Indoor Localization based on Advanced Point-Mass Filtering Method

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Localization

Key component of all navigation applications. The aim is to determine a current user or device position.

Outdoor

Widely adopted solution exists based on Global Navigation Satellite System (GNSS) such as GPS.

Indoor

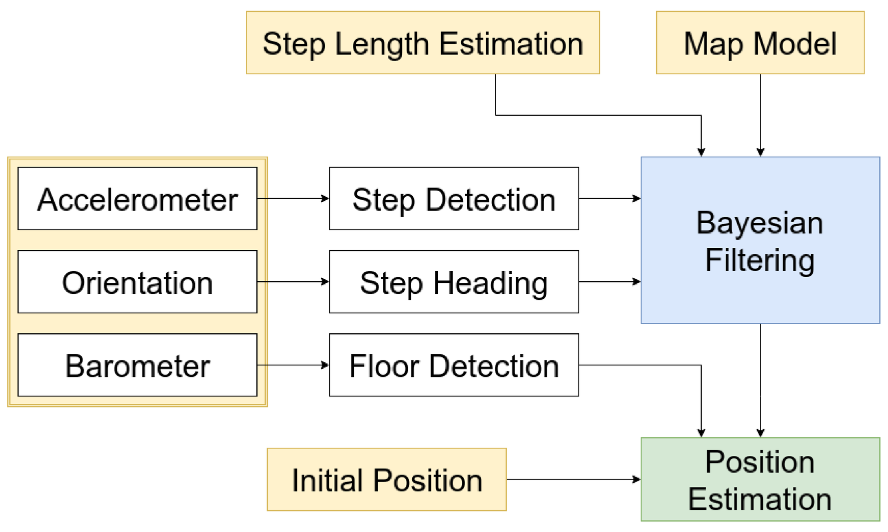
GNSS signal unavailable. No unique solution is established for positioning. Multiple use cases and approaches.

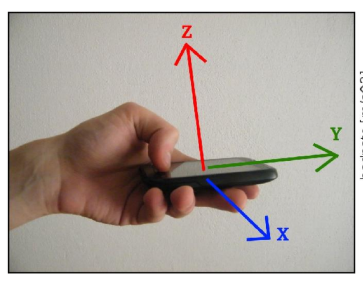
Considered Use Case

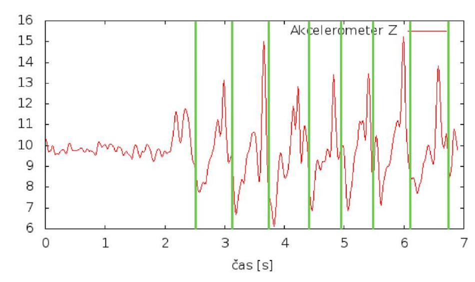
- **low-cost smartphones** with embedded sensors
- no additional infrastructure in building required
- available **maps** (floor plans)
- minimum or no calibration required

Position Estimation

Pedestrian Dead Reckoning (PDR) exploiting human kinematics to estimate the succeeding relative position.







STEPS – steps are detected from accelerometer measurements. **Step length** may be computed but for evaluation of bayesian filtering method we assume fixed estimation. Acquired data from magnetometer and/or gyroscope are filtered to obtain more stable **heading** values.

INITIAL POSITION – by scanning QR codes strategically placed in the building. Possible to incorporate another approach (e.g. Wi-Fi fingerprinting).

MAP MODEL – generated from floor plans with a few centimeter precision to declare **accessible positions** in the building.

FLOOR DETECTION – based on barometer measurements to detect a **transition between floors**. A current position is estimated on a single floor. If a floor transition is detected, the map is loaded with an **initial position** estimation.

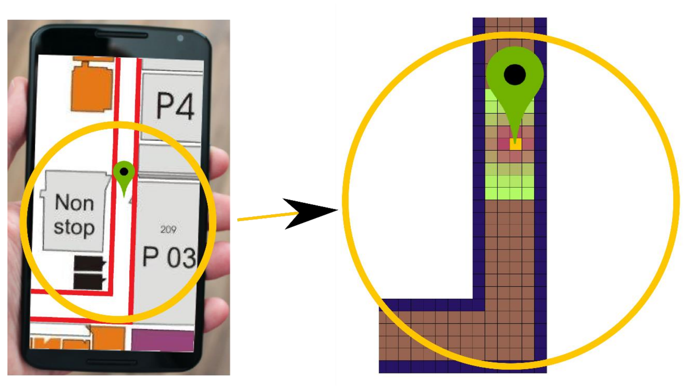
Advanced Point-Mass Filter

Bayesian Filtering

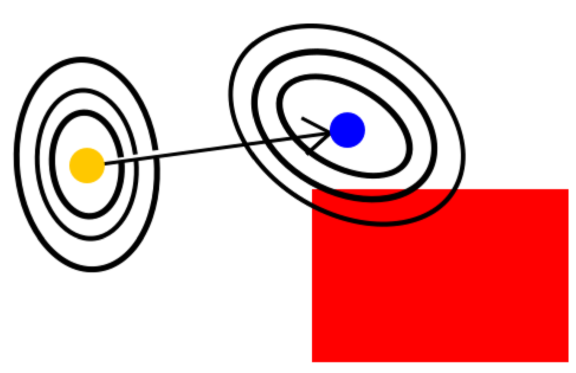
Probabilistically estimate a dynamic system state recursively over time using noisy measurements.

Existing implementations:

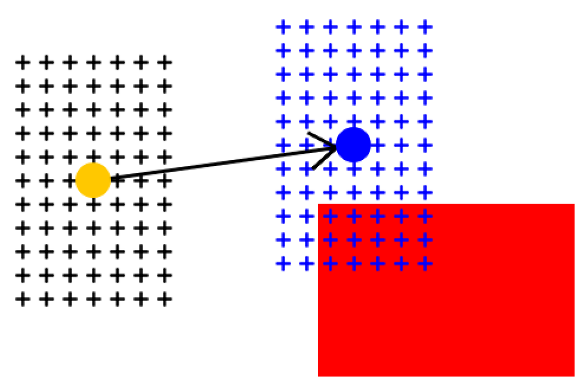
- Kalman Filter
- Particle Filter
- Grid-based Filter
- Advanced Point-Mass Filter



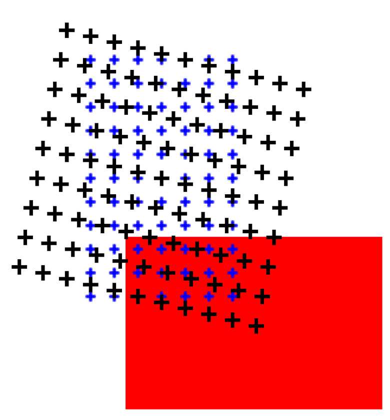
Grid-based Filter [1] tessellates the map into regular grid where belief values are computed.



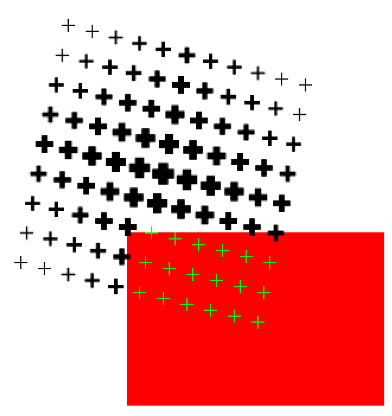
Step from the yellow point to the blue point. A black ellipse denotes probability density function (pdf) to model the uncertainty.



The black grid is transformed to the blue grid according to the step length estimation and the step heading.



The new black grid is created from the transformed blue grid with the same structural properties as the original grid.



Values of the approximate pdf are computed for the new grid. A point width denotes the belief value. The red rectangle represents inaccessible positions (e.g., walls) where belief values are set to zero.

Algorithm Overview

Method introduced in [2] applied on the indoor localization problem.

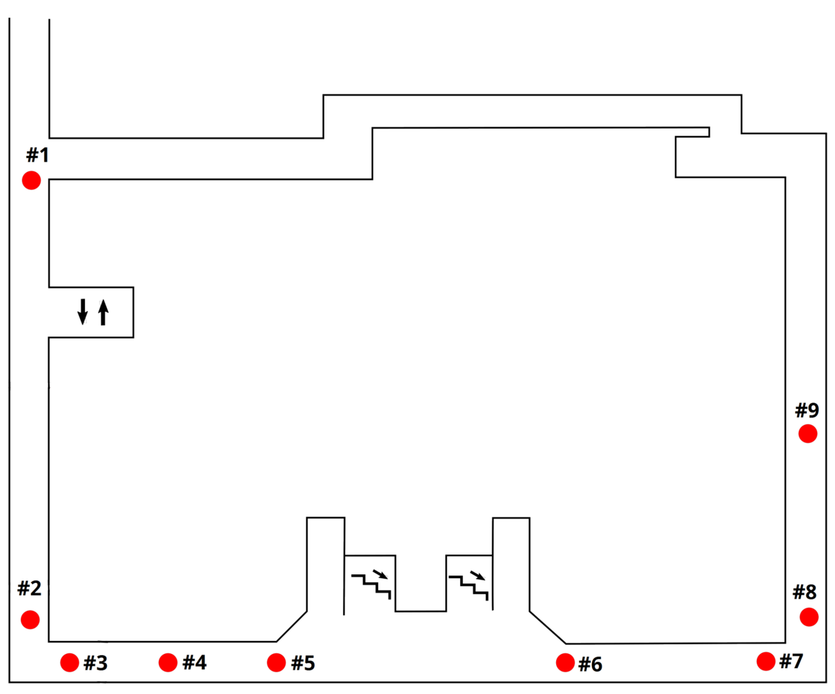
Probability density function is approximated by one or more grids of points and belief values at the points.

When a step is detected, 4 phases are executed:

1) **Filtering** – compute values of approximate pdf at grid points.
2) **Time update of grid** – grid is transformed according to the system dynamics.
3) **Grid redefinition** – a new grid created from the transformed grid and rotated to the support of pdf.
4) **Prediction** – belief values are computed using convolution.

Evaluation

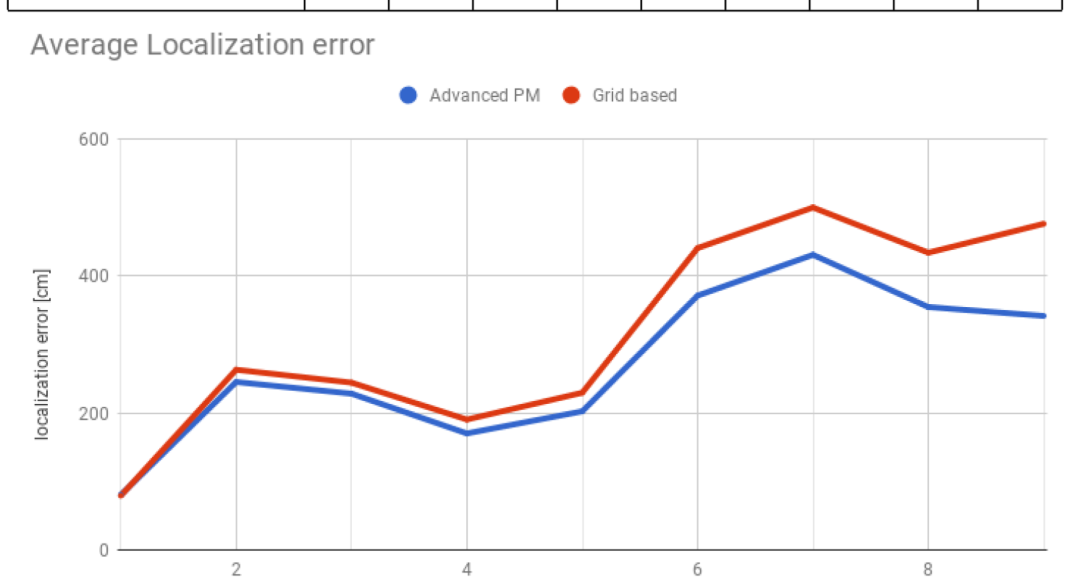
- **87m** path, **7** subjects
- 9 checkpoints to measure error (euclidean distance between estimated and real positions)
- Offsite simulation for comparison of methods with different parameters.
- APM compared to the Grid-based approach [1]



Results

Map model helps to reduce the overall localization error (after 90° turns)

Method/Marker	#1	#2	#3	#4	#5	#6	#7	#8	#9
Grid-based	0.79	2.63	2.44	1.90	2.29	4.41	5.00	4.34	4.77
Advanced PM	0.80	2.45	2.28	1.70	2.02	3.71	4.31	3.55	3.42



Advanced Point-Mass Filter achieves better average accuracy with the same configuration (step length estimation and noise model)

Grid design in APM with dynamic distance between neighbouring points and grid rotation reduces the discretization error.

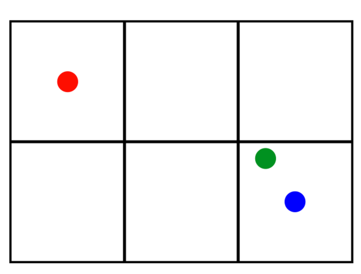
References:

[1] Galčík, F., Opiela, M.: **Grid-based indoor localization using smartphones.** *In: 2016 International Conference on Indoor Positioning and Indoor Navigation (IPIN). pp. 1–8. IEEE (oct 2016)*

[2] *Šimandl, M., Královec, J., Söderström, T.:* ***Advanced point-mass method for non-linear state estimation.*** *Automatica 42(7), 1133–1145 (2006)*

Discretization error:

- **Real step:** from the **RED** point to the **GREEN** point
- **Model step:** from the **RED** point to the **BLUE** point



SUMMARY:

- Advanced Point-Mass filter applicable on indoor localization
- APM achieves better results compared to the Grid-based filter