Indoor Positioning in Smartphones by Adopting Inertial Sensors and Radio Information

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21 March, 2016

Outline

- Motivation.
- Proposed Tracking Algorithm
  - Radio Information Component.
  - Inertial Sensor Component.
  - Floor Plan Information Component.
  - Data Fusion Component.
- Implementation of the Tracking Algorithm in Smartphone
- Preliminary Experiment and Results
- Conclusions and possible future work.

Motivation

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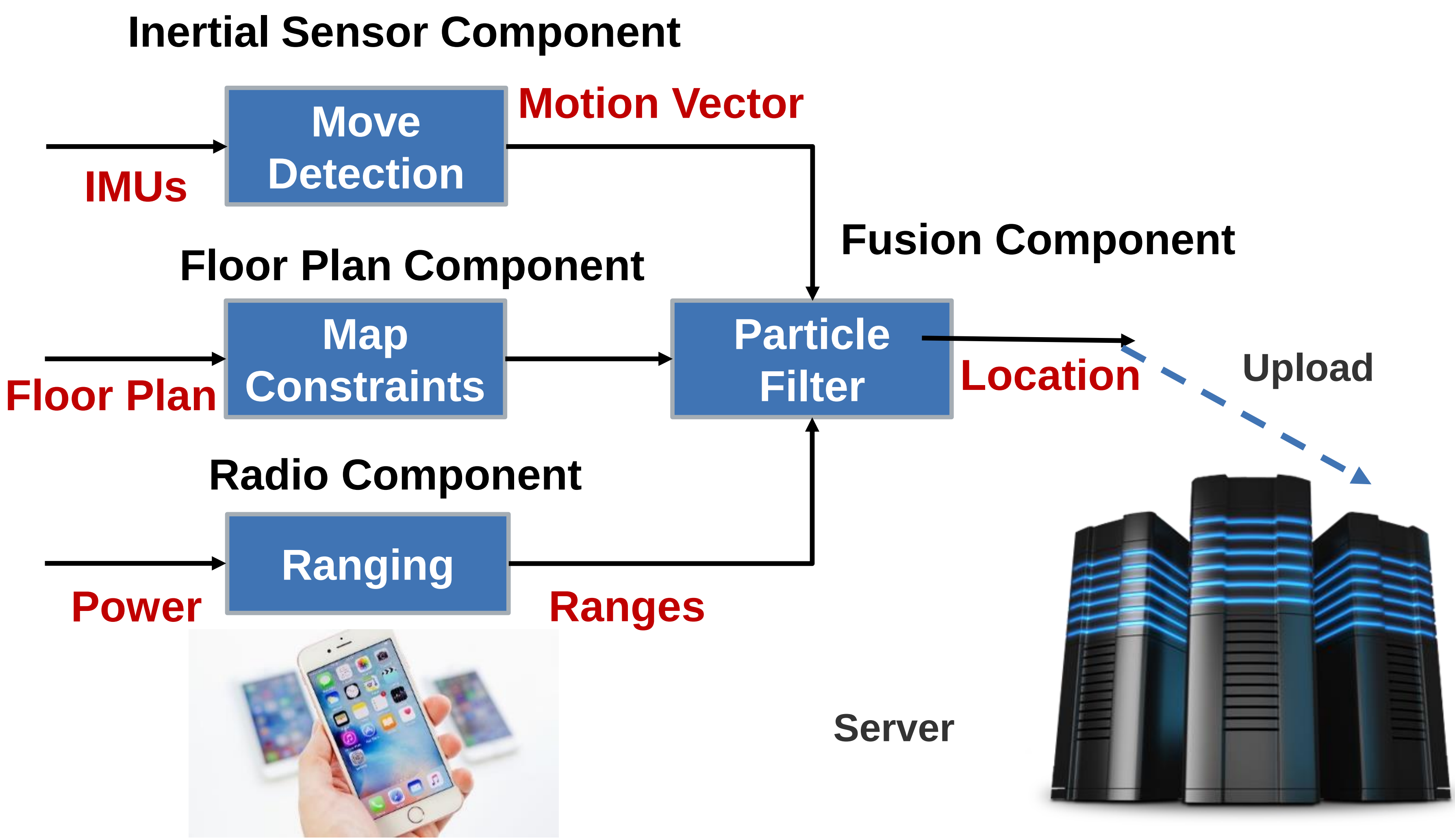
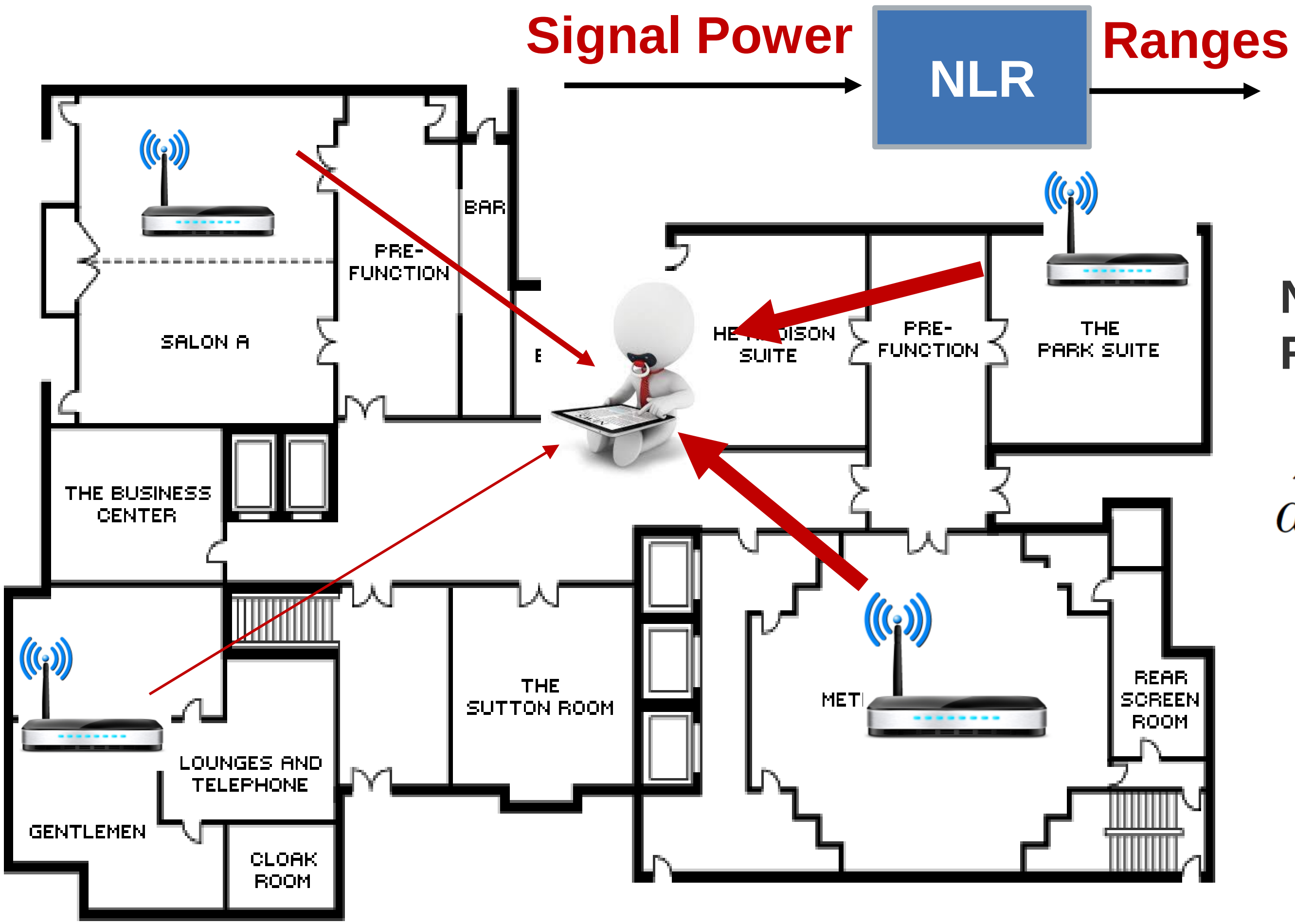
- Locating in indoor environments has become a key issue for emerging location based application.
  - Mobile phones important interface user-environment.
- Crucial for pervasive mobile applications:
  - Tracking of medical equipment
  - Store navigation
  - Parking lots
  - Tracking in disaster areas
- No easy and accurate solution nowadays.
- No accepted standards do yet exist.
- SwissSenseSynergy project

Indoor Tracking System



Radio Information Component



Non-Linear Regression Model [1]

$$\hat{d}_i = \alpha_i \cdot e^{\beta_i \cdot \mathrm{RSS}_i}$$

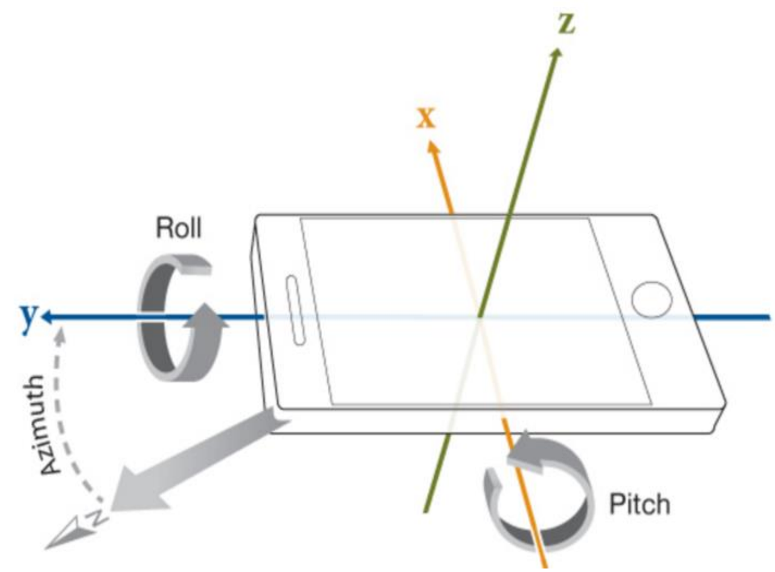
[1] Z. LI, T. Braun, "A Passive WiFi source localization system based on fine-grained power-based trilateration ", University of Bern, IEEE International Symposium on a World of Wireless, Mobile and Multimedia Networks (WoWMoM), June 2015

Inertial Sensor Component

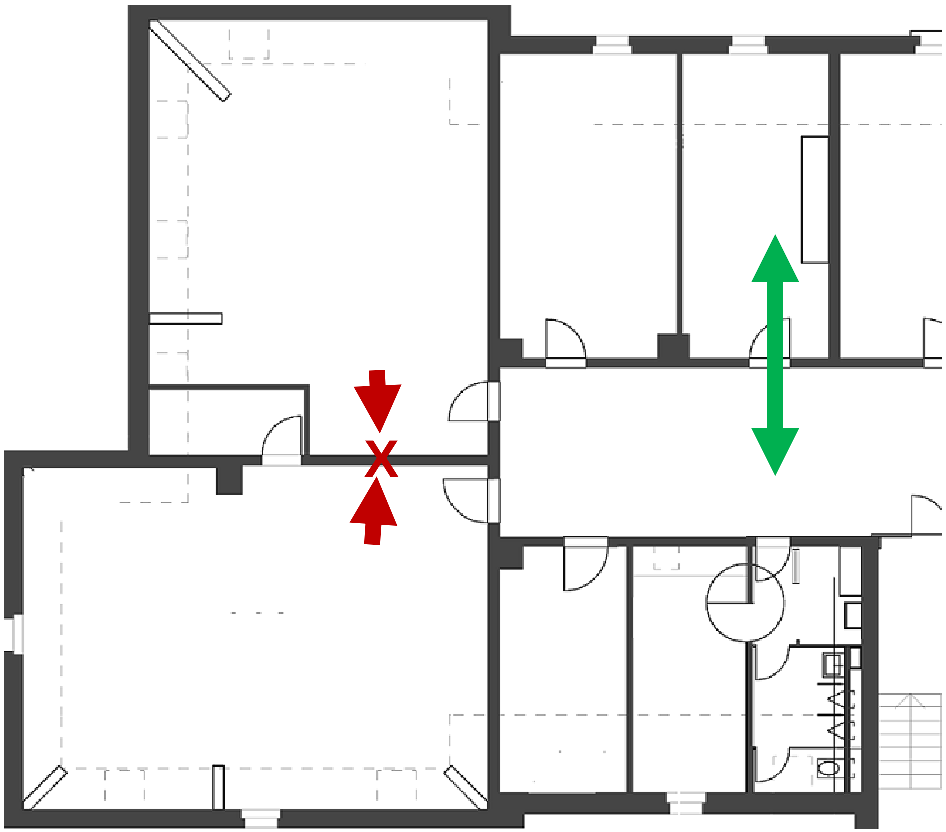
Accelerometer:
- Linear acceleration.

Gyroscope
- Angular rotation velocity

Magnetometer
- Azimuth value

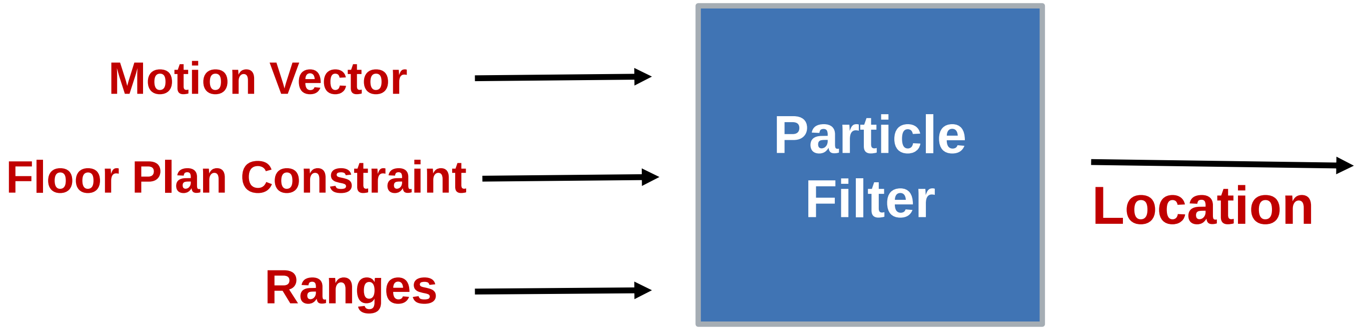


Floor Plan Component



Define “allowed” zones

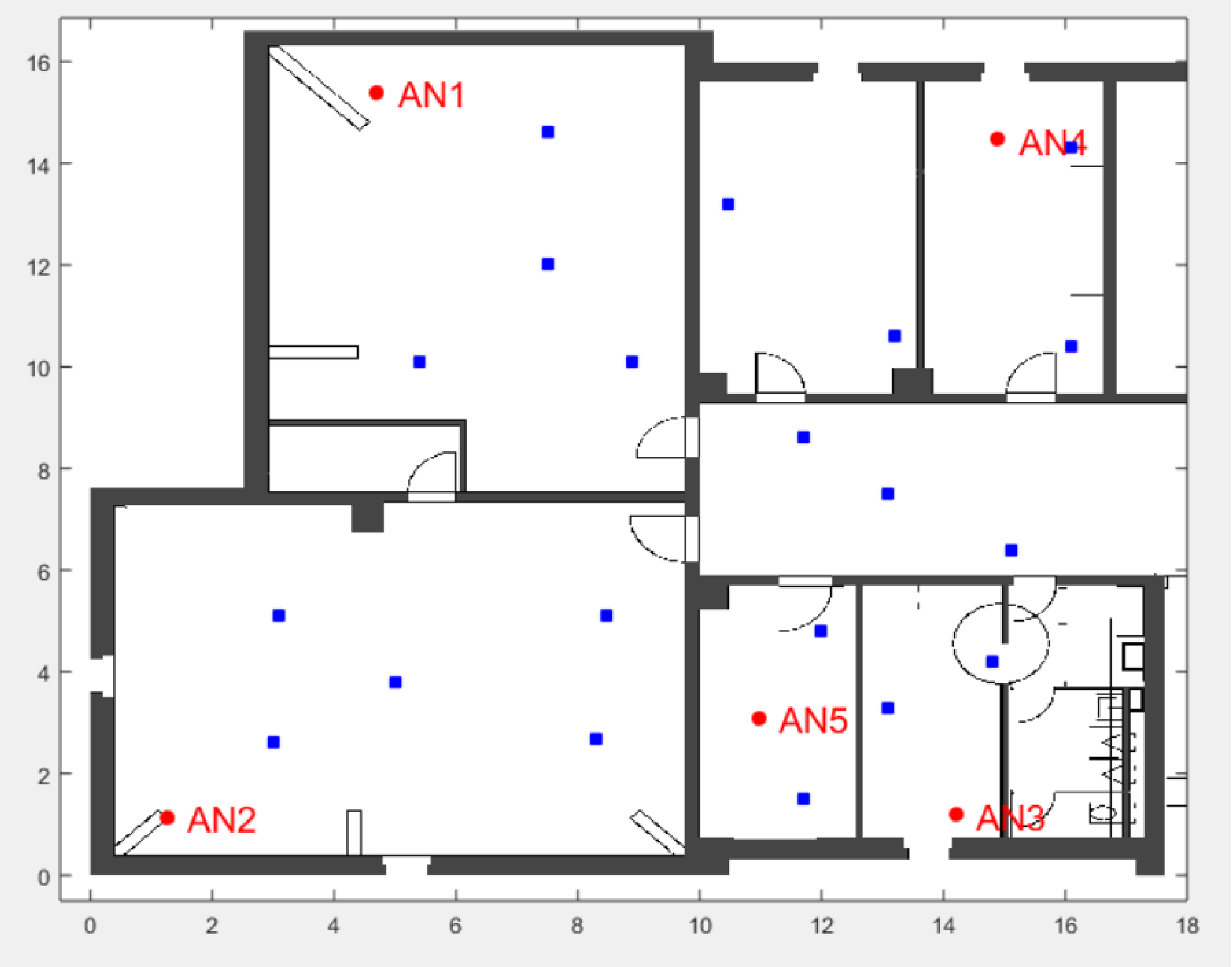
Data Fusion Component



Bayesian Filter

- Model of how state changes in time.
- Model of what observations you should see.
- Represents a PDF as a set of samples (particles).
- Belief of the current state given all the observation so far.

Implementation
Ranging I



Implementation Ranging II

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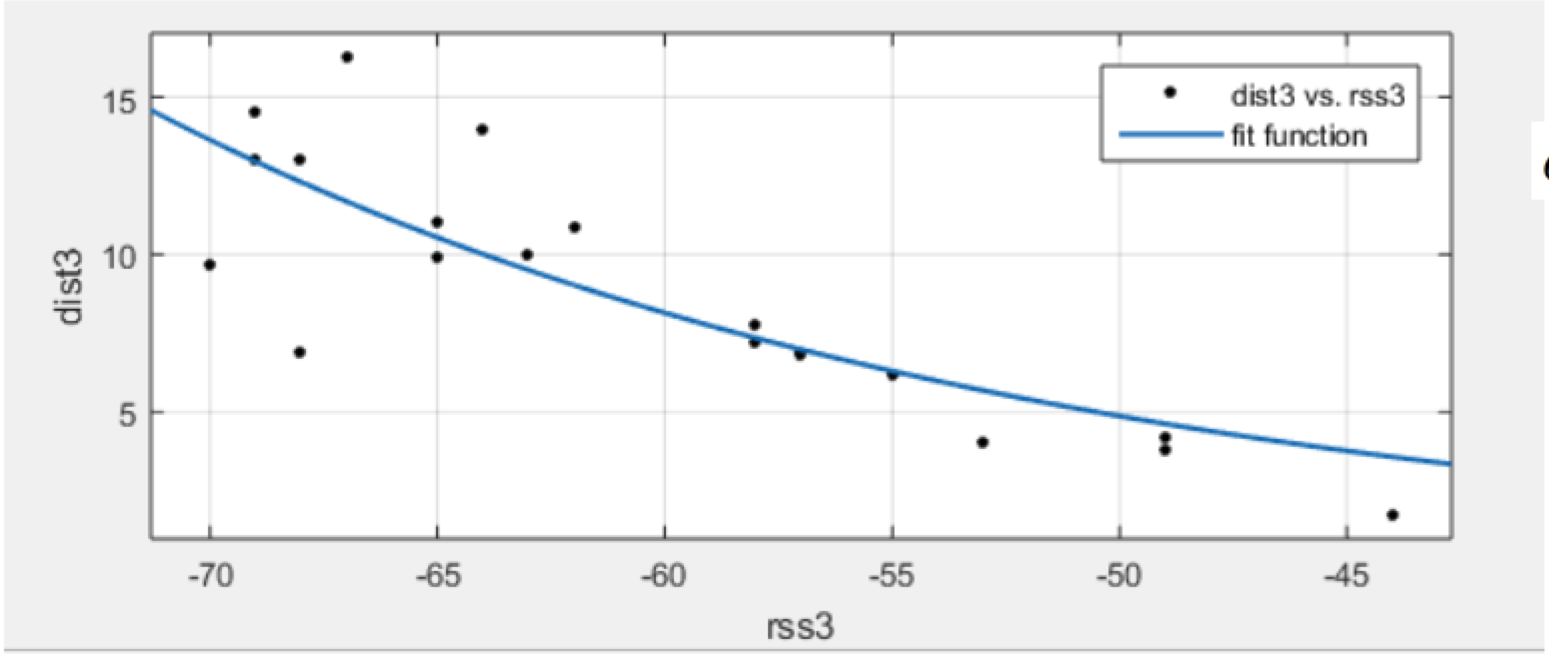
Non-Linear Regression Model

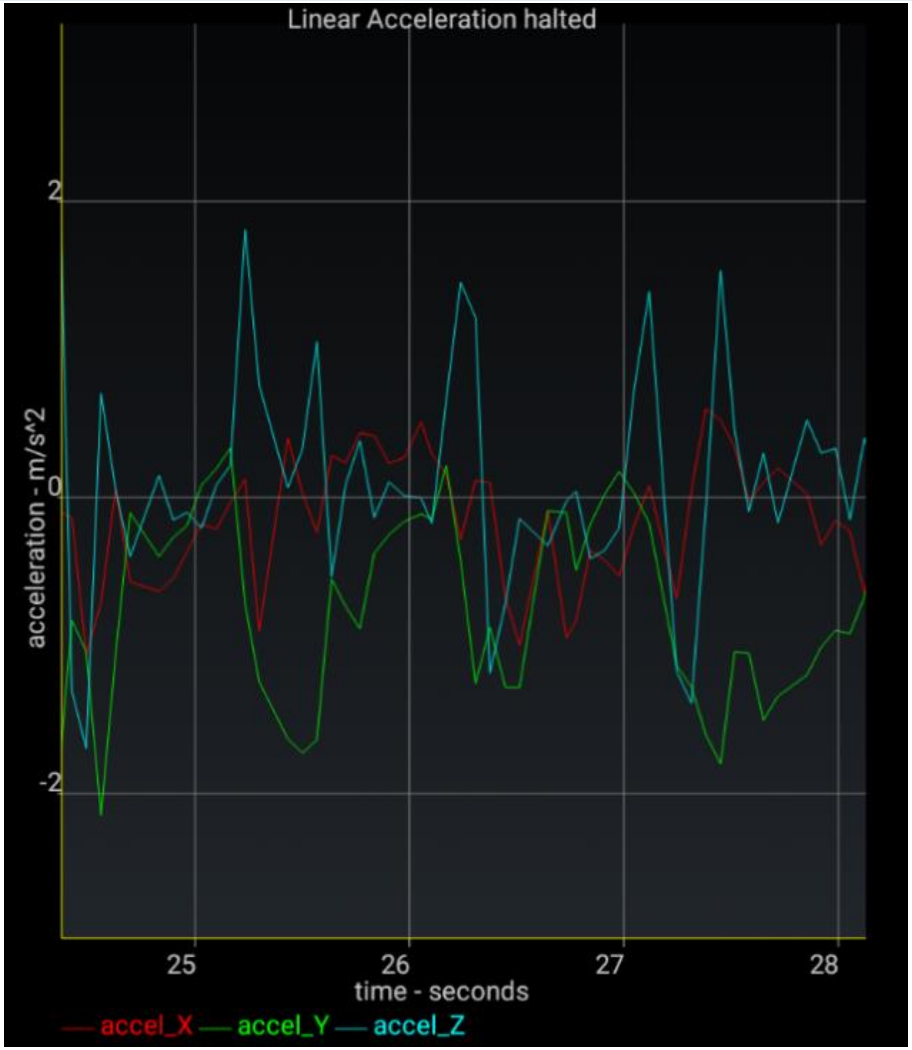
$$\hat{d}_i = \alpha_i \cdot e^{\beta_i \cdot \mathrm{RSS}_i}$$



$\alpha_3 = 0.37$

$\beta_3 = -0.05$

Implementation
Inertial Measurement Unit I

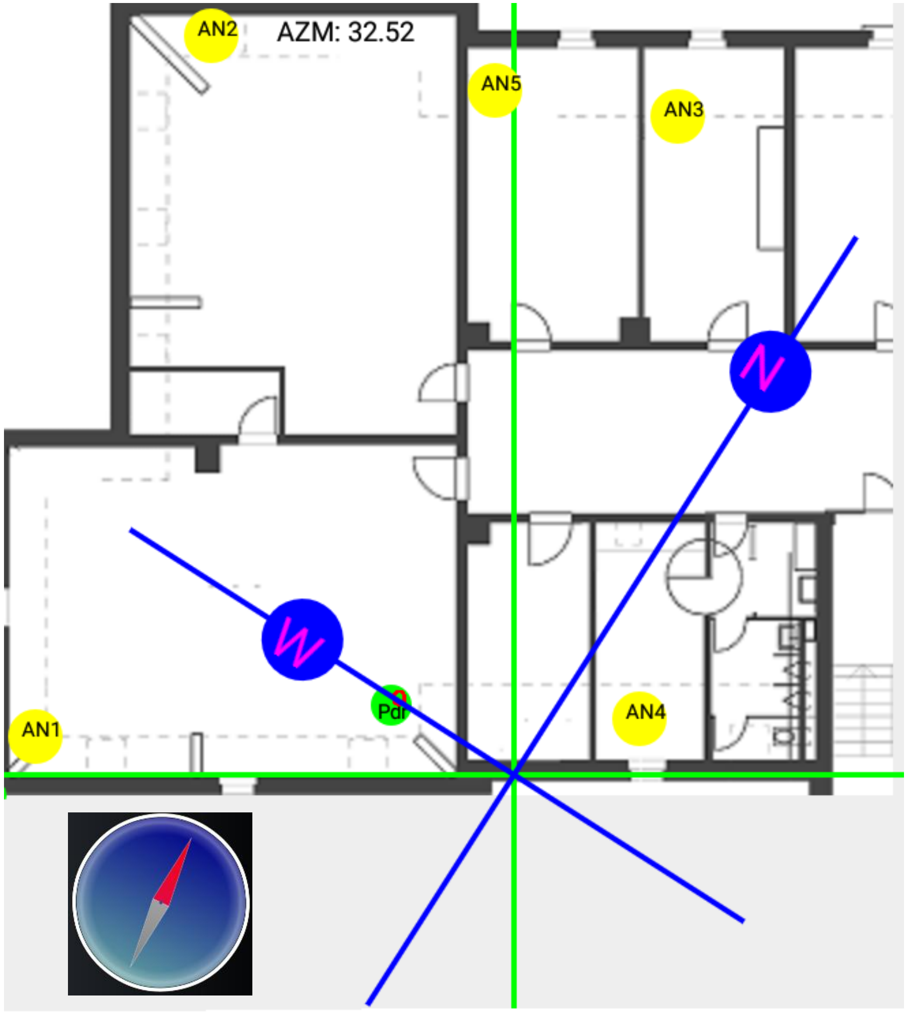


Accelerometer

Step Recognition

$$\hat{a}_{z,t} > Threshold \ \&\&$$
$$\hat{a}_{z,t-1} < \hat{a}_{z,t} \ \&\&$$
$$\hat{a}_{x,t} < \hat{a}_{z,t} \ \&\&$$
$$\hat{a}_{y,t} < \hat{a}_{z,t}$$

Implementation
Inertial Measurement Unit II



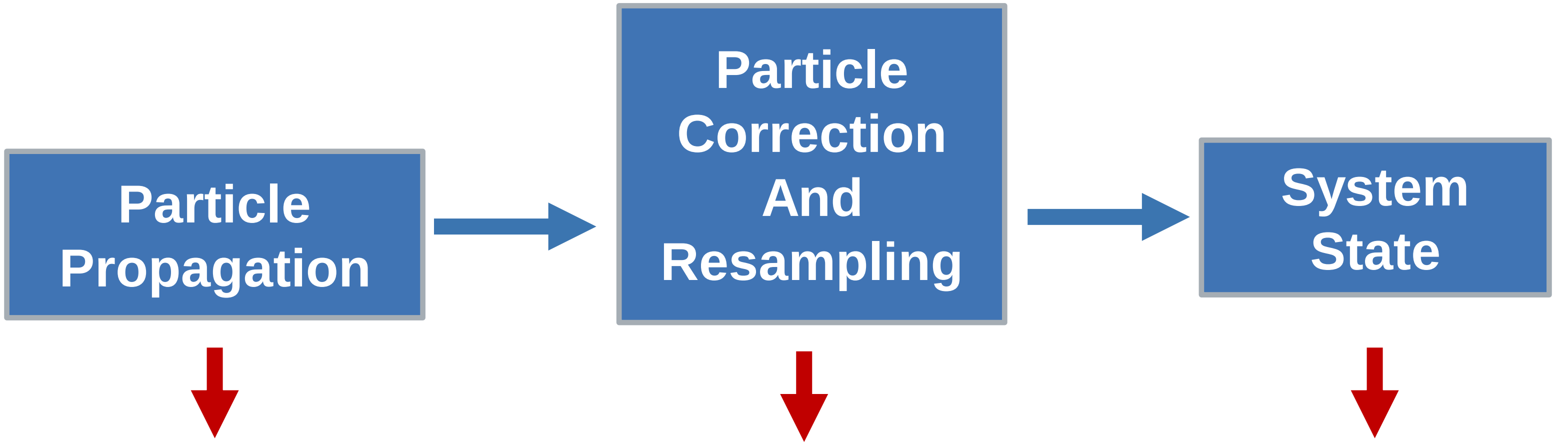
Magnetometer, Accelerometer, Gyroscope

Heading Orientation

OffsetX: Inclination X axis Magnetic North
Azimuth: Magnetic North and Y axis

θ=(*OffsetX-Azimuth****).***
st=*stride length.*

Implementation
Particle Filter



Motion Vector

X= $\widehat{st}$**cos(θ).*

Y= $\widehat{st}$**sin(θ).*

Likelihood

RSS observation

- **Ranging**

Floor Plan

- **Constraints**

$$\mathbf{x}_k = \sum_{i=1}^{N_s} w_k^i \mathbf{x}_k^i$$

$$w_k^i = \hat{w}_k^i / \sum_{n=1}^{N_s} \hat{w}_n^i$$

Implementation
Technical Challenges

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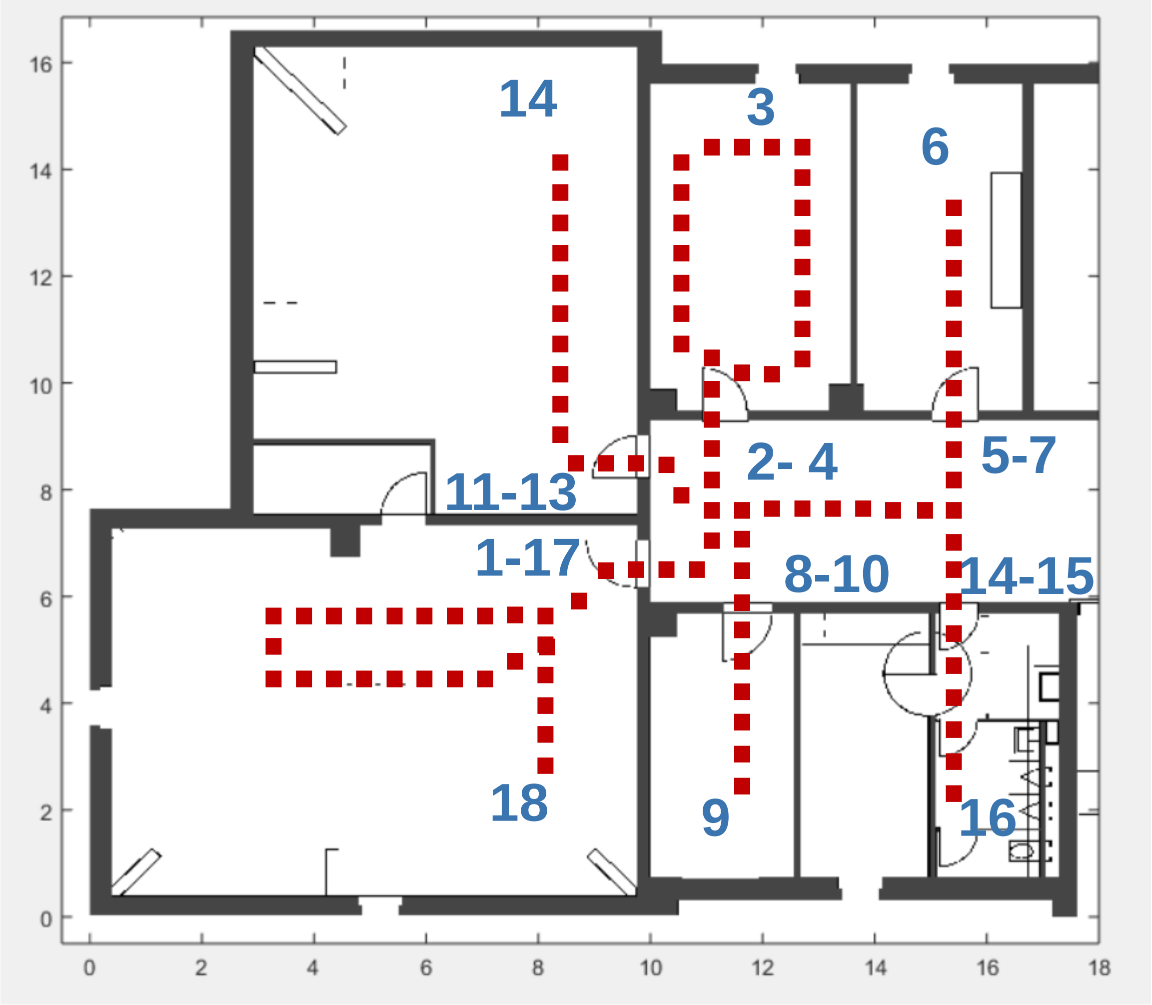
- **Resources: Android solution.**

- **Sampling Rate.**
  - IMU 14Hz
  - WiFi sensor 3Hz.

- **Delay Uploading Position Information.**
  - Stop scanning process.
  - Cellular network (Future work).

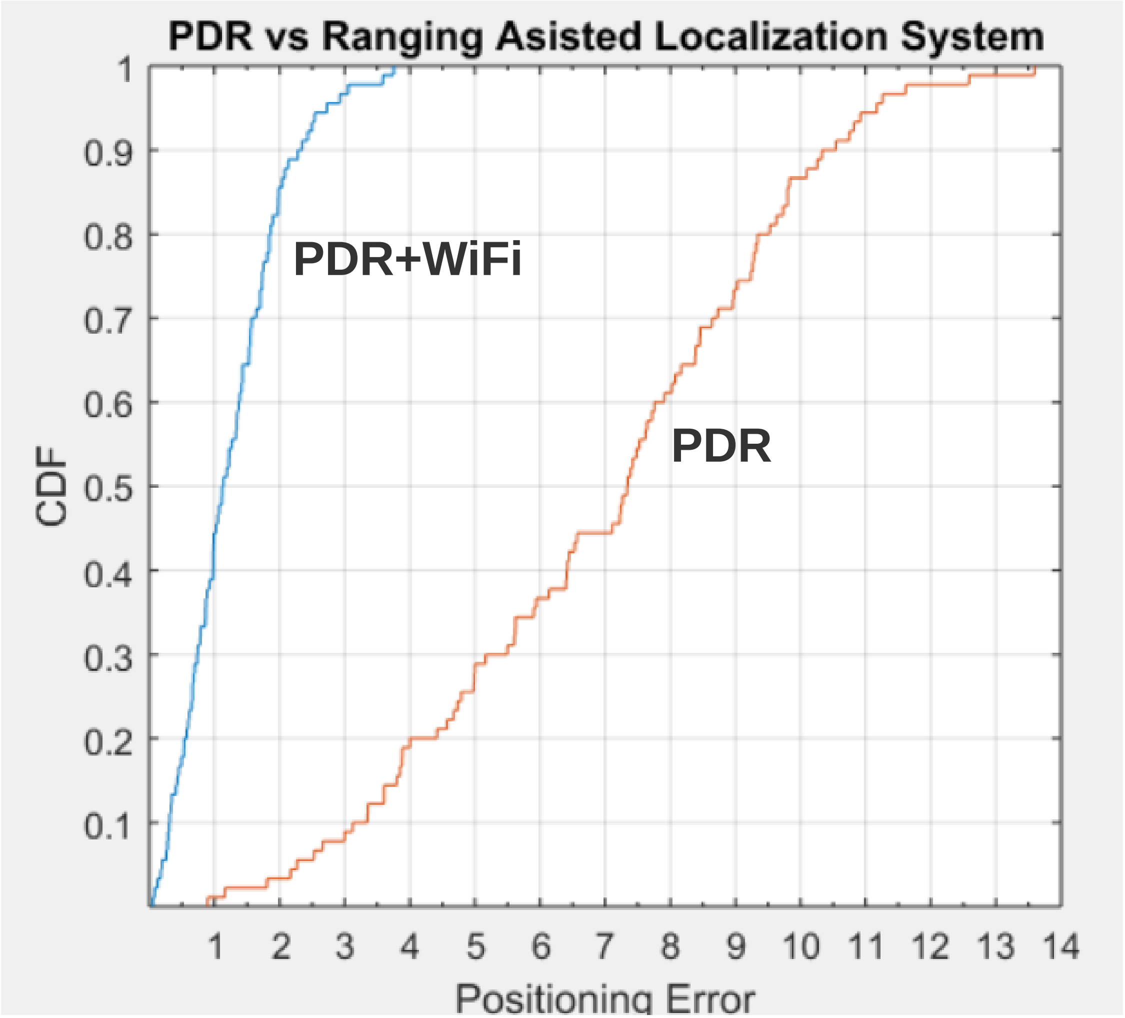
Experiment



EXPERIMENT

- 5 Trajectories
- 18 Check Points each
- 90 Check Points

Preliminary Results



Results

- 90 points.
- **Mean Error:** 1.25m.
- **Std:** 0.79 m.

Conclusions

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- Tested complex scenario. Room entrance prone to error.
- Proposed Ranging-PF assisted approach higher accuracy, more stable than PDR.
  - 50% accuracy achieve around 1m. (PDR: 7.5m.)
    - Outperforms PDR by 86%.
  - 90% accuracy achieve around 2m. (PDR: 11m.)
    - Outperforms PDR by 81%.
- Use RSSI information to recalibrate PDR system and deal with accumulative errors.

Future Work

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- Design more experiments.
- Publish results.
- Try different technologies to upload information to the server.
- Implement solution in the server side.
  - Share computation server-phone. (more particles)
- Test multiple user performance.
  - Using cloud.
- Include room recognition.

DEMO

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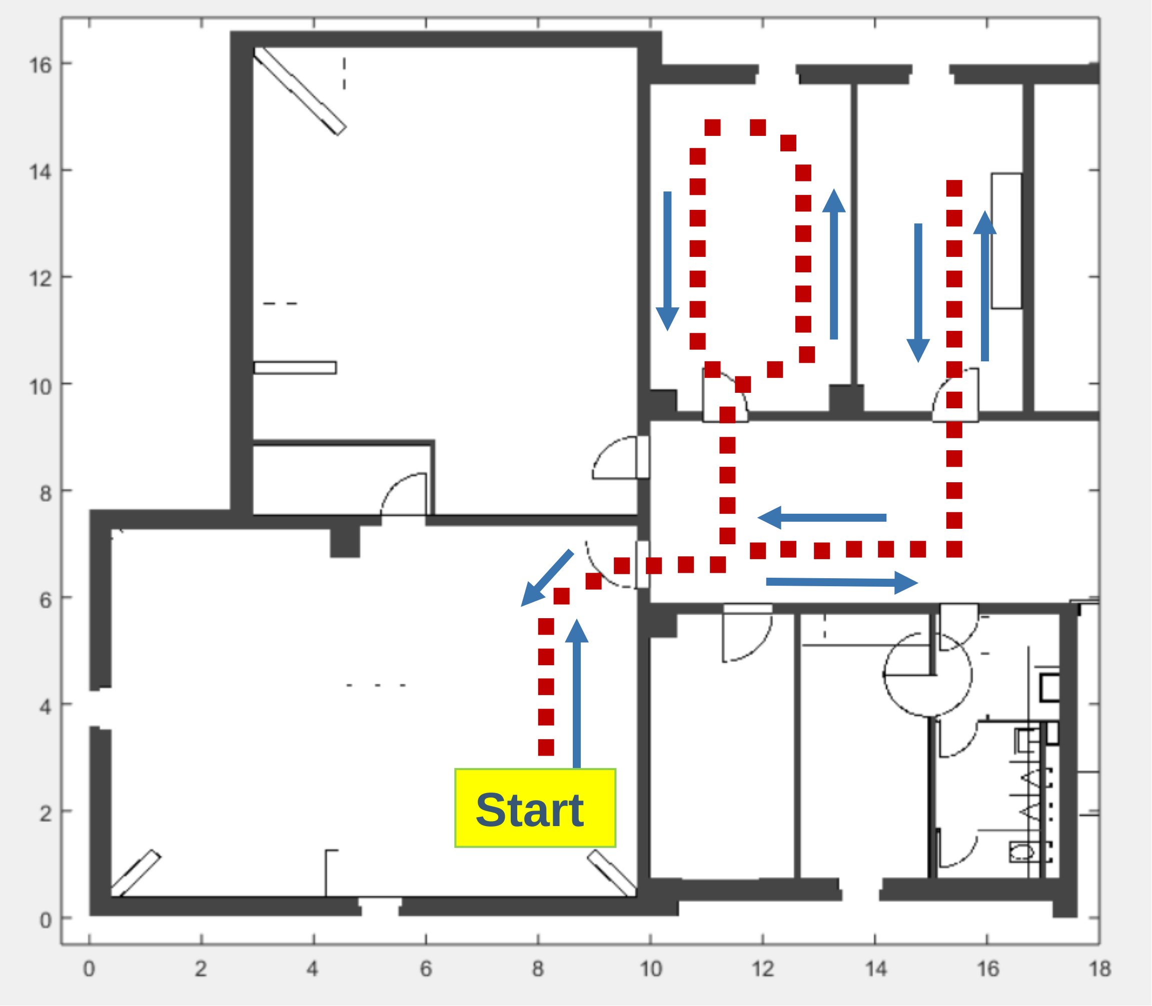
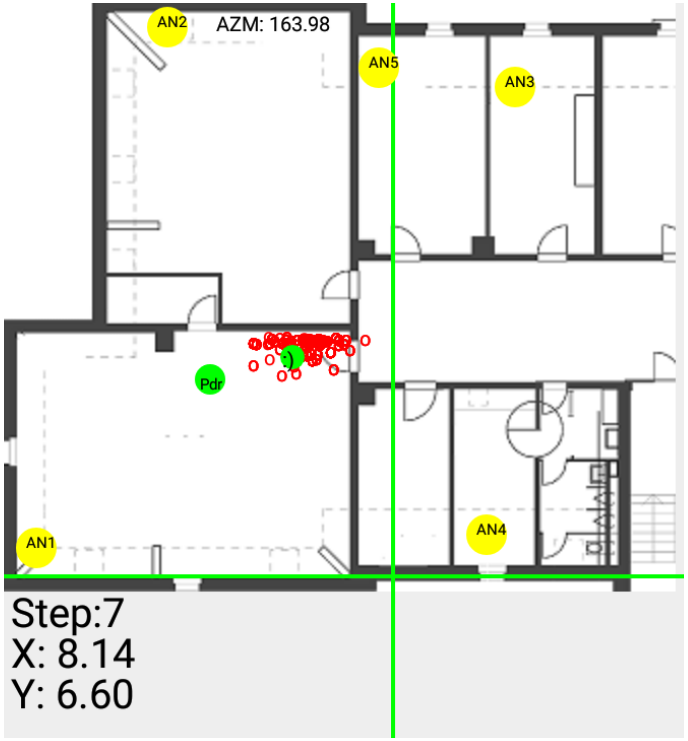


Android Application



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Questions