



Indoor Localisation using Smartphones

Miroslav Opiela

03.03.2021

M Sciences

S'orienter là où le GPS est aveugle

Une compétition a mis aux prises des prototypes de navigation « indoor ».

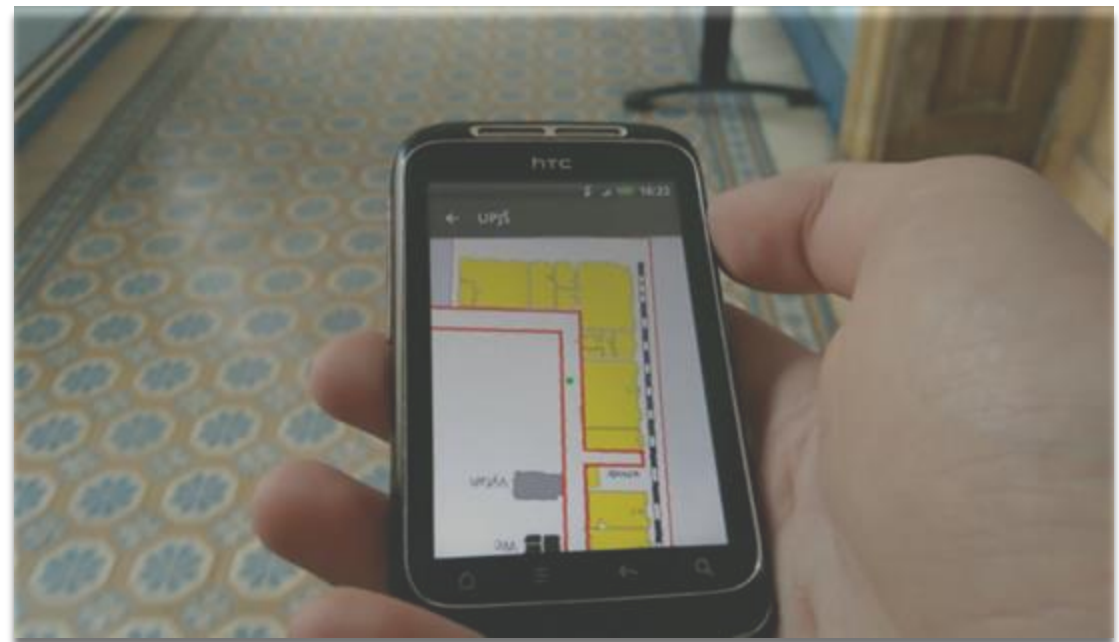
LE MONDE | 03.10.2018 à 06h00 |

Par David Larousserie

Abonnez vous à partir de 1 € Réagir Ajouter Partager (6) Tweeter



Les clients du centre commercial Atlantis de Nantes ont assisté, samedi 22 septembre, à une étrange première mondiale. Des jeunes en tee-shirt bleu



Accuracy?

Indoor Positioning

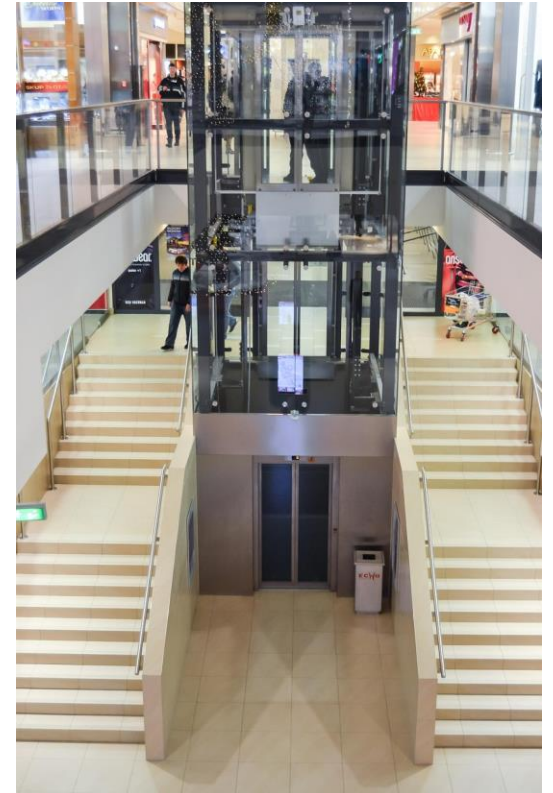
- **Smartphones**
(bring your own device)
- Floor plans
- No infrastructure
- On device computing



Problem solved?

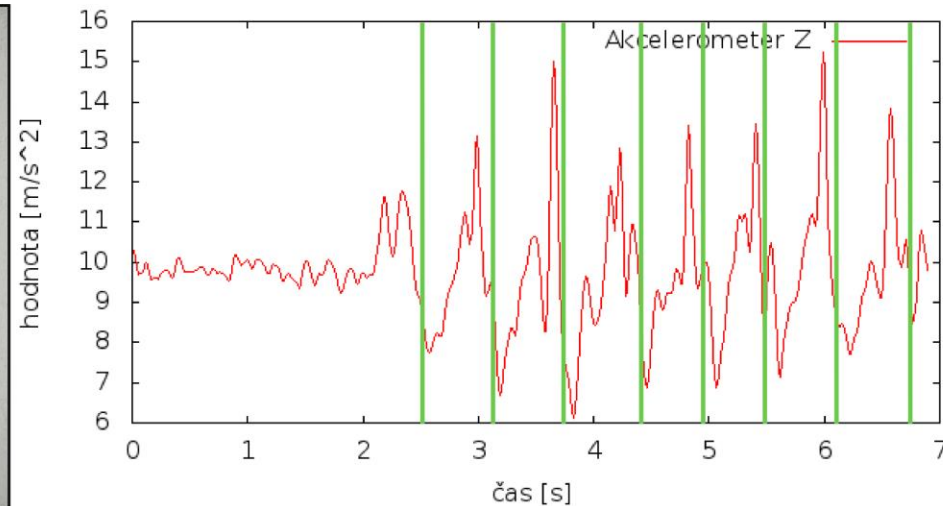
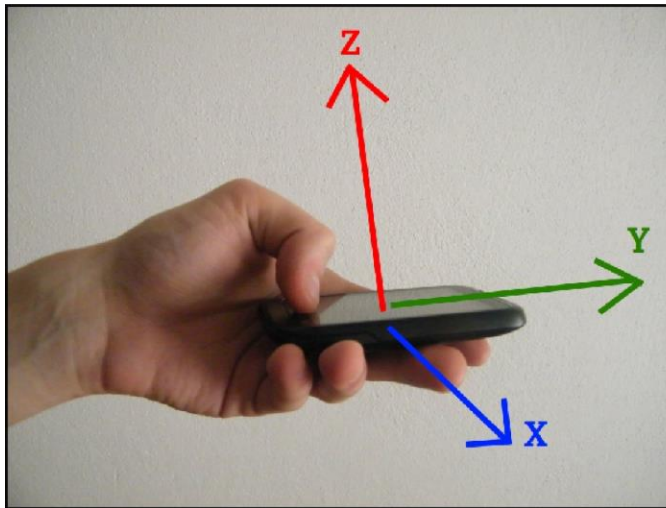
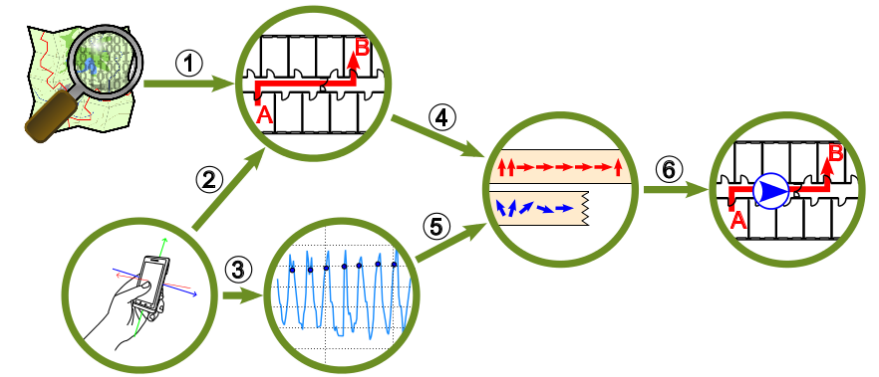
- Outdoor vs. Indoor
- Positioning vs. Localisation
- Business vs. Academy
- Smartphone vs. IMU, robots ...

USE CASES



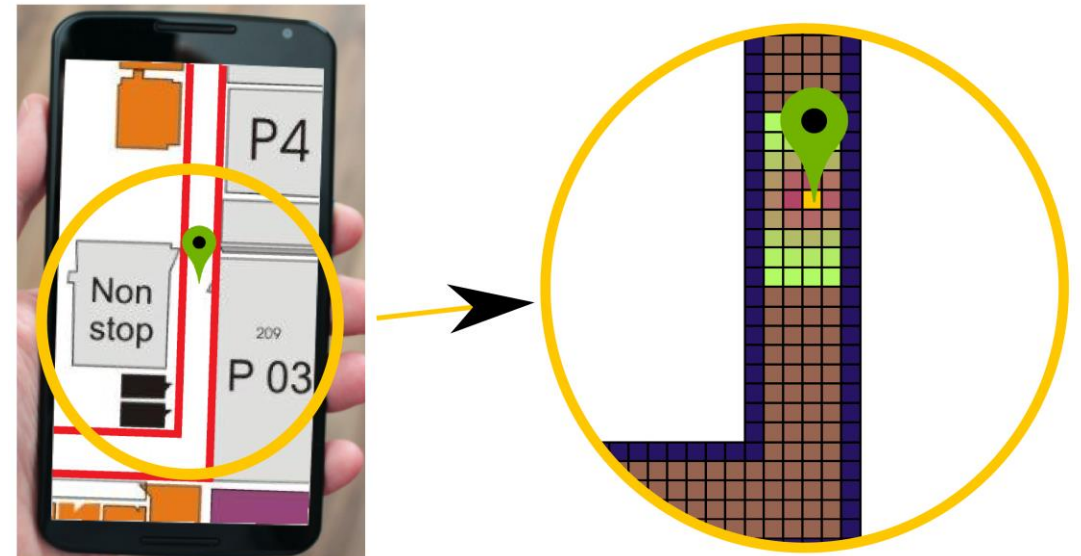
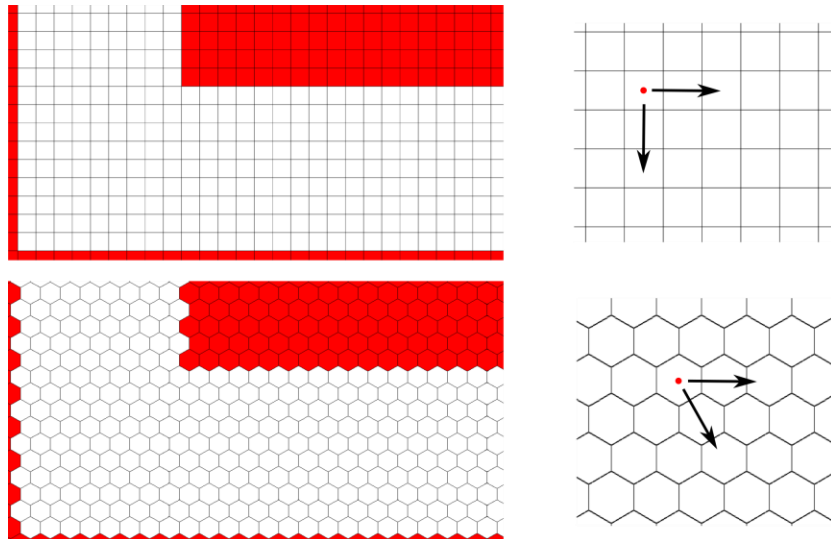
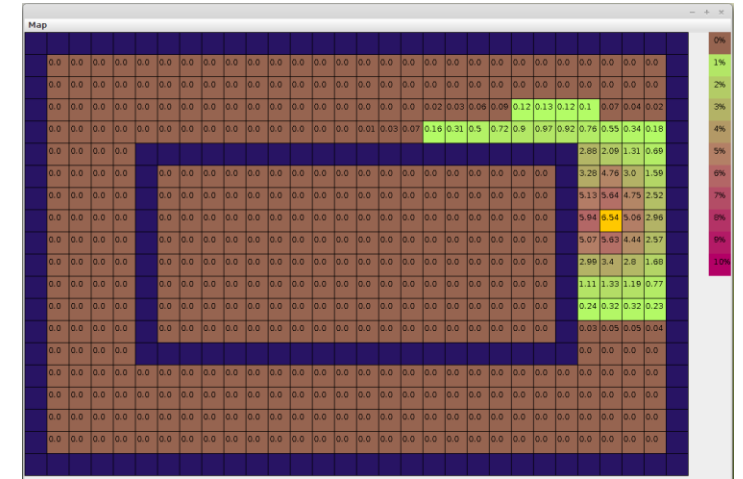
Bachelor Thesis – Step Detection

- Step detection – accelerometer
- Orientation – compass
- Known path



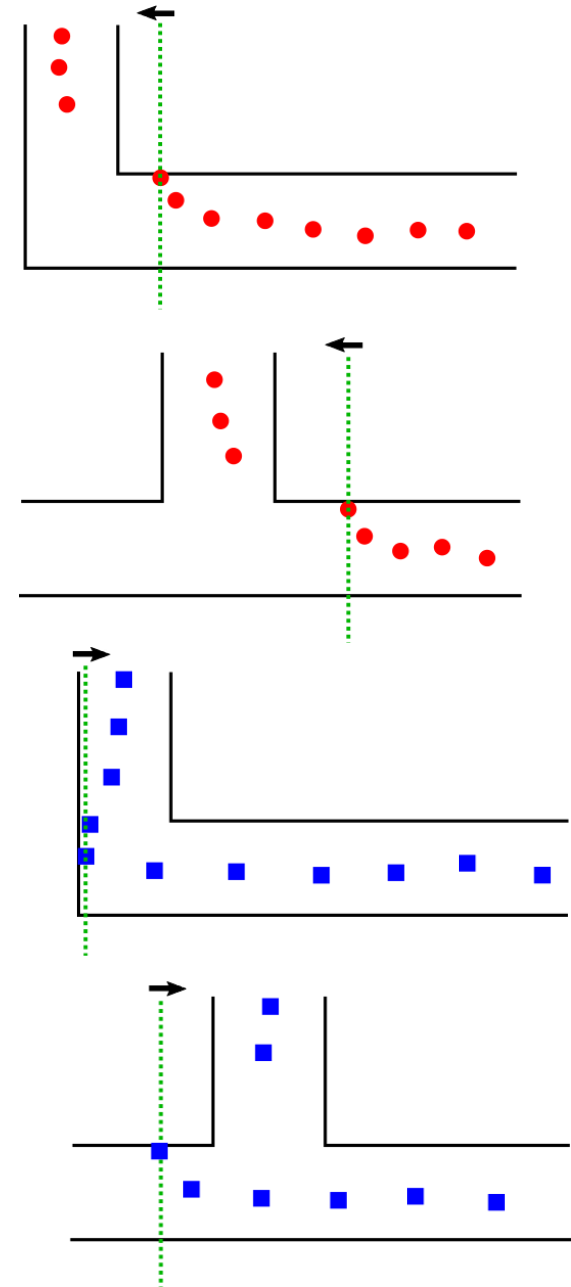
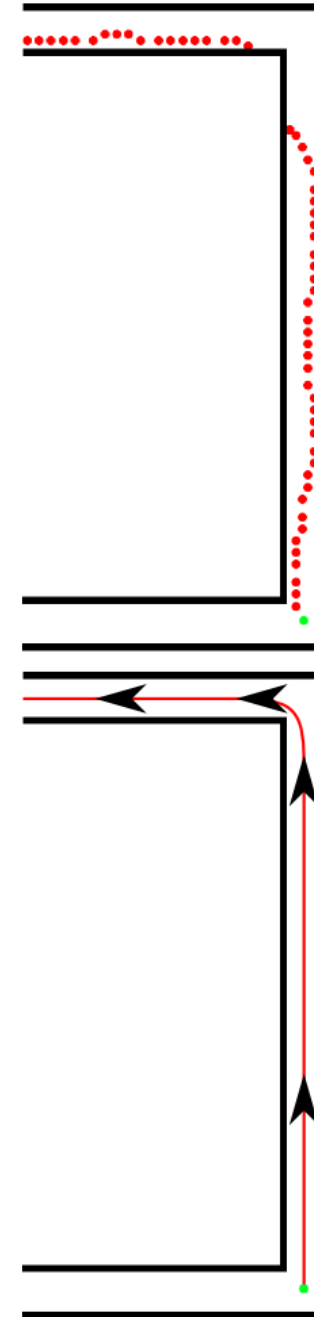
Master Thesis - Localisation

- Map tessellation
- Single floor 2D positioning
- Grid cells - **square vs. hexagonal**
- Robot positioning related work



PhD. Study - Evaluation

- Black Box evaluation



Grid-based indoor localization using smartphones

Miroslav Opiela

joint work with František Galčík

IPIN 2016

(Everybody) uses particle filter.
Why?

ORS:

PS9

IEEE
SPAIN



IPIN 2016

SEVENTH INTERNATIONAL CONFERENCE ON
INDOOR POSITIONING AND INDOOR NAVIGATION
October 4-7, 2016 / Alcalá de Henares, Madrid - Spain



COMPETITION SPONSORS:

ETRI



KICS



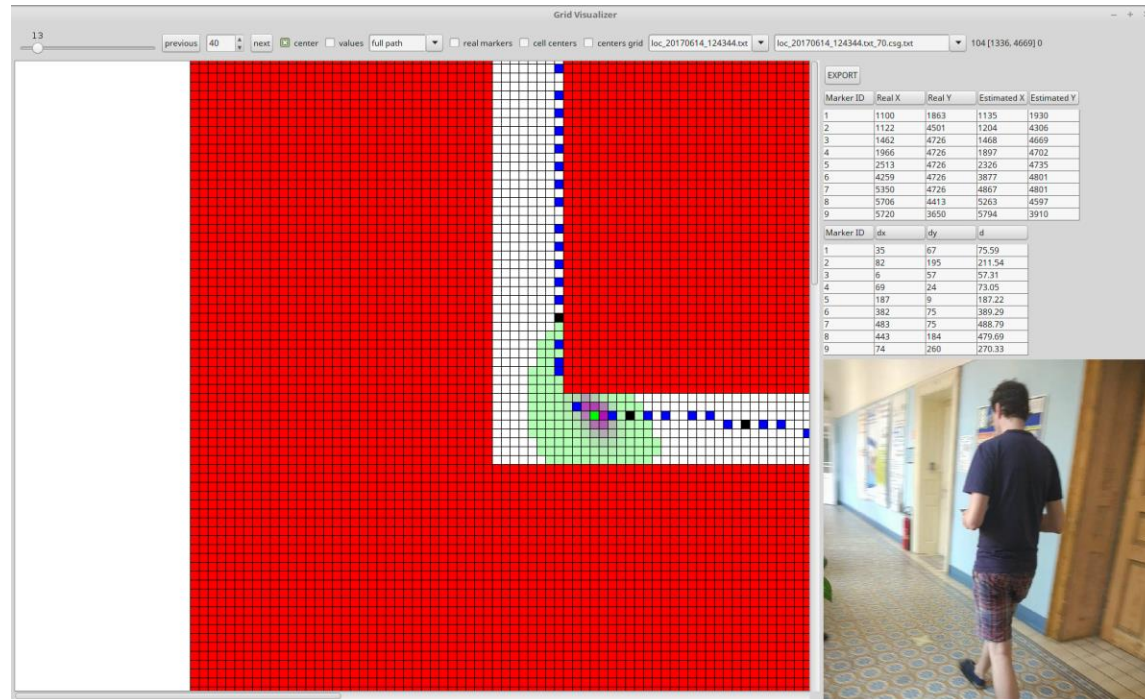
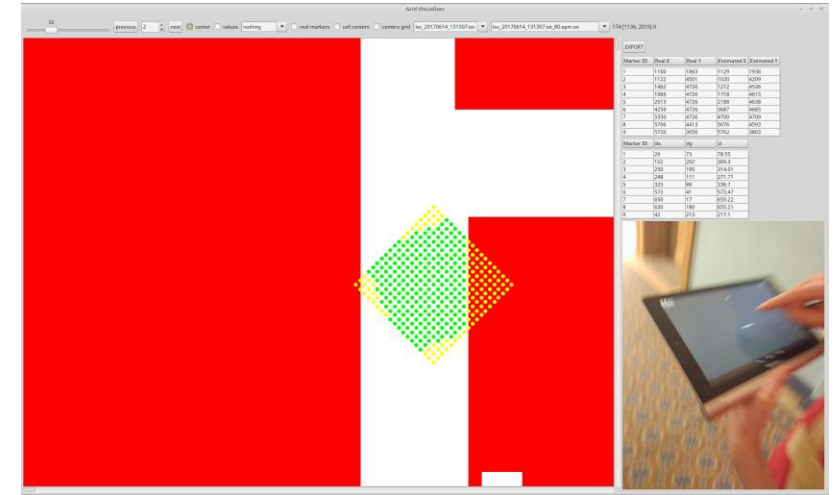
CULTURAL SPONSOR

ALCALÁ DE HENARES
AYUNTAMIENTO



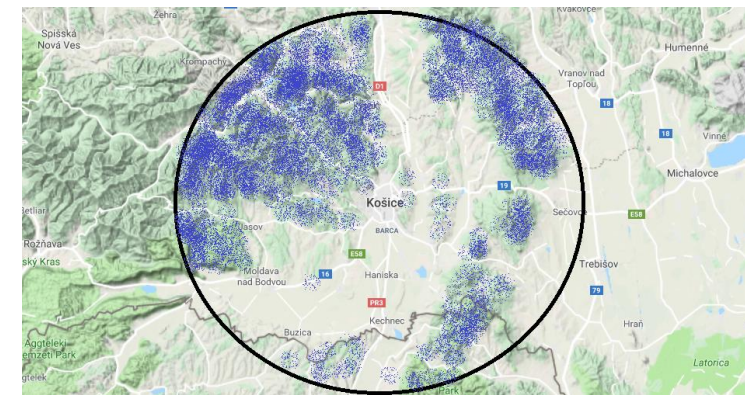
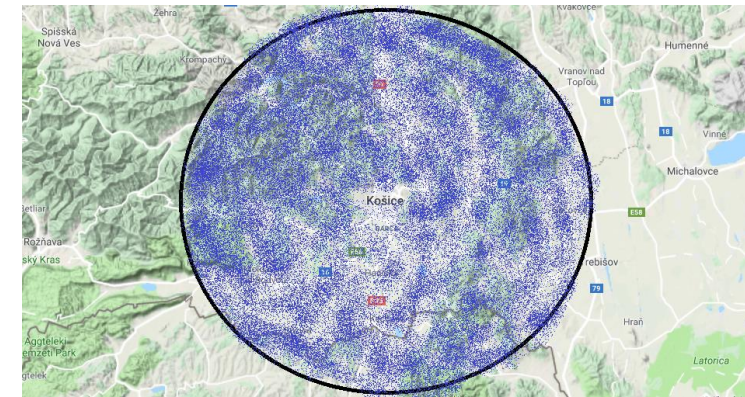
Dissertation Goals

- Main goal – indoor positioning
- Research goal – **Bayesian filtering**

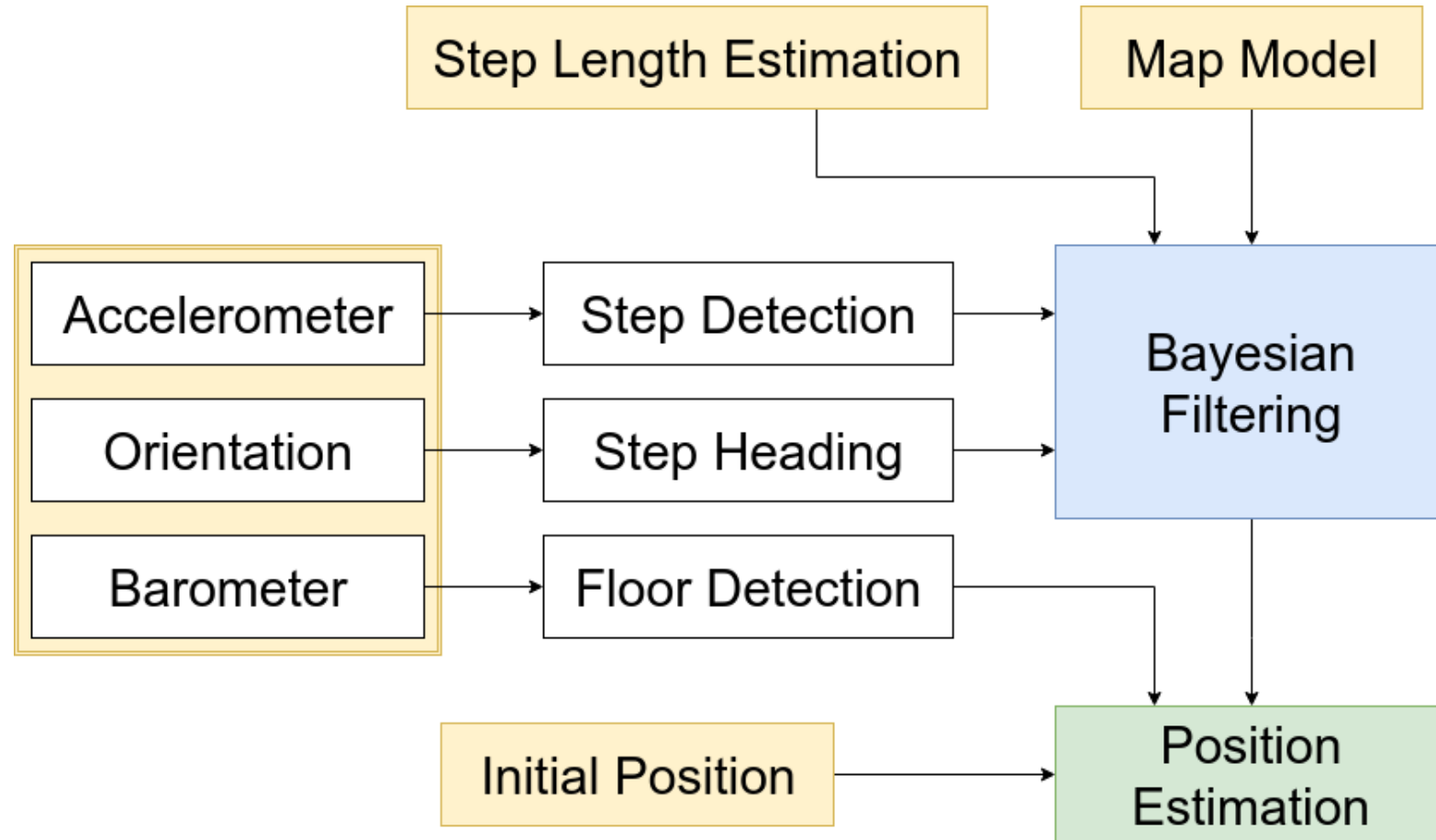


Bayesian Filtering

- Probabilistically estimate a **state** of a dynamic system using noisy **measurements** obtained up to the current time of the estimation
- State – **2D position**
- Implementations:
 - Kalman filter
 - **Particle filter**
 - **Grid-based filter**
- Prediction & Correction

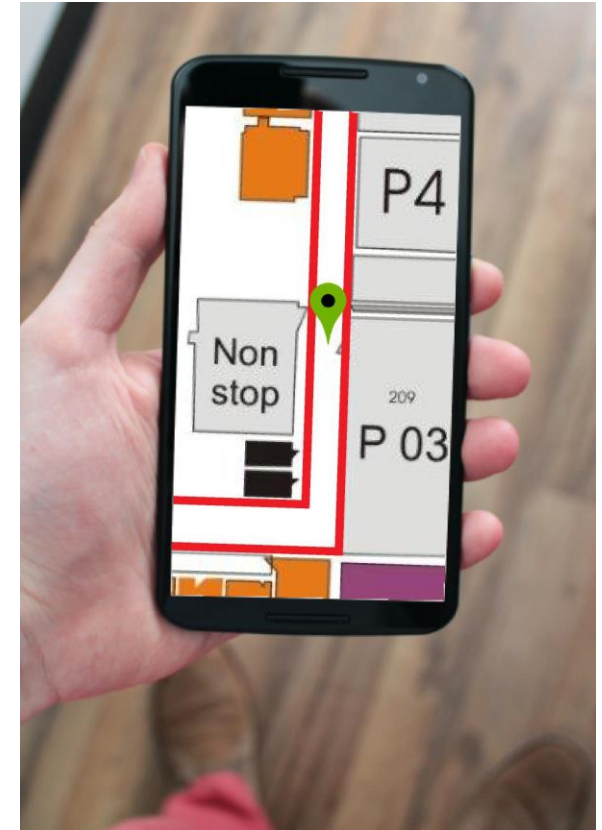
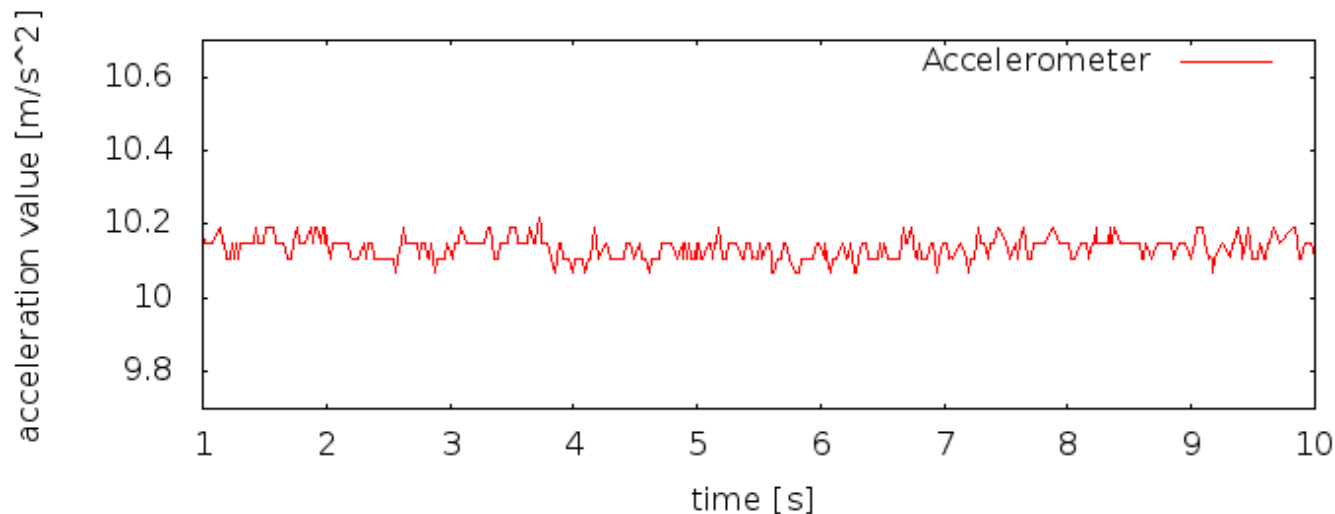


Proposed Approach



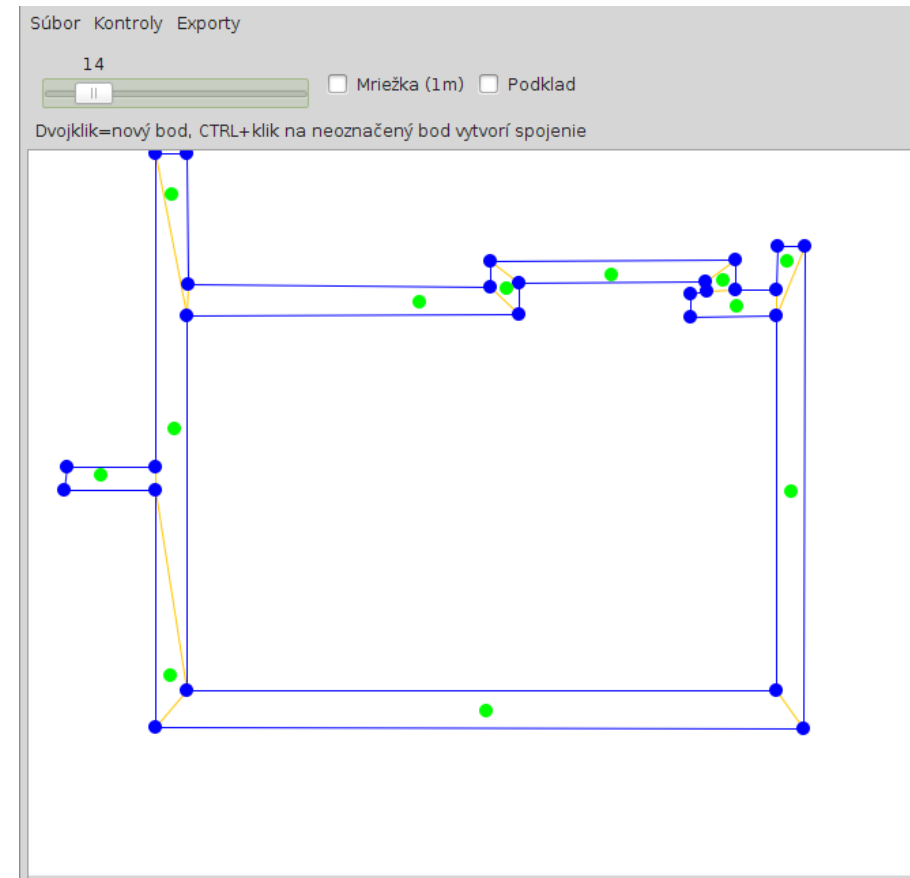
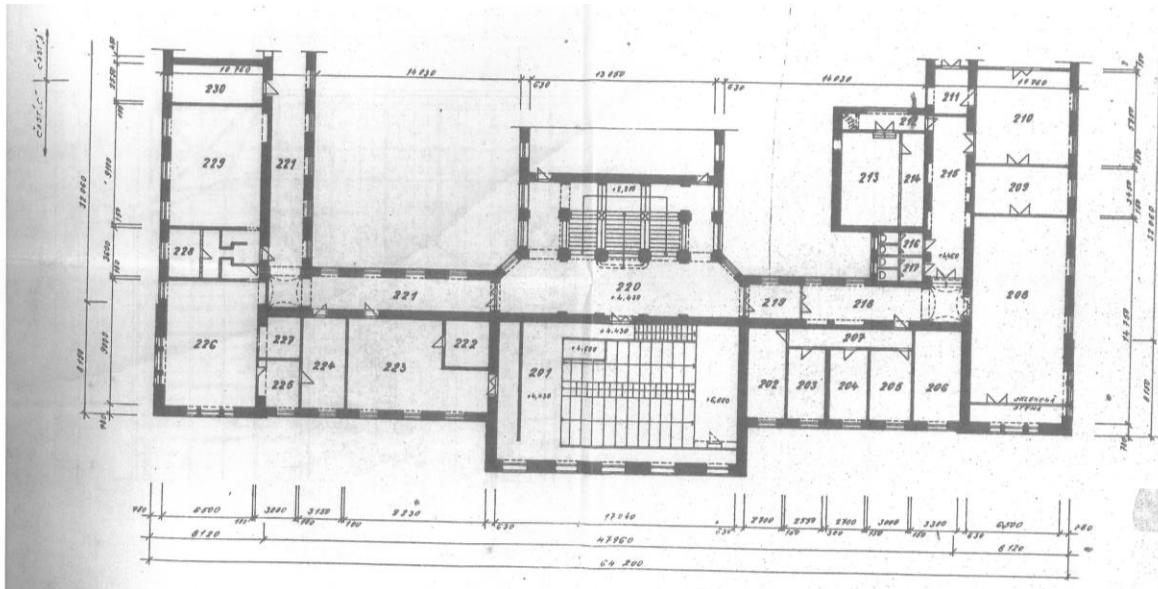
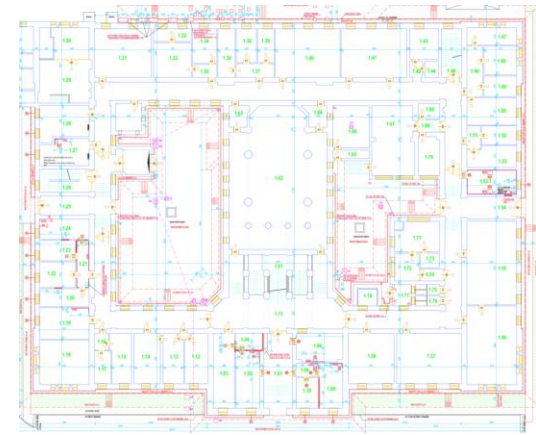
Prediction phase - PDR

- Relative position
- Step detection, heading, **step length**
- Smartphone sensors



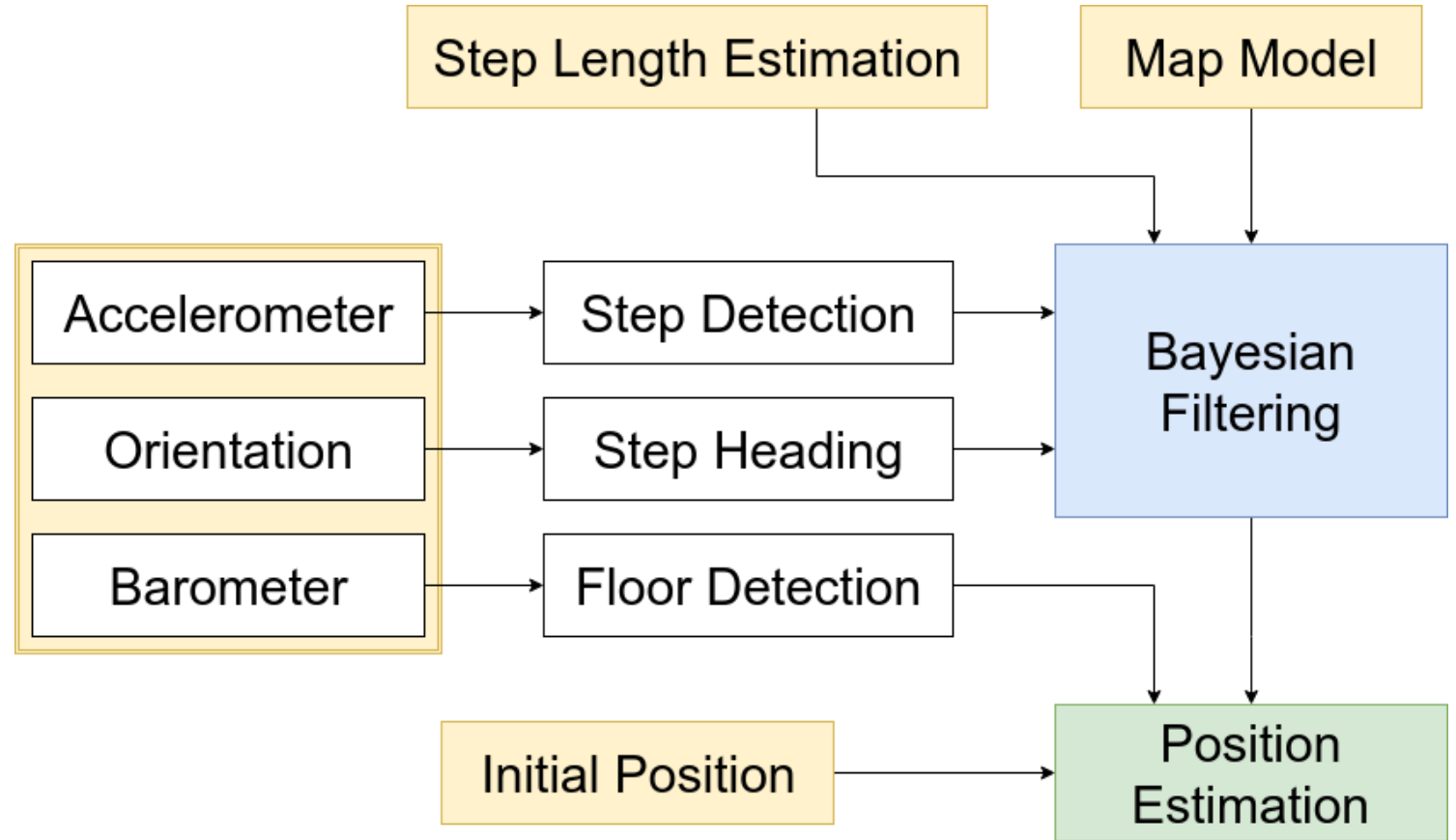
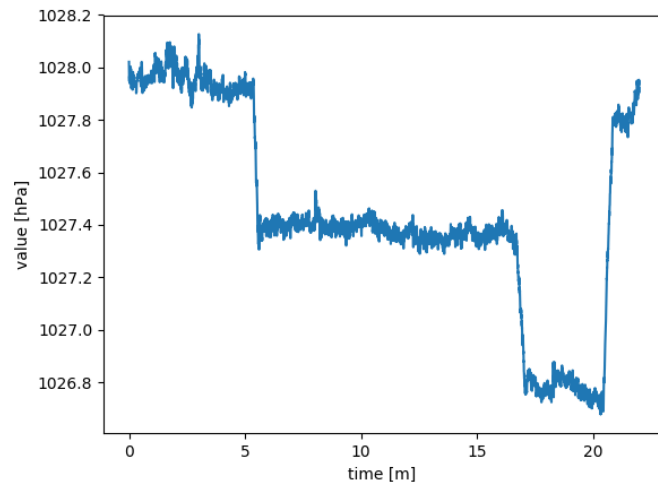
Correction phase – Map Model

- Floor plans -> Labels -> Export -> Grid
- Points, Connections, Zones
- **Accessibility** (position, transition)



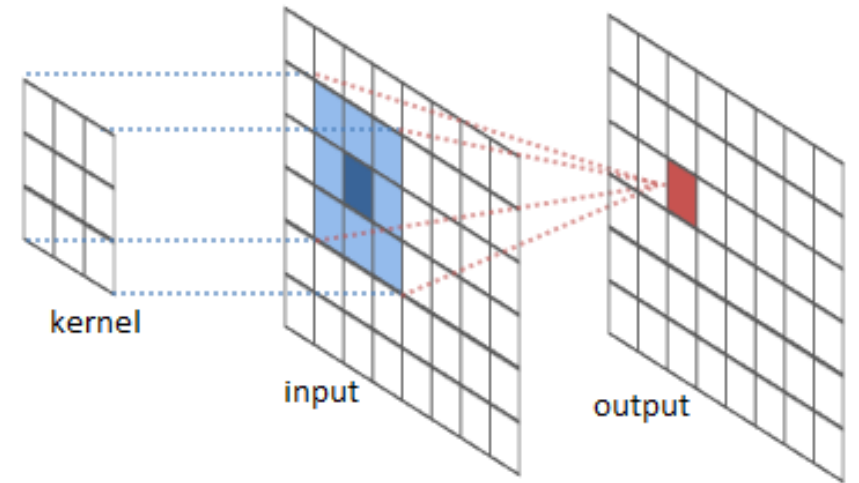
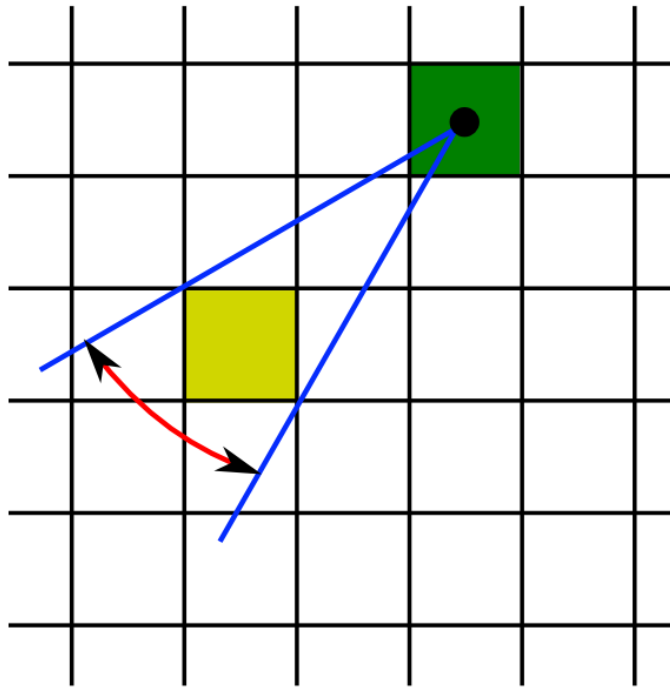
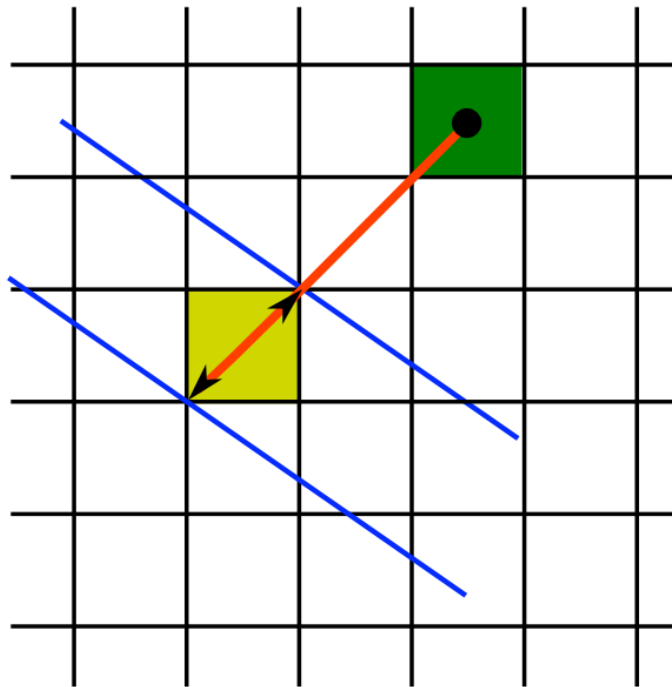
Positioning

- Initial position
- Relative position
- Floor transition
- Filter reset



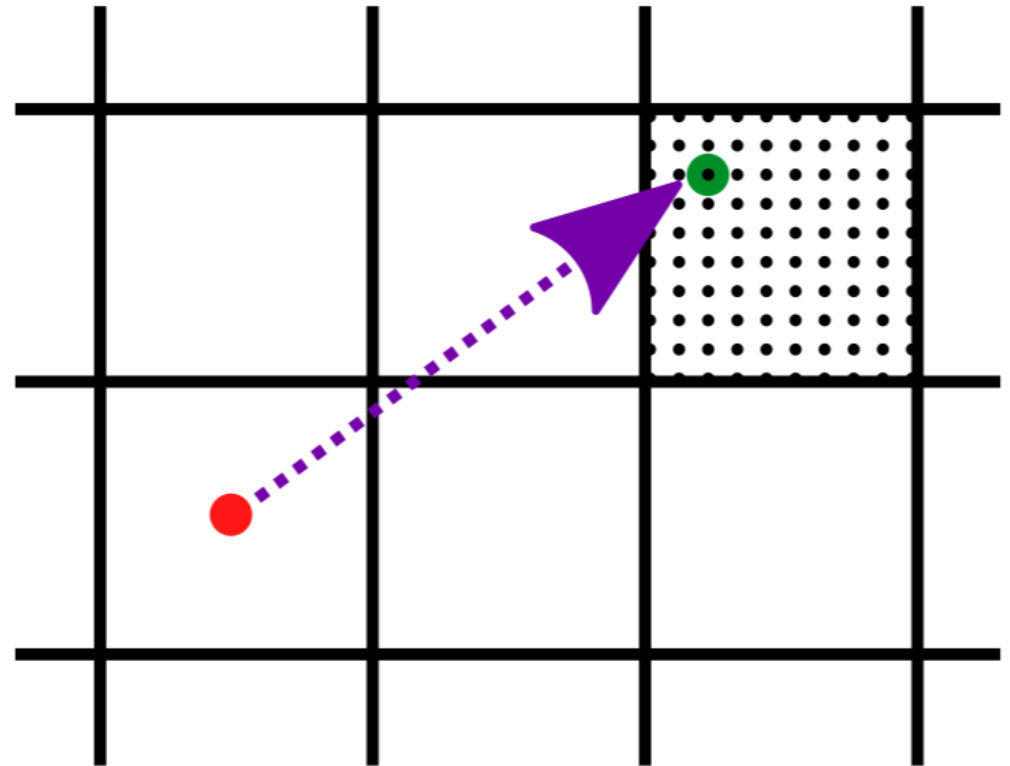
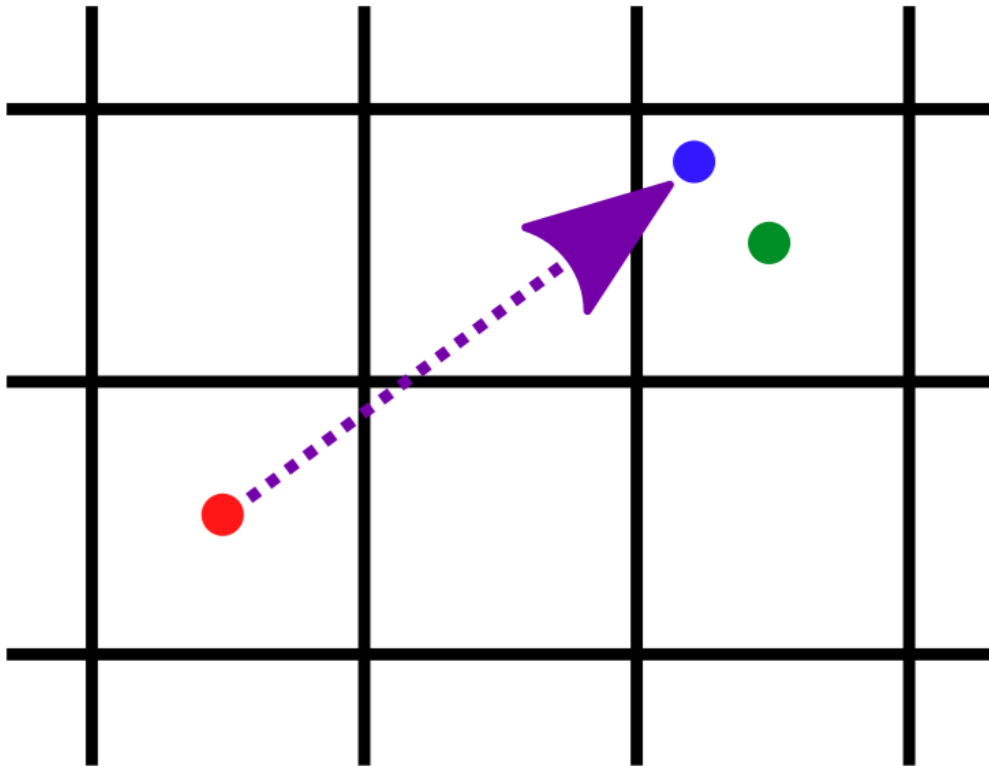
Fine Mask Grid Filter

- Upgraded mask computation, grid cell size
- **Precomputed** convolution masks



Centroid Grid Filter

- Real-time computing – position loss problem



Algorithm	CPU time (s)	Avg. V_k	Avg. N_k
Basic	1235	0.0895	4141
Anticipative	182	0.0073	1964
Boundary-based	210	0.0068	1675
Thrifty convolution	59	0.0068	1675
Multigrid design	72	0.0068	702
Particle filter #1	1	0.7039	500
Particle filter #2	35	0.4386	4000
Particle filter #3	6830	0.1105	50000

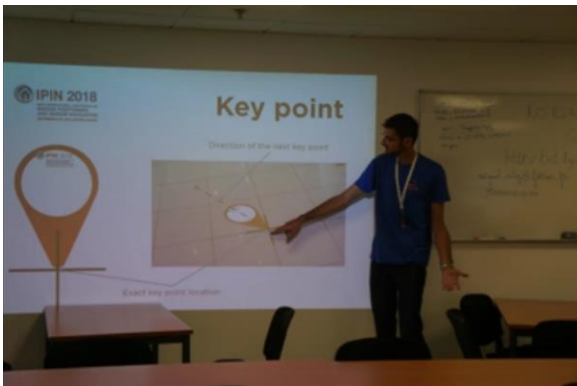
Is grid-based approach
better than particle filter?



Is it really working?

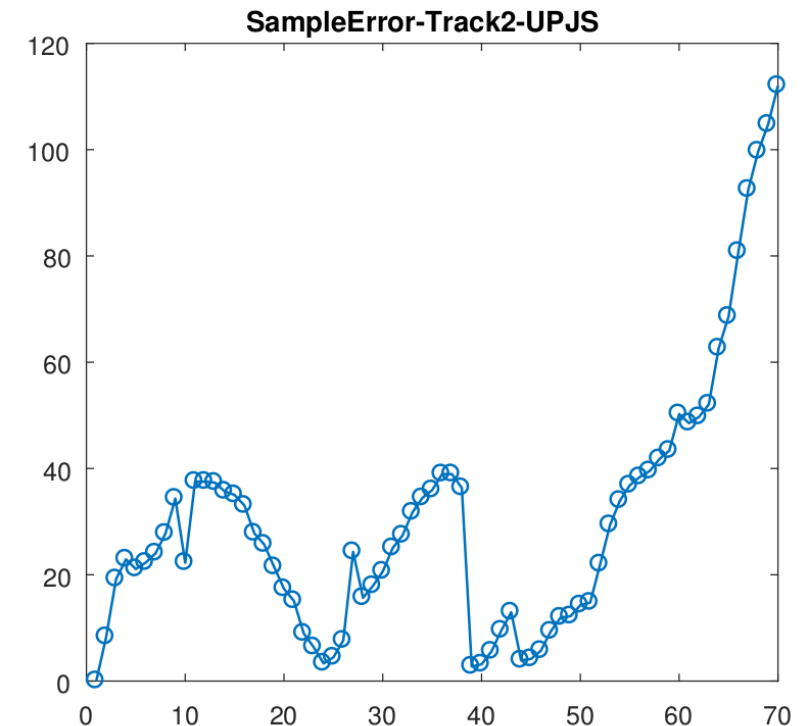
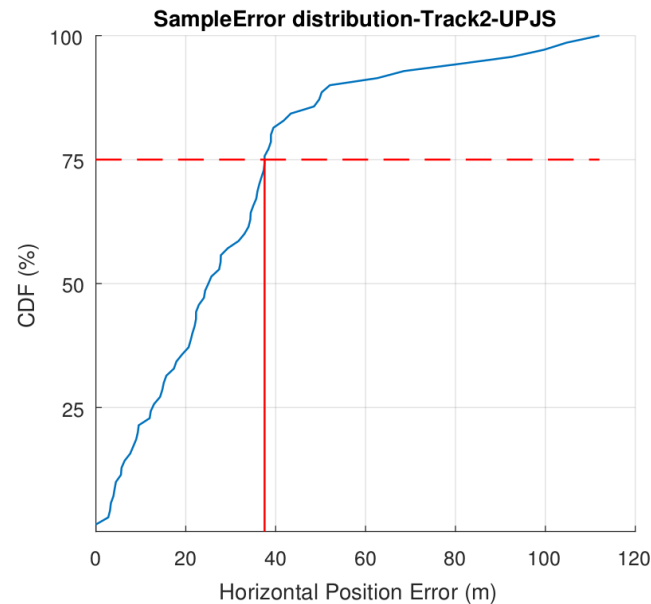
IPIN 2018 Competition – Nantes, France

- **840 m**
- **70 checkpoints**
(Error computation)
- Saturday afternoon (+ setup)
- 17 teams, 2 tracks



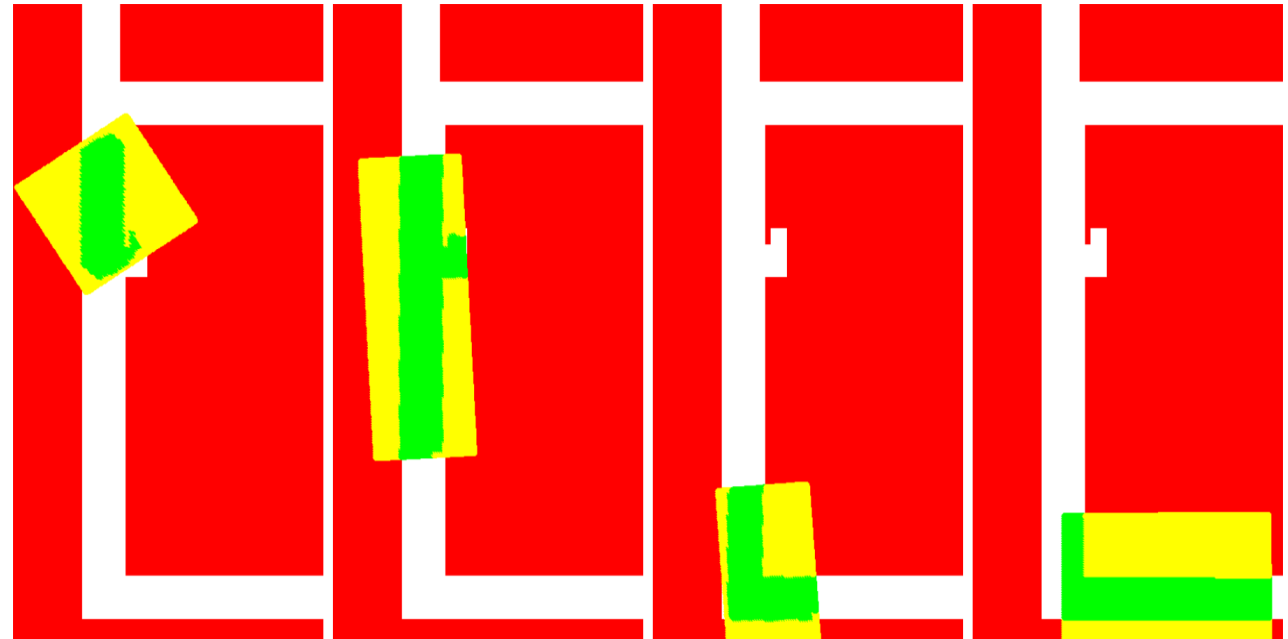
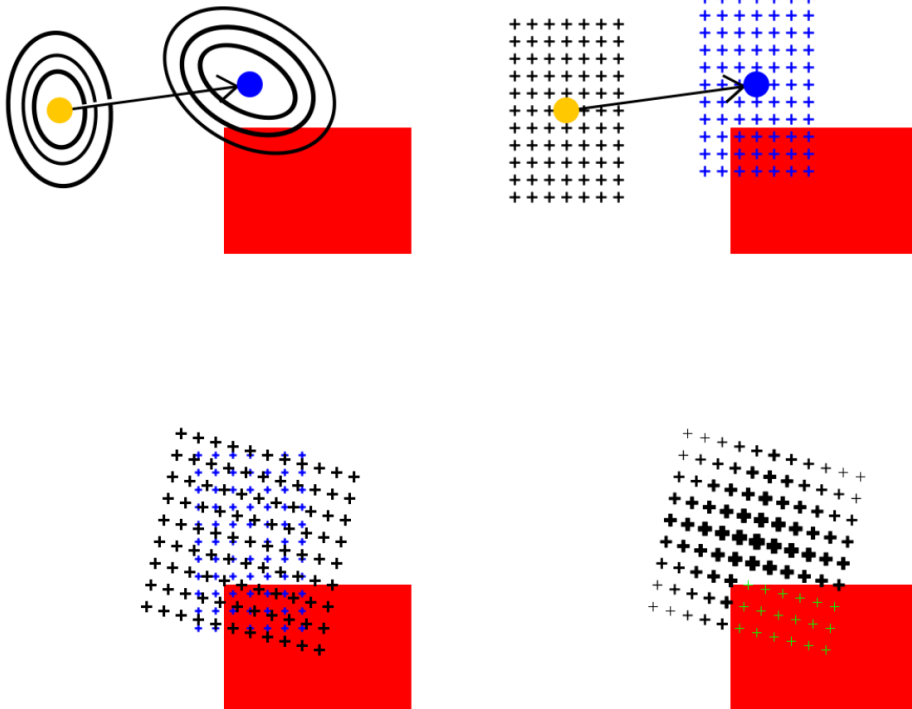
IPIN 2018 On-Site Competition

- 75th percentile – **37.5 m**
- Step length, pace, wide corridors
- Best 5.5 m



Advanced Point Mass Filter

- Šimandl, M., Královec, J. and Söderström, T., 2006. Advanced point-mass method for nonlinear state estimation. Automatica, 42(7), pp.1133-1145.



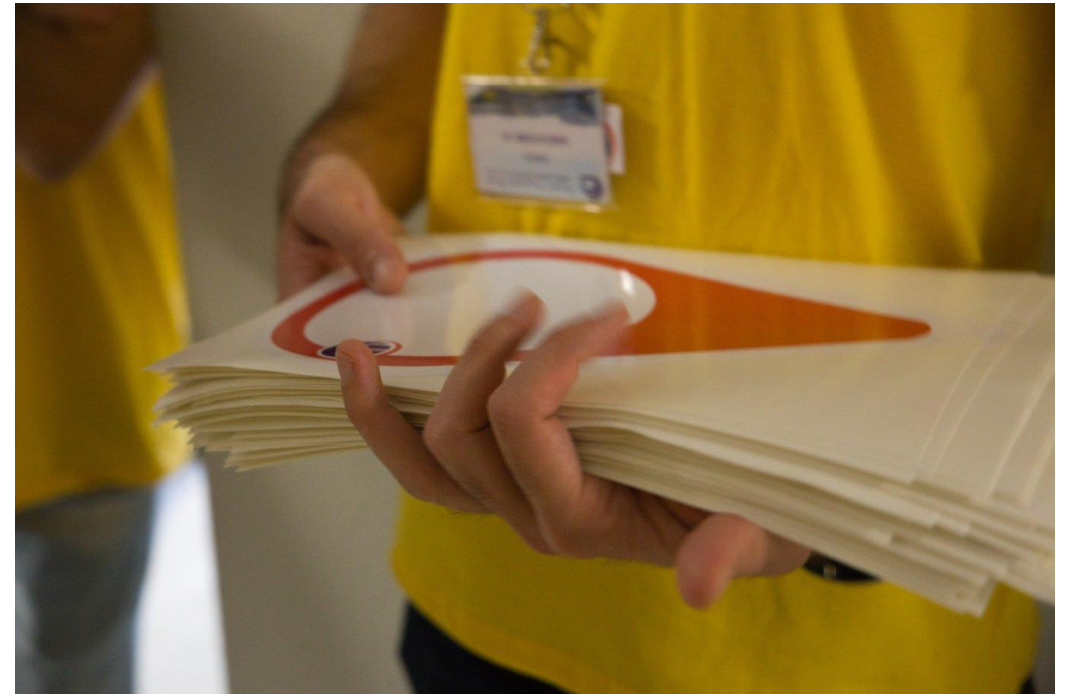
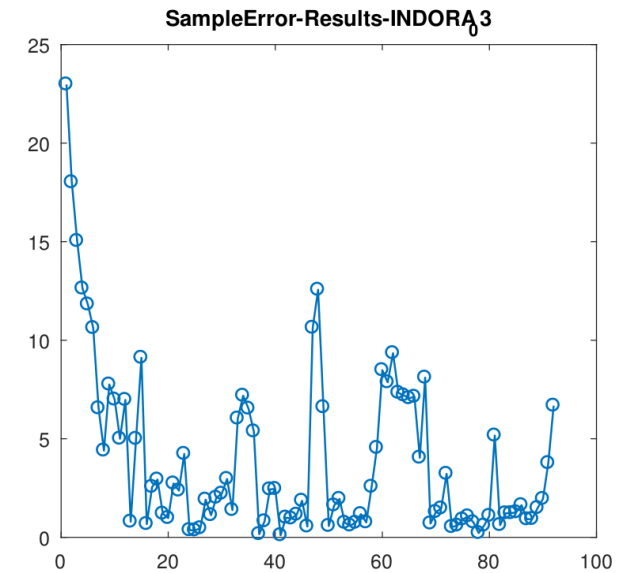
IPIN 2019 Competition – Pisa, Italy

- App crash, actor, step length, balcony



IPIN 2019 Competition - Results

- On-site – 75.3 m / **33.9 m** / 16.2 m
 - Best 3.8 m
- Off-site – **6.6 m**
 - Best 2.3 m

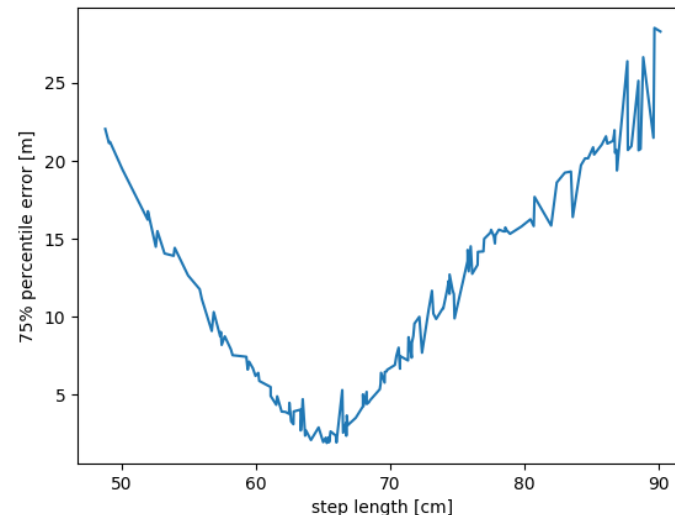
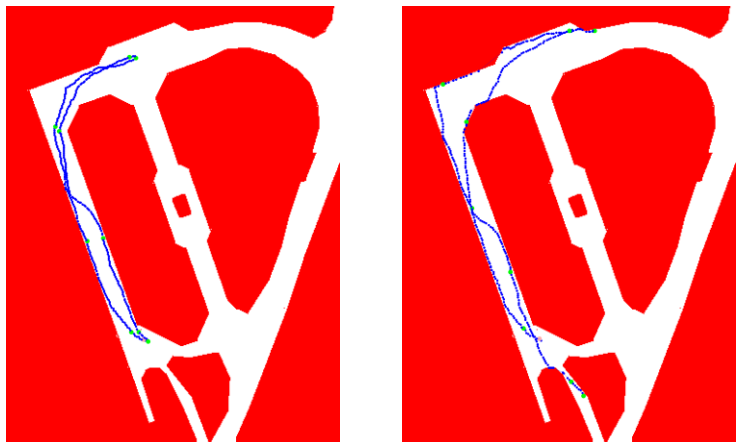


Average of 75%		Označenia stĺpcov									
Označenia riadkov		5,00	10,00	15,00	20,00	25,00	30,00	40,00	50,00	Celkový súčet	
60,00											
5,00		2,37	3,41	3,89	5,49	7,12	8,74	14,06	21,15	8,28	
10,00		2,90	4,47	4,90	6,40	7,53	9,08	14,49	22,05	8,98	
15,00		4,71	4,04	3,92	4,92	6,69	8,19	13,91	21,23	8,45	
20,00		5,29	3,67	2,64	2,70	3,91	6,20	11,76	19,48	6,96	
25,00		5,77	5,18	5,02	3,18	1,95	3,10	9,02	16,77	6,25	
60 Celková hodnota								12,65	20,13	7,78	
70,00											
5,00								8,74	16,23	6,70	
10,00								7,91	15,50	6,76	
15,00								6,61	14,42	7,19	
20,00		7,09	9,86	10,00	8,78	6,49	5,52	4,35	12,65	7,92	
25,00		9,89	12,30	12,71	11,67	9,56	6,59	2,37	10,30	9,44	
70 Celková hodnota		7,92	9,00	8,57	7,15	5,73	3,37	5,99	13,82	7,65	
80,00											
5,00		14,29	14,52	13,58	11,47	8,32	5,35	3,28	11,14	10,24	
10,00		14,70	15,00	15,58	14,17	11,67	8,38	1,90	8,74	11,26	
15,00		15,15	15,22	15,48	15,40	12,91	10,40	2,36	7,43	11,79	
20,00		15,59	15,48	15,32	15,73	14,19	11,69	4,51	5,88	12,30	
25,00		15,85	16,25	15,82	16,01	15,56	13,33	6,91	3,77	13,23	
80 Celková hodnota		15,11	15,29	15,15	14,55	13,03	9,83	3,79	7,39	11,80	
90,00											
5,00		21,29	28,30	28,54	26,66	21,75	16,40	10,52	2,24	19,46	
10,00		19,32	20,77	25,14	26,40	20,17	15,79	10,20	2,11	17,49	
15,00		19,25	20,41	20,68	20,70	20,17	17,69	10,52	2,27	16,46	
20,00		19,73	21,05	21,11	20,70	20,52	18,61	11,45	3,03	17,02	
25,00		20,88	21,97	21,58	21,48	20,95	19,39	12,76	4,40	18,26	
90 Celková hodnota		20,09	22,50	23,41	23,18	20,75	17,57	11,09	2,81	17,75	
Celkový súčet		11,83	12,74	12,80	12,36	11,49	9,46	8,38	11,04	11,27	

Best configuration?
My best result?

Validation Datasets

- Hexagonal – not robust
- IPIN 2019 – APM outperformed PF
- APM – multigrid, **plan B**
- PF - output



Method	Result
Fine Mask GF	4.60 m
Centroid GF	4.60 m
Hexagonal GF	4.92 m
Basic GF	5.11 m
APM	5.30 m
Particle Filter	6.18 m

Method	Result
Fine Mask GF	6.23 m
Hexagonal GF	7.09 m
Centroid GF	7.27 m
APM	7.49 m
Particle Filter	8.01 m
Basic GF	8.21 m

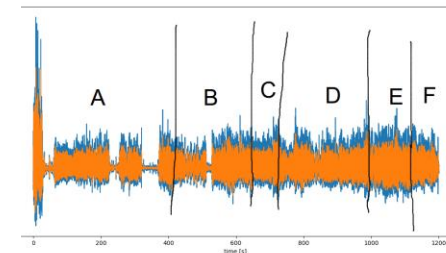
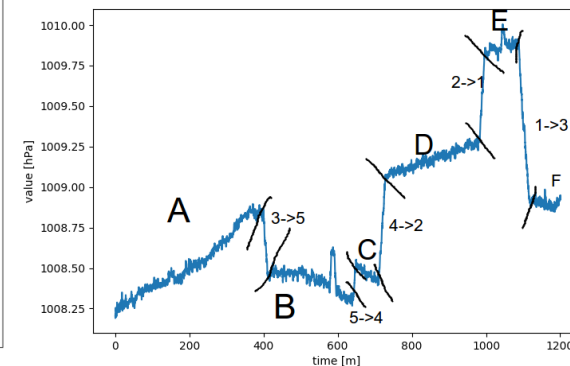
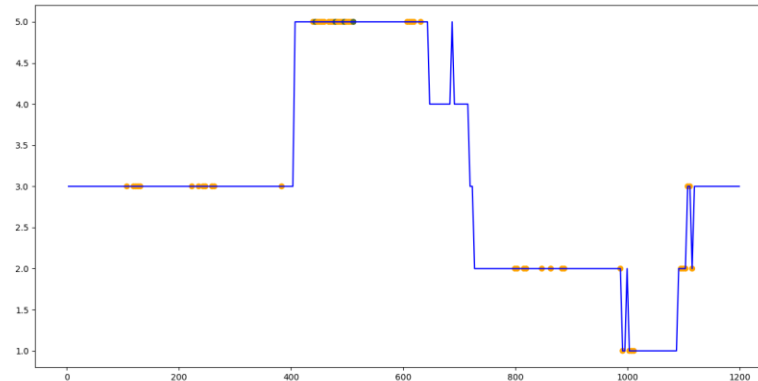
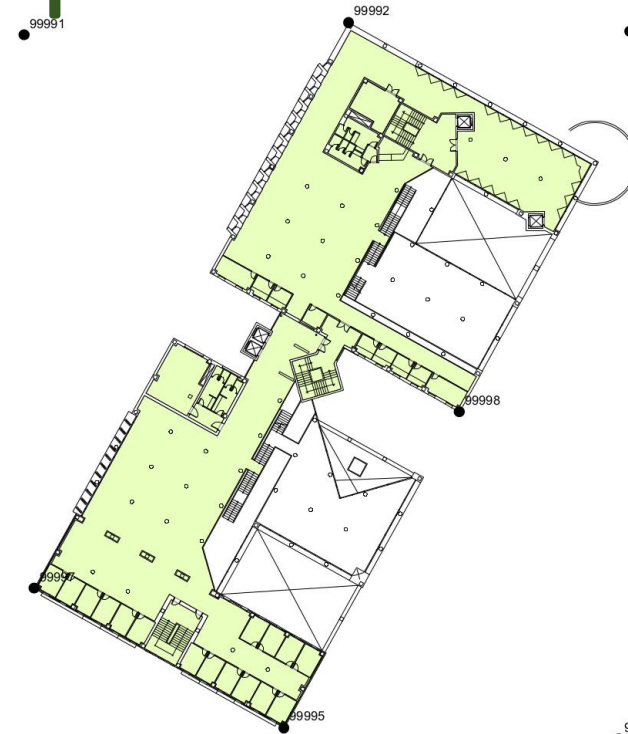
IPIN 2018 On-site

- 773 configurations
- Competition best – 5.5 m
- Below 6 m (2x hexagonal, 3x centroid)
- Average for all configurations
 - **APM 12 m**, Fine GF 26 m, Centroid GF 27 m
Basic GF 31 m, Hexagonal GF 35 m, PF 39 m
- APM matching real path
- Configuration and method for live performance?

Method	75th
Hexagonal GF	5.46 m
Centroid GF	5.68 m
APM	6.03 m
Fine Mask GF	6.13 m
Basic GF	6.37 m
Particle Filter	7.00 m

IPIN 2020 - Castellón de la Plana, Spain

- Official: 6.85 m / 8.39 m / 7.02 m
- Centroid GF – 4.46 m
- PF – 4.38 m (with outliers)
- PF + Wi-Fi – **3.86 m**



Theses

- Maroš Koval' – app development
- Slavomír Slovenkai - elevators
- Bianka Šimková – augmented reality
- Jakub Džama - **particle filter + application**
- Patrik Rojek – activity recognition, neural networks, steps
- Tomáš Hvišč - navigation
- Lucia Hajduková – computer vision, neural networks

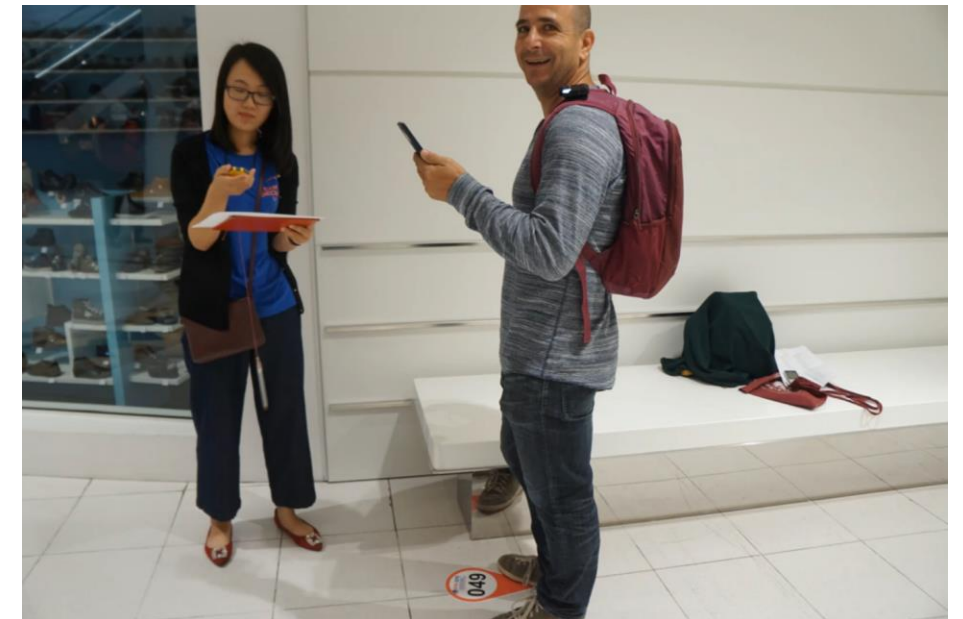
Summary

- **Grid-based filters**
 - deterministic alternative to particle filter
 - **evaluation** in realistic scenario
 - recommendations for configuration
- **Advanced point mass filter**
 - adapted existing method
 - innovative in the field of indoor positioning
- Particle filter - method for a reference

Future work – ideas for short-term goals

- **Indoor Navigation Application** (practical aspects)
- Improved map model
- Particle filter review
- **Sensor fusion** and integration of computer vision, neural networks, activity recognition ...

Application vs. Research





Thank you for your attention.

$$\underbrace{p(\mathbf{x}_k | \mathbf{z}_{1:k-1})}_{\text{prediction}} = \int \underbrace{p(\mathbf{x}_{k-1} | \mathbf{z}_{1:k-1})}_{\text{prior PDF}} \underbrace{p(\mathbf{x}_k | \mathbf{x}_{k-1})}_{\text{transition}} d\mathbf{x}_{k-1} \quad (4)$$

$$\underbrace{p(\mathbf{x}_k | \mathbf{z}_{1:k})}_{\text{correction (posterior PDF)}} = \frac{\overbrace{p(\mathbf{x}_k | \mathbf{z}_{1:k-1})}^{\text{predicted PDF}} \overbrace{p(\mathbf{z}_k | \mathbf{x}_k)}^{\text{evaluation}}}{\underbrace{\int p(\mathbf{x}_k | \mathbf{z}_{1:k-1}) p(\mathbf{z}_k | \mathbf{x}_k) d\mathbf{x}_k}_{\text{normalizing constant}}} \quad (5)$$