Indoor Localisation with Sensor fusion of PDR and single RTT Wi-FI

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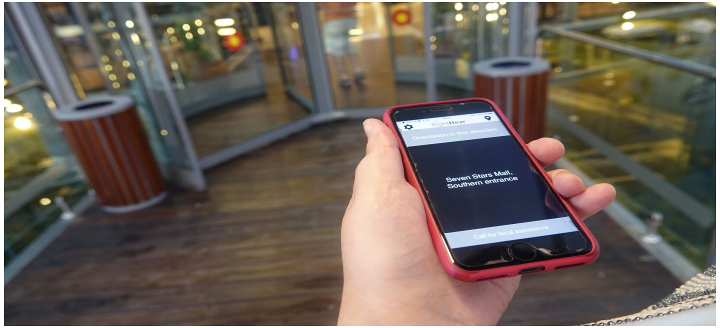
Problem definition

- ➢ Indoor localization without using trilaterization.
- ➢ We are only considering Single access point for Wi-Fi RTT.
- ➢ Initial position is also known .
- ➢ Position of AP is fixed.

Application Examples

➢ Supermarket Cart Location Analysis

➢ Localization for the Visually Impaired in Public Places



Getting IMU Data

- Why we used PDR?
  - TYPE_LINEAR_ACCELERATION
  - Low-pass filter and high-pass filter
  - Double integration
  - Error accumulation

PDR

$$X_t = X_{t-1} + L_t \begin{bmatrix} sin(\theta_t) \\ cos(\theta t) \end{bmatrix}$$

Where, L is the step length

and, θ is the heading w.r.t phone

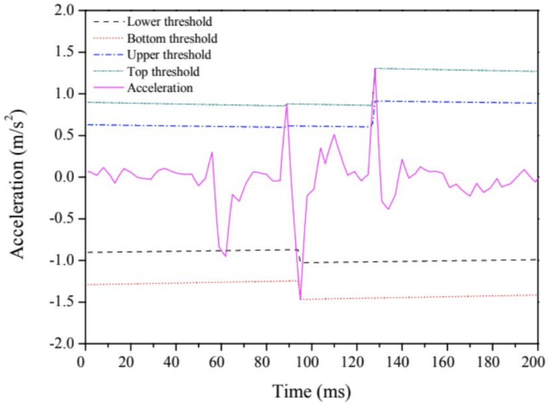
Step length

$$L = K\sqrt[4]{a_{max} - a_{min}}$$

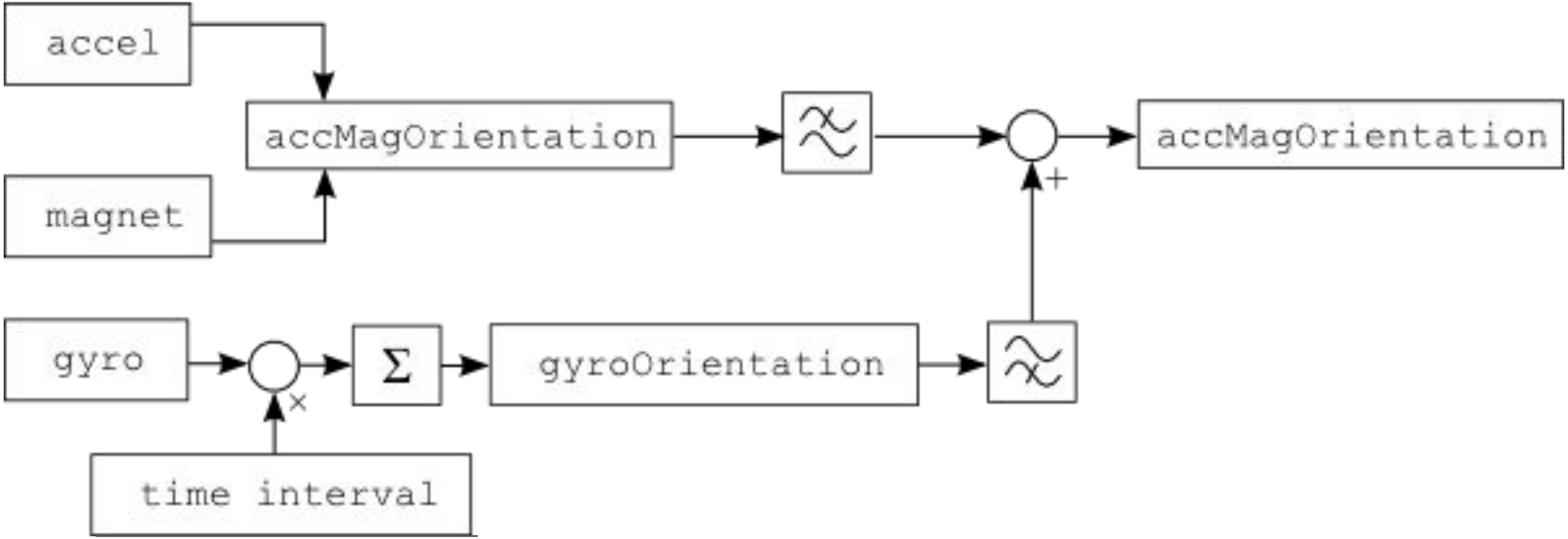
Where, K = 0.68 - 0.37 * v + 0.15 *pow(v,2)

and, v is the average step velocity

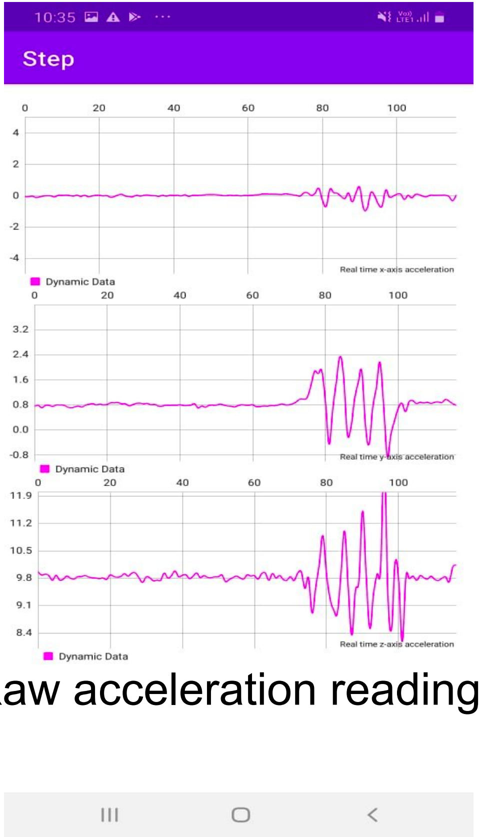
Step detect



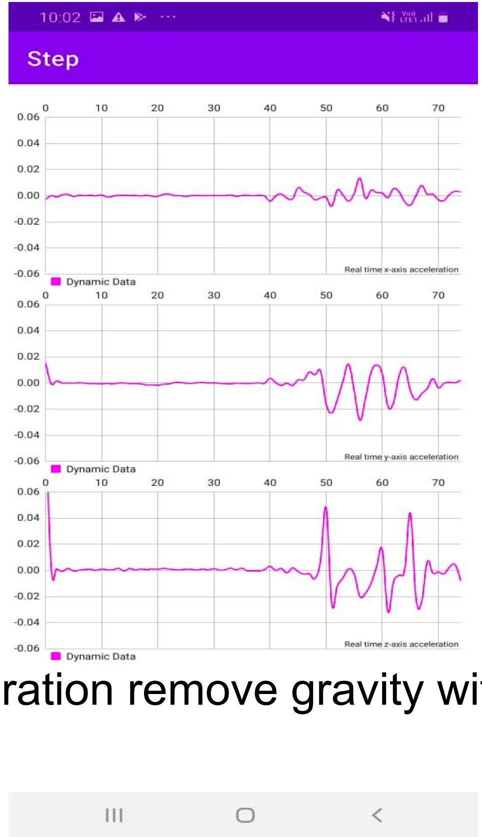
Sensor fusion using complementary filter



Acceleration



Raw acceleration readings



Acceleration remove gravity with LPF

RTT range simulation

- ➢ Gaussian noise added with mean 0 and std. Dev 0.5
- ➢ Effect of Position of AP
  - ○ Any point on perpendicular at the ends
  - ○ On the circumference
- ➢ Effect of Radius of circle
  - ○ Bigger circle better
- ➢ Effect of update frequency
  - ○ updating less often better!

Single RTT Localization

➢ Infinite solutions problem

➢ Using PDR estimate position and find the closest point to this estimate:

$$x = x_a + (x_p - x_a) * r/d$$

$$y = y_a + (y_{pdr} - y_a) * r/d$$

➢ Downside

- Bad estimate if drift overpowers.

Kalman filter

➢ Assumes all the noise is gaussian and all the models are linear.

Algorithm Kalman_filter($\mu_{t-1}, \Sigma_{t-1}, u_t, z_t$):

$$\bar{\mu}_t = A_t \, \mu_{t-1} + B_t \, u_t$$
$$\bar{\Sigma}_t = A_t \, \Sigma_{t-1} \, A_t^T + R_t$$

$$K_t = \bar{\Sigma}_t \, C_t^T (C_t \, \bar{\Sigma}_t \, C_t^T + Q_t)^{-1}$$
$$\mu_t = \bar{\mu}_t + K_t(z_t - C_t \, \bar{\mu}_t)$$
$$\Sigma_t = (I - K_t \, C_t) \, \bar{\Sigma}_t$$

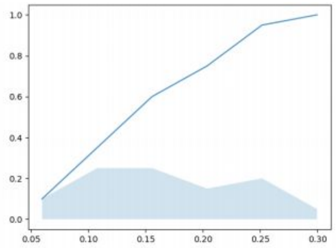
return μ_t, Σ_t

- Adjustment to make the model stay linear.
- Achieving different update frequencies
  - Button
- Downside
  - Measurement model may not be linear (EKF)

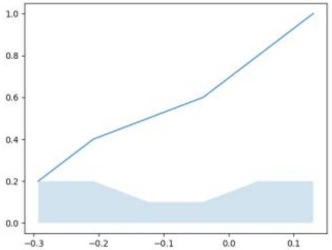
Bias variance estimation

➢ Experiment procedure

- Step length

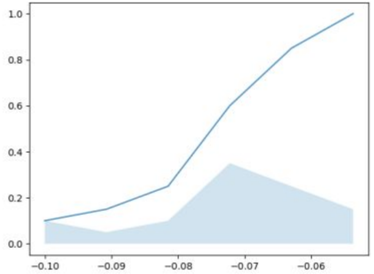


Errors in each step length — Almost Gaussian



Errors in step length and step detect combined

- Orientation



Almost Gaussian

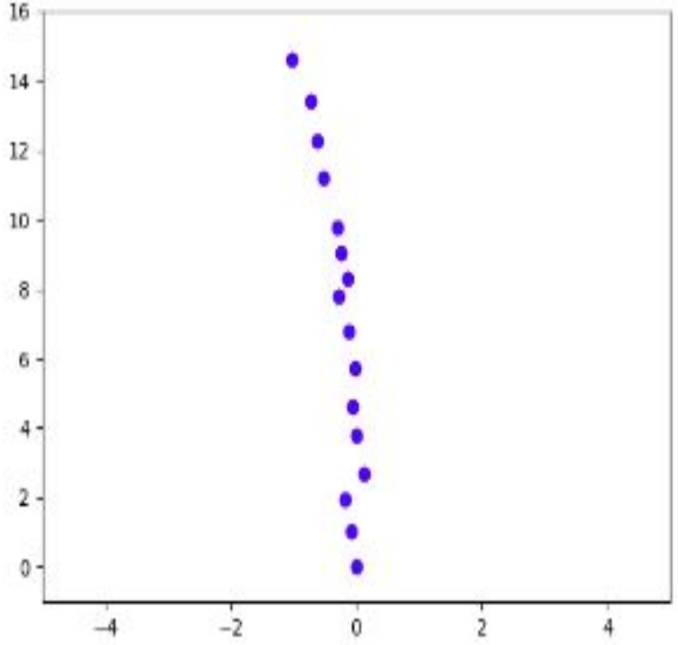
➢ Downside

Walking simulation and post error analysis

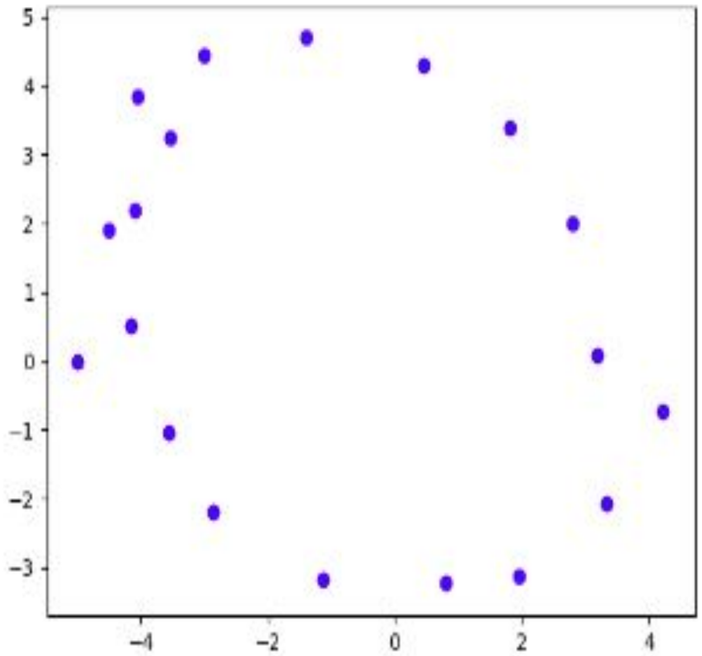
- For the line each step is taken to be 1m and and every 3m the RTT reading is also taken.
- For the circle each step is taken as 1.73m, and a rotation of 20 degrees. Every 60 degrees the RTT is also taken into account.
- Drift simulation
  - Sample output

$$(x, y, \theta)(v_{xx}, v_{yy}, v_{\theta\theta})$$

- Mean and max localization errors are calculated

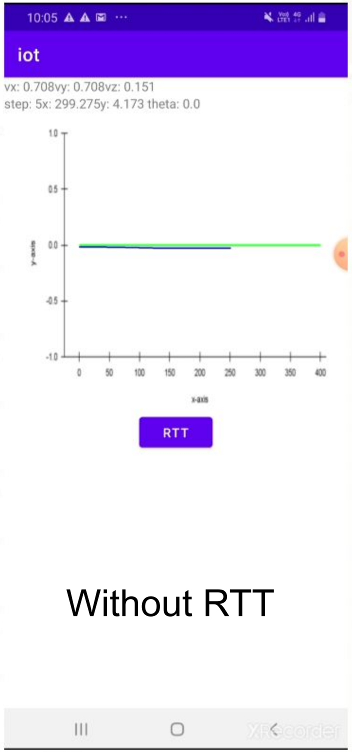


Line Simulation

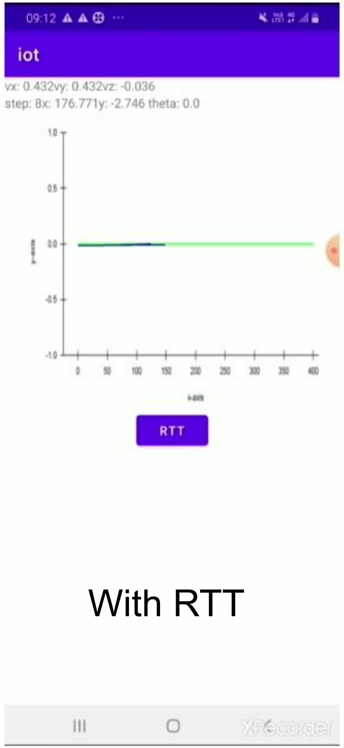


Circle Simulation

Android App



Without RTT



With RTT

Thank You!