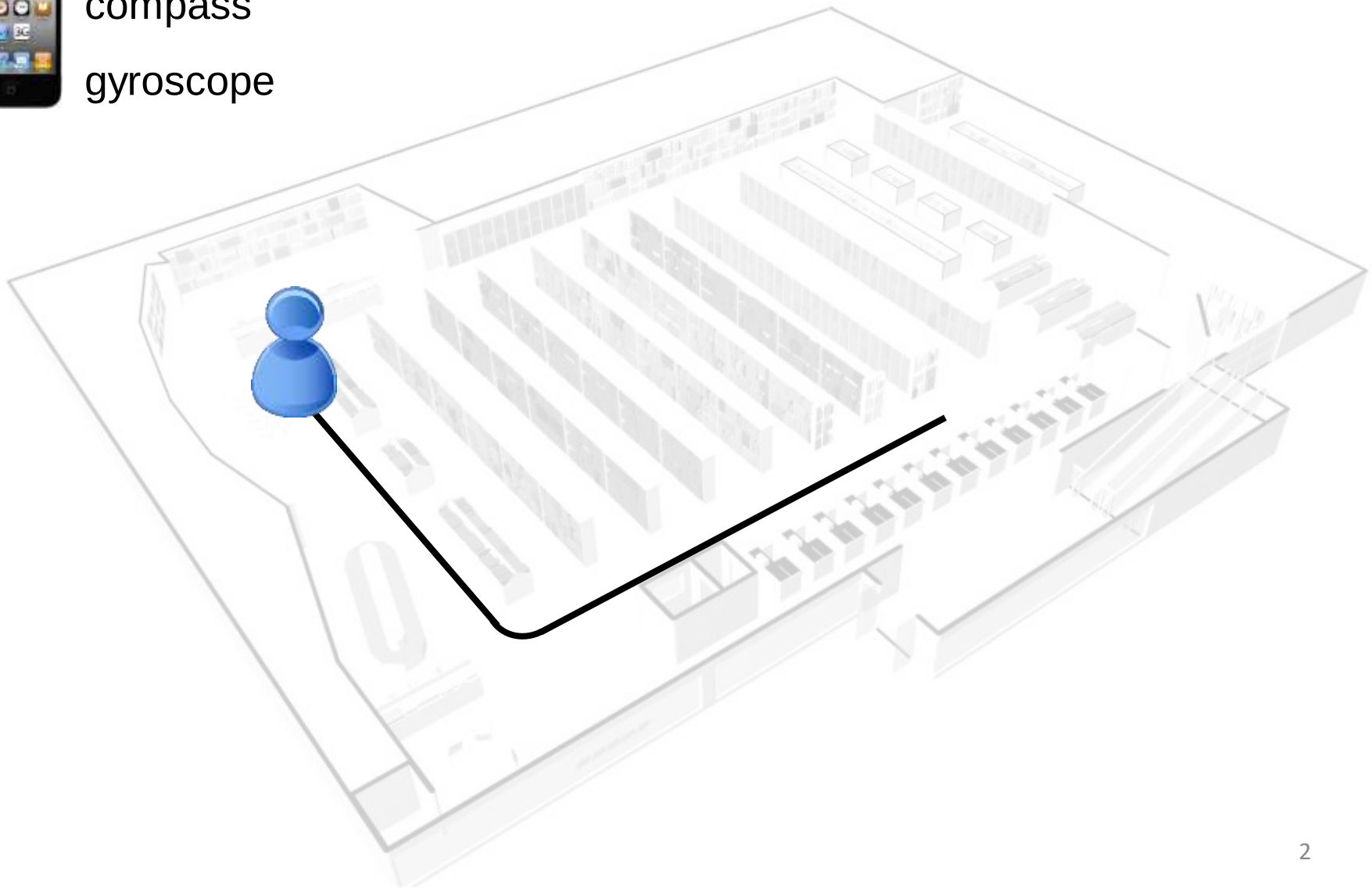
Unsupervised Indoor Localization (UnLoc)

Pedestrian Dead Reckoning (PDR)

accelerometer

compass

gyroscope



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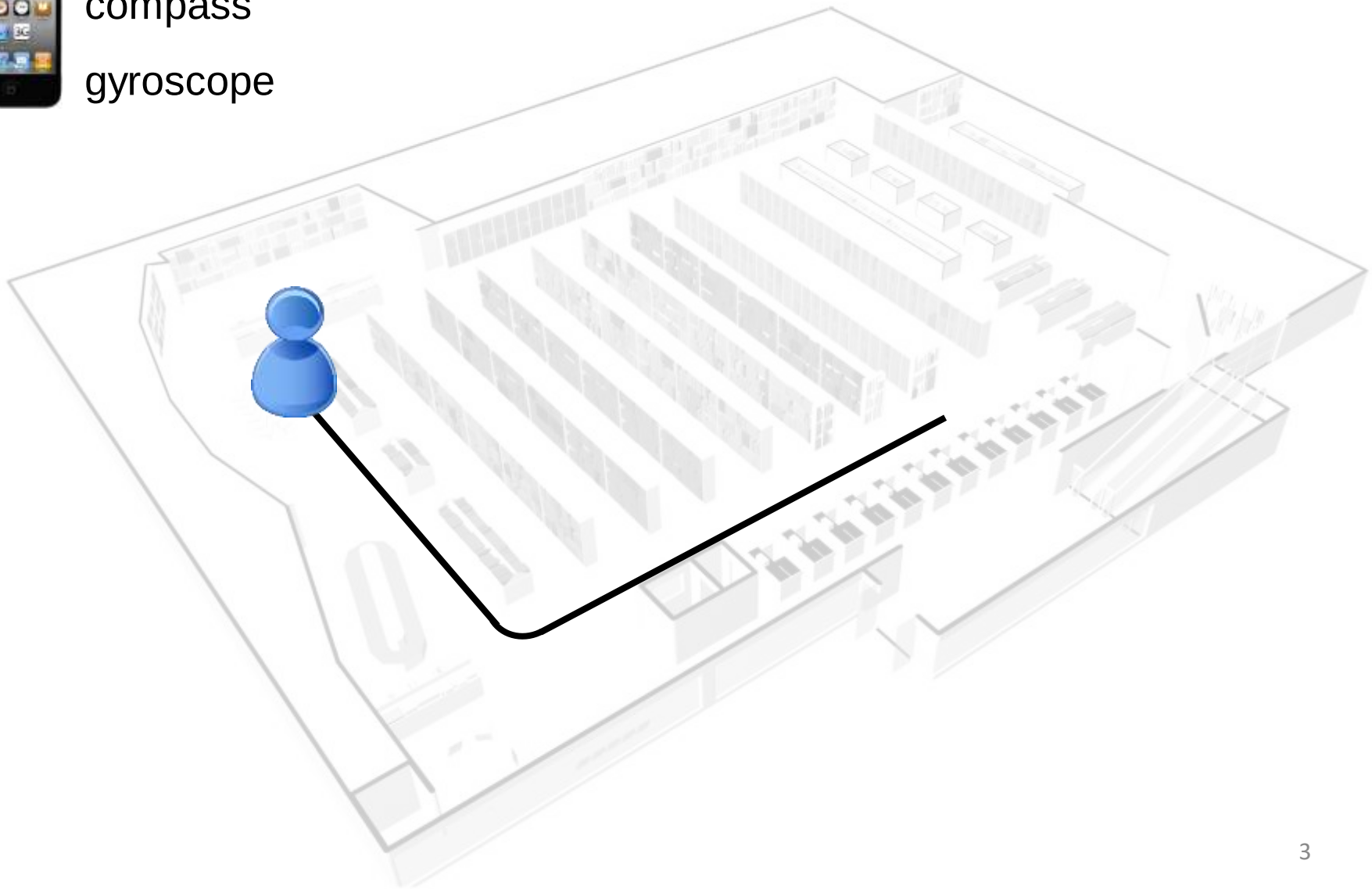

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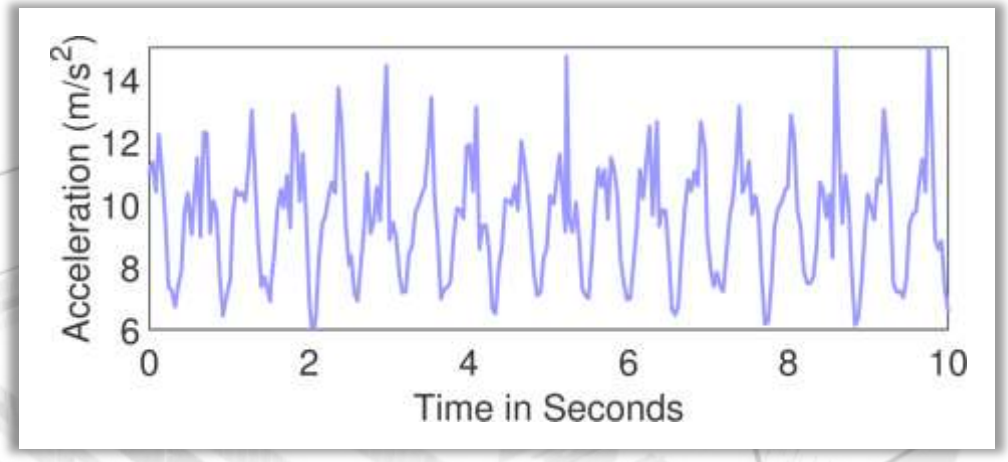

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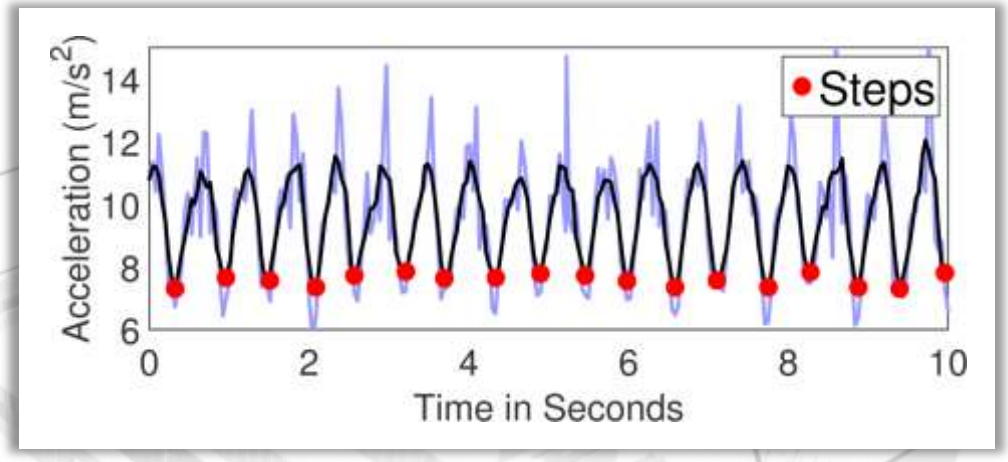

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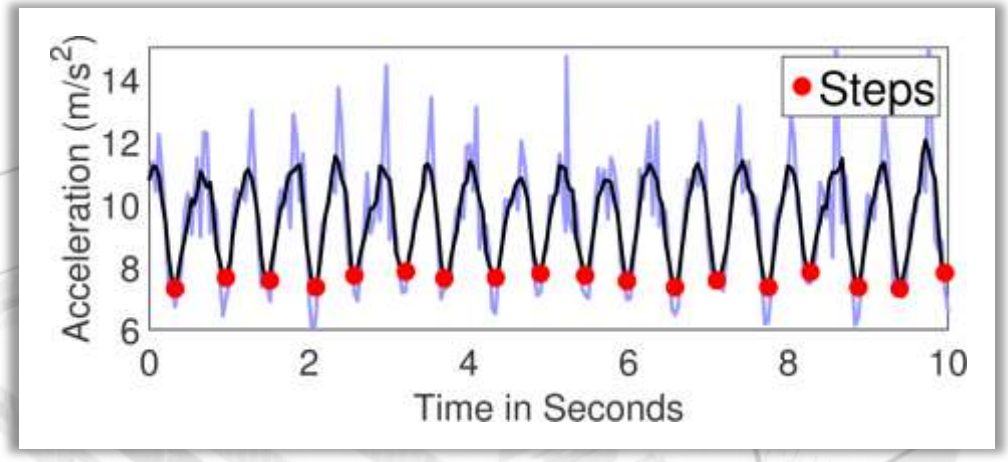
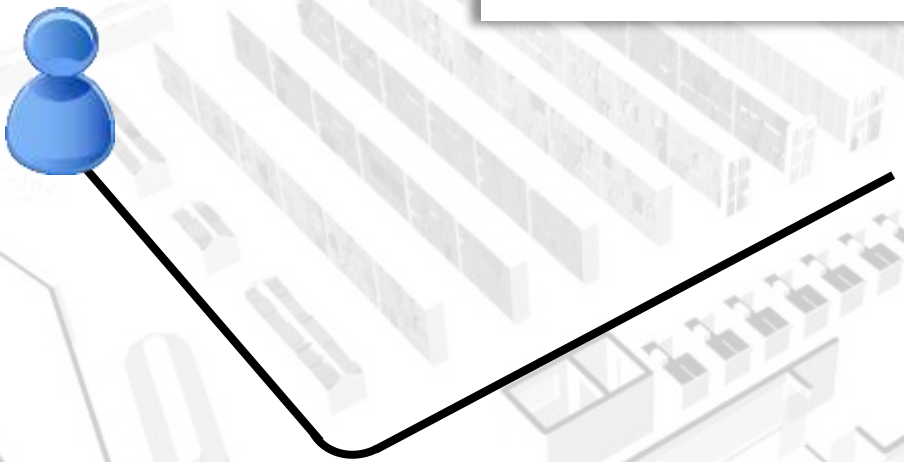
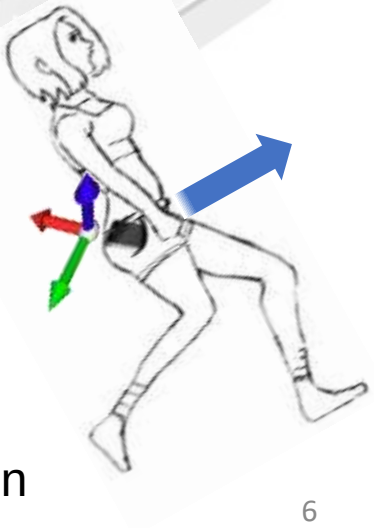
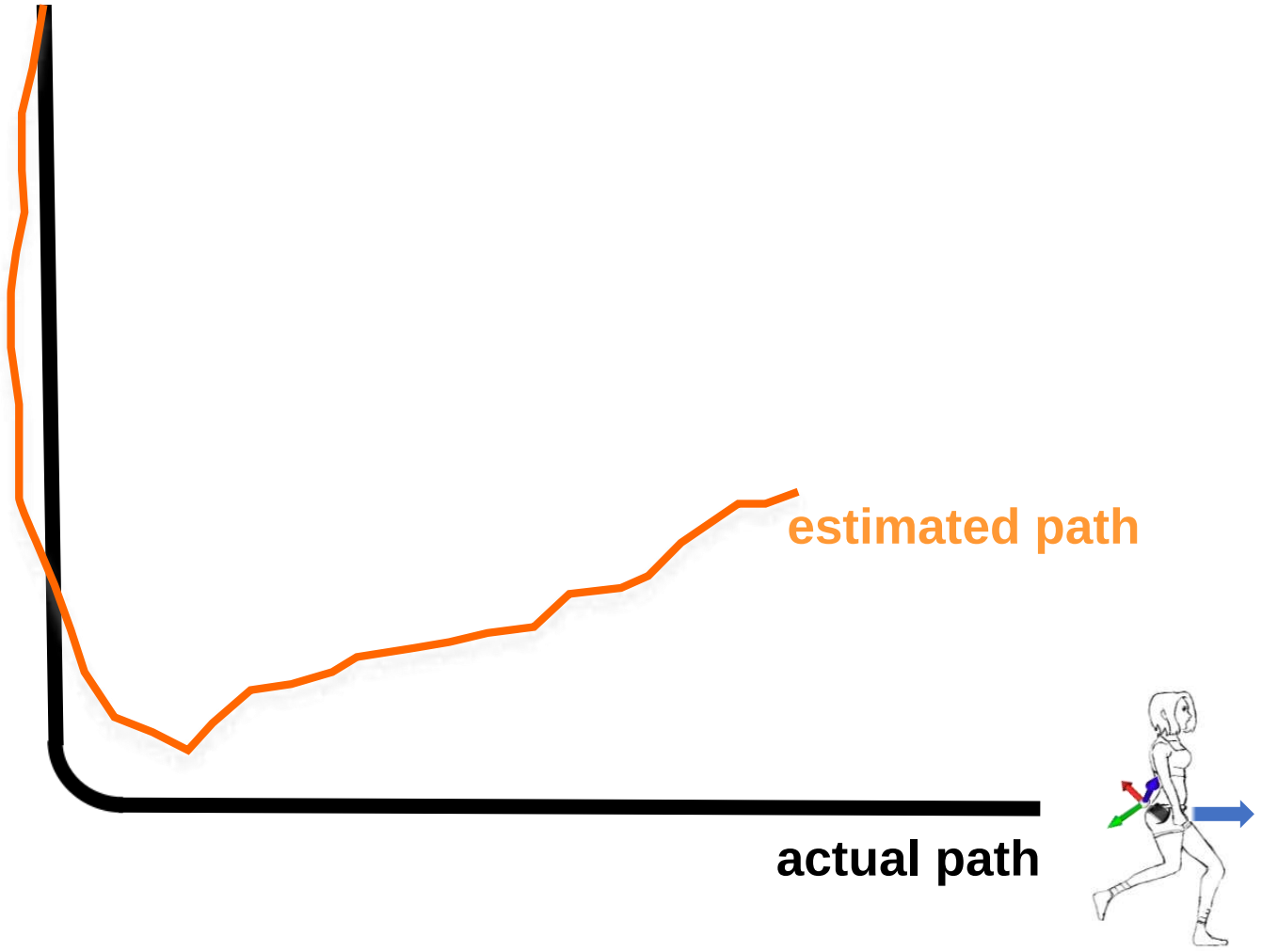






Step length
Walking direction

Pedestrian Dead Reckoning (PDR)



Charles Lindbergh landed in Paris from New York.

No GPS

He used dead reckoning and obtained fixes from the stars.

Pedestrian Dead Reckoning (PDR)

If we had “indoor stars” …
meaning some form of “electronic landmarks” …
the IMU could periodically course correct

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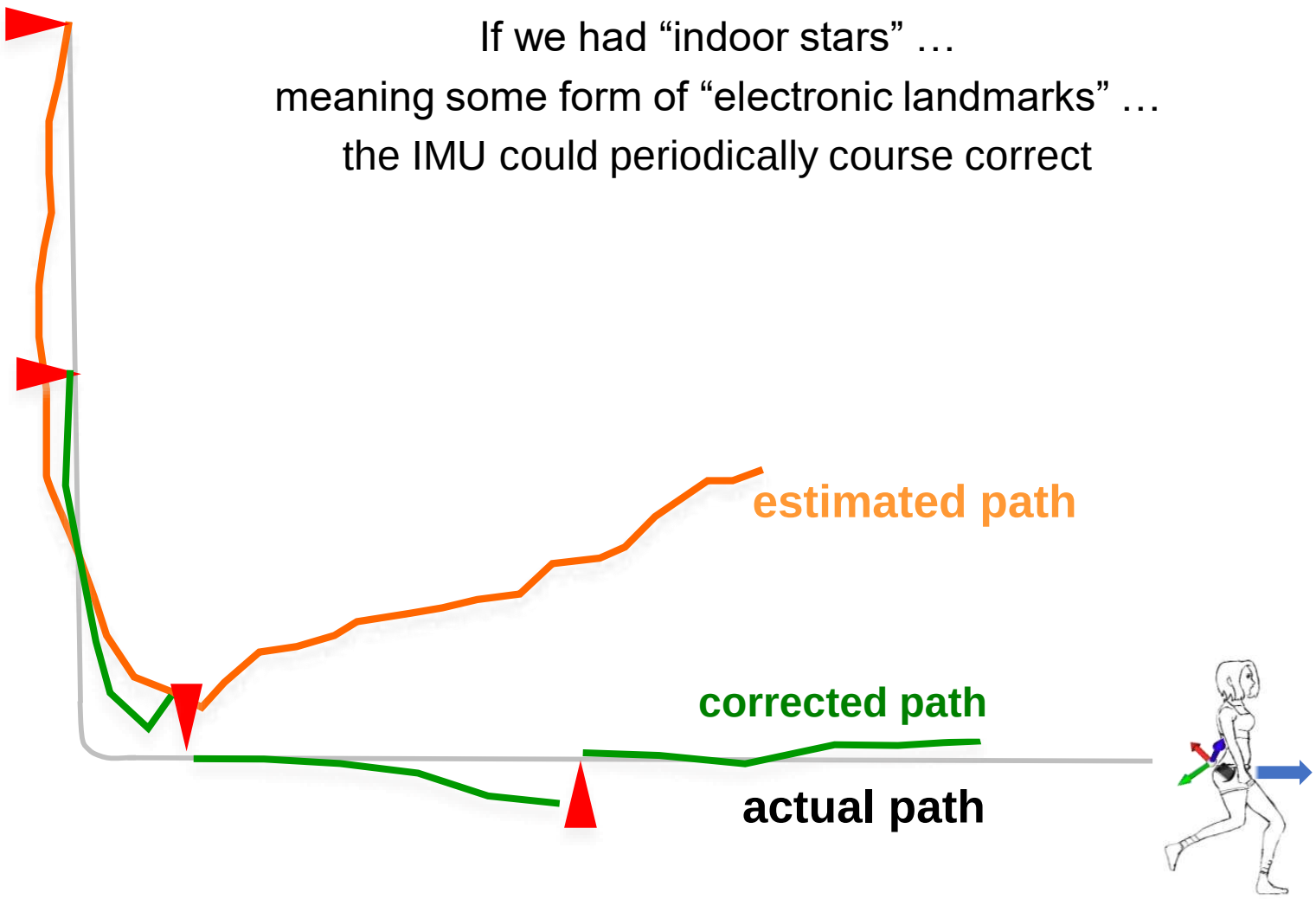


If we had “indoor stars” …
meaning some form of “electronic landmarks” …
the IMU could periodically course correct

Idea

If sensor data about the ambience embed natural patterns in them,
can these patterns be viewed as landmarks …
and can those landmarks be used for PDR course correction

Unsupervised Localization (UnLoc)

Automatically identify sensor landmarks and recalibrate IMU errors

Cellular pattern

Acceleration pattern

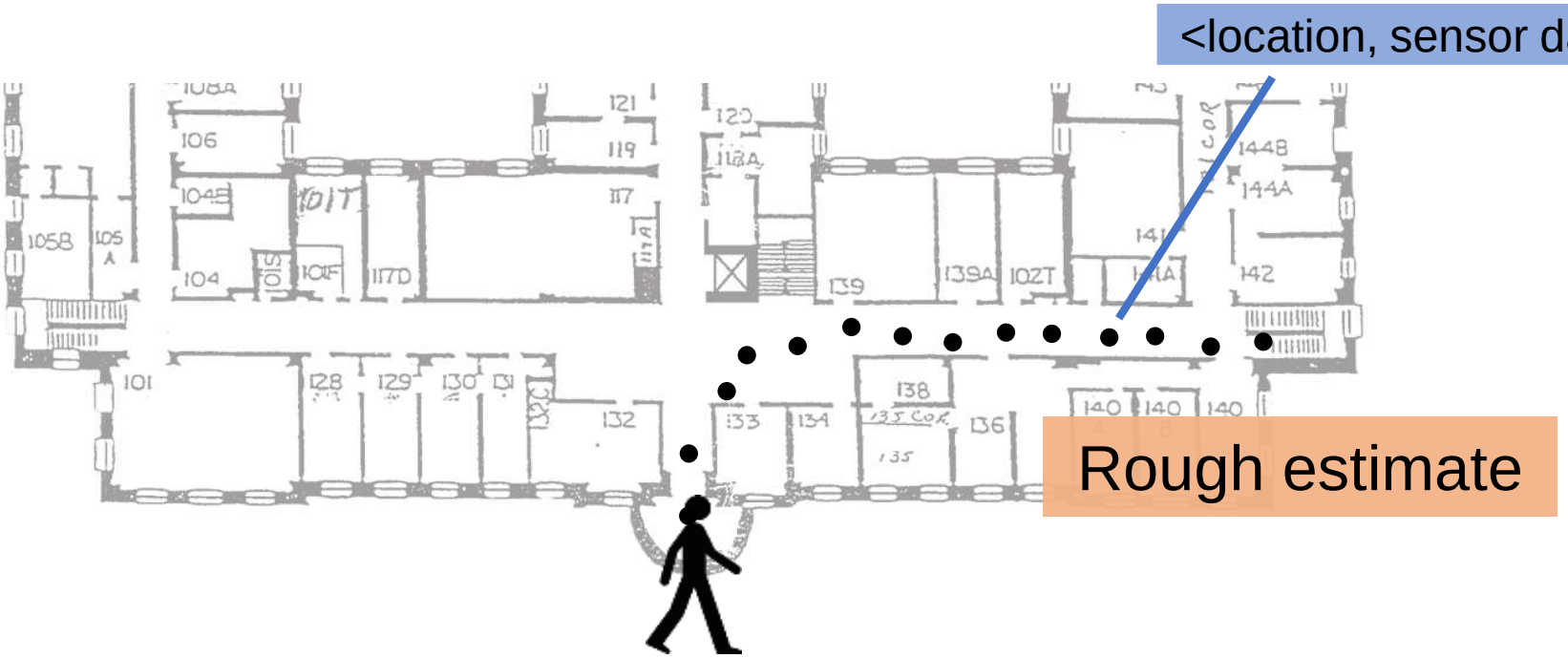
Pressure change

3 step iterative algorithm

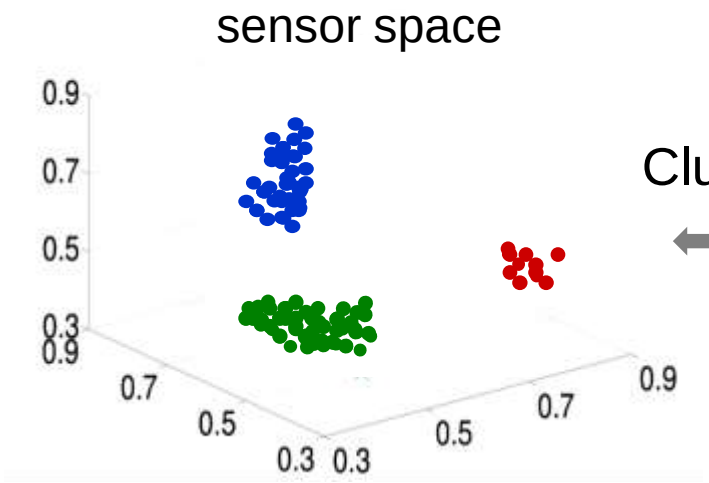
1. Detect landmarks (from ambient sensing)
2. Estimate rough landmark locations (from rough PDR and multiple measurements)
3. Localize users from landmarks and refine landmarks from users (iterate until convergence)

1. How to automatically detect landmarks

Raw Sensor → Landmarks



Raw Sensor → Landmarks

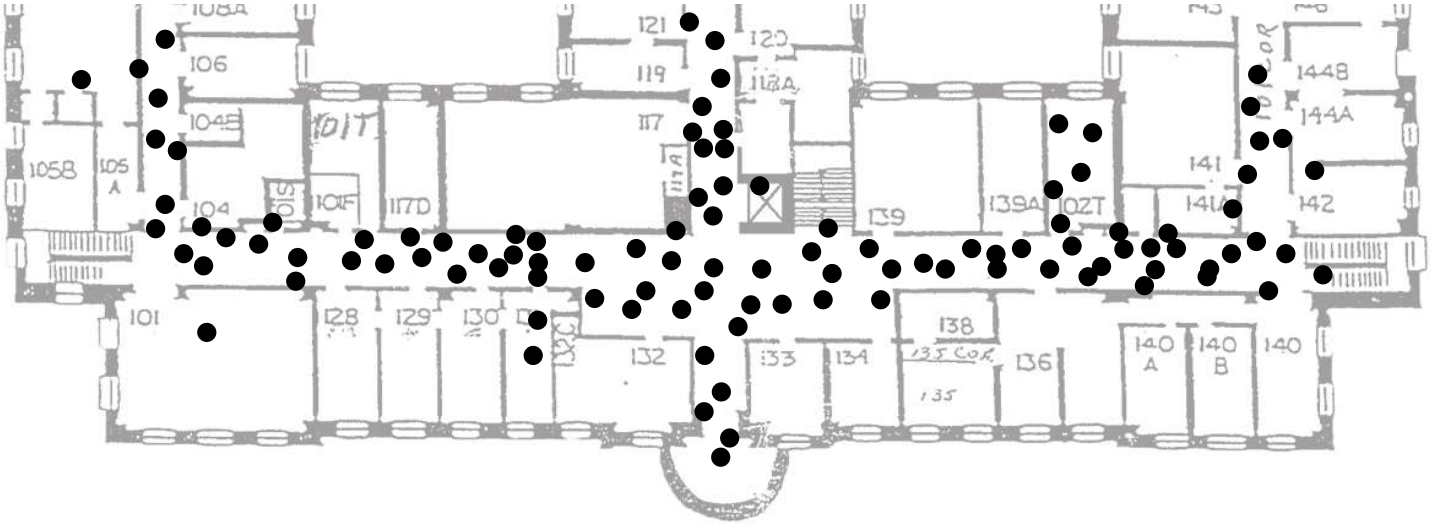


Clustering

<location, f1, f2, f3, …>

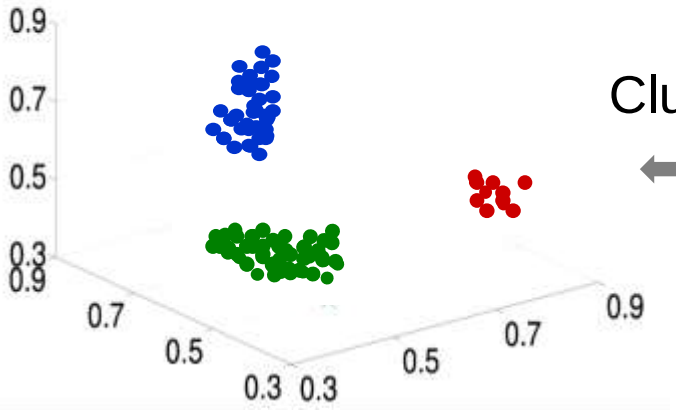
Feature Extraction

<location, sensor data>



Raw Sensor → Landmarks

sensor space



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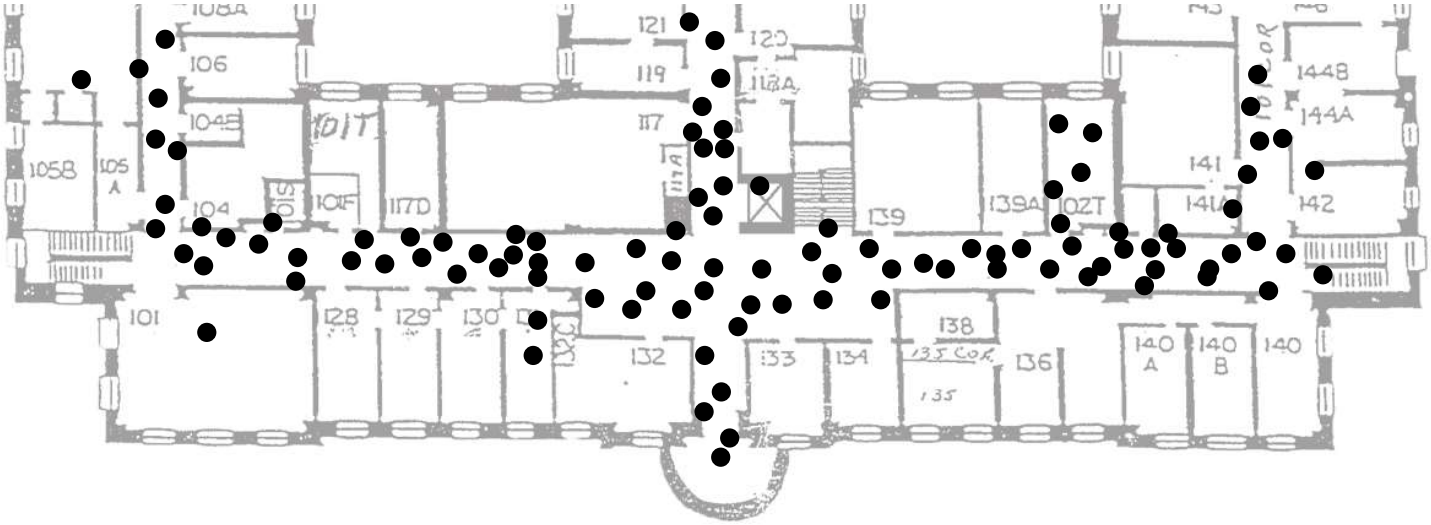

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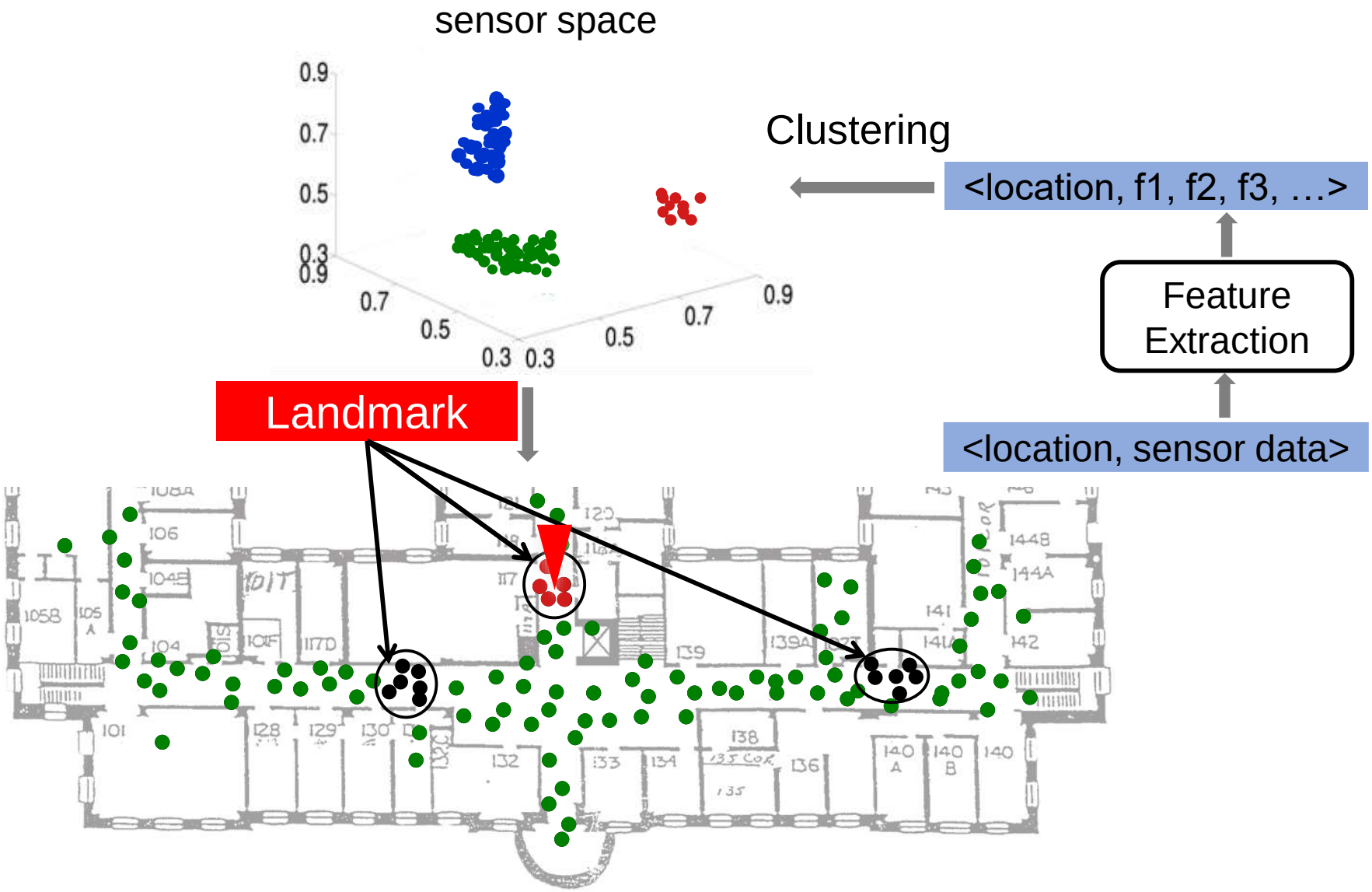
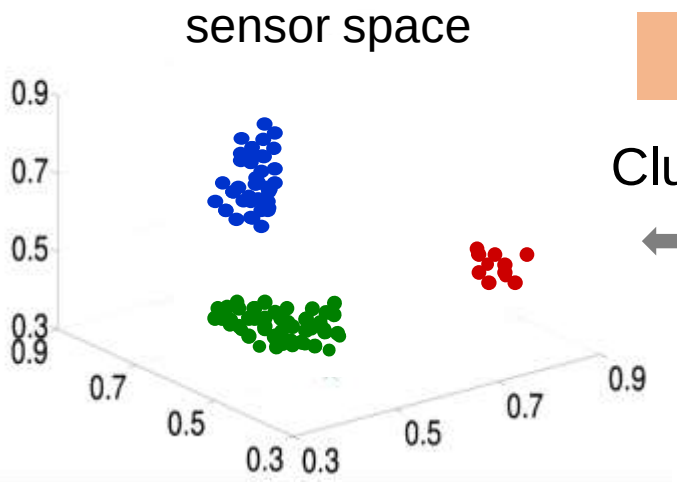


Landmarks from Multiple Sensors



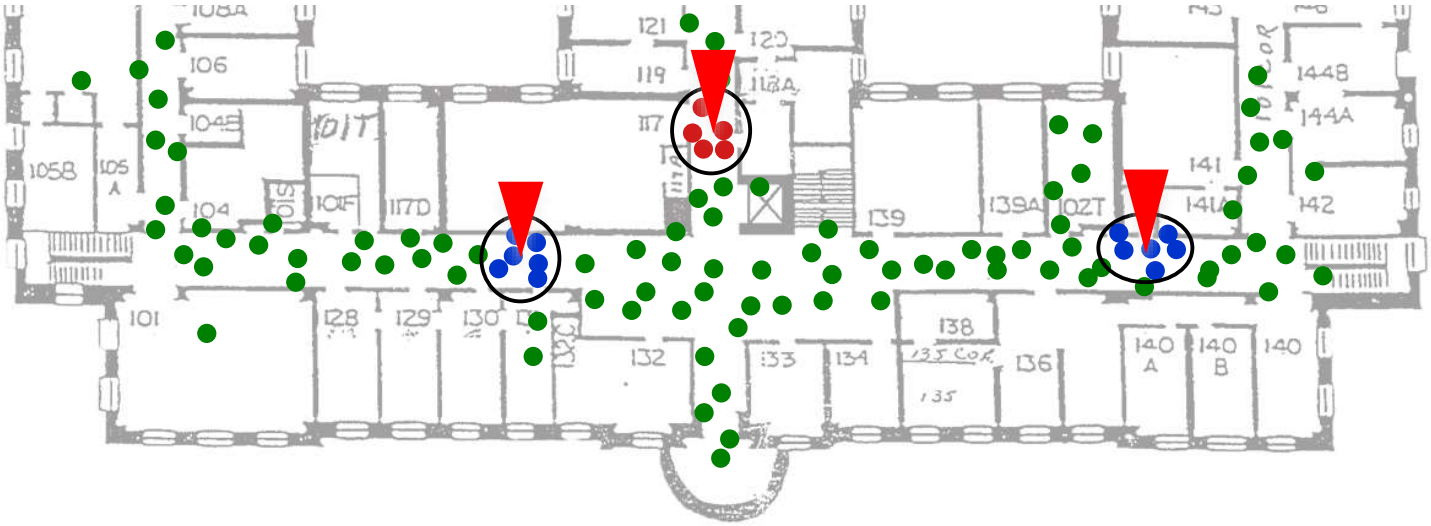
Inertial, Magnetic, Wi-Fi

Clustering

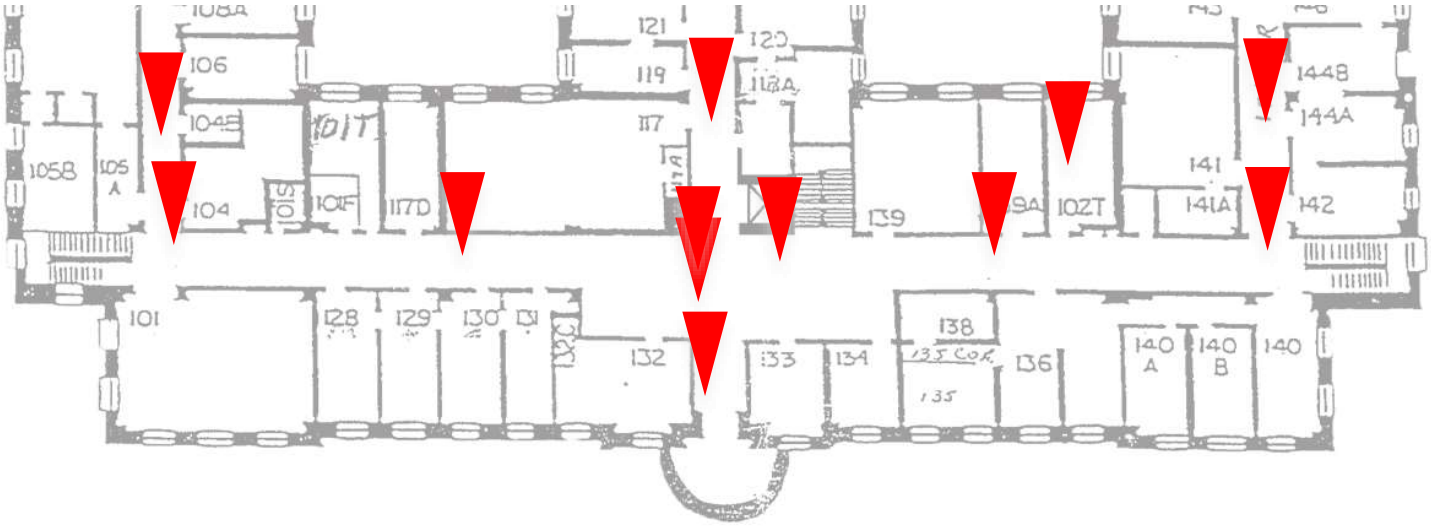
<location, f1, f2, f3, …>

Feature Extraction

<location, sensor data>



Say we find many landmarks (using multiple sensors).
Are we done?



Say we find many landmarks (using multiple sensors).
Are we done?

No, landmark locations can be very poor.

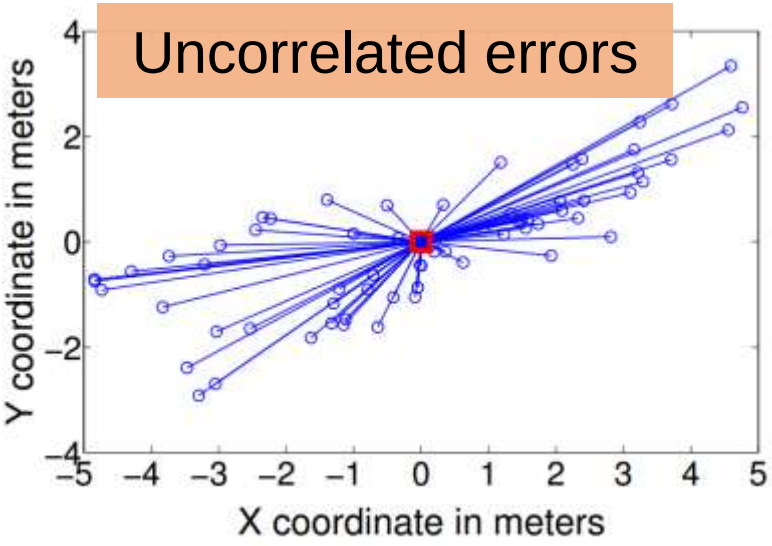
origin

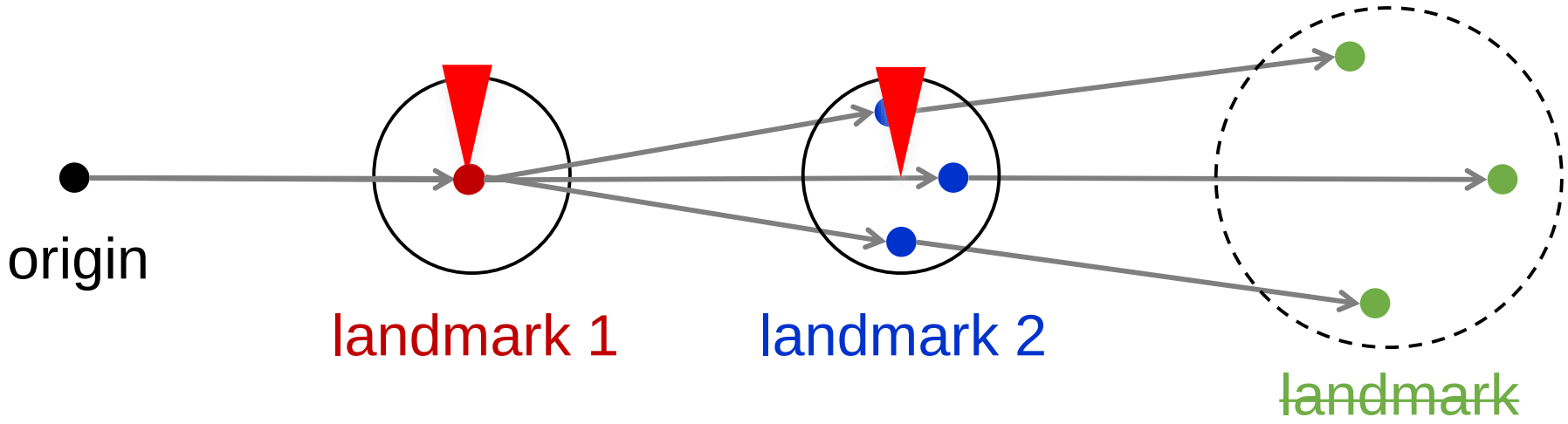
landmark 1

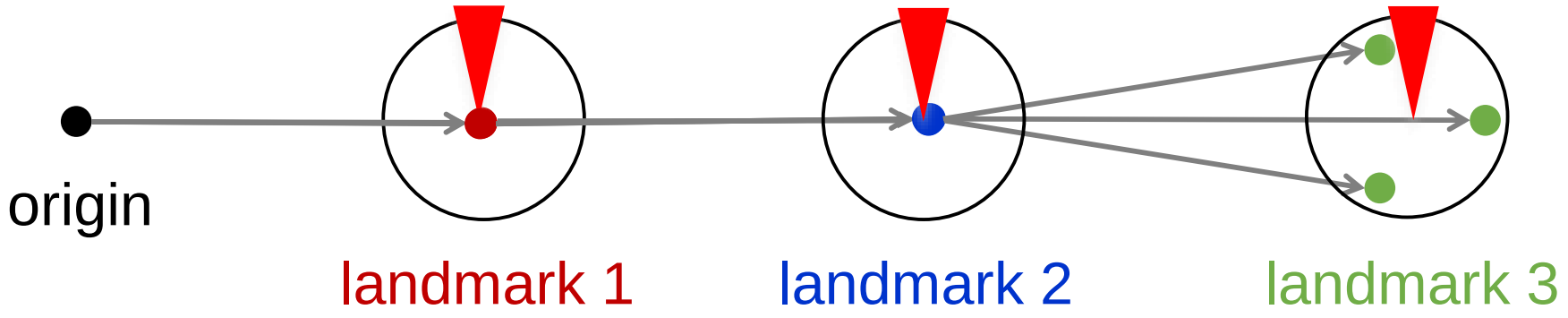
~~landmark~~

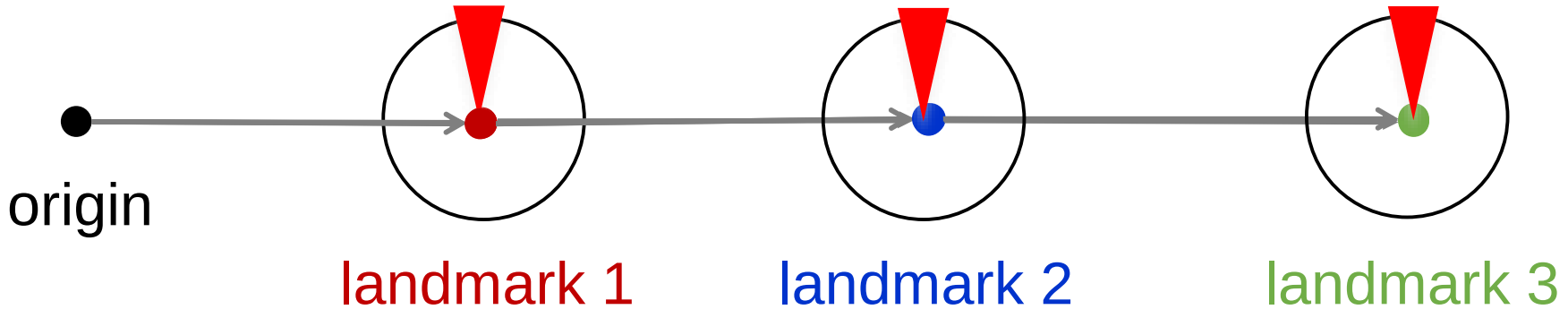
~~landmark~~

Uncorrelated errors




origin
landmark 1
landmark 2
landmark


origin
landmark 1
landmark 2
landmark 3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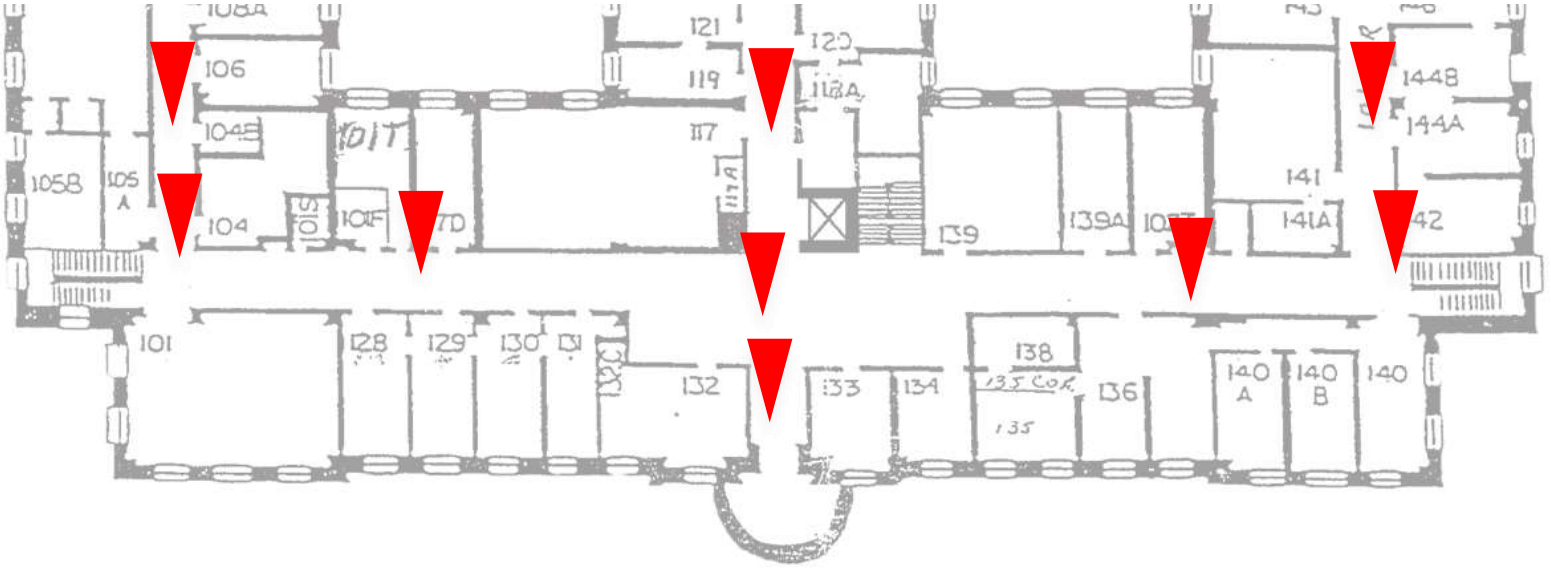
Growing landmarks outward from initial location



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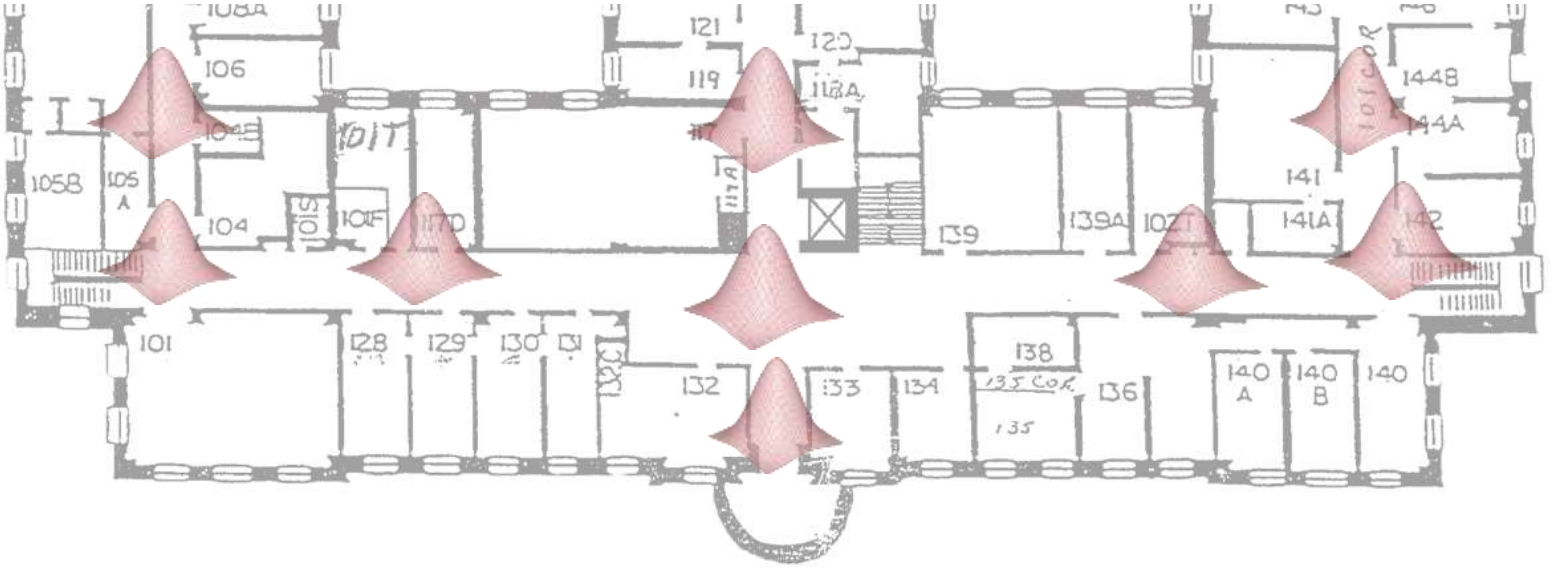


Recursive Algorithm

Users' motion traces
<time, sensor value>

Landmarks

Dead Reckon
using existing landmarks

User Location Error

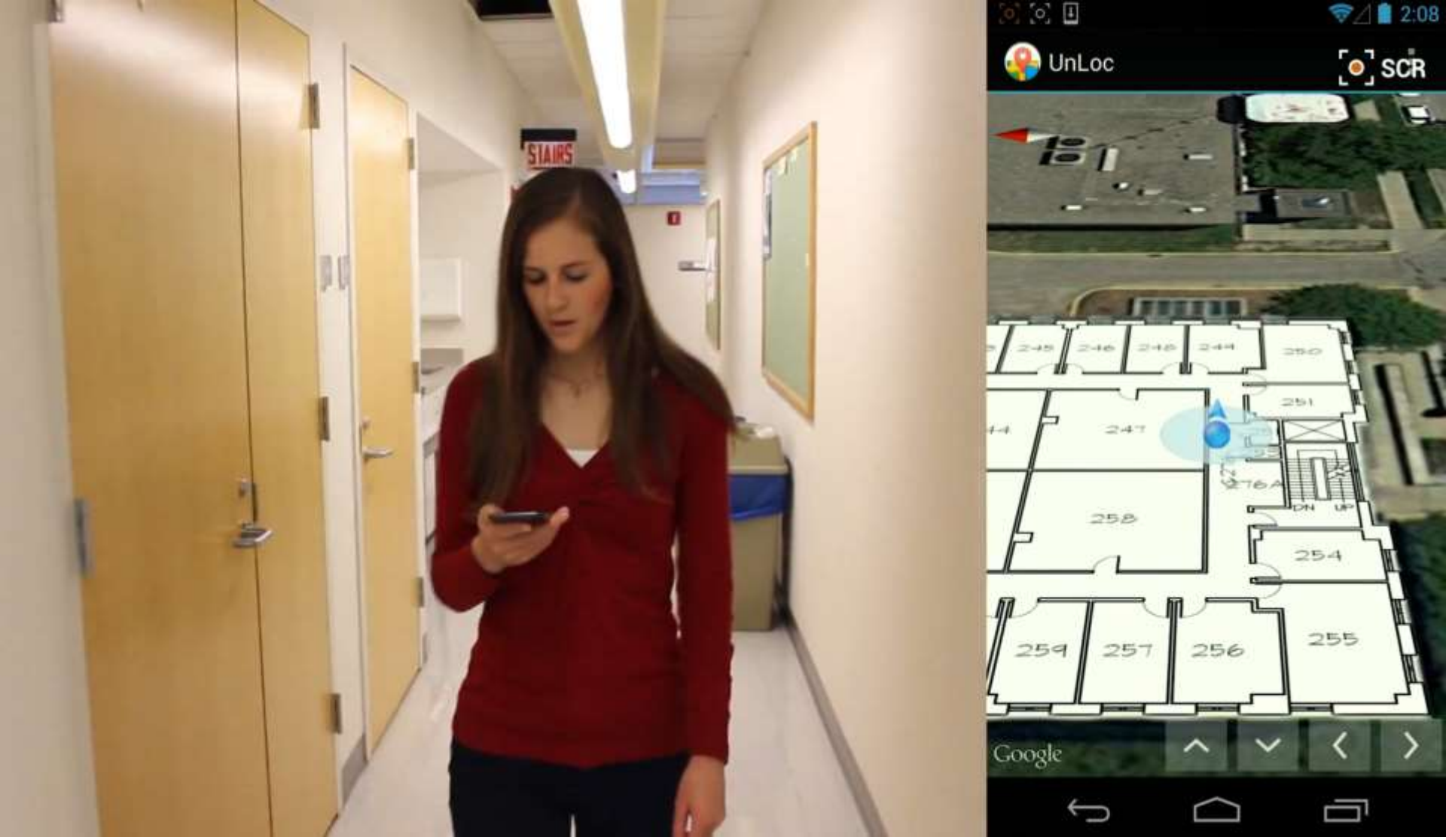
Unique Sensor Fingerprint?

Find Landmark Location

Update Landmark list

Landmark Location Error

UnLoc Demo



intel
SAMSUNG
cisco
ThyssenKrupp
SCIENTIFIC AMERICAN™
WIRED
THE VERGE
FAST COMPANY ...

http://localhost:8080/UnLocFront-debug/UnLocFront.html
UnLoc
UnLoc
Building: CSL
Floor: 2
load
Trace #: 1
load
replay
show sensors
calculate landmarks
show panel
Legend
Inertial
Magnetic
Wi-Fi
clear
trace display:
trace
marker
Terms of Use

Questions?

Evaluation:

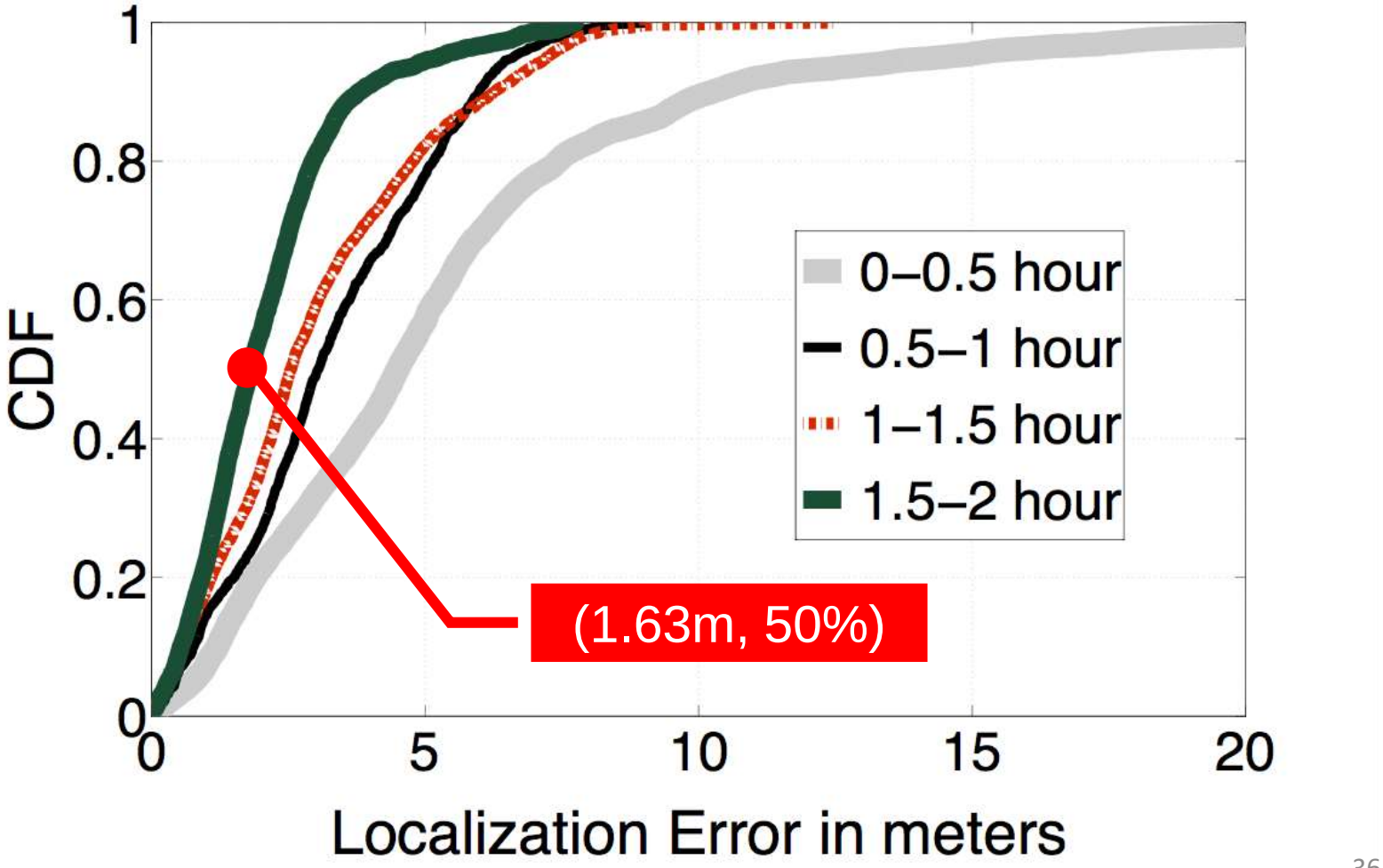
- Deployed in 6+ buildings
- Shopping mall, univ., industry
- Results from 5 Android models
- 20 users

- Running live in CSL 2nd floor
- Landmarks 6 months stale
- Robust

Performance

Experimentation on 8000 sq. meters

Shopping mall, ECE and CS buildings



Indoor environments rich in landmarks