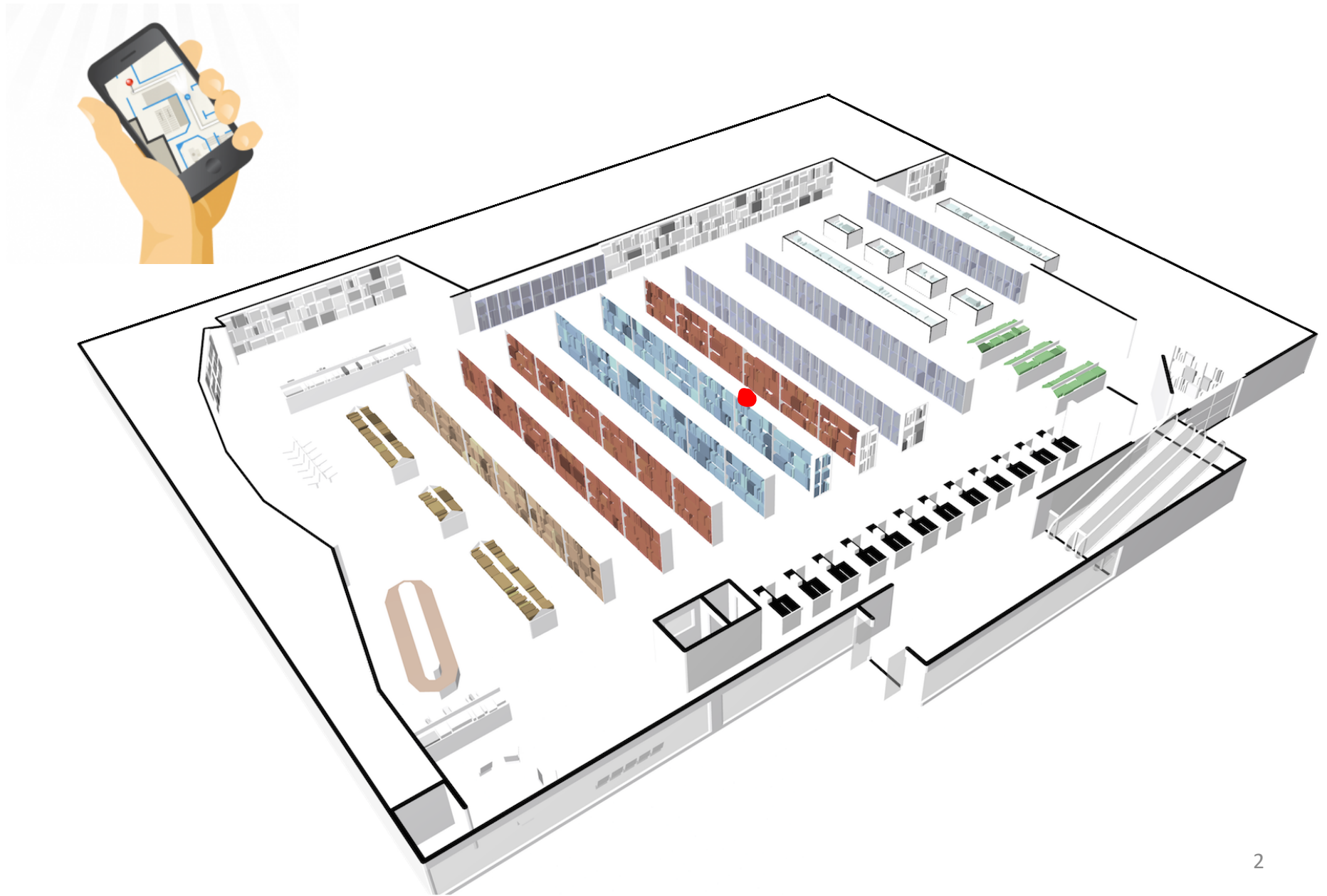


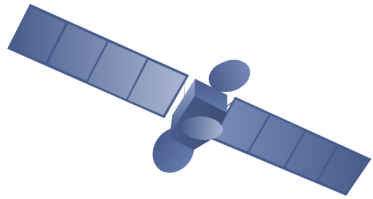
A wide-angle, low-perspective shot of a multi-level shopping mall. The mall has a glass and steel structure with a large skylight at the top. Various stores are visible on different levels, including 'CARROT', 'WEEKENDER', 'KASHVEE', 'YAMAHA', 'SUBURBIA', 'Pizza Hut', and 'CAPSULE'. There are many advertisements and banners hanging from the ceiling and on the walls. A large Christmas tree is in the center of the ground floor. People are walking around the mall, and some are sitting on the ground floor. The overall atmosphere is busy and commercial.

*No Need to WarDrive ...* ←  
Unsupervised Indoor Localization

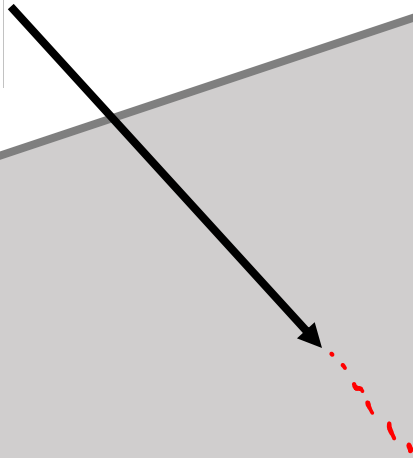
# Where am I in a hotel, mall, office, cruise ship?



GPS



GPS satellite



Why not outdoor localization technology?

# Wi-Fi

| (x1,y1)   | (x2,y2)   | (x3,y3)   |
|-----------|-----------|-----------|
| AP 1: -65 | AP 1: -60 | AP 1: -90 |
| AP 2: -50 | AP 2: -62 | AP 2: -90 |
| AP 3: -80 | AP 3: -55 | AP 3: -53 |
| AP 4: -85 | AP 4: -50 | AP 4: -50 |

...



*training  
war-driving*

AP 1: -90  
AP 2: -90  
AP 3: -53  
AP 4: -50



AP 1: -65  
AP 2: -50  
AP 3: -80  
AP 4: -85



AP 1: -60  
AP 2: -62  
AP 3: -55  
AP 4: -50



AP 4



Periodic calibration needed

# BLE Beacon



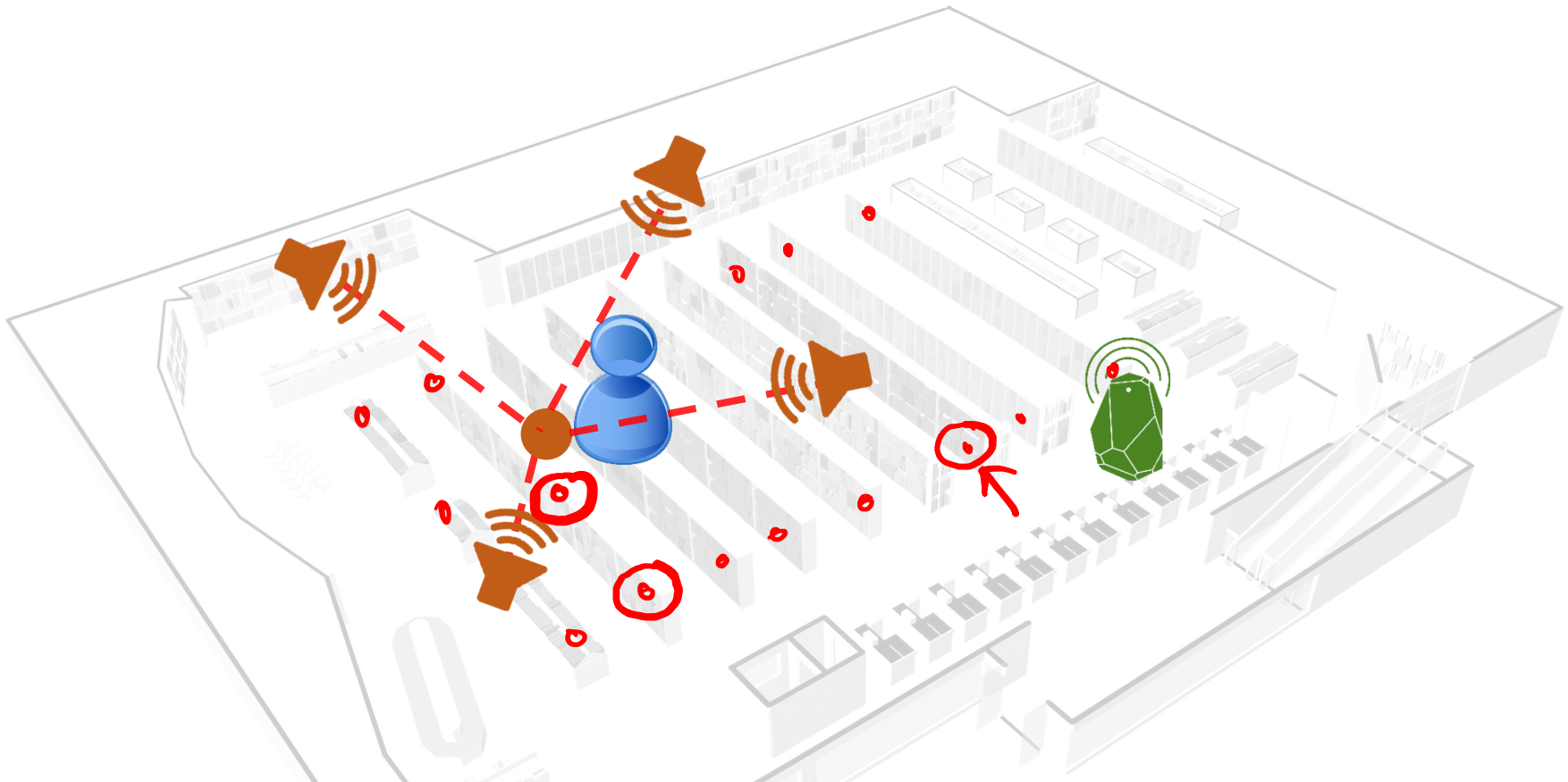
sound beacon



Bluetooth beacon



listener



Installation and maintenance costs

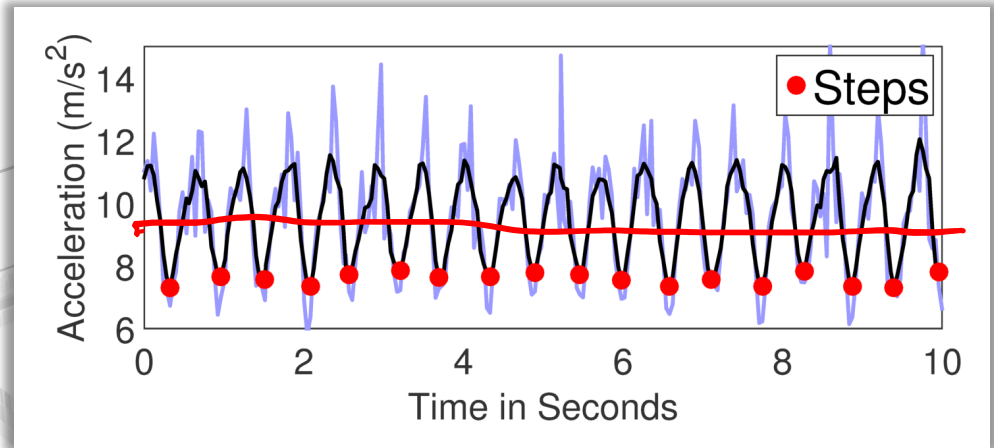
We do not want to rely on infrastructure

We want a ***scalable software solution***

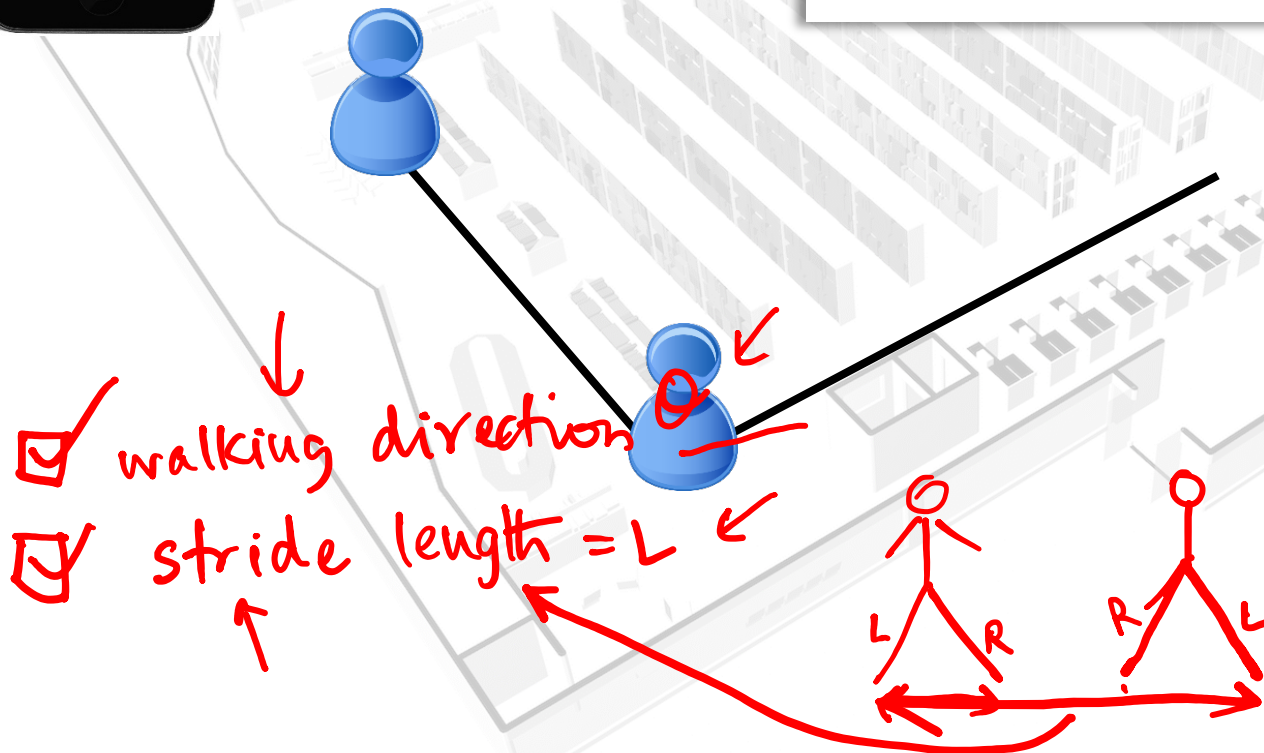
# Infrastructure-less Localization



2006  
 accelerometer  
 compass  
 gyroscope



# of steps walked. =  $n$

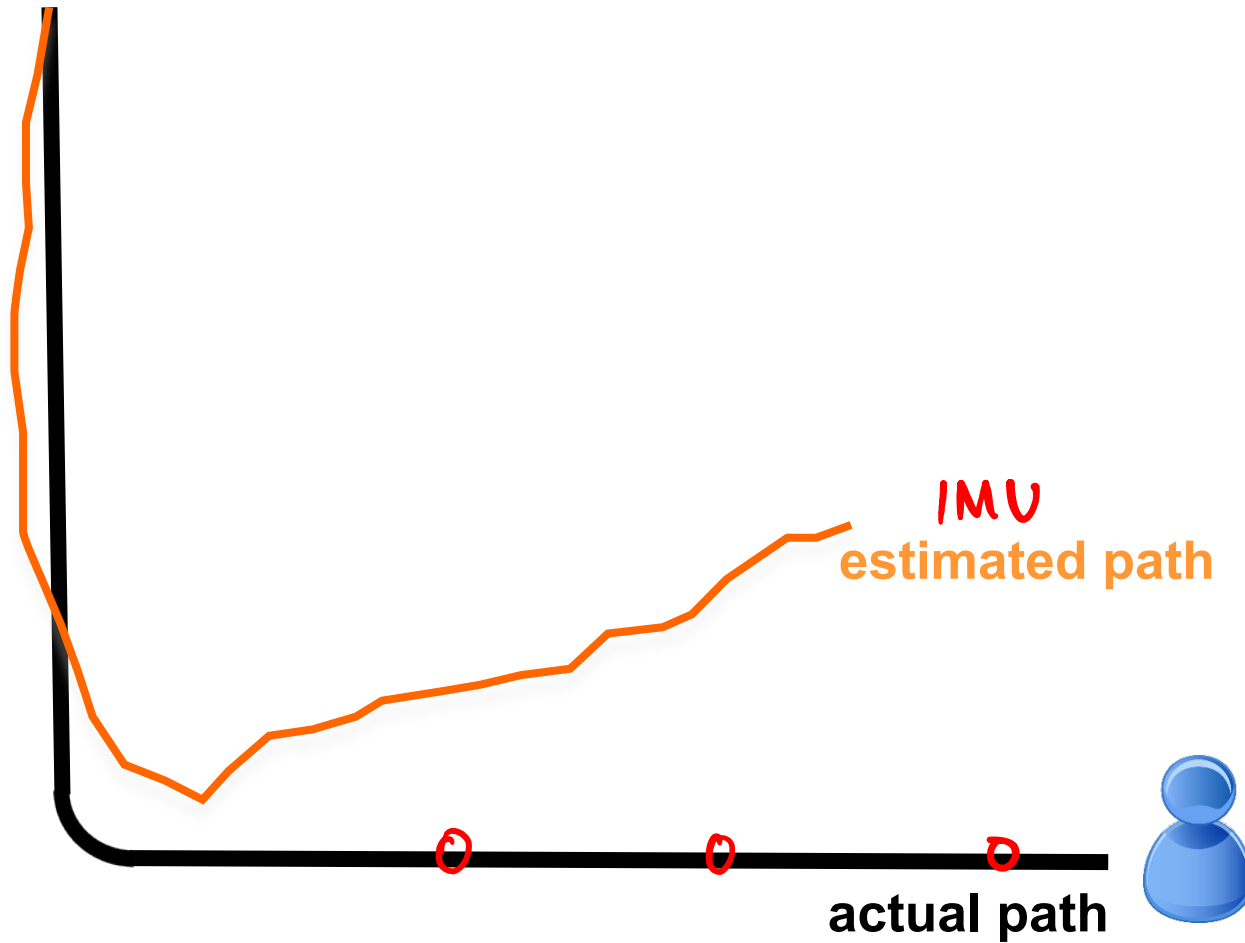


$$\sum_{i=1}^n L_{\theta}^{(i)}$$

$\bar{g} + \text{bounce}$

pedestrian

# Dead reckoning (PDR)





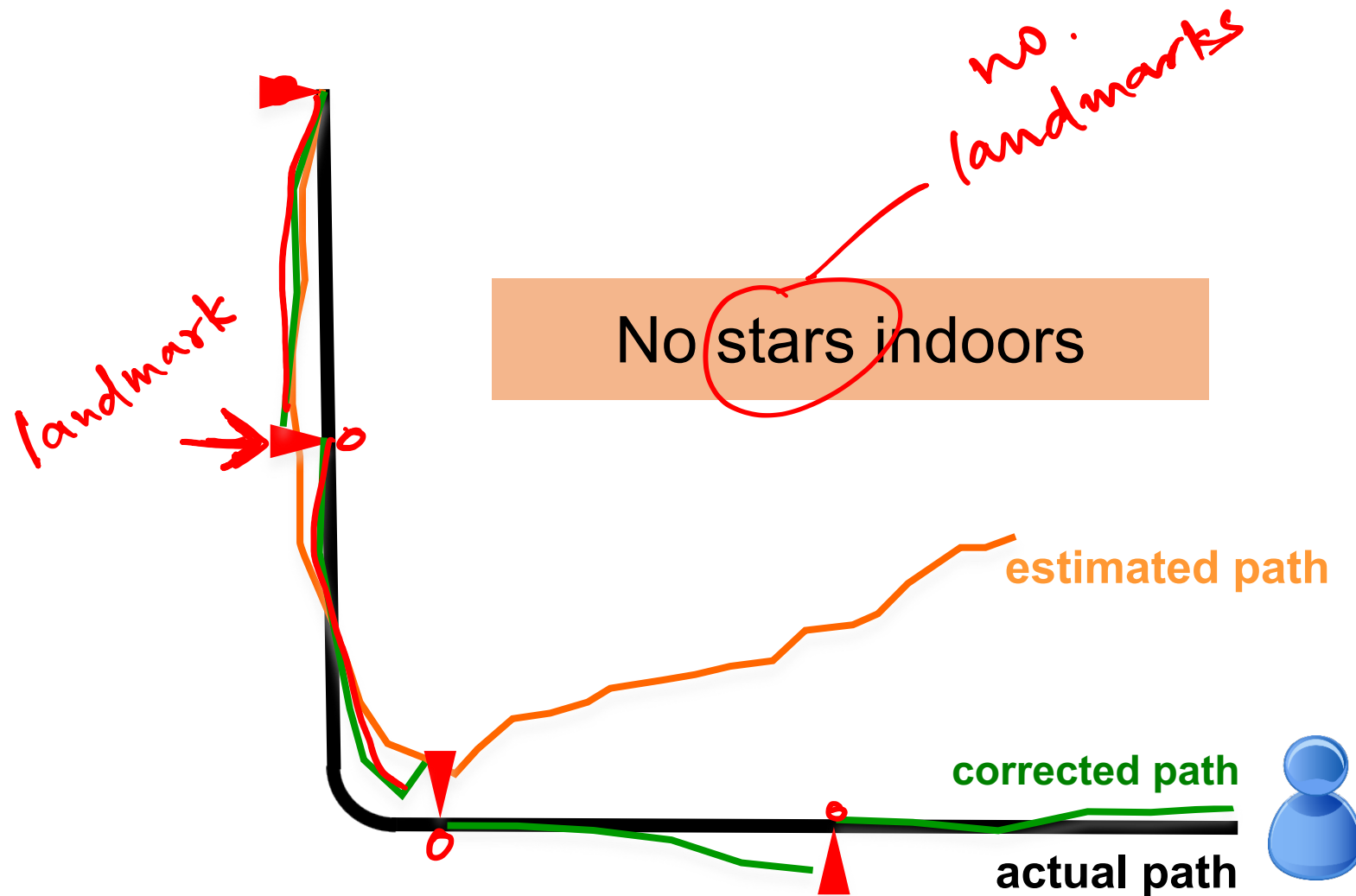
Charles Lindbergh landed in Paris from New York.

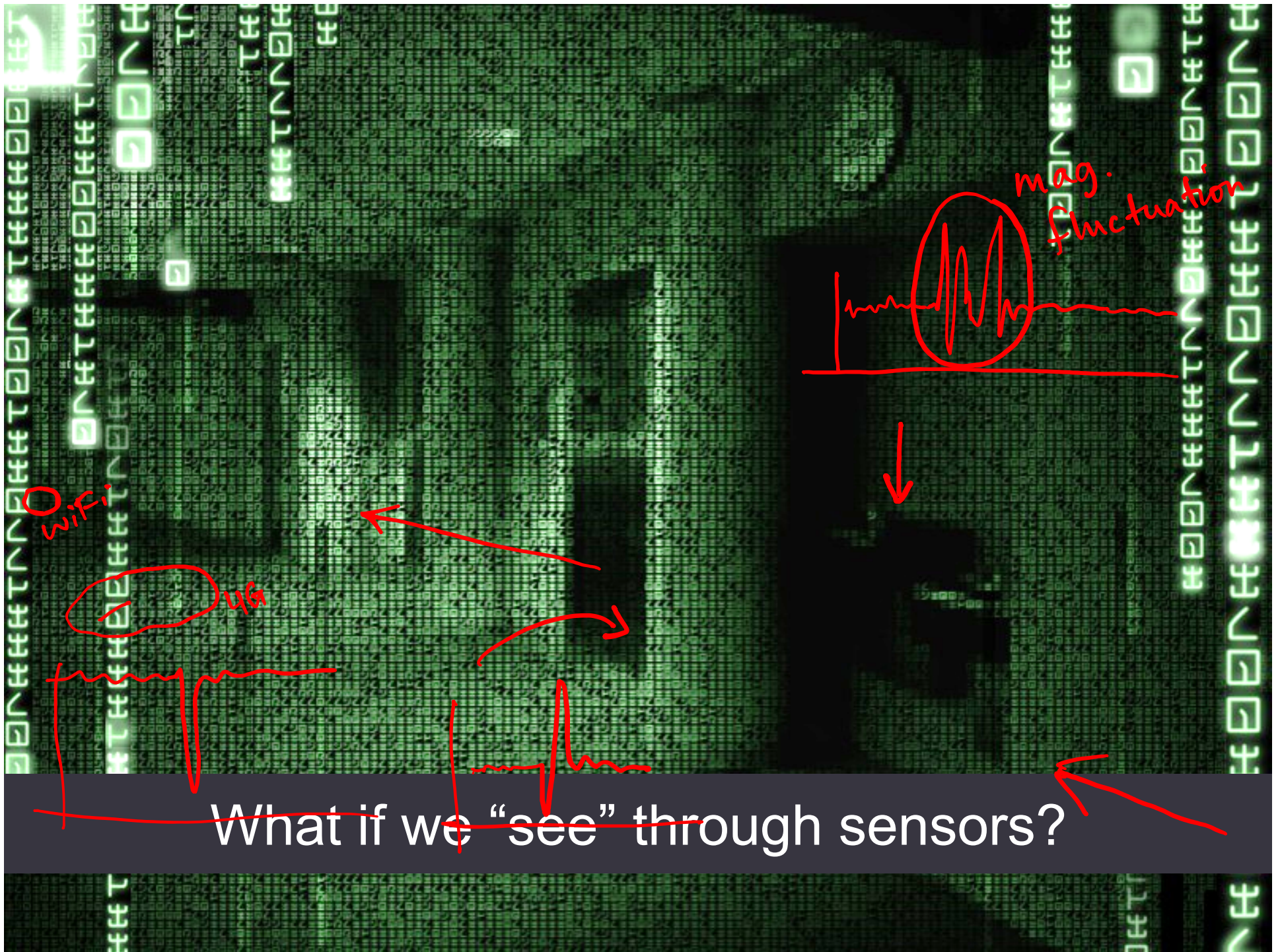
No GPS

He used dead reckoning  
and obtained fixes from the stars.



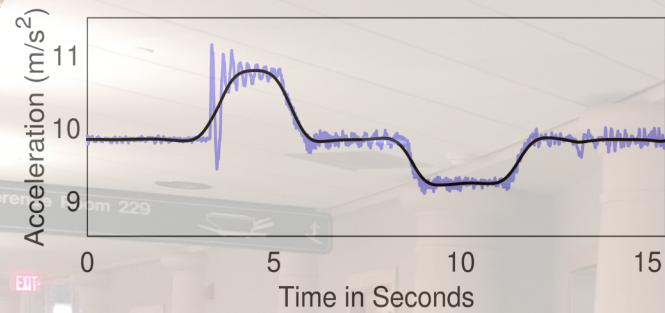
# Dead reckoning



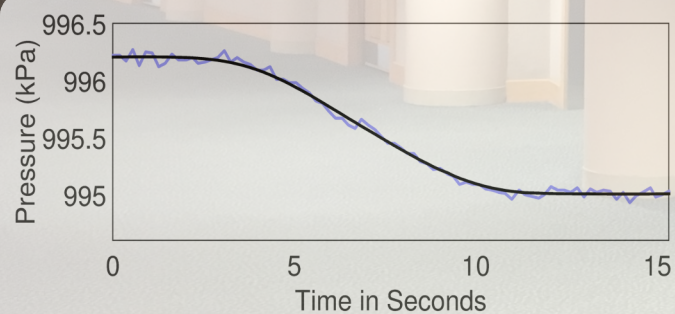


What if we "see" through sensors?

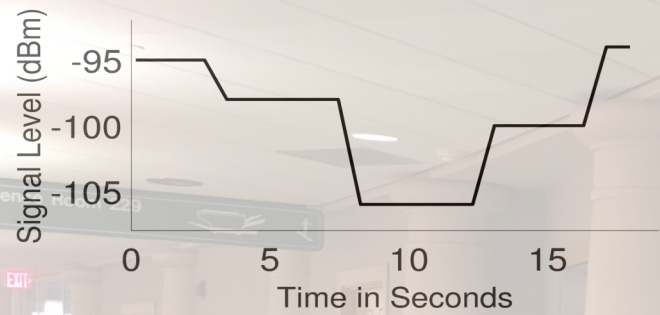
## Acceleration pattern



## Pressure change



# Cellular pattern



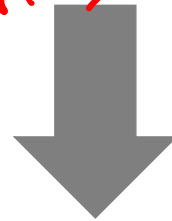
← "starts"  
landmarks.

We use this core idea to design  
**UnLoc: Unsupervised Indoor Localization**

---

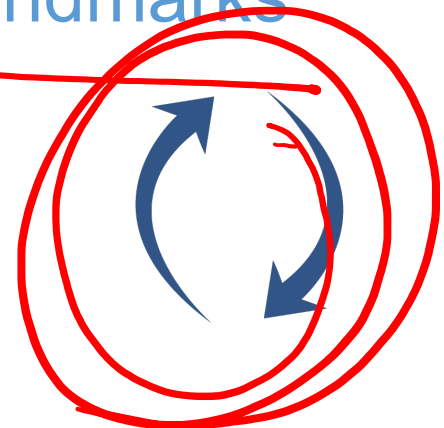
# We use this core idea to design UnLoc: Unsupervised Indoor Localization

reset error using electronic sensor patterns ("landmarks")



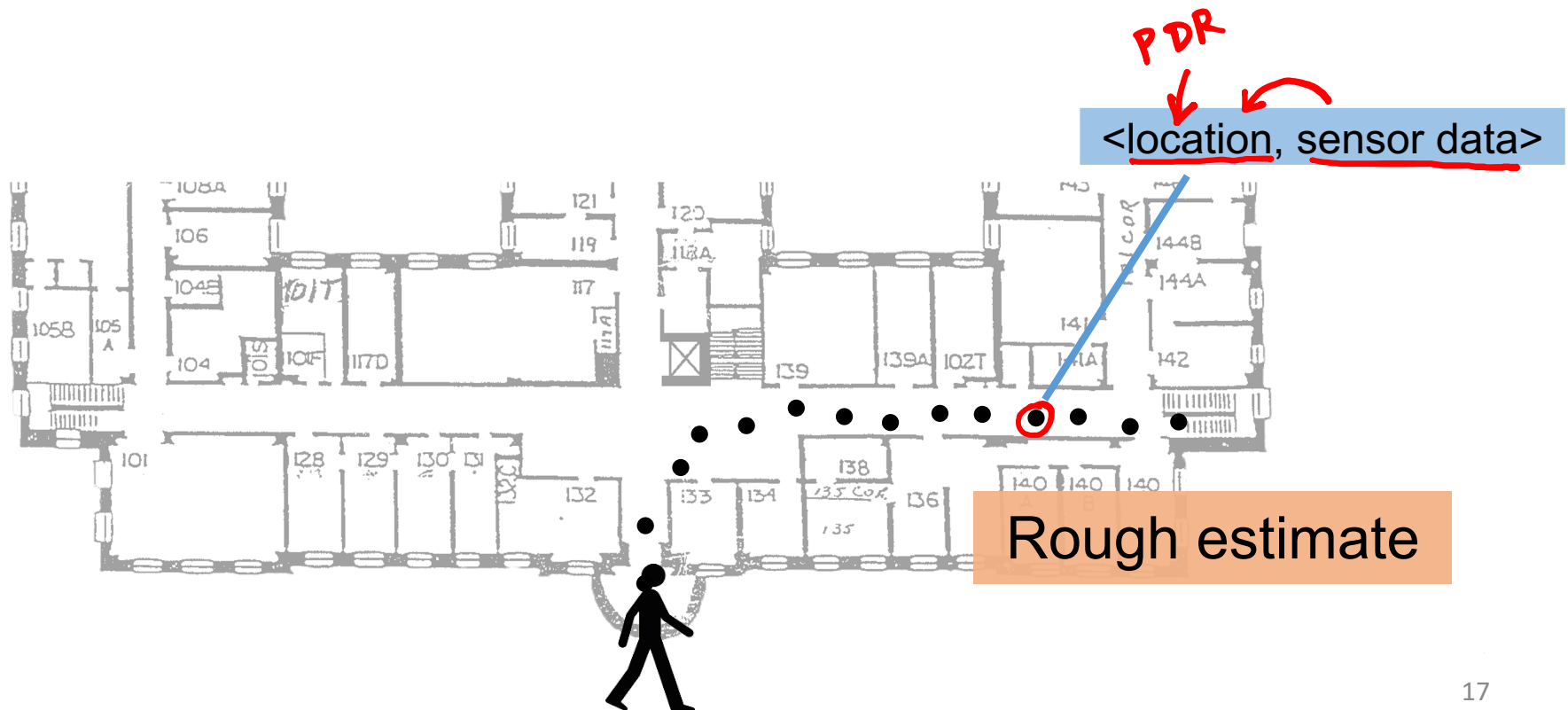
3 main design questions:

1. How to automatically detect landmarks
2. How to localize the landmarks
3. How to localize users

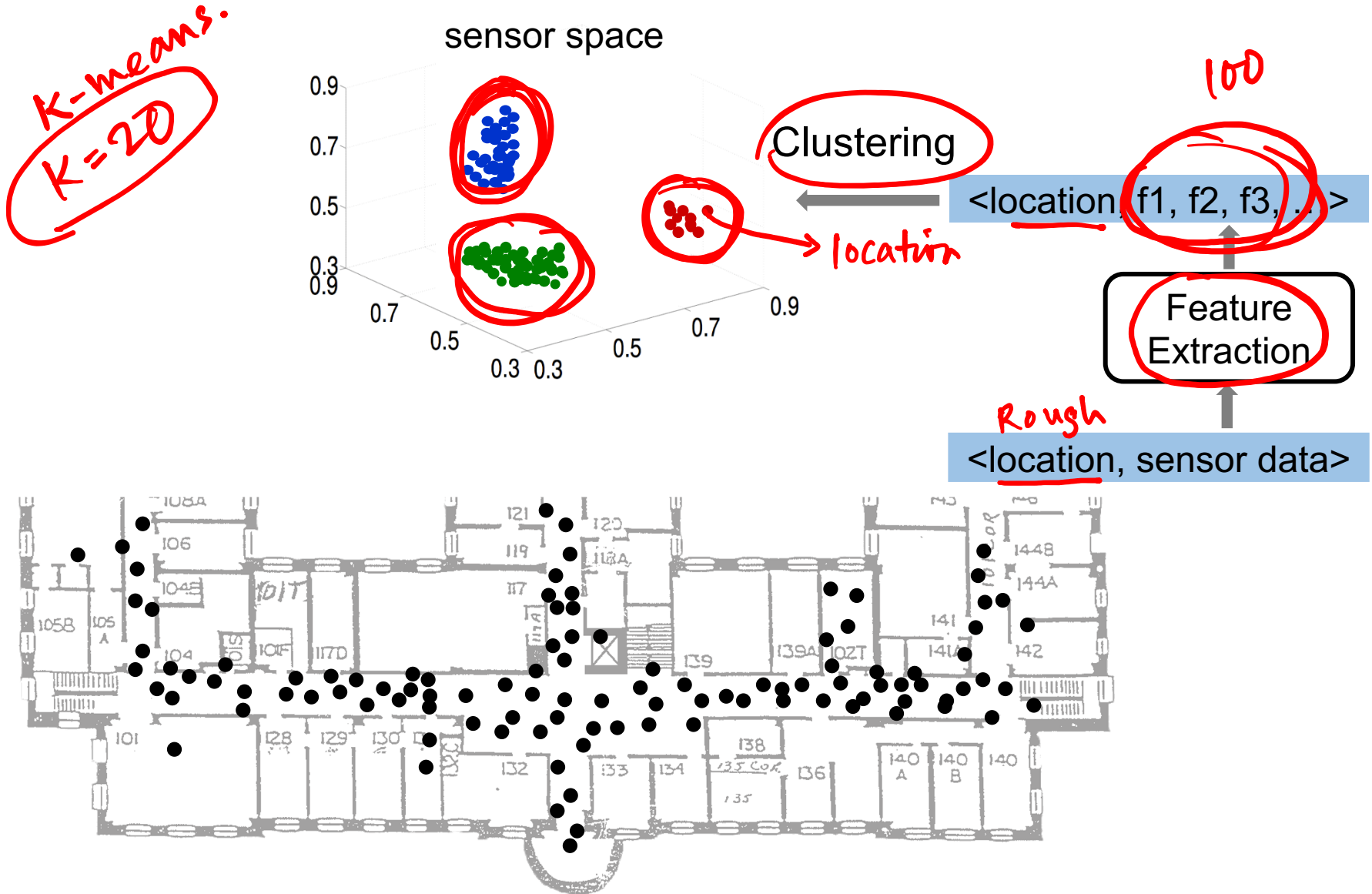


1. How to **automatically** detect **landmarks**

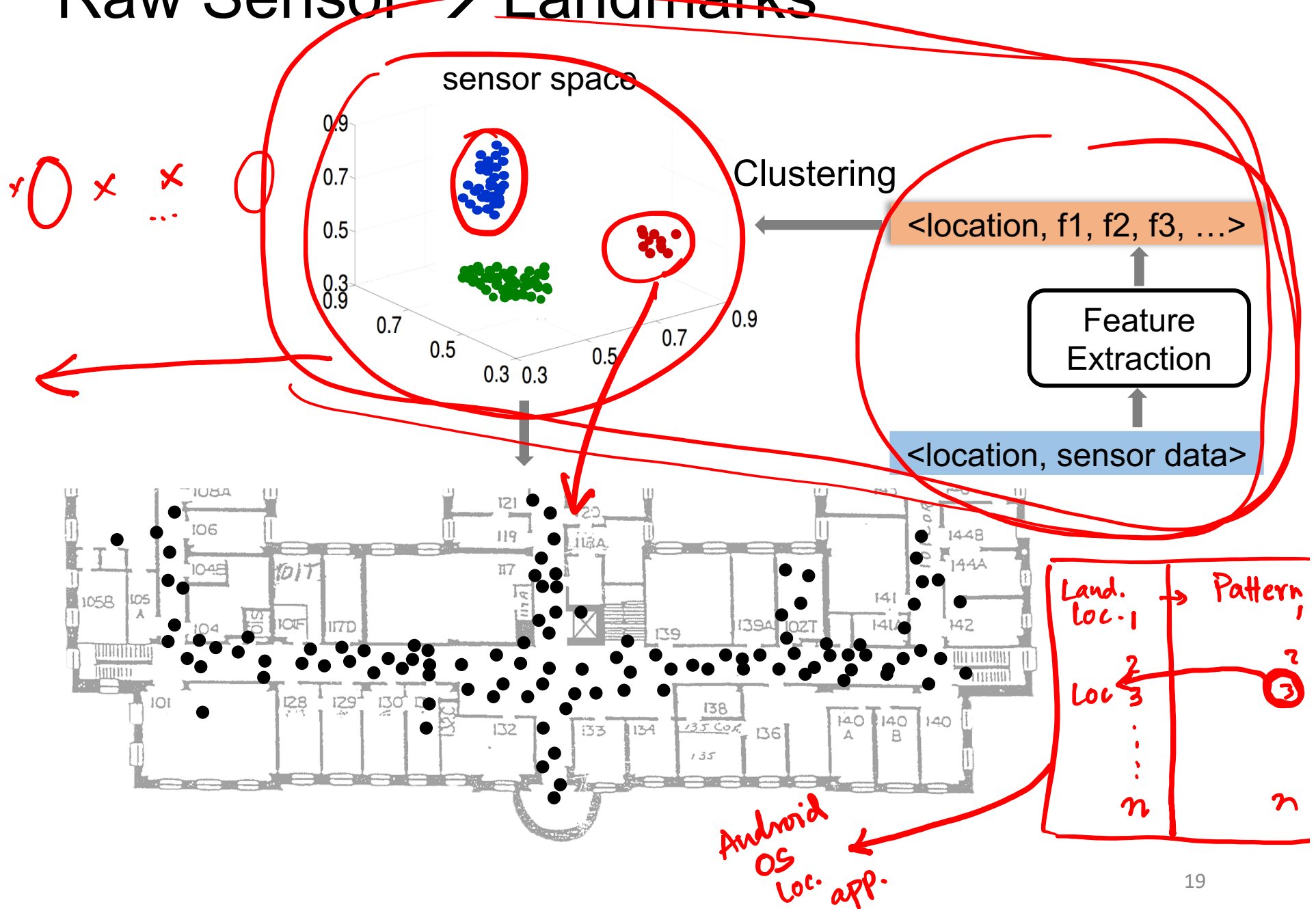
# Raw Sensor → Landmarks



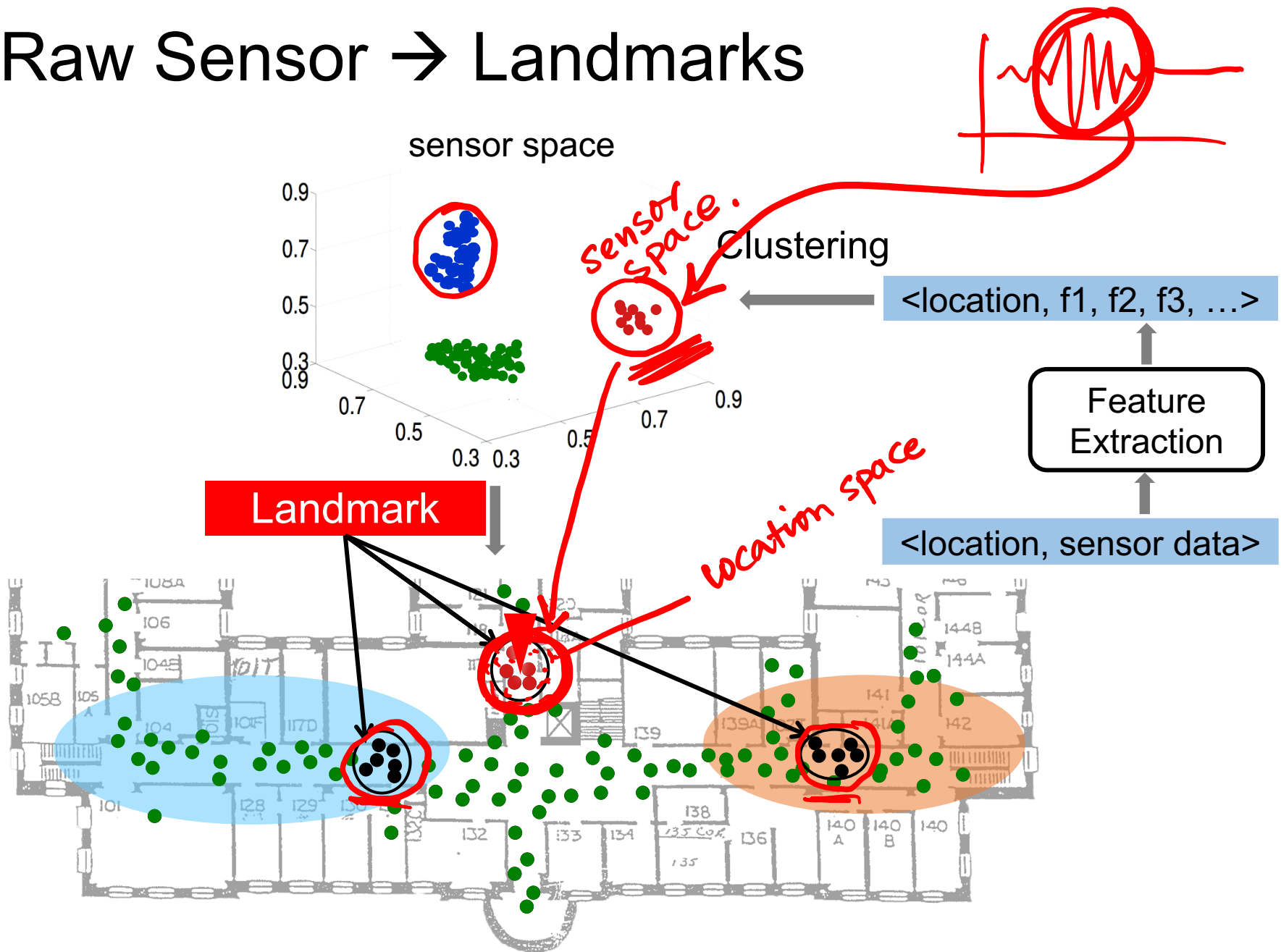
# Raw Sensor → Landmarks



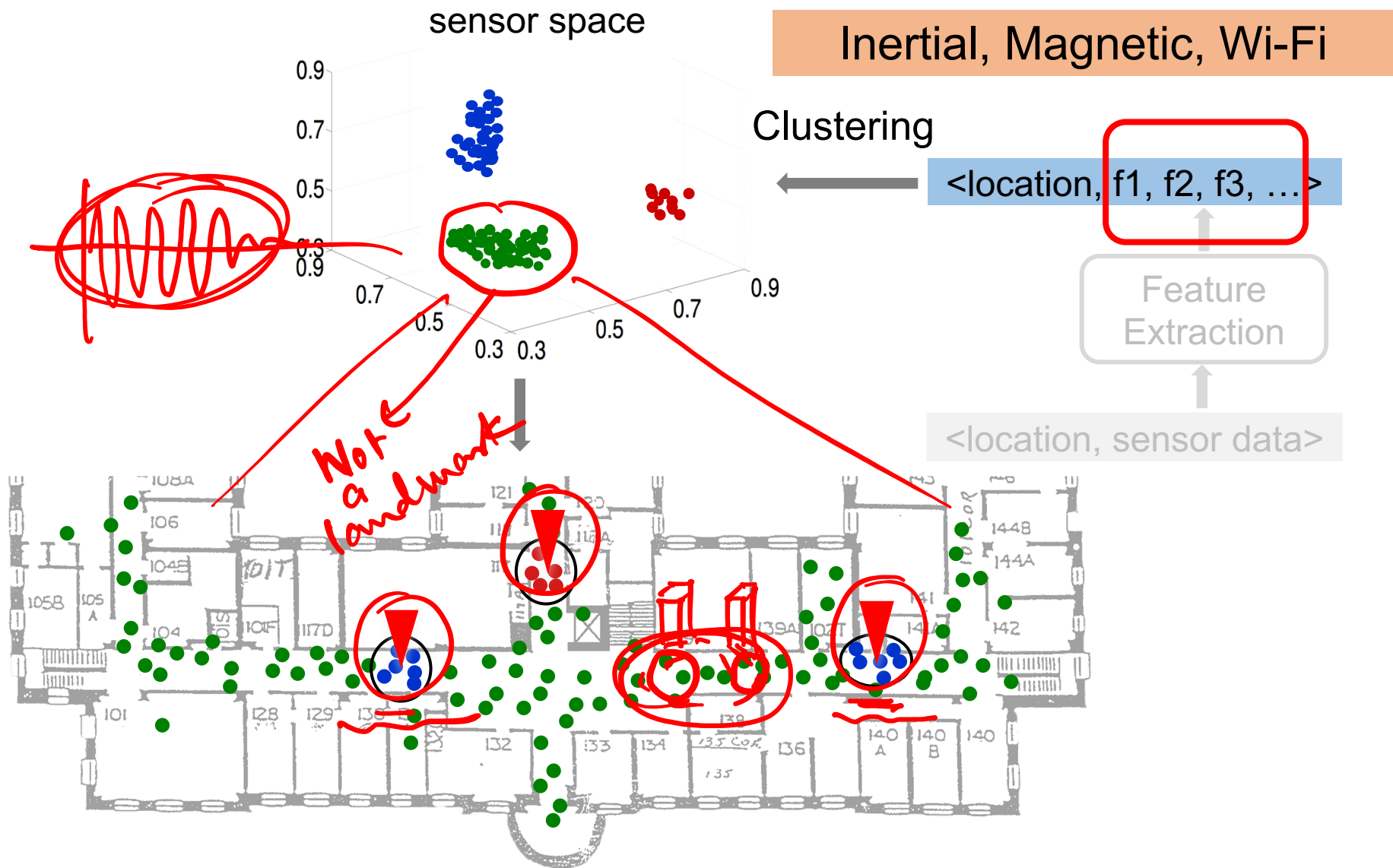
# Raw Sensor → Landmarks



# Raw Sensor $\rightarrow$ Landmarks

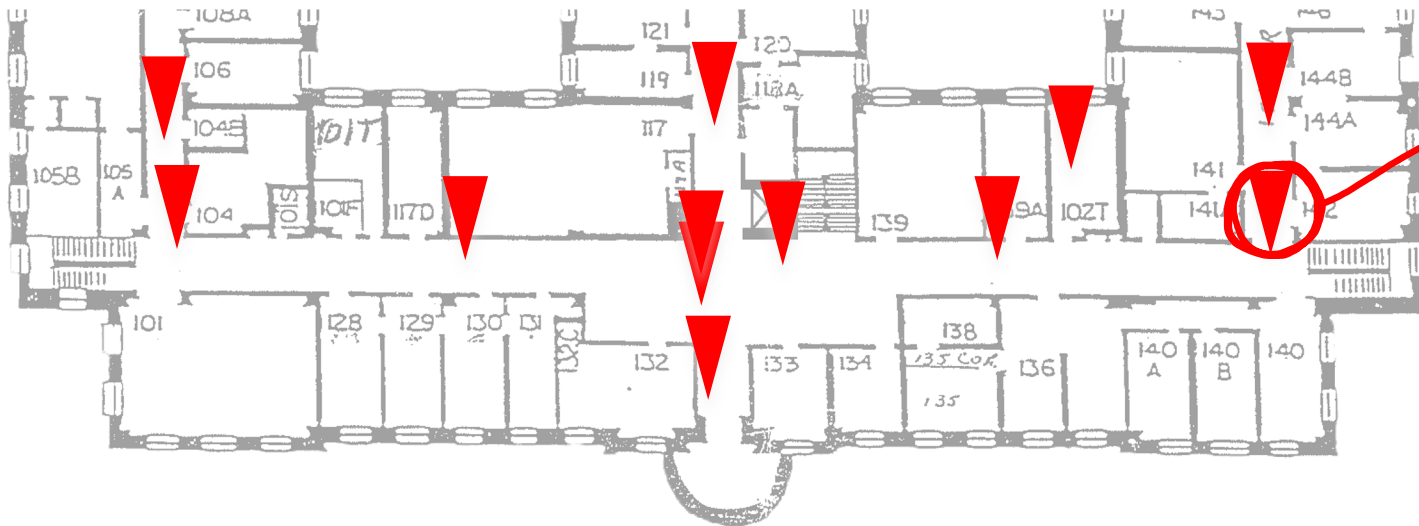


# Landmarks from Multiple Sensors



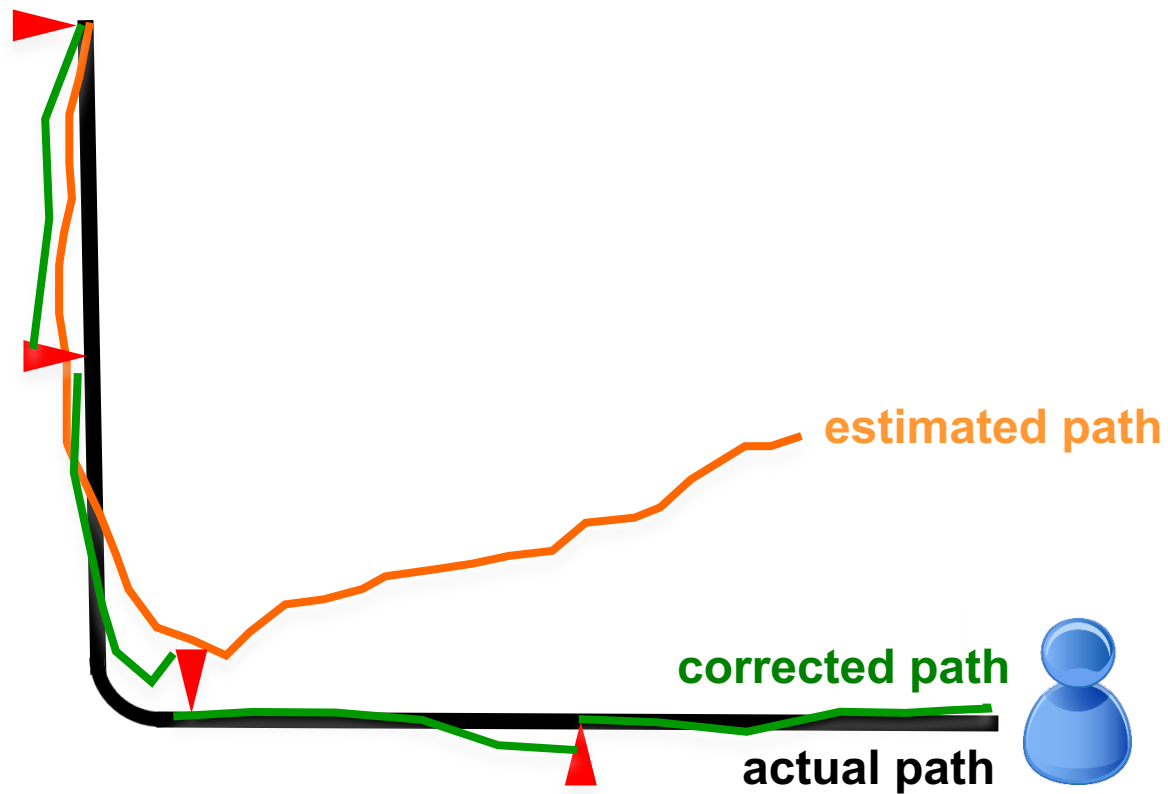
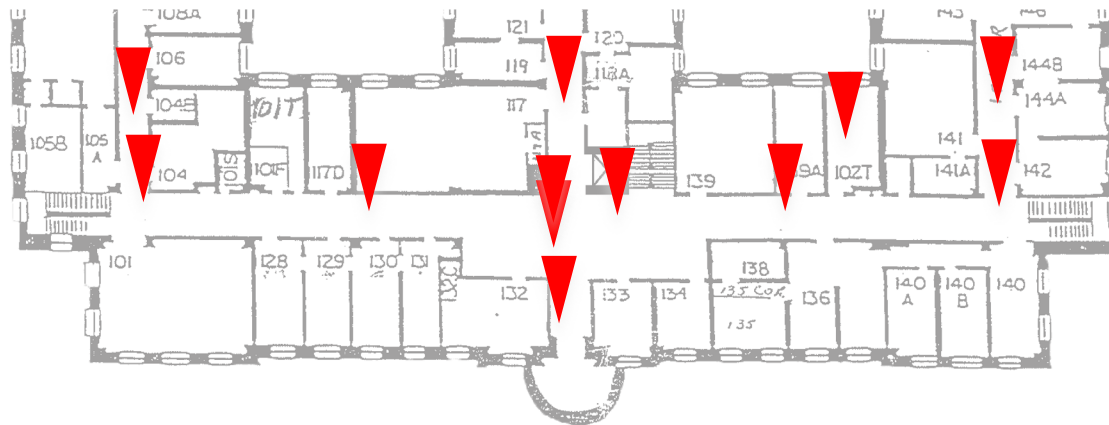
# Our Hypothesis

Indoor environments have adequate landmarks.



  
water fountain

We have found “stars”!

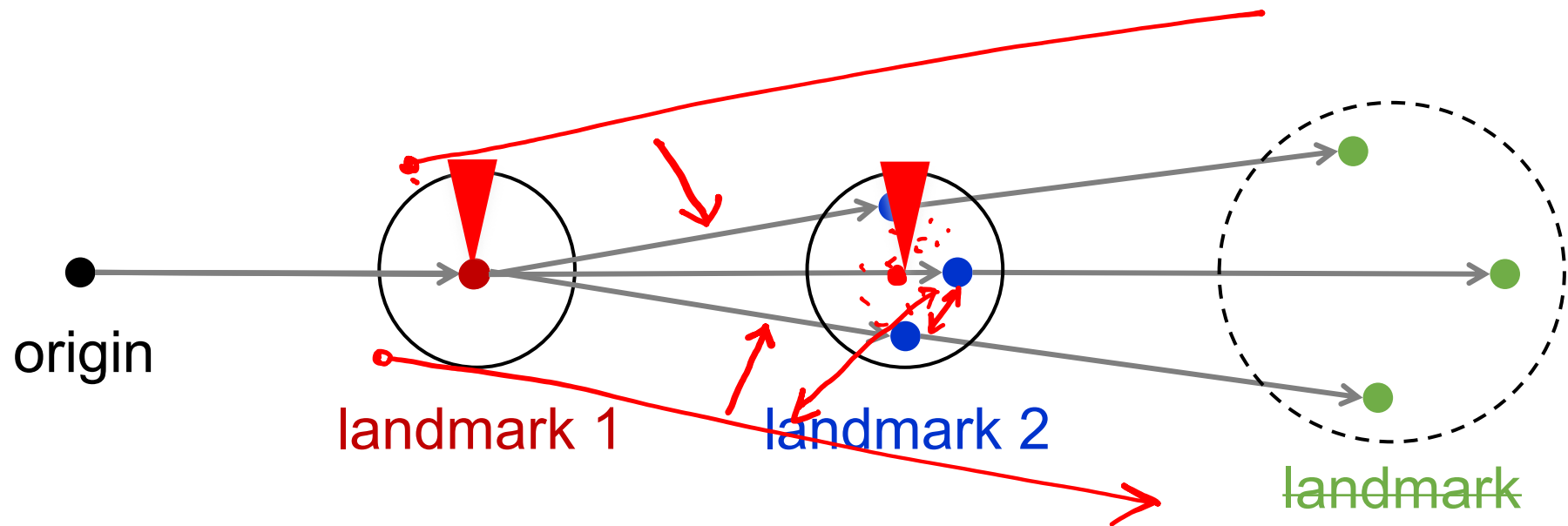


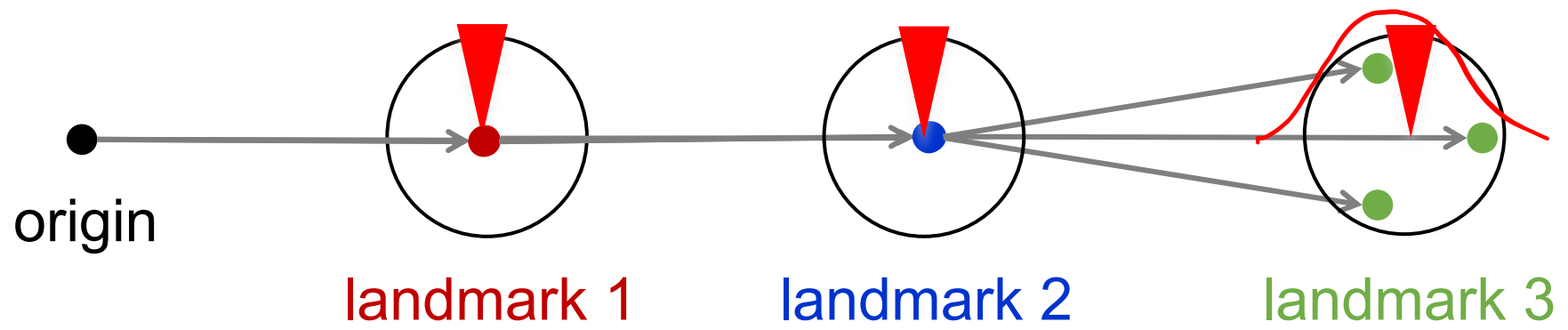
But, wait ...

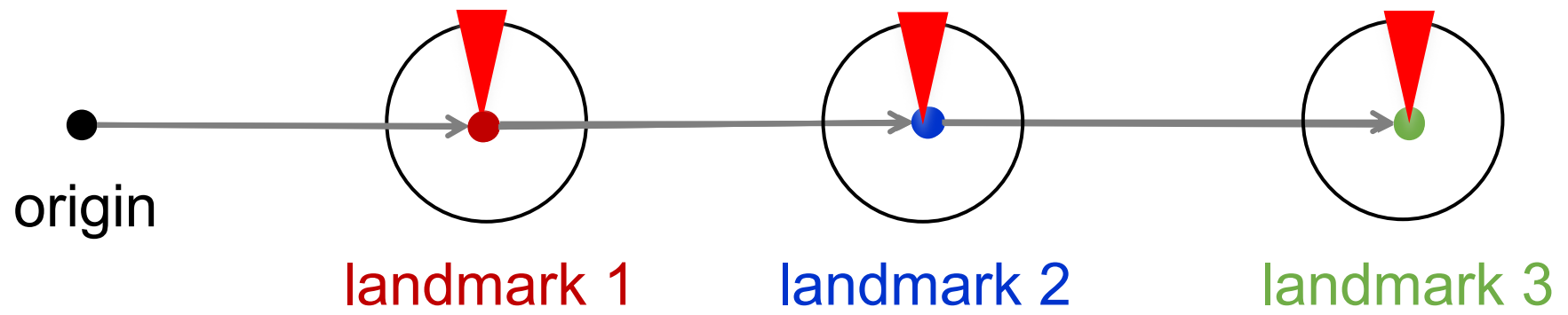
We assumed dead reckoning is not too bad ...  
But in reality it diverges poorly.

What happens then?

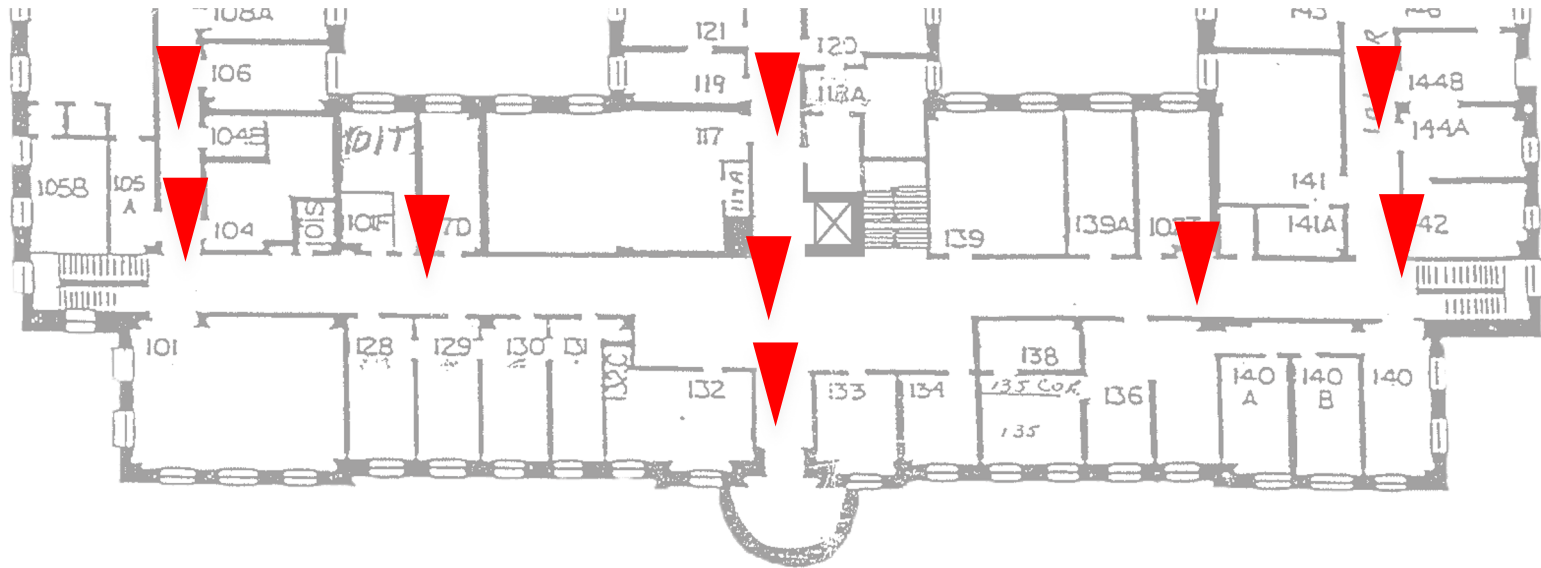




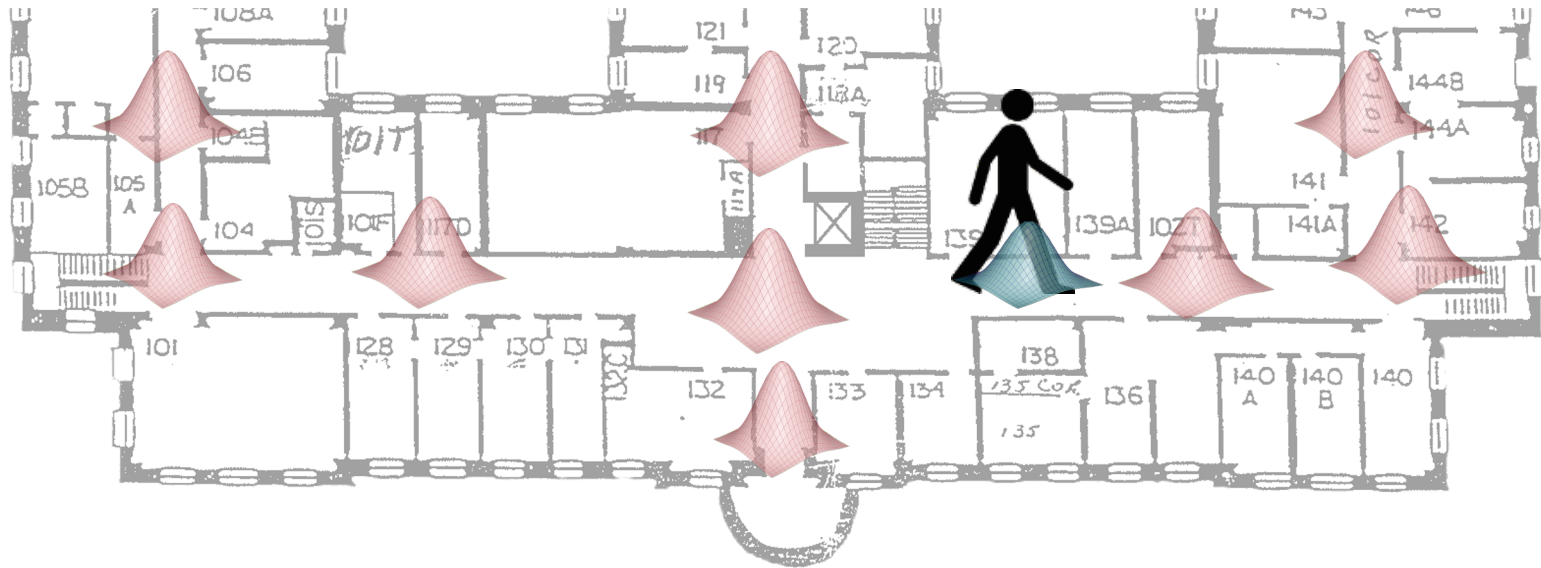




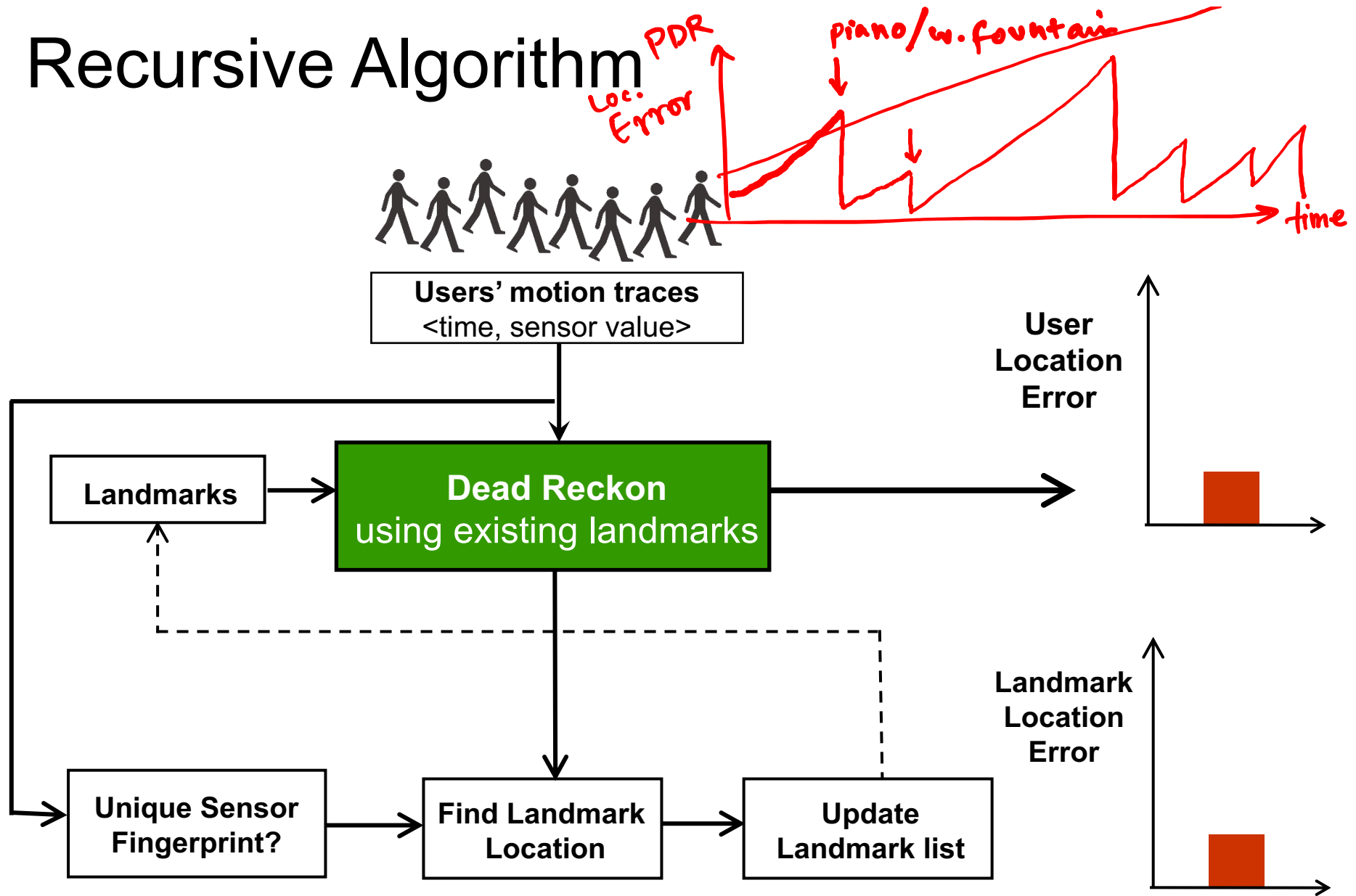
# Growing landmarks gradually



# Growing landmarks gradually



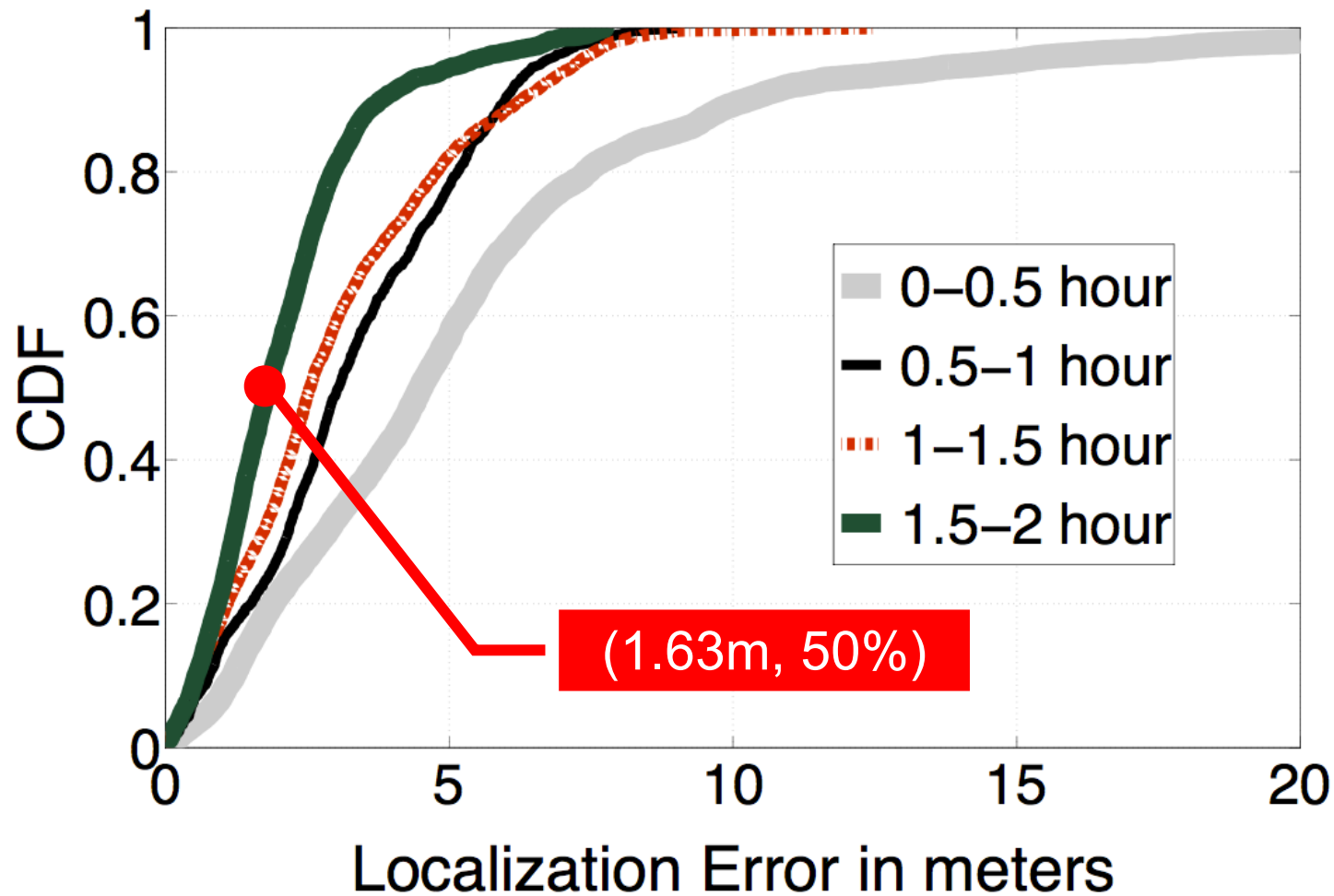
# Recursive Algorithm



# Performance

Experimentation on 8000 sq. meters

Shopping mall, ECE and CS buildings





Indoor environments rich in landmarks

