Localization (3)

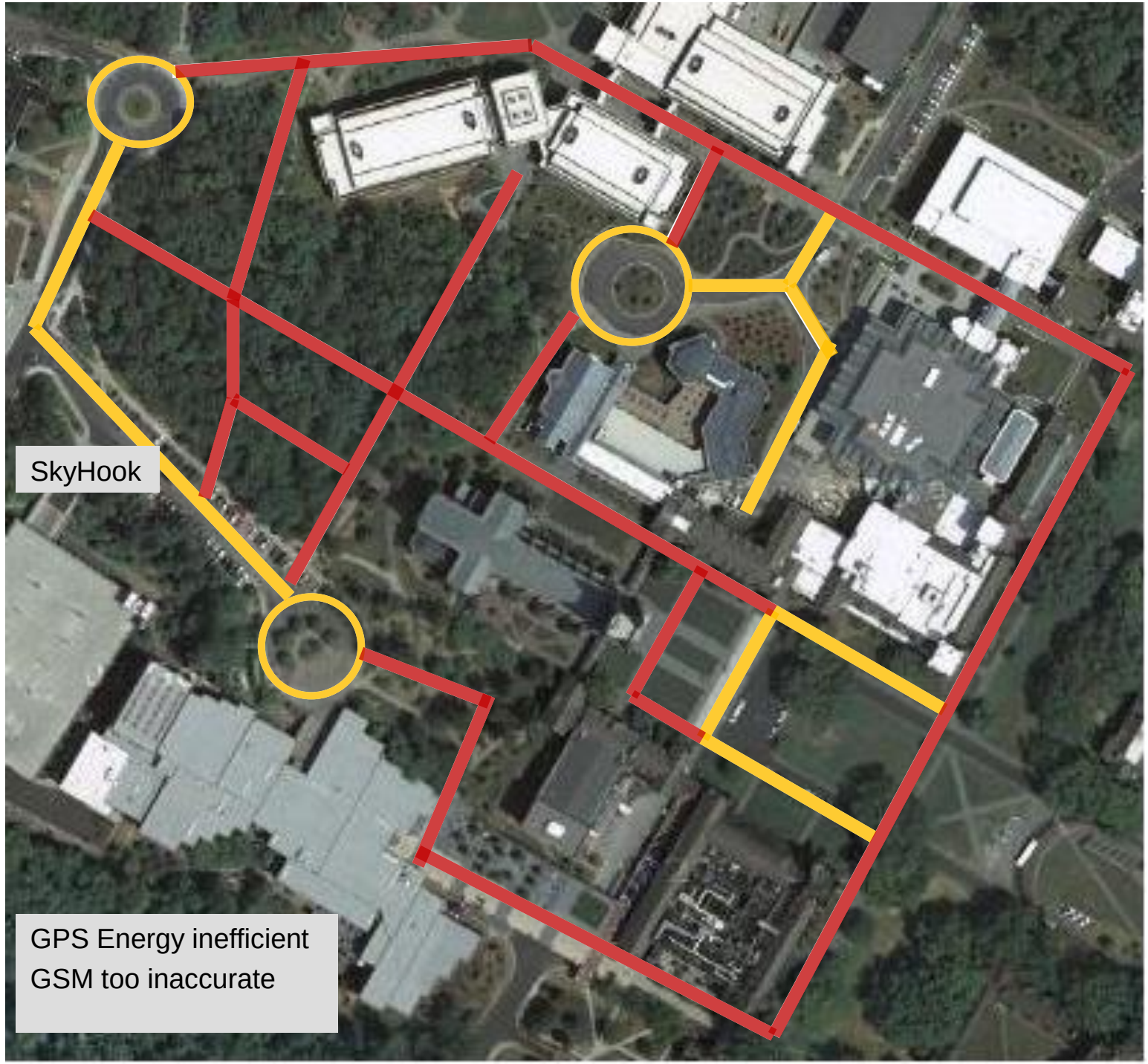
CSE 162 – Mobile Computing

Hua Huang
Department of Computer Science and Engineering
University of California, Merced

In this lecture

- Energy Efficient Localization on Mobile Devices
- Logical Localization using Mobile Devices

Energy Efficient Localization on Mobile Devices



GPS
No Eng. Eff. & Acc.
Solution

WiFi
Better than GPS Eng. Eff.

Recap: existing localization techniques have limitations

Technology	Pro	Con
Mobile GPS	High accuracy	High energy consumption
GSM Signature	Energy-efficient	Low accuracy
WiFi (Skyhook)	Medium accuracy & medium power	War-driving, AP infrastructure

Contents

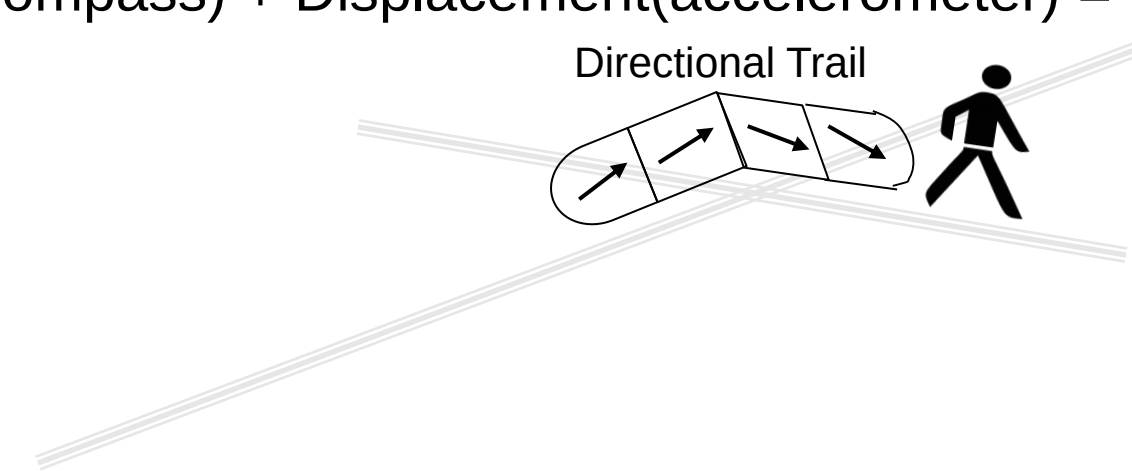
- CompAcc
- Evaluation
- Limitations and Future Work
- Conclusion

Goals

- No War-Driving
  - Cannot drive walking paths (campus, parks, …)
  - Expensive / Environment unfriendly
- No reliance on WiFi infrastructure
  - Rural regions / developing countries
- Good accuracy (~GPS)
- Improve energy-efficiency
  - Better than Skyhook, GPS

CompAcc: Basic Idea

- Direction(compass) + Displacement(accelerometer) = User's directional trail



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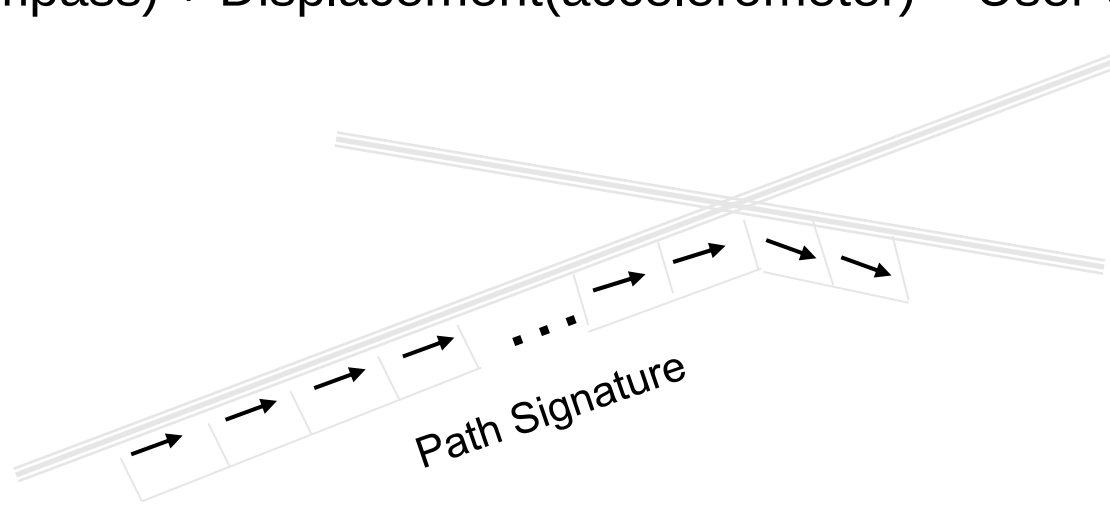

- Compute path signatures
  - Derived from a local electronic map (Google Maps)

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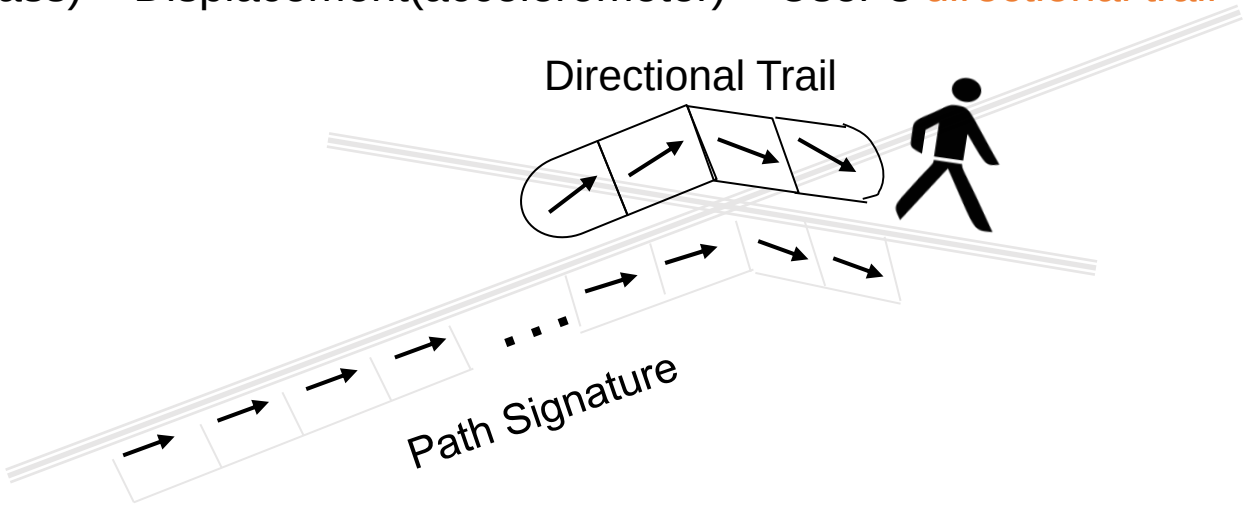
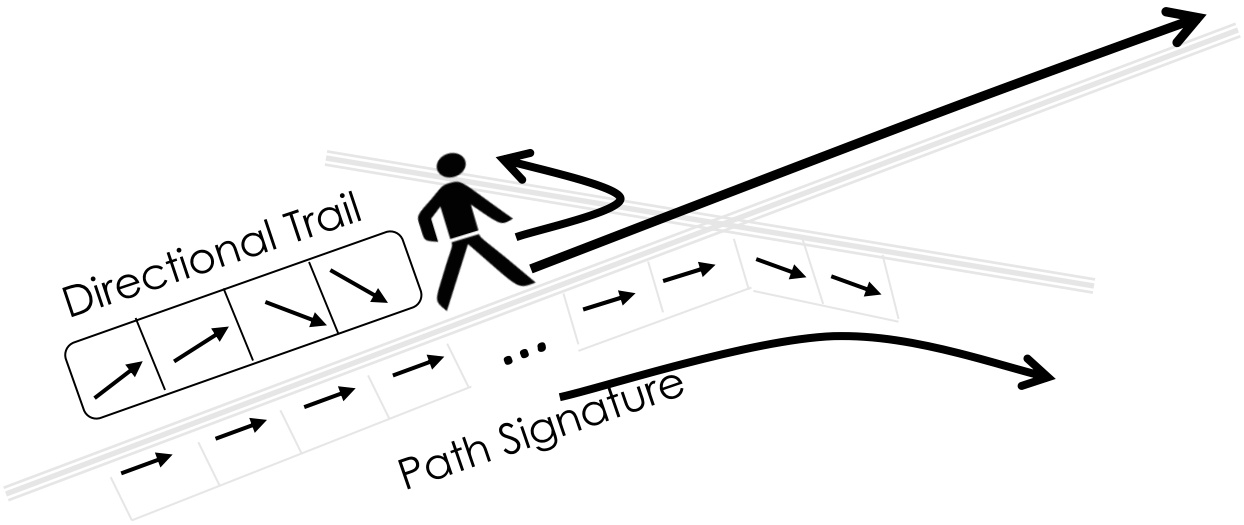


- Compute path signatures
  - Derived from a local electronic map (Google Maps)

- Compare directional trail with path signatures
  - Best match provides the user location

Correct location errors at turns



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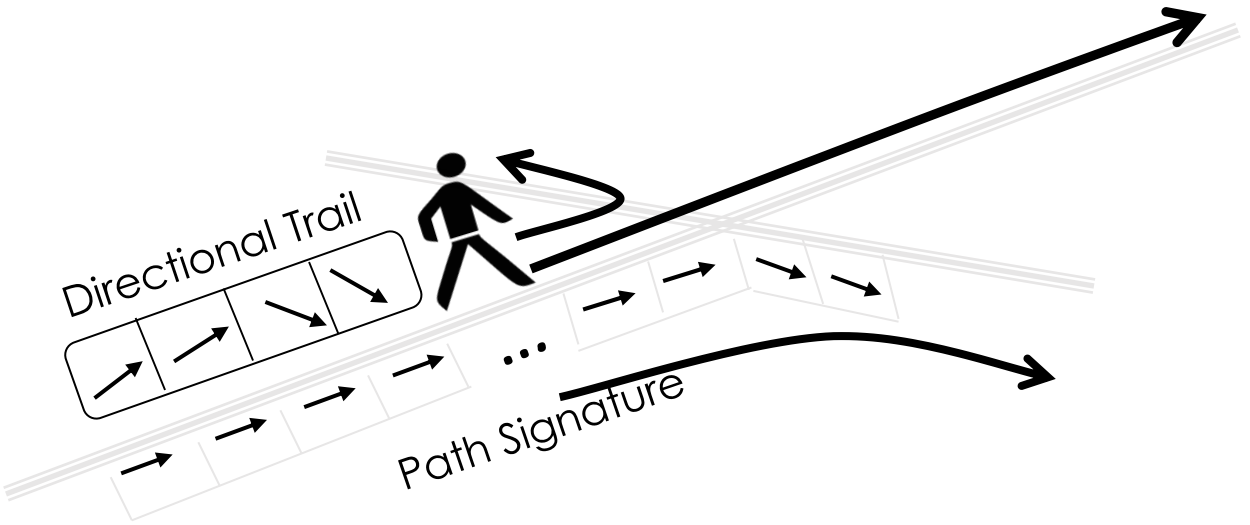
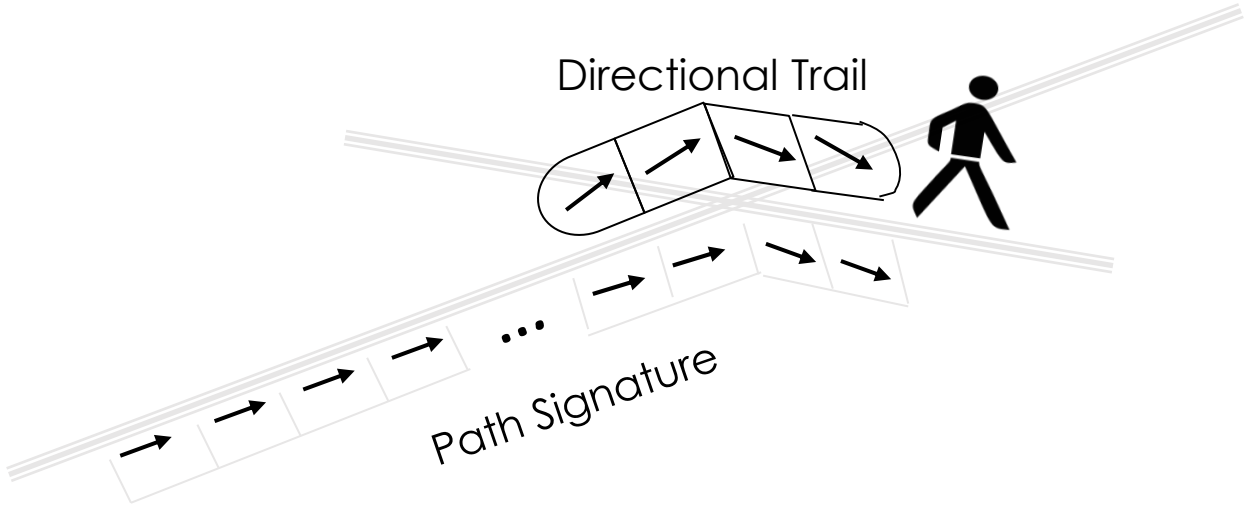
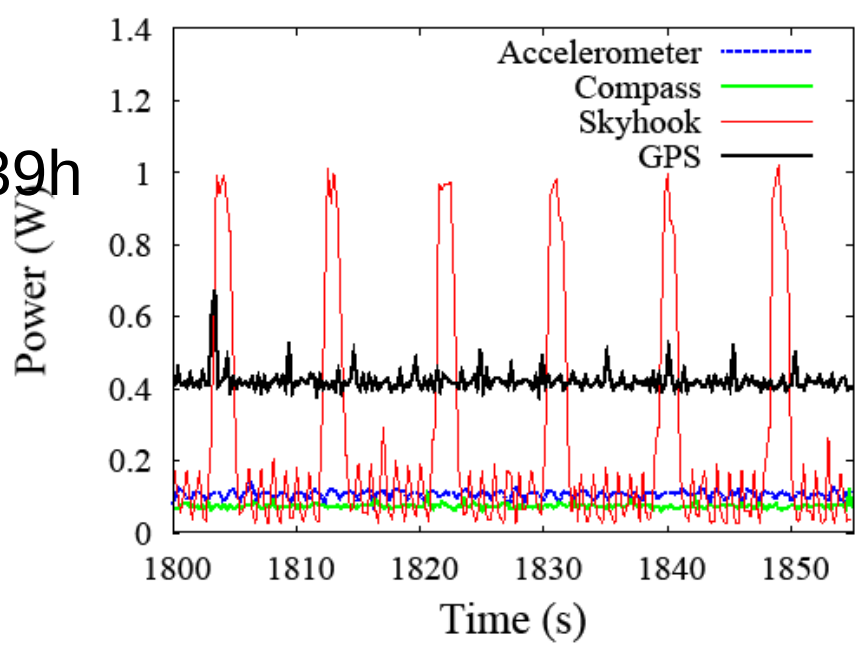




Advantages

- No war-driving
- No reliance on WiFi infrastructure
  - Maps available ubiquitously
- Improves battery lifetime
  - GPS ~10h
  - WiFi ~16h
  - Accelerometer ~ 39h
  - Compass ~48h



Architecture

1. Initial location GPS:
(lat X, long Y)

Tile
Database

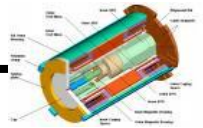
Tile

3. Obtain paths in
the user vicinity

6. Current location
(lat A, long B)

2. Report initial location
(lat X, long Y)

4. Direction
(Compass)



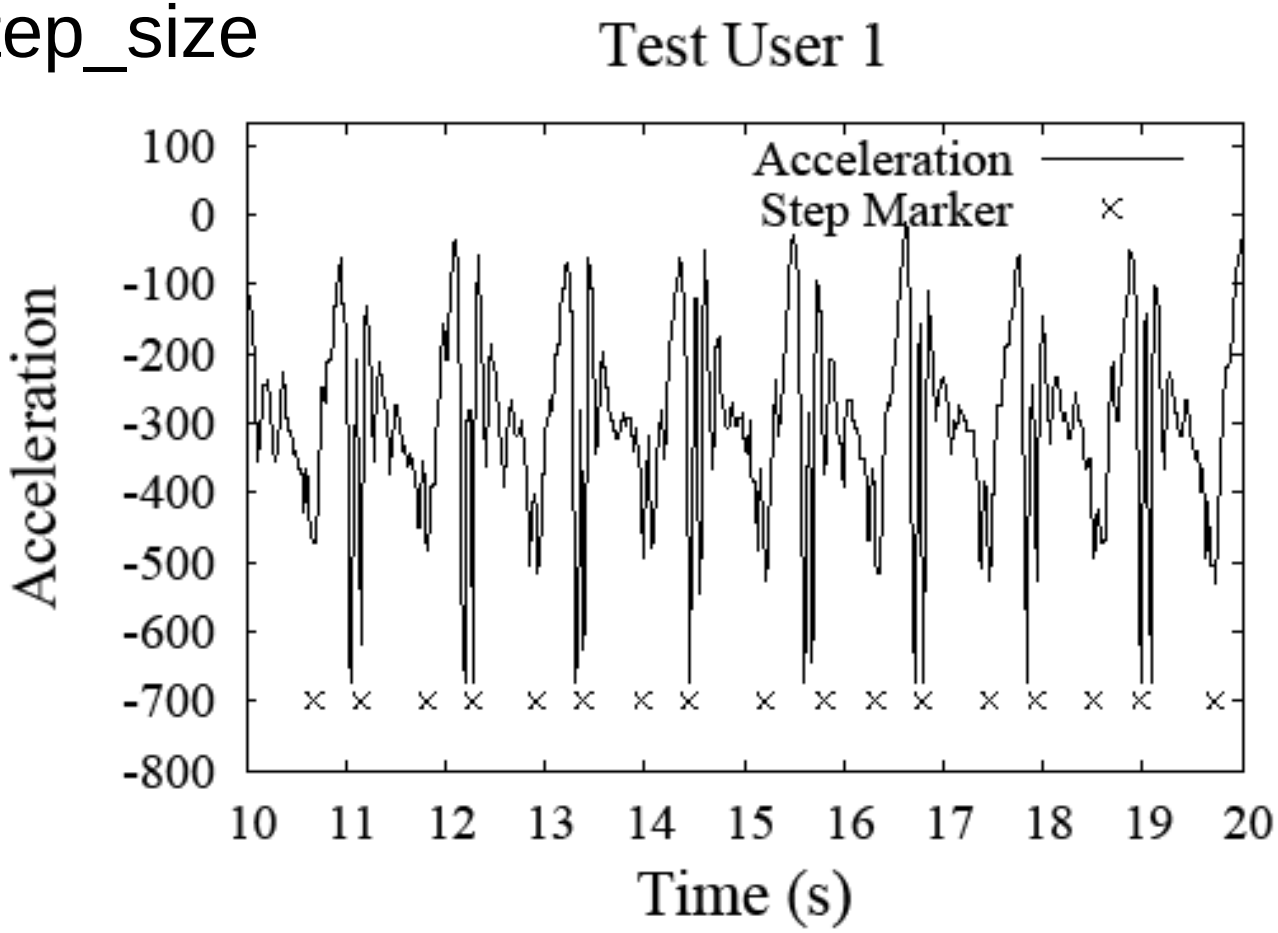
5. Displacement
(Accelerometer)

Initial location
Directional trail
Current location

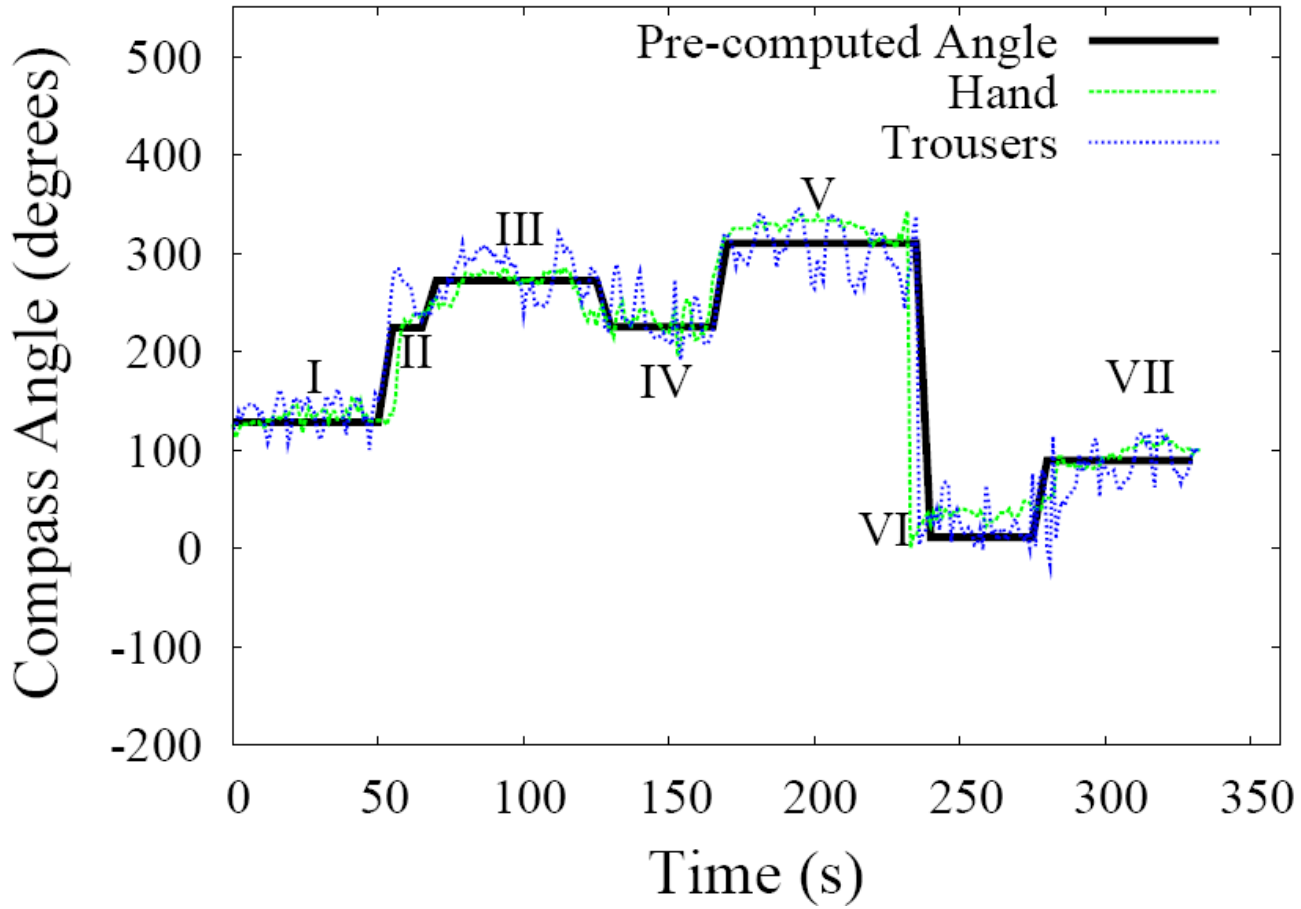
CompAcc

Directional trail: displacement

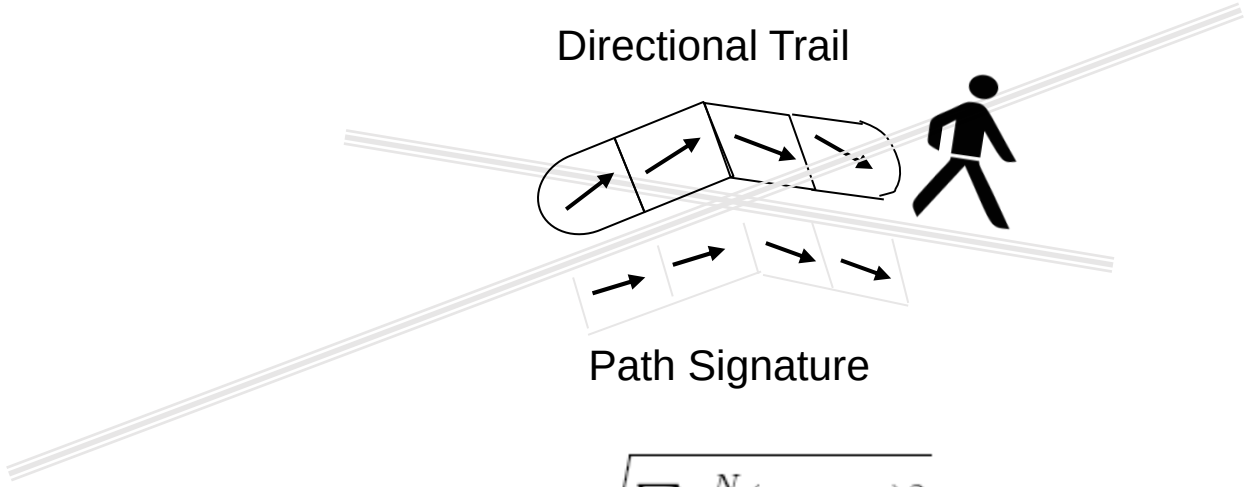
- Accelerometer based step count
- displacement = step_count * step_size



Directional trail: direction



Matching Directional Trail with Path Signatures



$$\phi_0 = \sqrt{\frac{\sum_{i=0}^{-N}(c_i - p_i)^2}{N}}$$

Dissimilarity Metric:

c_i = compass readings
p_i = path computed direction
N = directional trail size

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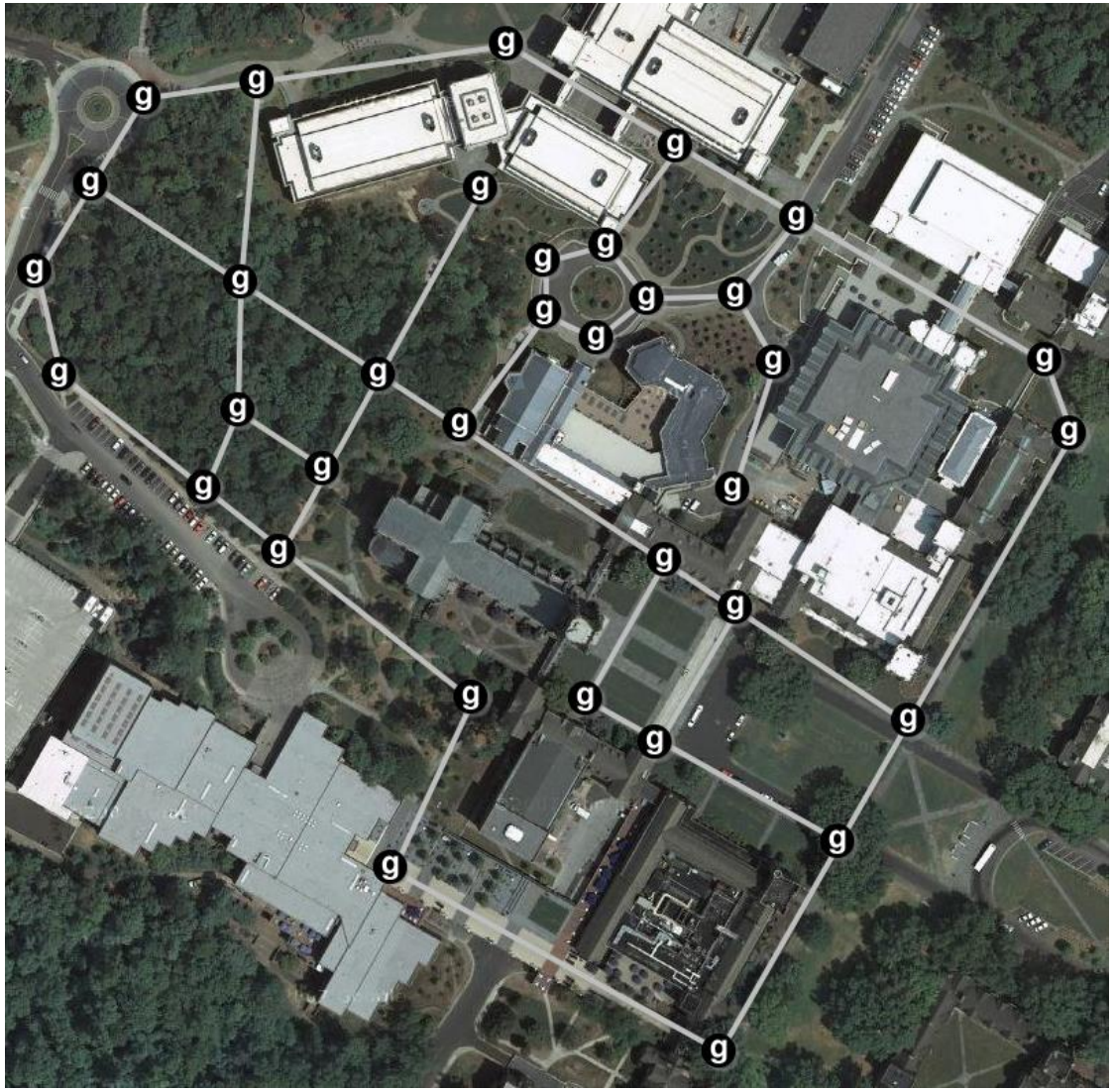
Experiment Site



Results

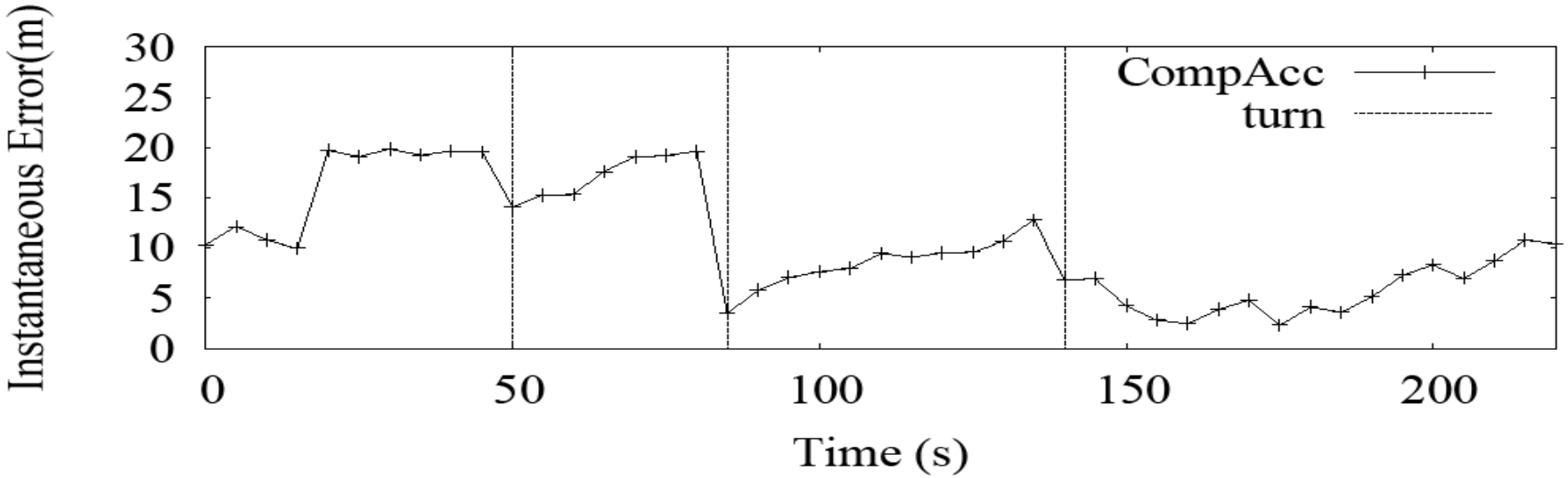
- Compared 3 localization schemes
  - CompAcc
  - WiFi-War_Drive (Skyhook)
  - Wifi-War-Walk (We war-droved walking paths in campus)

- Metrics

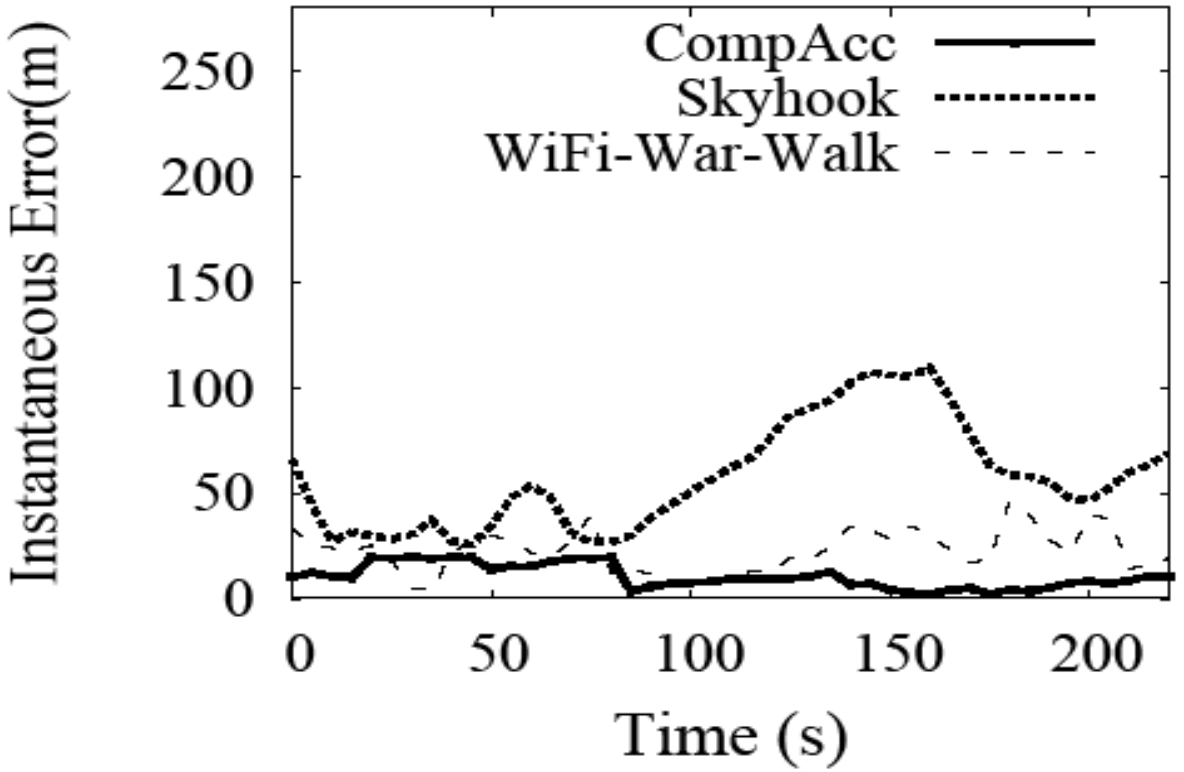
  Instantaneous Error = distance(estimated, real)

  Average Localization Error (ALE) = Average Instantaneous Error

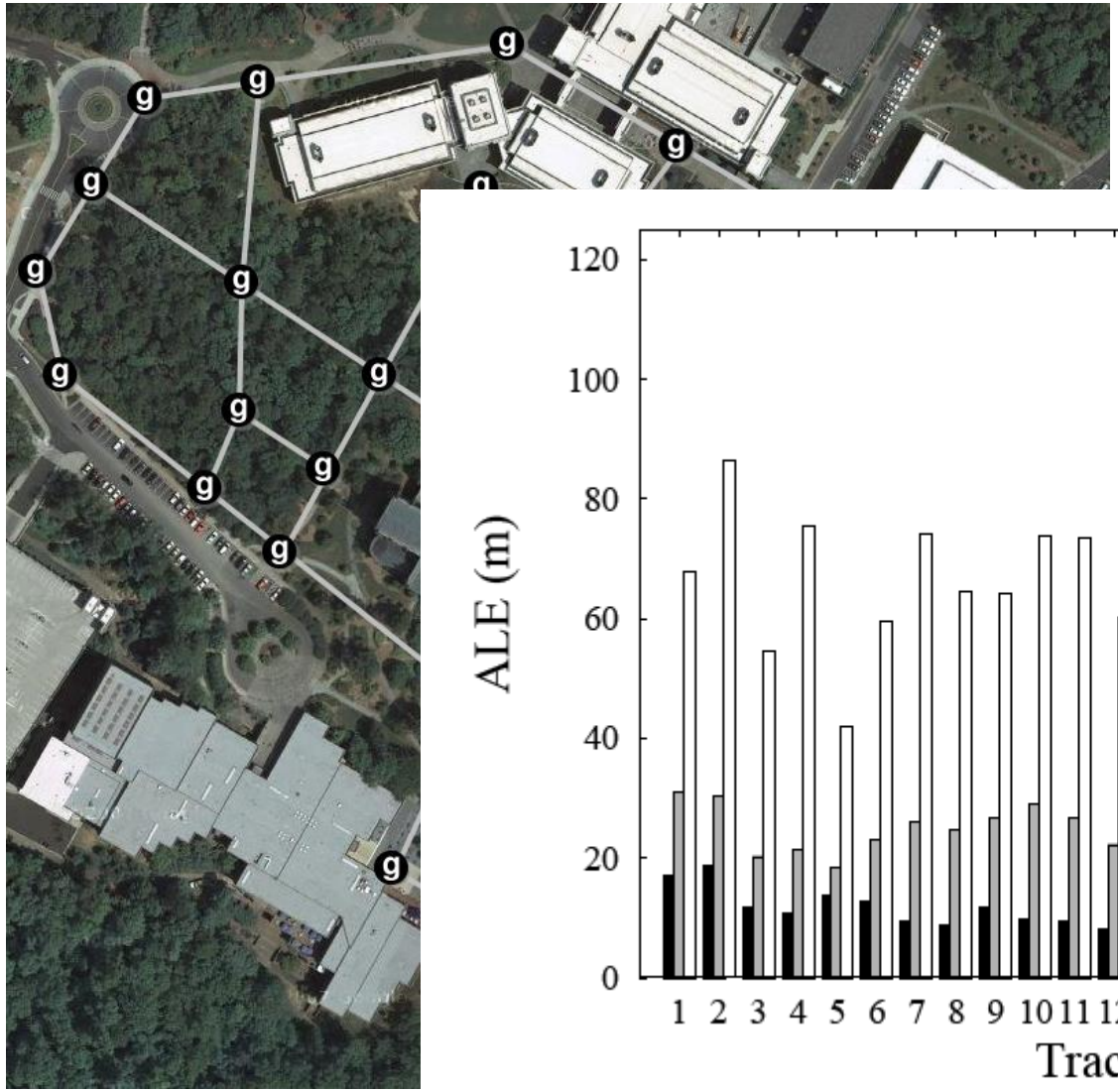
CompAcc Instantaneous Error



CompAcc Instantaneous Error

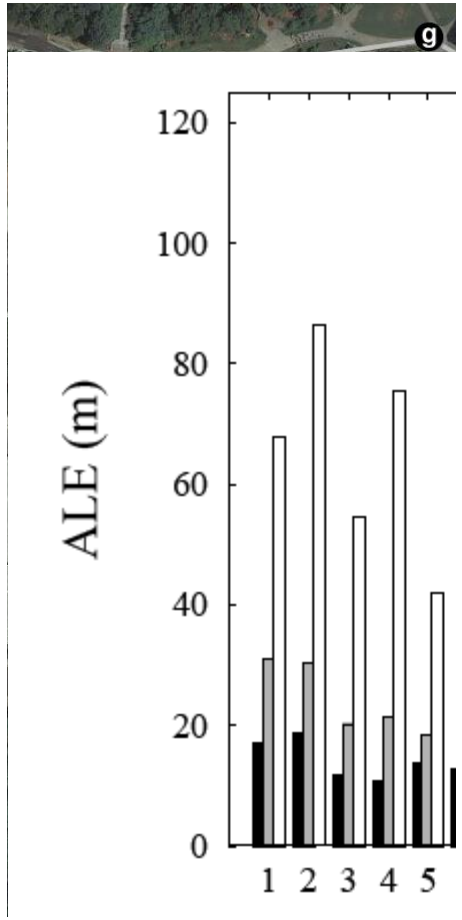


Results



CompAcc
WiFi-War-Walk
Skyhook
ALE (m)
0
20
40
60
80
100
120
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
Trace Index

Results



Average ALE
GPS: 10m
CompAcc: 11m
WiFi-War-Walk: 30m
Skyhook: 70m

Energy
GPS: 10h
CompAcc: 23h
WiFi-War-Walk:16h
Skyhook:16h

Logical Localization using Mobile Devices

Location Based Services

- An application that provides users with information based on the geographical position of the mobile device
- Main difference from other applications/systems
  - Availability of the user’s position in real-time
  - This single difference makes a BIG difference
- Initial LBS systems were subscription-based
  - Traffic congestion notifications based on road selections
  - Received congestion updates about I-75 when on travel in NYC!

Location Based Services

- LBS can be either Reactive (“pull”) or Proactive (“push”)
- A Reactive LBS application is triggered by the user who queries the system in search of information based on the current location
- **Reactive LBS** examples
  - Finding restaurants or places of interest
  - Obtaining directions
  - Obtaining weather information
  - Sending emergency notifications to police, insurance companies, roadside assistance companies, etc.

Location Based Services

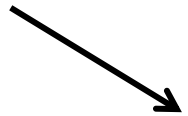
- In Proactive LBS applications, the system needs to continuously know where you are.
- Localization queries or actions are automatically triggered once a predefined set of conditions are met
- **Proactive LBS** examples
  - Geofencing, e.g., children outside predefined boundary
  - Fleet management
  - Real-time traffic congestion notifications
  - Real-time friend finding
  - Proximity-based actuation
  - Travel assistant device for riding public transportation, tourism, museum guided visits, etc

Questions: Proactive or Reactive?

- Location-based advertisement
- Payment based on proximity (EZ pass, toll watch)
- Play a local radio station
- App shows grocery list when near Walmart
- App queries users at a museum

Most emerging location based apps

do not care about the **physical location**



GPS: Latitude, Longitude

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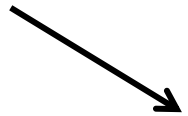
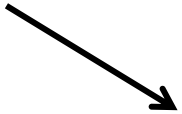


GPS: Latitude, Longitude

Instead, they need the user's **logical location**



Starbucks, RadioShack,
Museum, Library

Physical Vs Logical

- Unfortunately, most existing solutions are physical
  - GPS
  - GSM based
  - SkyHook
  - Google Latitude
  - RADAR
  - Cricket
  - …

Given this rich literature,

Why not convert from
Physical to Logical Locations?

Physical Location Error


Starbucks
Pizza Hut
Physical Location Error

The dividing-wall problem

SurroundSense:

A Logical Localization Solution

Hypothesis

It is possible to localize phones by sensing the ambience

such as sound, light, color, movement, WiFi …

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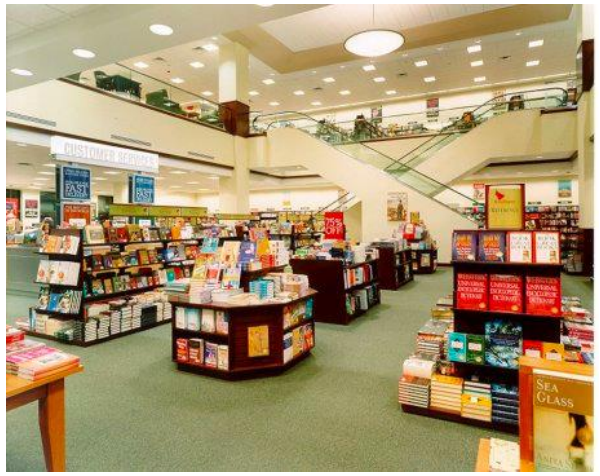
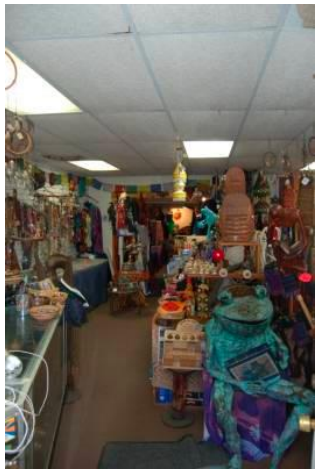


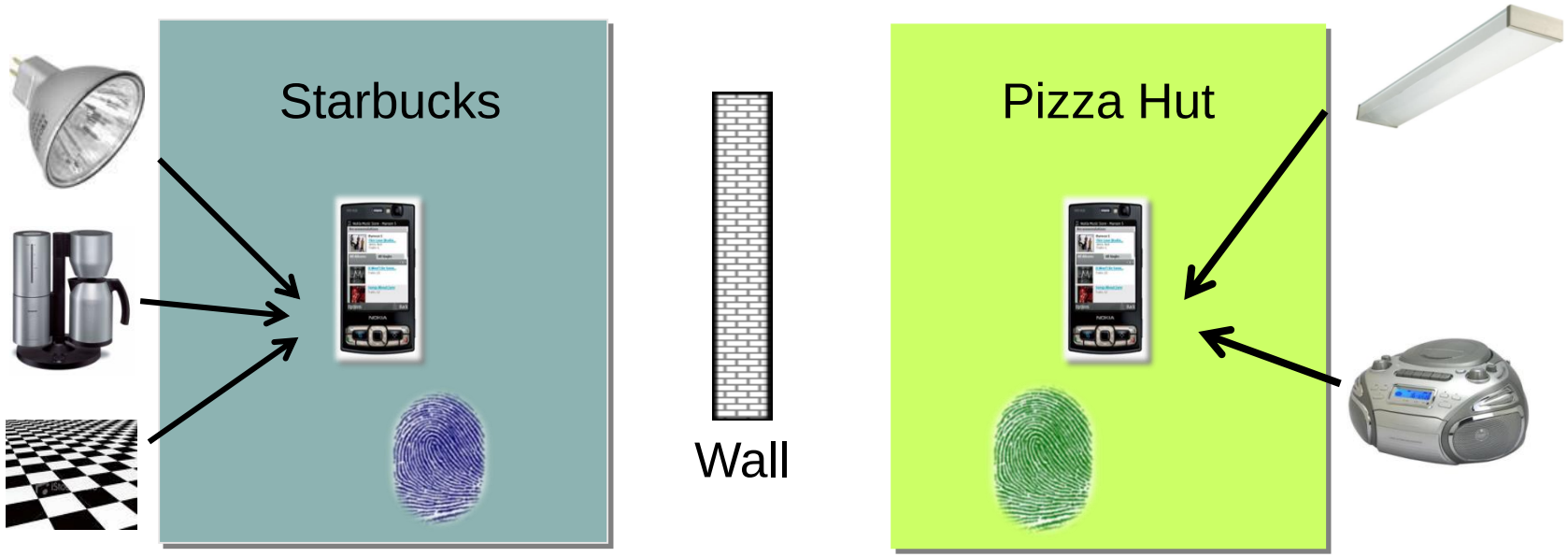


Multi-dimensional sensing extracts more ambient information

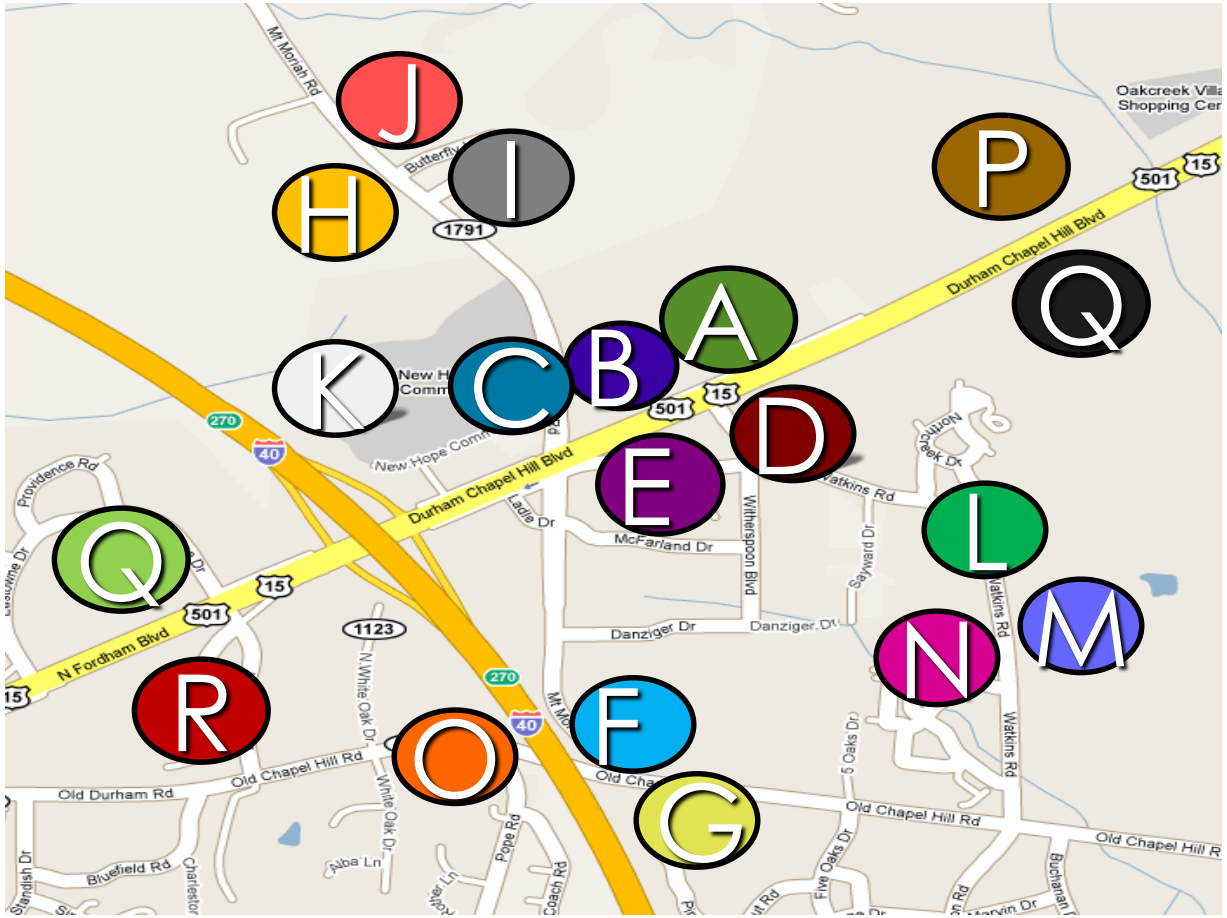
Any one dimension may not be unique, but put together, they may provide a unique fingerprint

SurroundSense

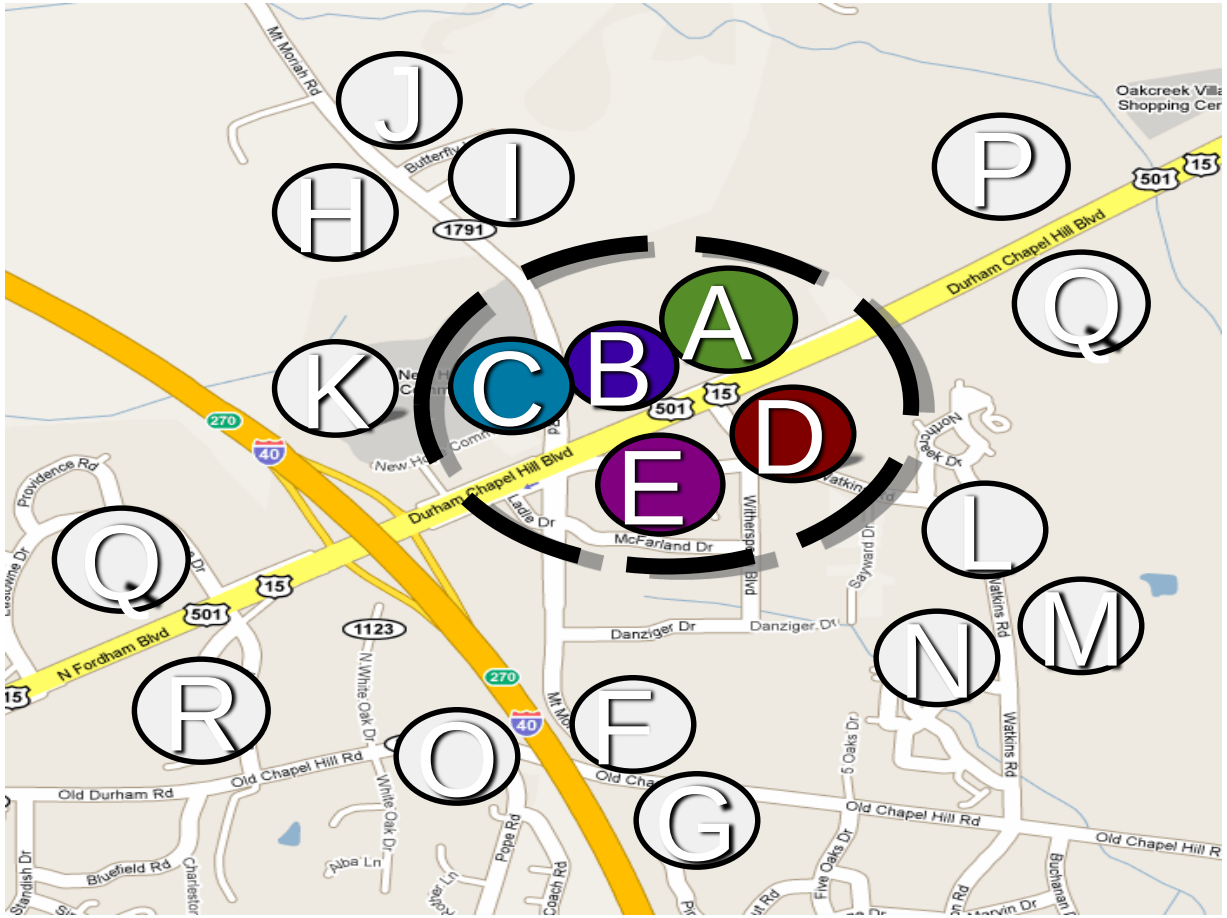
- Multi-dimensional fingerprint
  - **Based on ambient sound/light/color/movement/WiFi**



Should Ambiences be Unique Worldwide?



GSM provides macro location (strip mall)
SurroundSense refines to Starbucks



Why does it work?

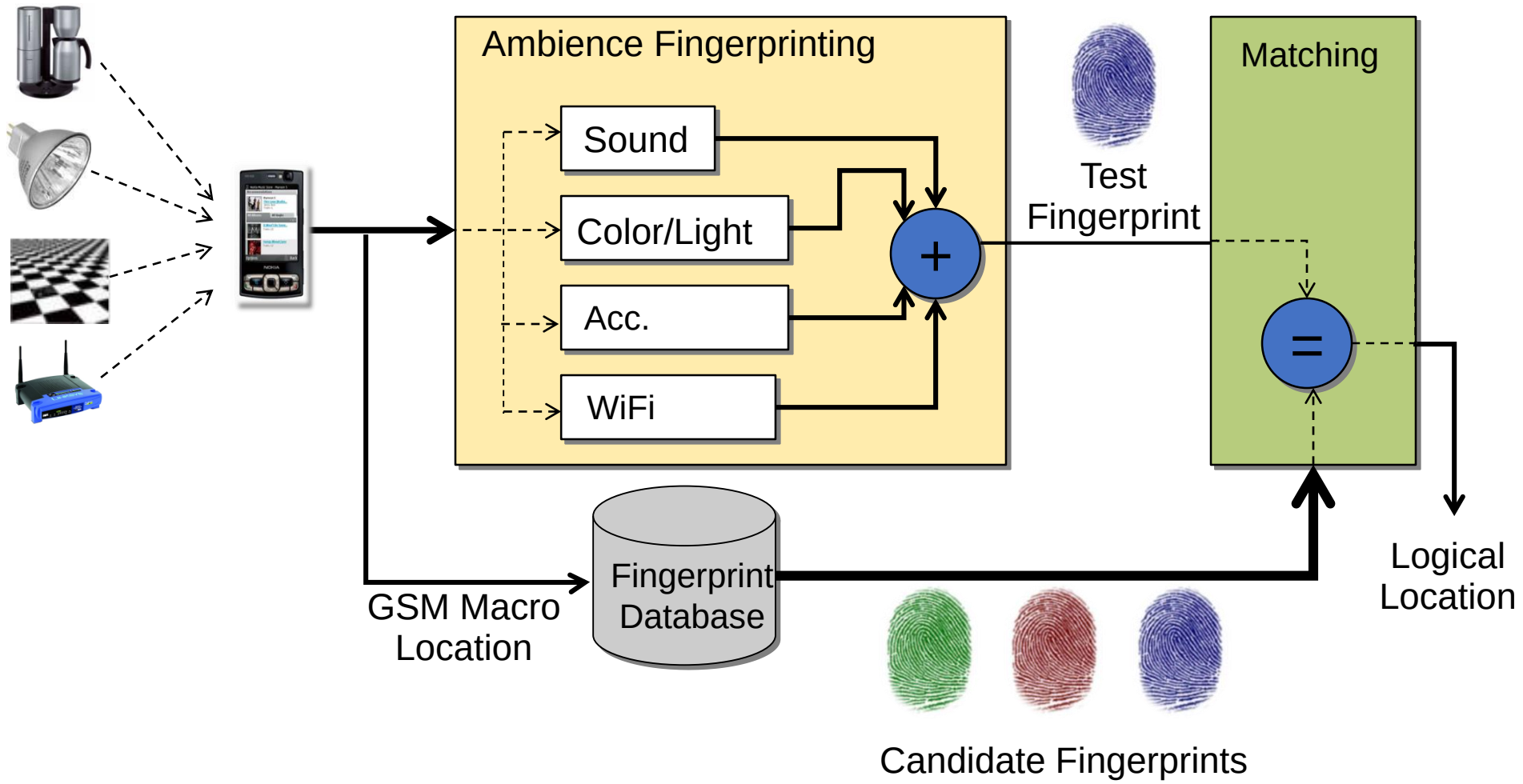
The Intuition:

Economics forces nearby businesses to be diverse

Not profitable to have 3 adjascent coffee shops with same lighting, music, color, layout, etc.

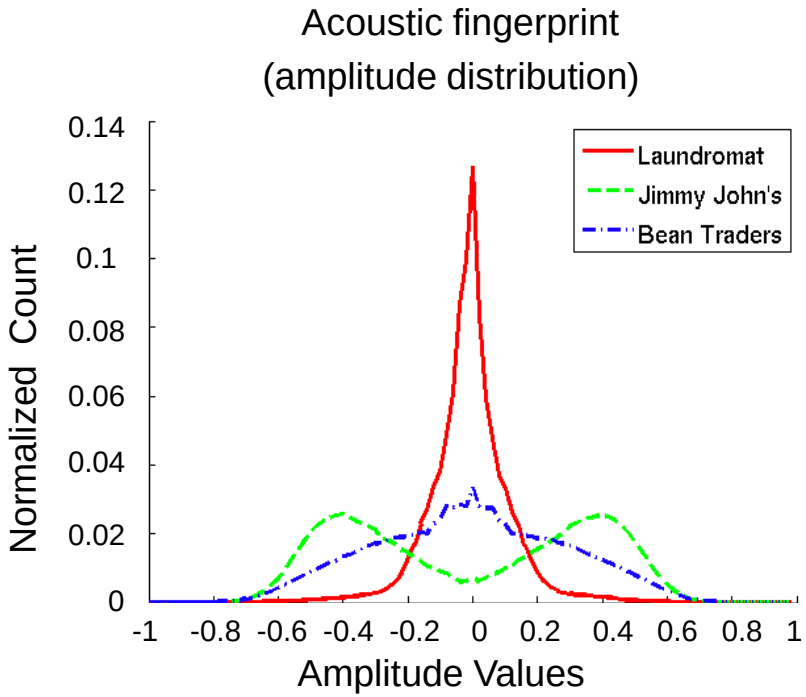
SurroundSense exploits this ambience diversity

SurroundSense Architecture

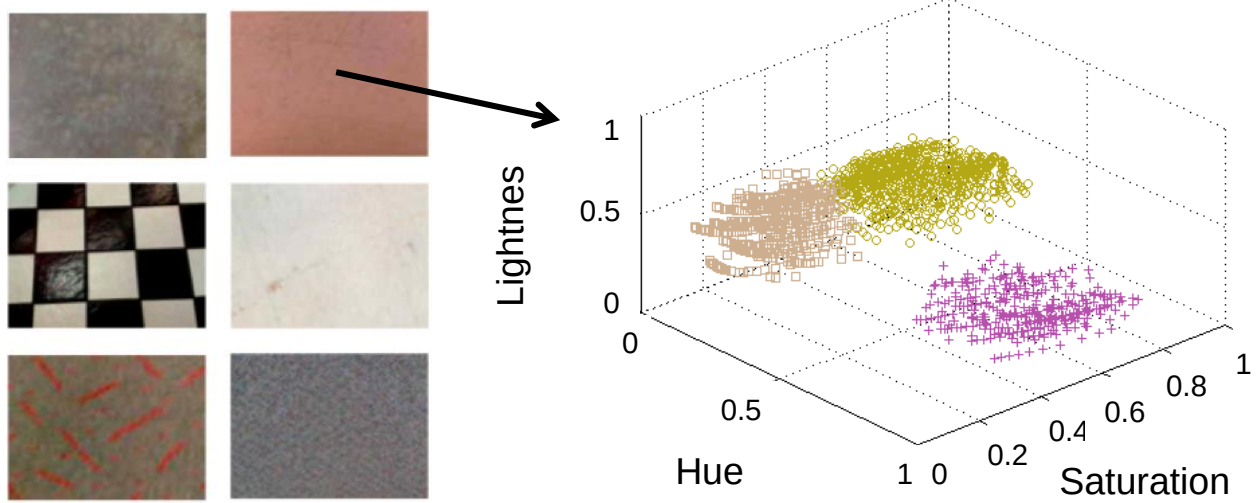


Fingerprints

■Sound:
(via phone microphone)



■Color:
(via phone camera)



Fingerprints

- Movement: (via phone accelerometer)

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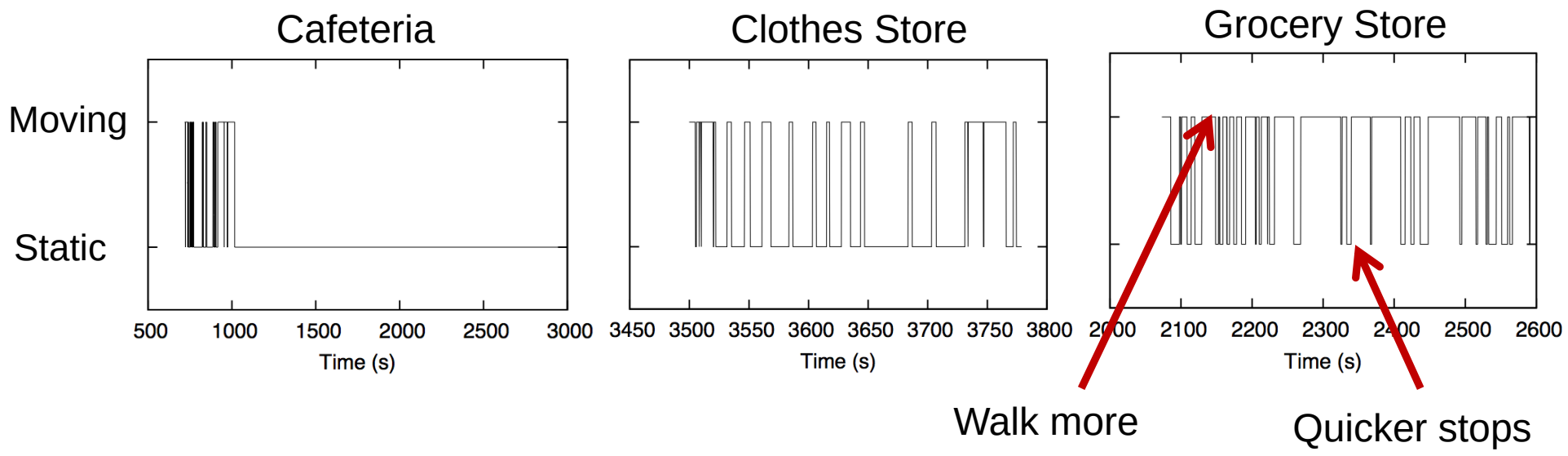


Fingerprints

- WiFi: (via phone wireless card)

f(overheard WiFi APs)

Discussion

- Time varying ambience
  - **Collect ambience fingerprints over different time windows**
- What if phones are in pockets?
  - **Use sound/WiFi/movement**
  - **Opportunistically take pictures**
- Fingerprint Database
  - **War-sensing**

Evaluation Methodology

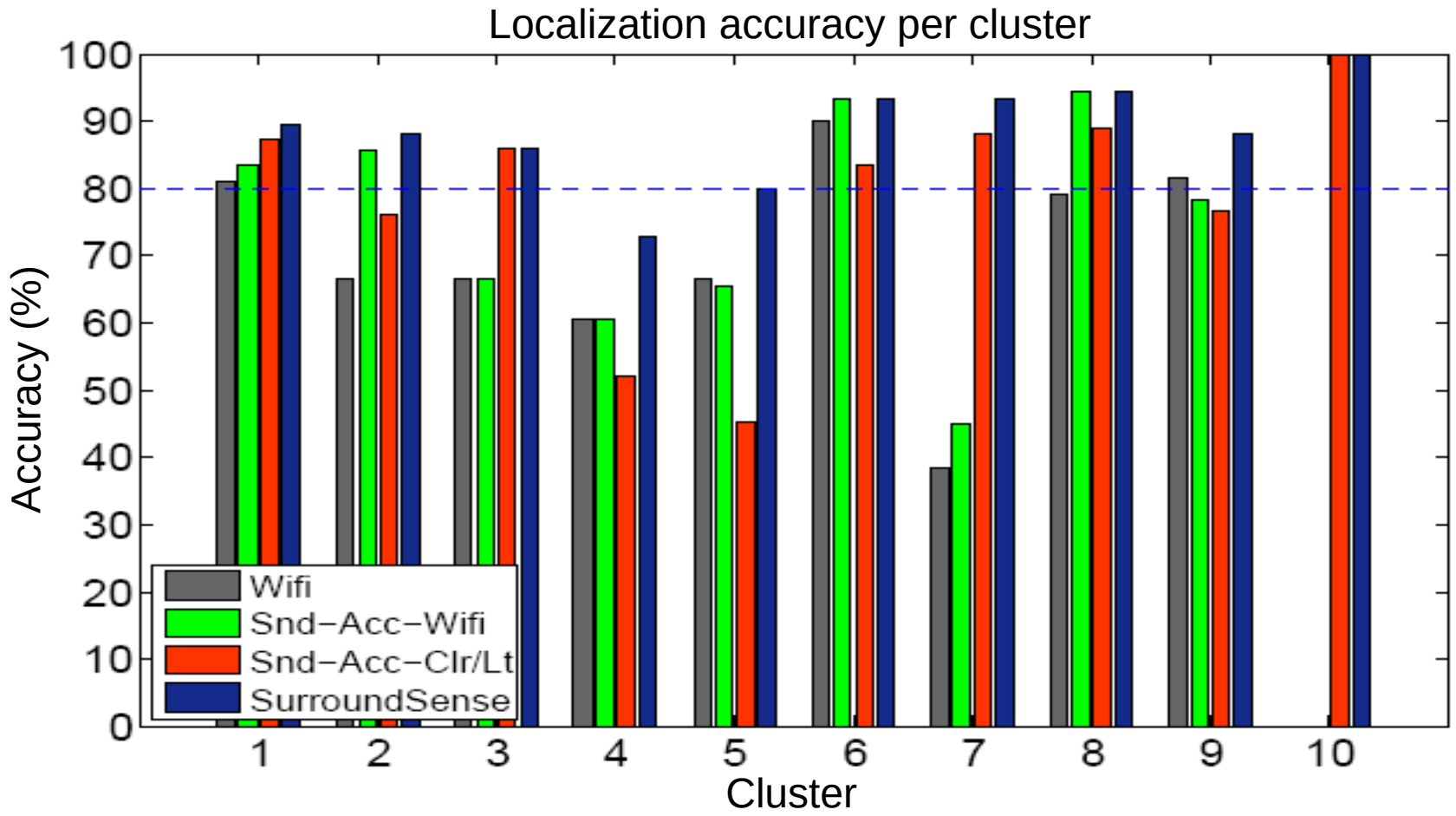
- 51 business locations
  - **46 in Durham, NC**
  - **5 in India**

- Data collected by 4 people
  - **12 tests per location**

- Mimicked customer behavior

Evaluation: Per-Cluster Accuracy

Cluster	1	2	3	4	5	6	7	8	9	10
No. of Shops	4	7	3	7	4	5	5	6	5	5



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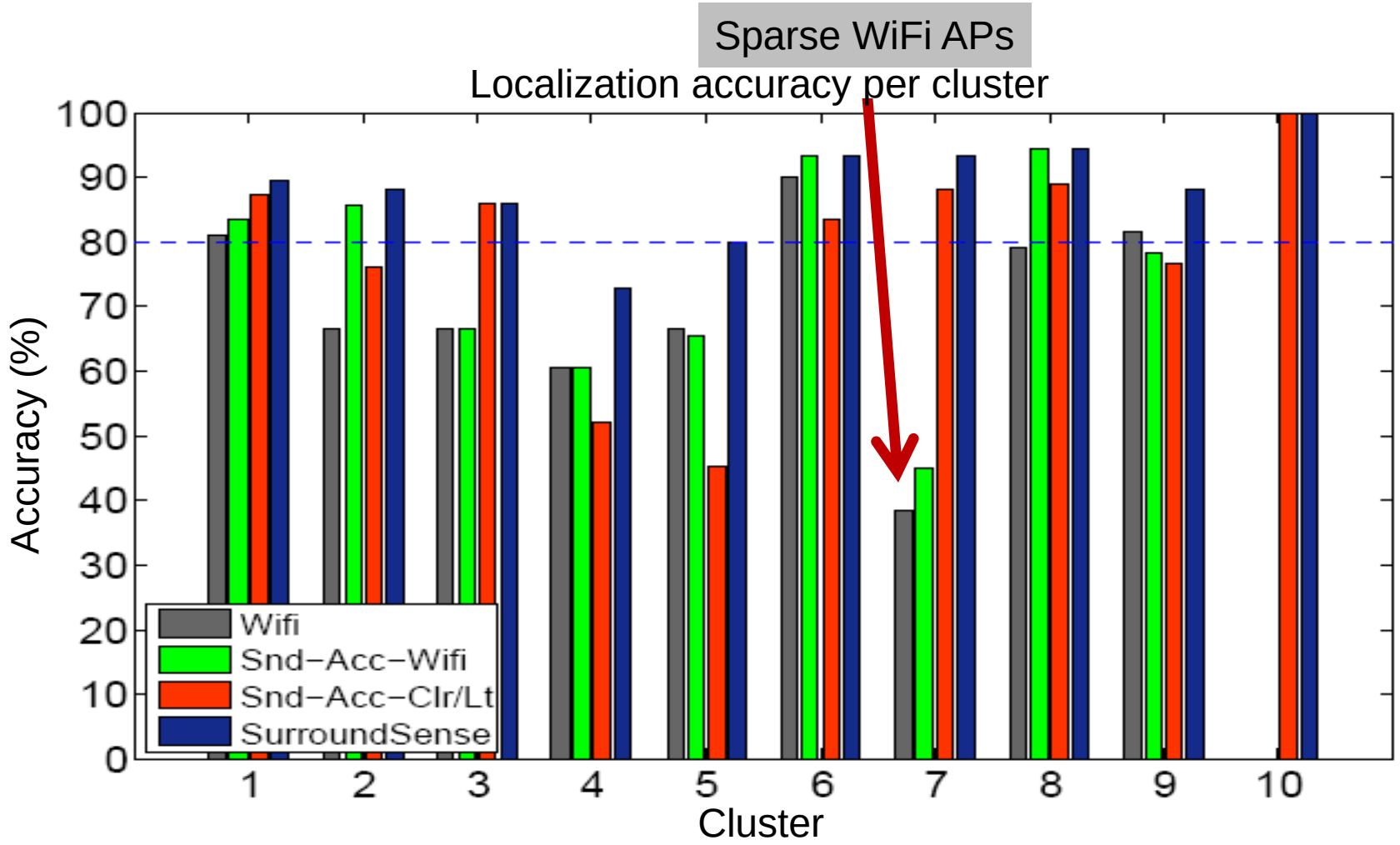

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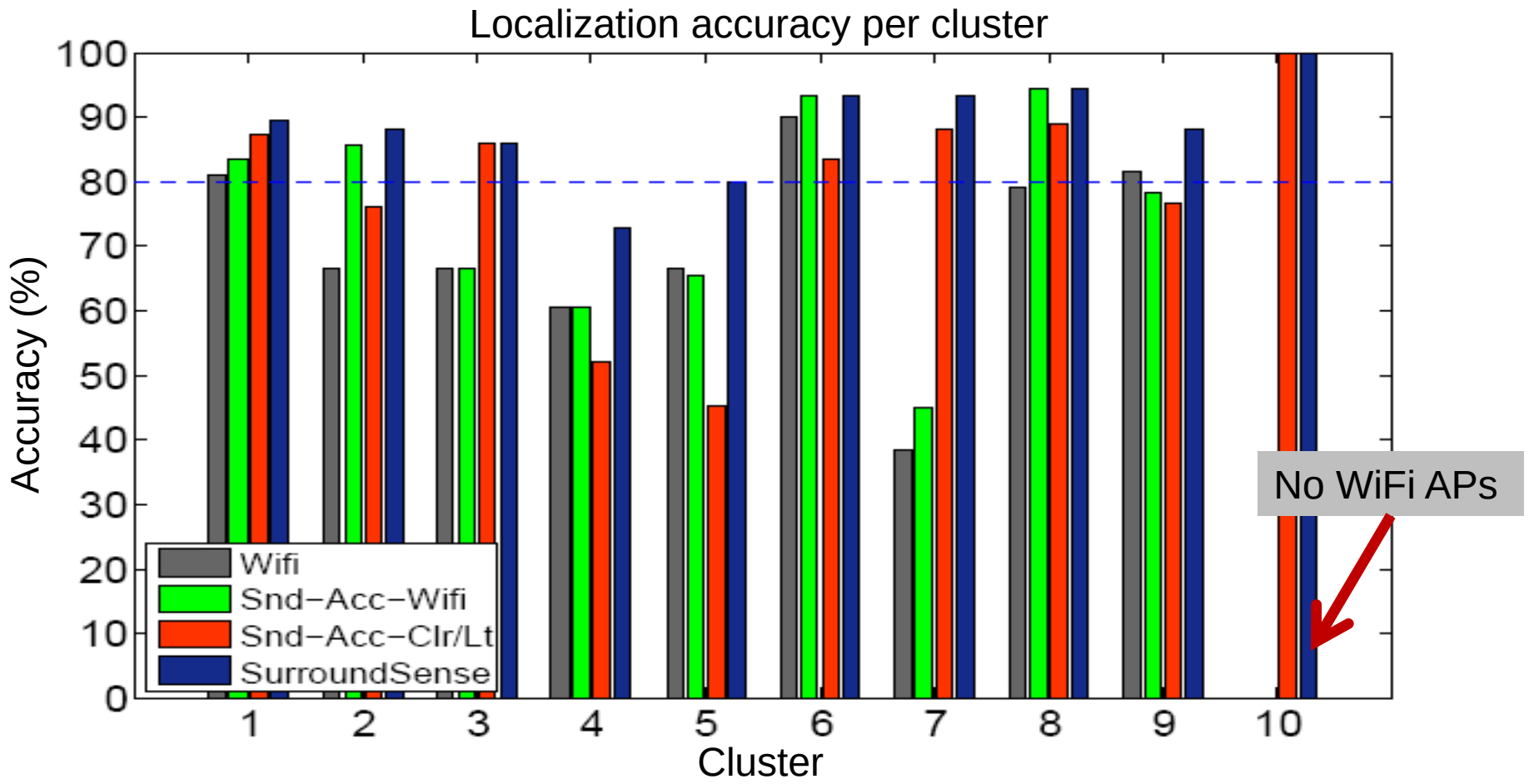
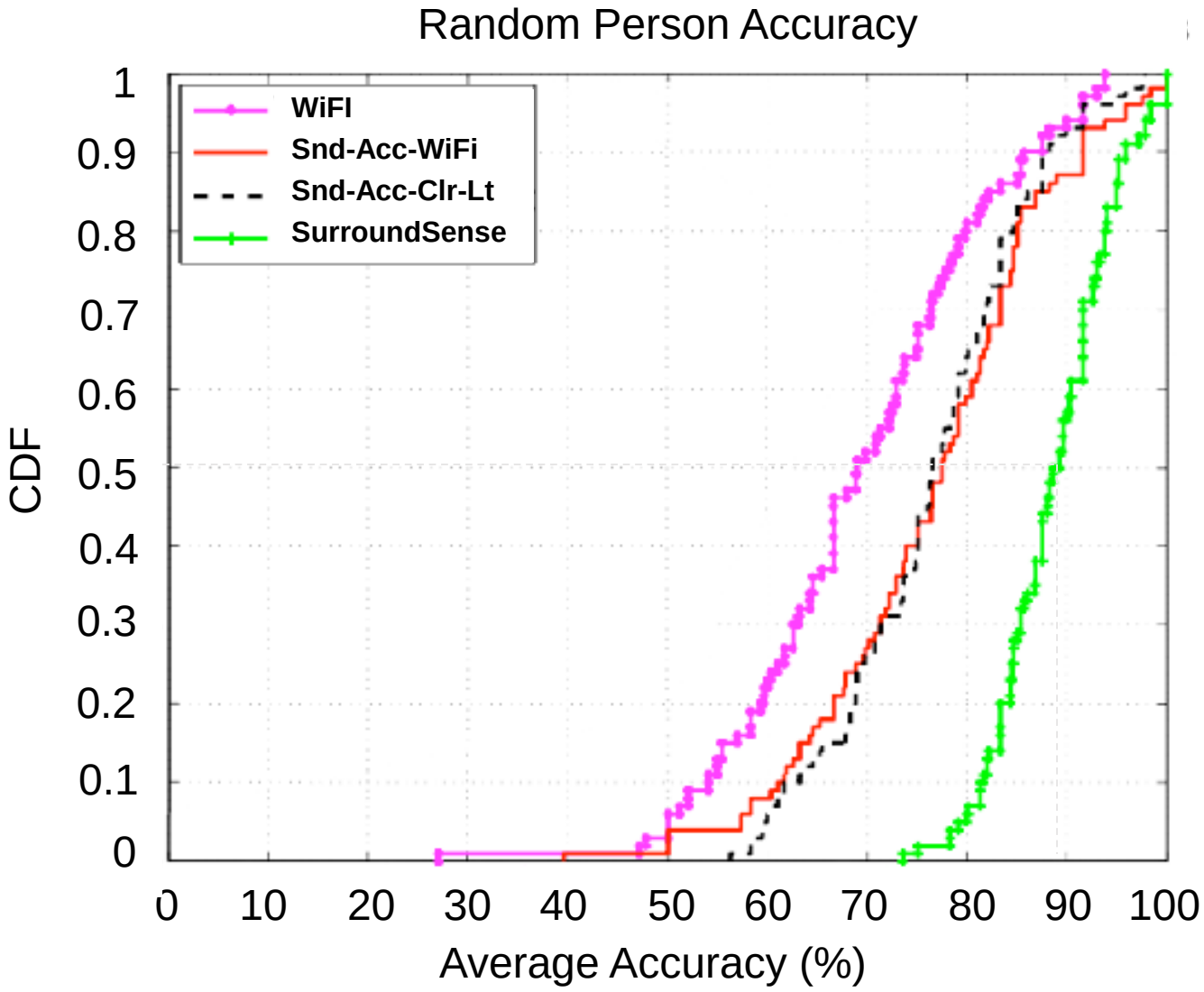


Evaluation: Per-Scheme Accuracy

Mode	WiFi	Snd-Acc-WiFi	Snd-Acc-Lt-Clr	SS
Accuracy	70%	74%	76%	87%

Evaluation: User Experience



Limitations and Future Work

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Limitations and Future Work

- Energy-Efficiency
  - **Continuous sensing likely to have a large energy draw**
- Localization in Real Time
  - **User's movement requires time to converge**
- Non-business locations
  - **Ambiences may be less diverse**

Conclusion

Ambience can be a great clue about location

Ambient Sound, light, color, movement …

None of the individual sensors good enough

Combined they may be unique

Uniqueness facilitated by economic incentive

Businesses benefit if they are mutually diverse in ambience

Ambience diversity helps SurroundSense

Current accuracy of 89%