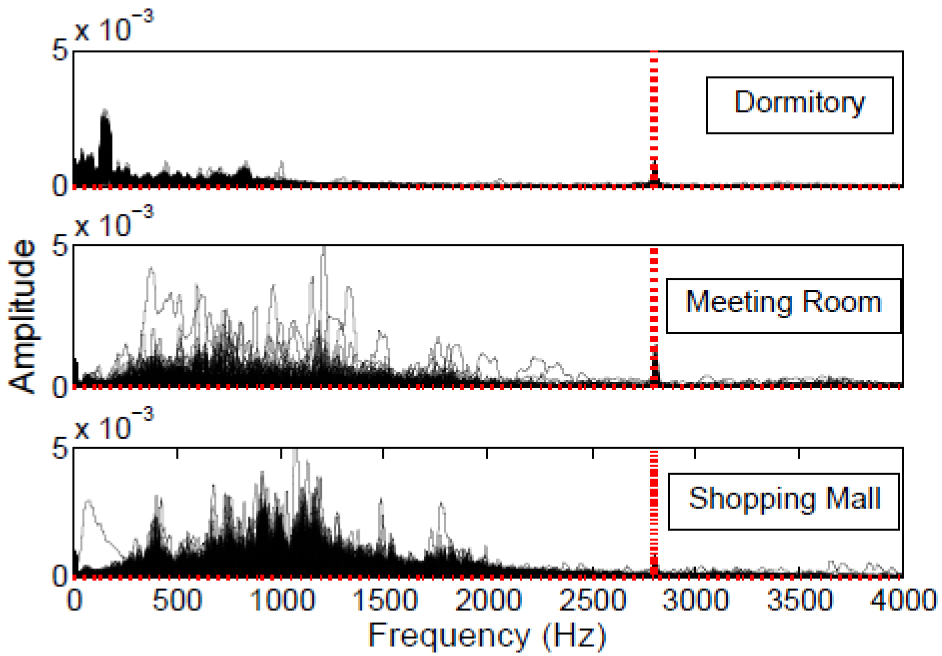


Figure 6: Tone detection in three test scenarios: (a) student dormitory, (b) meeting room, and (c) shopping mall. The red dotted line marks the tone frequency.

Introduction: system overview

- Detect **encounter**: Amplitude clear reduction at 5m (cause 5m error)

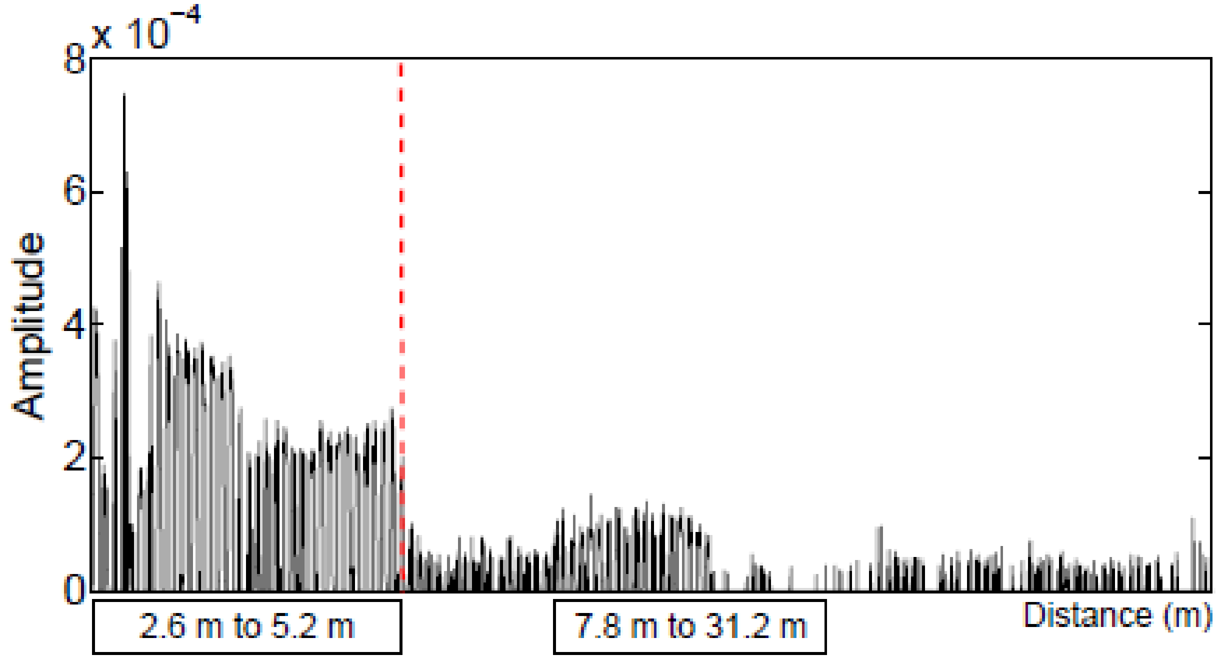


Figure 7: Variation of tone amplitude with distance – two classes of distances are marked.

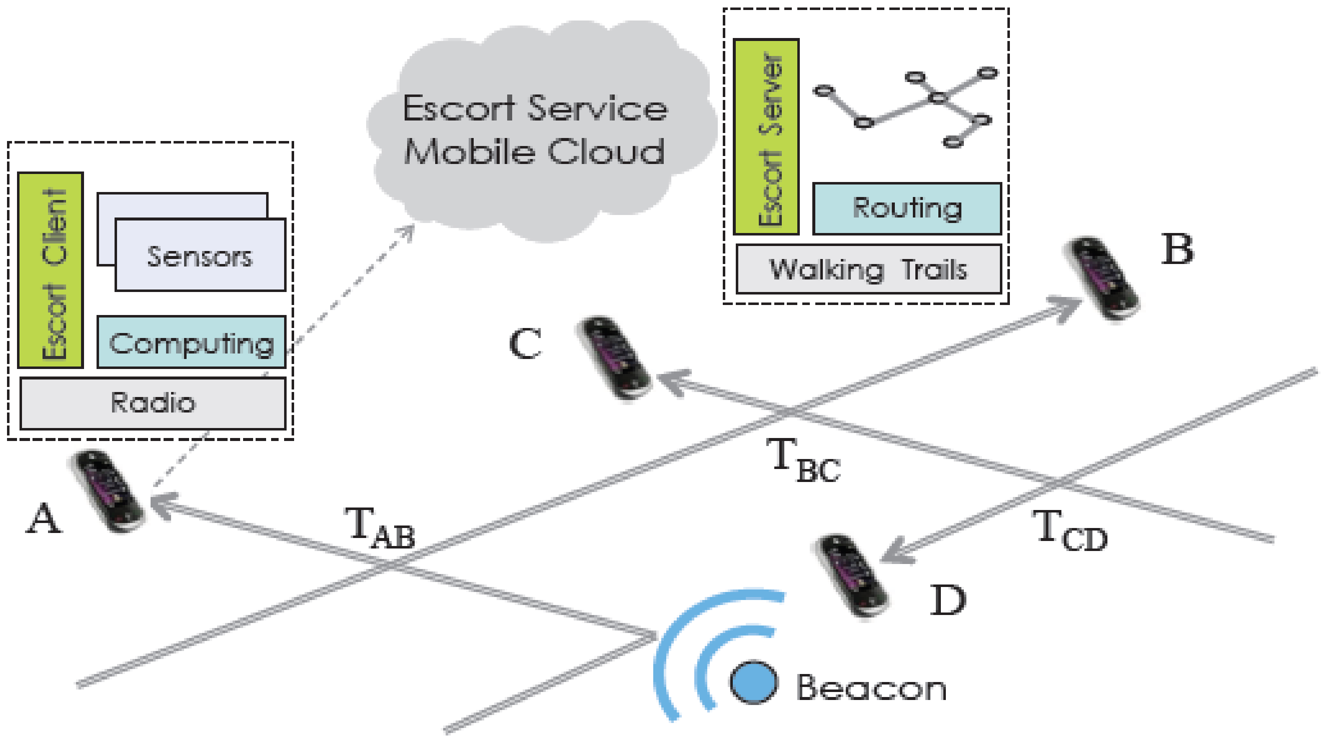
Introduction: system overview

- **Error correction** by server

1. One encounter Beacon
2. Others encounter reliable one

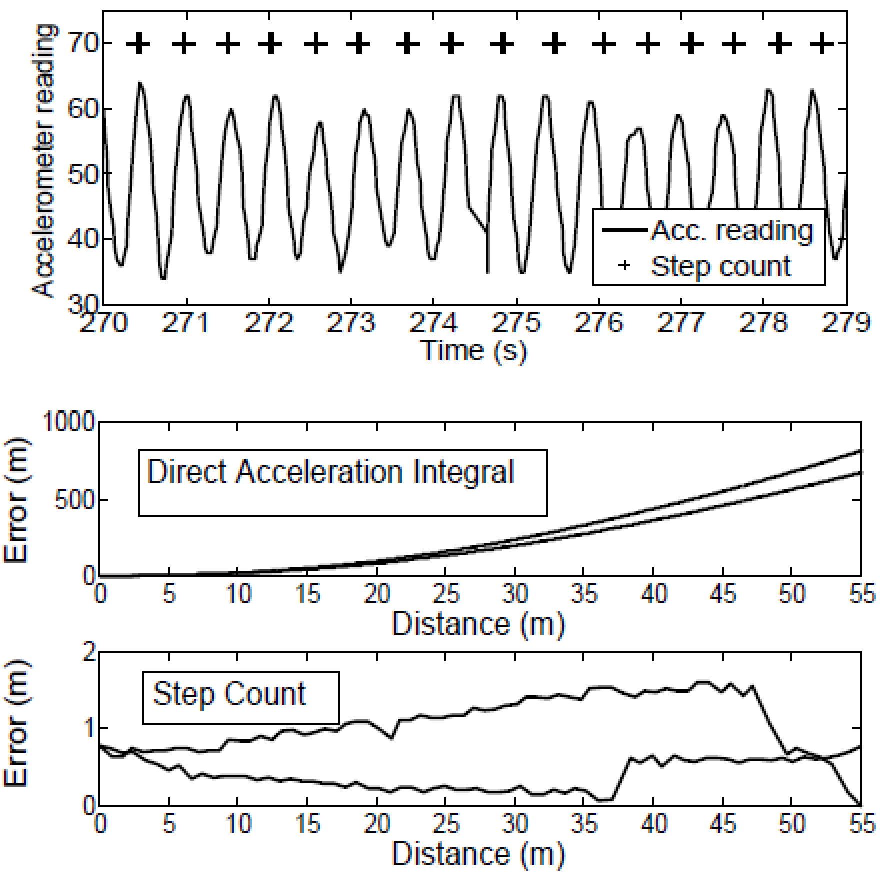
Introduction: system overview

- **Routing:** Server return < step i;θ i > : i-th step and its angle



Challenges: Noisy sensors

- Accelerometer: The step count accuracy is 96% on average.



Challenges: Noisy sensors

- Compass: walking in a constant direction, and turning.

$$Avg(t_{i+1}) - Avg(t_i) \geq \frac{StdDev(t_i) + StdDev(t_{i+1})}{2} + G$$

where $Avg(t_i)$ denotes the average compass readings over a t_i time period (e.g. 1 second), $StdDev(t_i)$ is the standard deviation of compass readings during t_i, and G, a guard factor.

Challenges: Correcting User Position via Diffusion

- A encountered beacon. –A’s position get corrected by beacon
- After a while, B meet A–B’s position get corrected by A.
- …

Challenges: Correcting User Trail (Drift Cancellation)

- V estimation of the cumulative drift over time

$$L'(t) = L(t) + \vec{V}\frac{t - t_{r1}}{t_{r2} - t_{r1}}$$

Challenges: Correcting User Trail (Drift Cancellation)

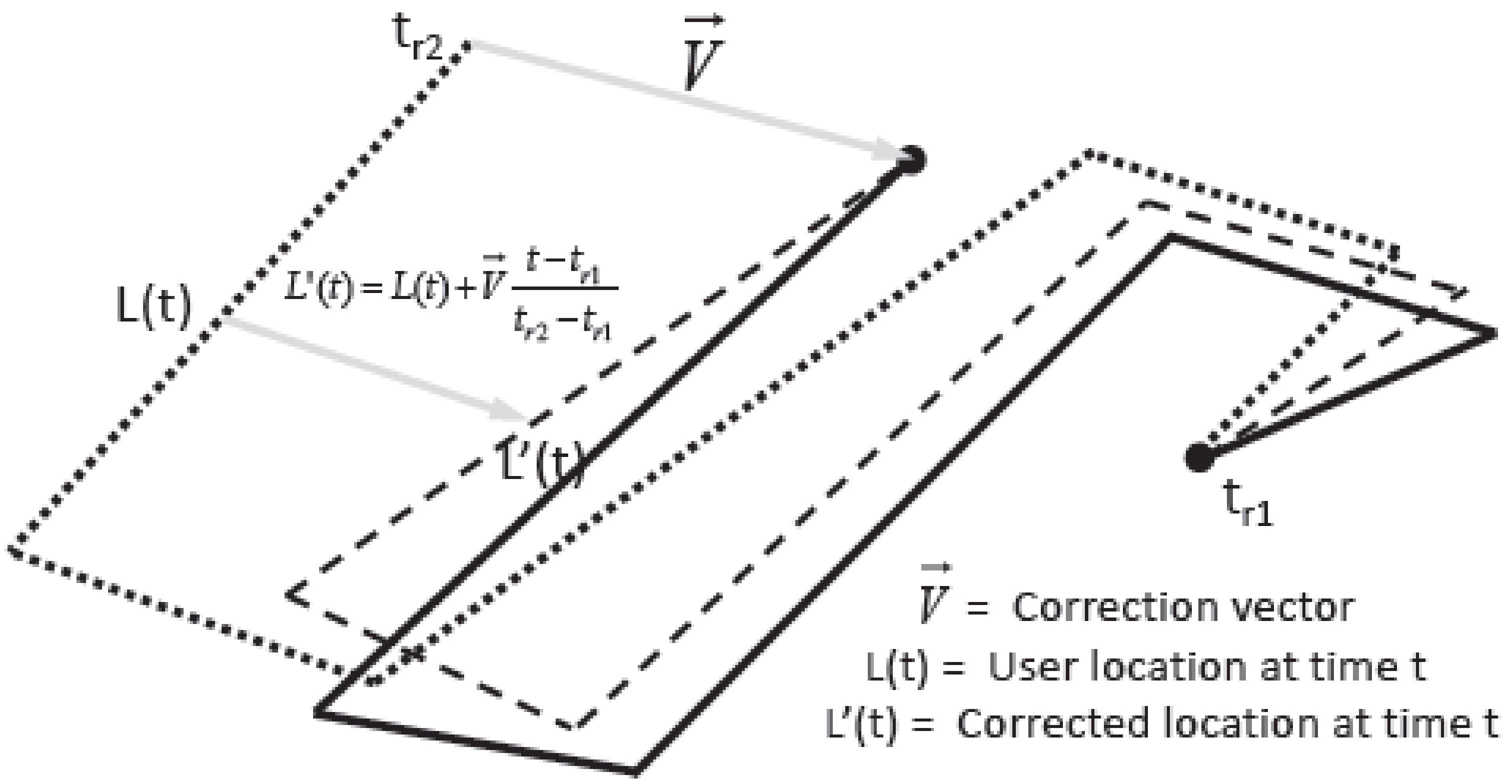


Figure 8: Drift Cancellation: the solid line is the actual user path, the dotted line represents the user computed trail, and the dashed line denotes the user trail corrected via Drift Cancellation.

Challenges: Computing Routing Directions

- Builds a trail graph: edges and vertices
- Periodically re-apply the pruning heuristic

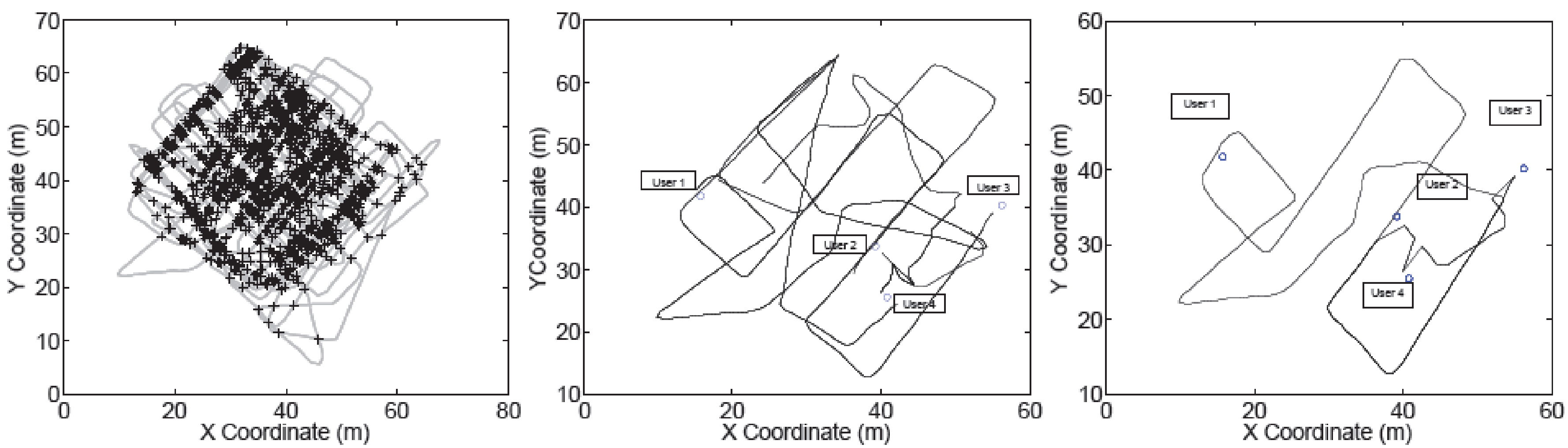


Figure 9: (a) The trail graph after tracking 4 users for 10 minutes. (b) The resulted graph after applying the pruning heuristic. (c) Running Floyd-Warshall and the graph of user paths.

Challenges: Visual Identification

- Segmenting images based on human contours
- Fingerprinting translates to extracting a set of (color) features that will discriminate that person from others.
- Matching requires comparing fingerprints

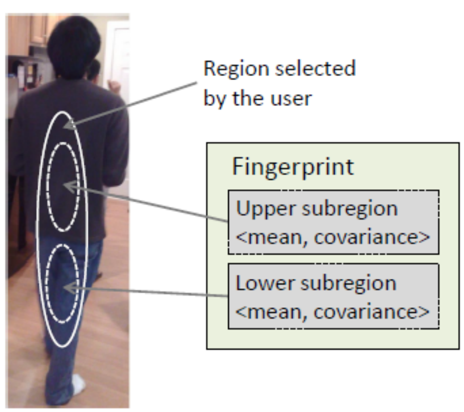
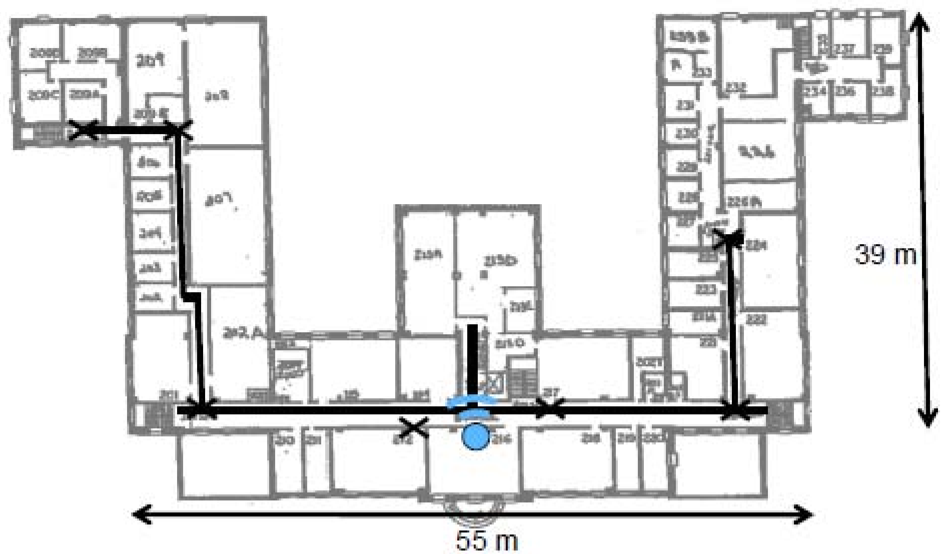


Figure 12: Generating the user fingerprint.

Evaluation: Methodology

- Campus parking lot and department building



Evaluation: Methodology

- Three different schemes: (1) Inertial, (2) Beacon and Encounters (3) Drift Cancellation. (The Inertial: only the compass and accelerometer sensors are used for localization.)

Evaluation: Results

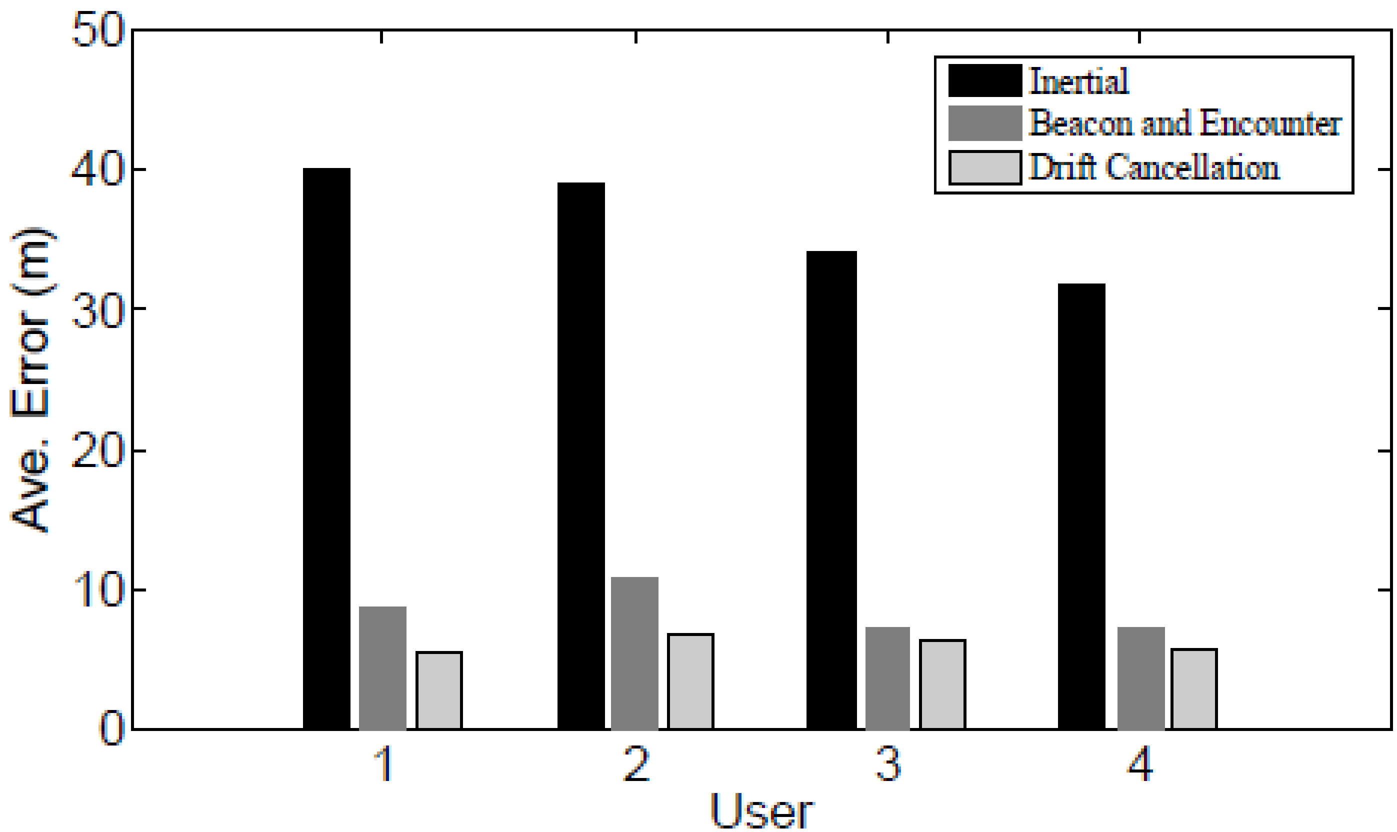


Figure 16: Average instantaneous error per user.

Evaluation: Results

- Parking lot

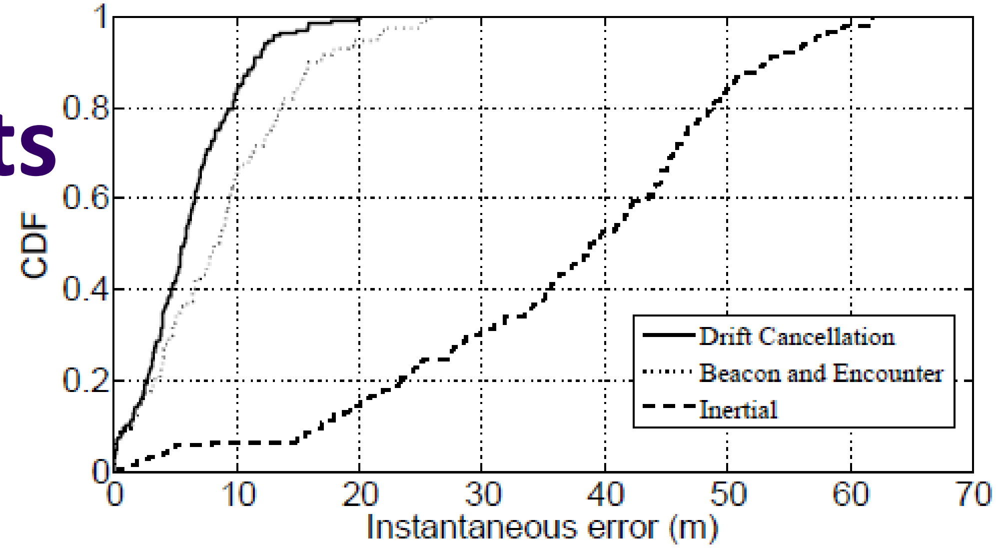


Figure 17: CDF of the instantaneous error in parking lot.

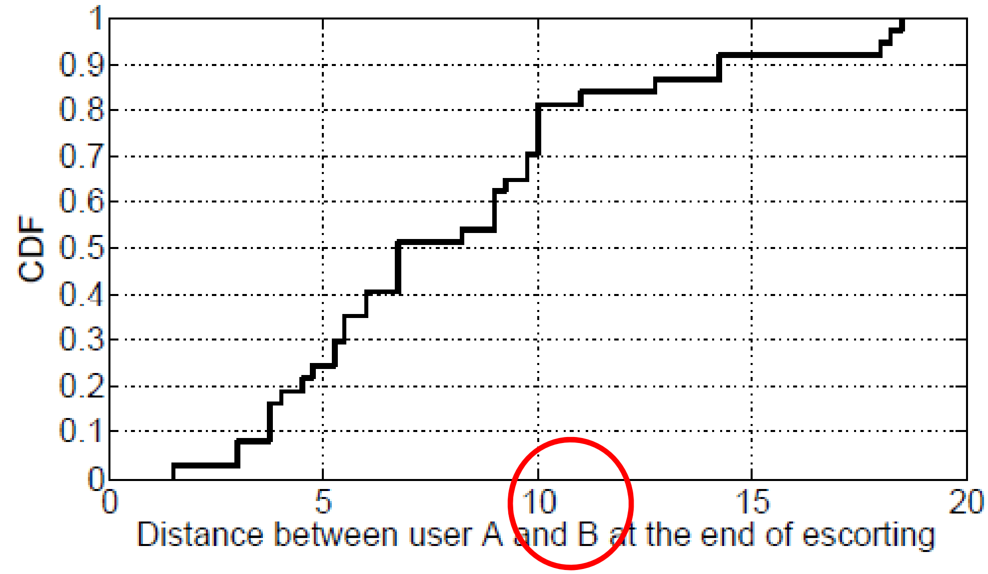


Figure 18: CDF of the final-distance error after routing in the parking lot.

Evaluation: Results

- Indoor

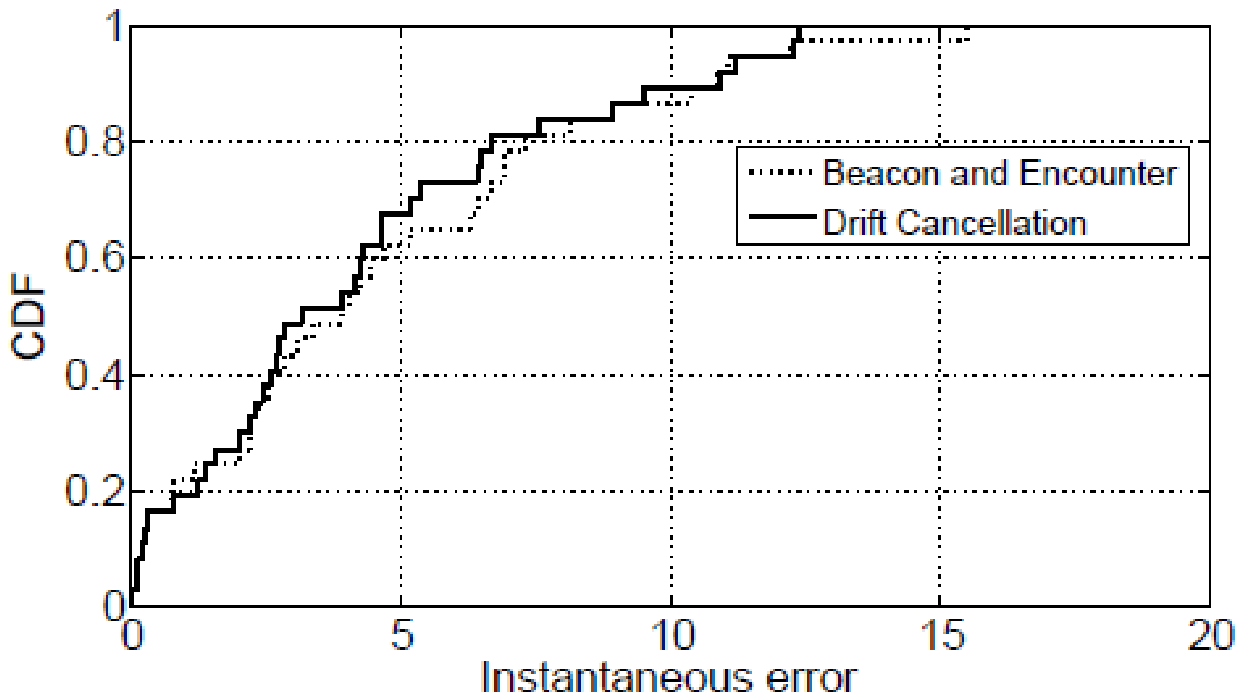


Figure 20: CDF of the instantaneous error in the indoor environment.

Evaluation: Results

- visual identification: color of clothes?

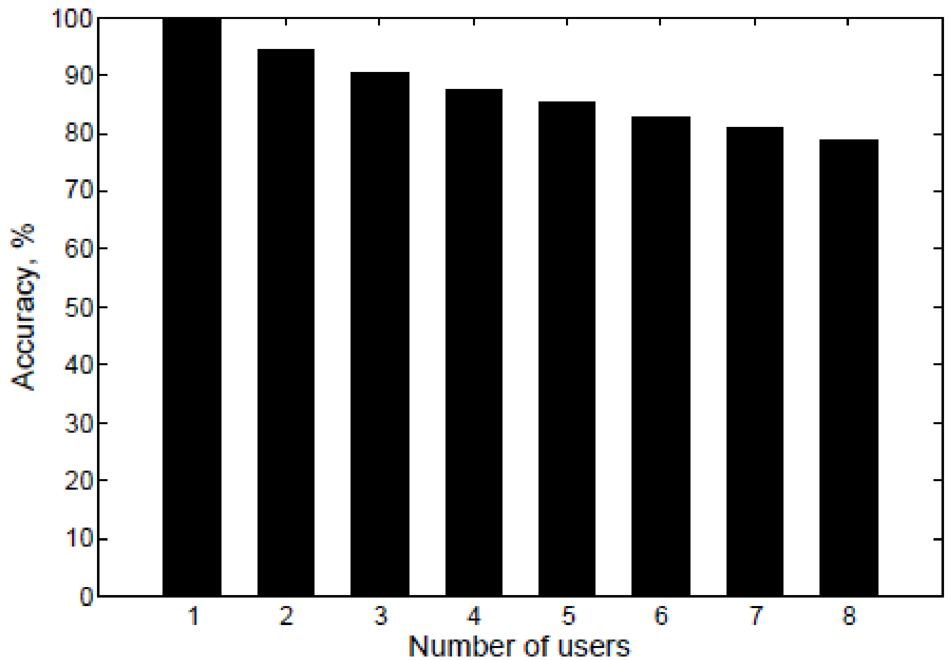


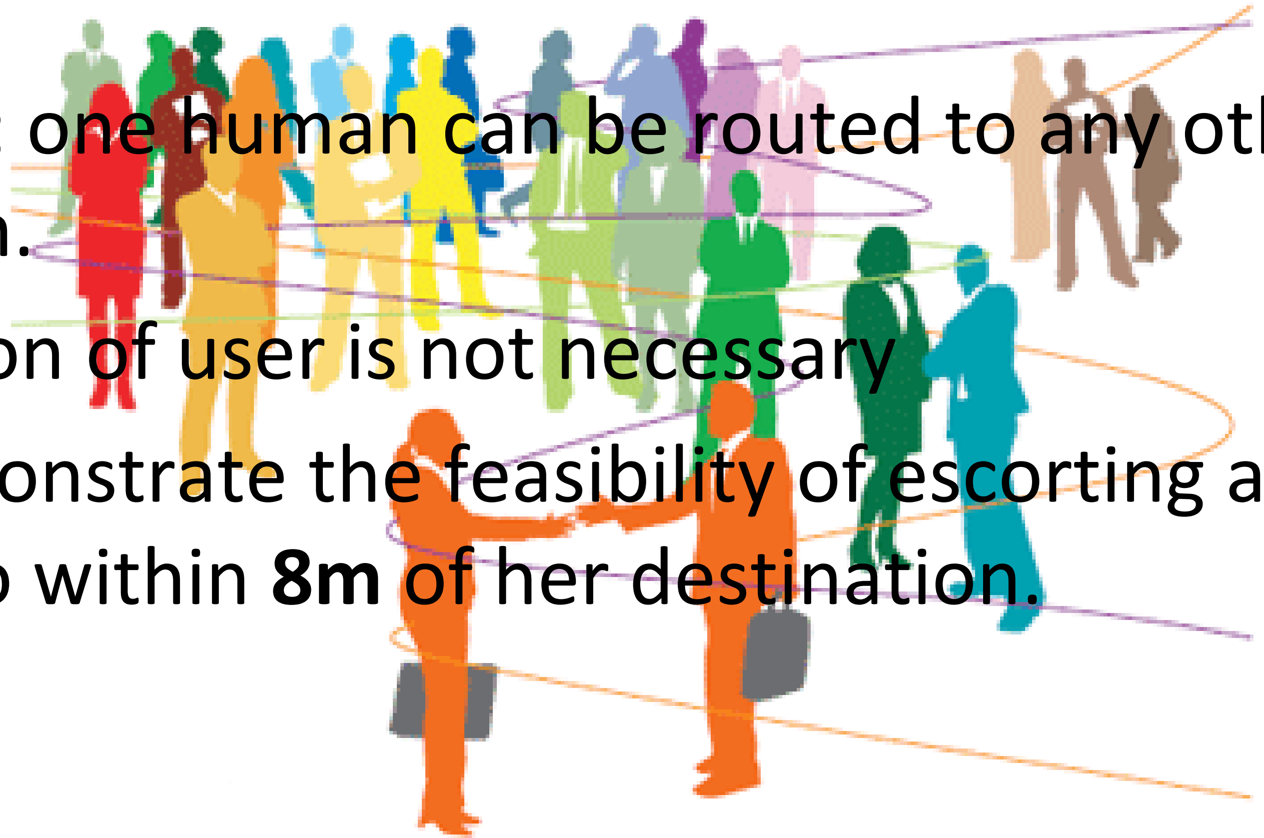
Figure 22: Accuracy of visual identification using the phone camera.

Future Work

- Energy- not efficient
- Routing through physical obstacles
- Long Routing Paths
- Routing Instructions under Low Location Accuracy
- Phone Placement

Conclusions:

- Escort: one human can be routed to any other human.
- Location of user is not necessary
- It demonstrate the feasibility of escorting a user to within **8m** of her destination.



Discussions

- Questions?
- Discussions?