No Need to WarDrive ...
Unsupervised Indoor Localization
Where am I in a hotel, mall, office, cruise ship?
Why not outdoor localization technology?
Periodic calibration needed
Beacon

- sound beacon
- listener
- Bluetooth beacon

Installation and maintenance costs
We do not want to rely on infrastructure

We want a **scalable software solution**
Infrastructure-less Localization

accelerometer
compass
gyroscope
Dead reckoning

- estimated path
- actual path
Charles Lindbergh landed in Paris from New York.

No GPS

He used dead reckoning and obtained fixes from the stars.
Dead reckoning

No stars indoors

estimated path

corrected path

actual path
What if we “see” through sensors?
Acceleration pattern

Pressure change
Cellular pattern

![Graph showing signal level in dBm over time in seconds]

- Signal Level (dBm)
  -95
-100
-105

- Time in Seconds
  0  5  10  15
We use this core idea to design

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

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 \rightarrow Landmarks
Raw Sensor $\rightarrow$ Landmarks

Feature Extraction

Clustering

$\langle \text{location, f1, f2, f3, ...} \rangle$

$\langle \text{location, sensor data} \rangle$
Raw Sensor $\rightarrow$ Landmarks

1. Sensor space
2. Feature Extraction
3. Clustering

$\langle\text{location, f1, f2, f3, \ldots}\rangle$

$\langle\text{location, sensor data}\rangle$
Raw Sensor $\rightarrow$ Landmarks

Clustering

<location, f1, f2, f3, ...>

Feature Extraction

<location, sensor data>

Landmark
Landmarks from Multiple Sensors

Feature Extraction

(sensor space)

<location, sensor data>

Clustering

Inertial, Magnetic, Wi-Fi

<location, f1, f2, f3, …>

Feature Extraction

<location, sensor data>
Indoor environments have adequate landmarks.
We have found “stars”!

estimated path

corrected path

actual path
But, wait …

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

What happens then?
origin

landmark 1  landmark 2  landmark 3
Growing landmarks gradually
Growing landmarks gradually
Recursive Algorithm

Users’ motion traces
<time, sensor value>

Landmarks

Dead Reckon
using existing landmarks

Unique Sensor Fingerprint?

Find Landmark Location

Update Landmark list

User Location Error

Landmark Location Error
Performance

Experimentation on 8000 sq. meters
Shopping mall, ECE and CS buildings

CDF

Localization Error in meters

0

5

10

15

20

0

0.2

0.4

0.6

0.8

1

0–0.5 hour
0.5–1 hour
1–1.5 hour
1.5–2 hour

(1.63m, 50%)
Indoor environments rich in landmarks

1.63m accuracy
No infrastructure cost
No calibration needed