Karlsruhe Institute of Technology

Institute of Systems Optimization (ITE)

ITE

Pedestrian Navigation in Indoor Environments Based on Foot-Mounted Sensors

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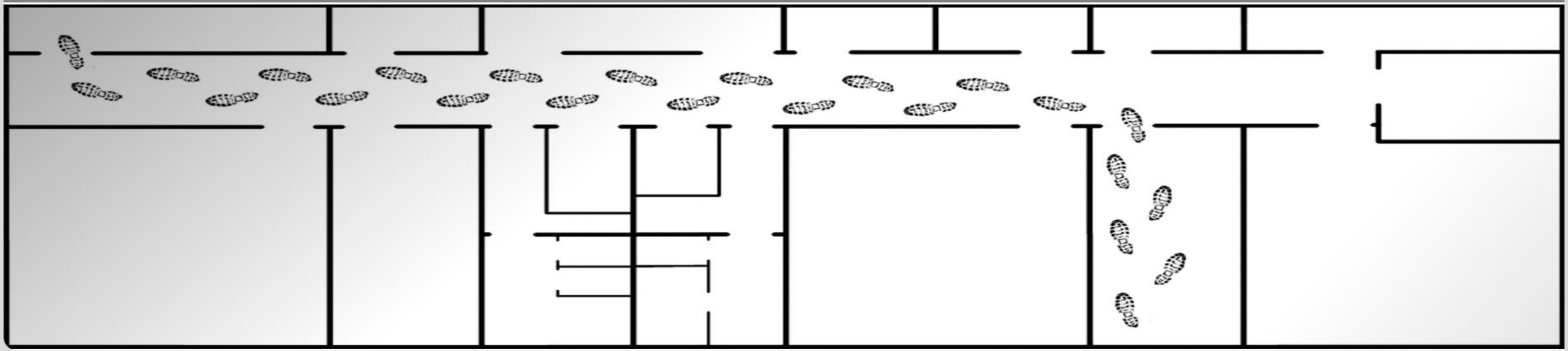
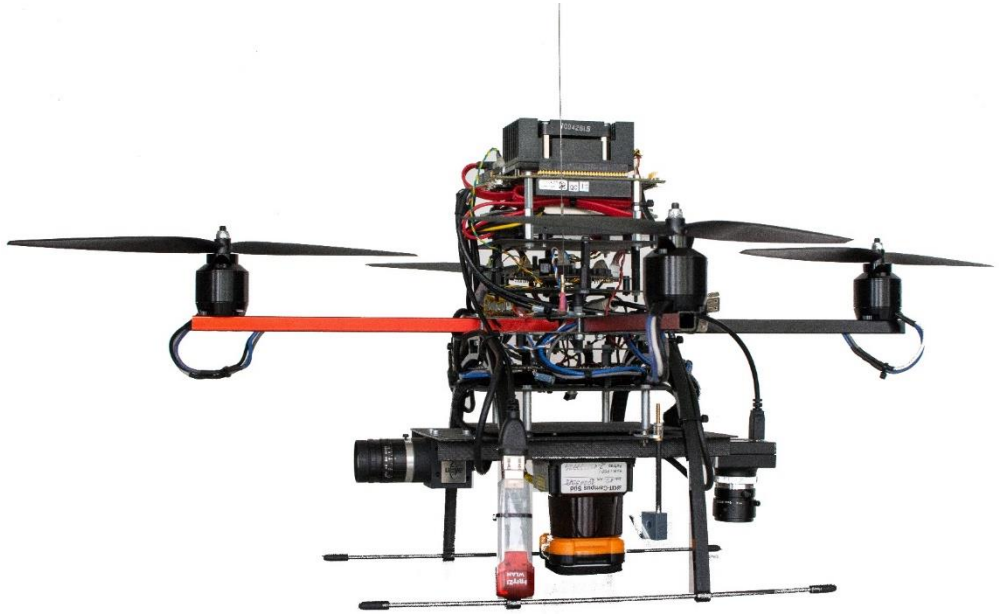
INSTITUTE OF SYSTEMS OPTIMIZATION (ITE)



Main Research ITE

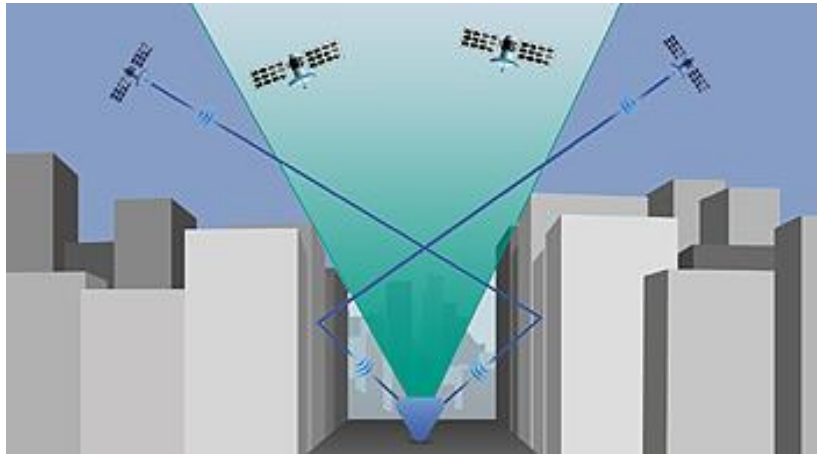
Systems

- **Micro Aerial Vehicle**
  - Fusion of **IMU**, **Cameras, Laserscanner** and **GNSS**
  - Focus on GNSS-denied envinroments
  - Navigation and exploration indoors
  - Collision avoidance
  - Map generation
  - Semantic segmentation



- **Pedestrian Navigation**

Introduction



Challenges:

- Independence of pre-installed infrastructure
- Outdoor-Indoor transitions
- Accurate localization
- Restrictions in weight, cost and size

Wide field of applications:

- Task force members
- Security & rescue personnel
- Visually impaired people
- Private users

Outline

Hardware Configuration

Foot Module

User Interface

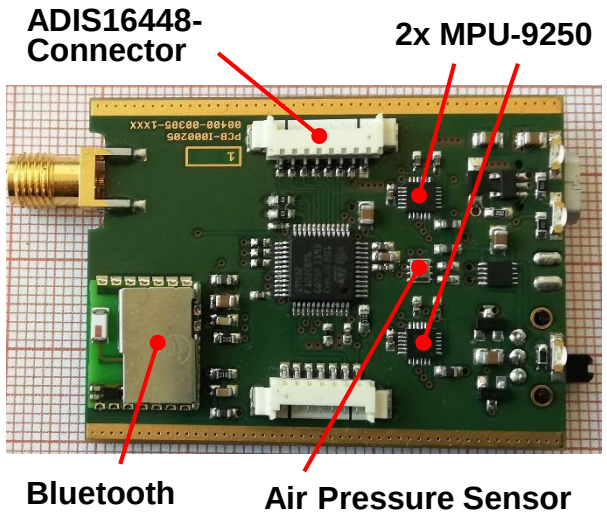
Datalink(WiFi)

Ground station

Hardware Configuration

Foot Module

- MEMS MPU-9250
- Air Pressure Sensor BMP 280
- NEO M8T GNSS Receiver
- MEMS Adis16448 Connector
- Bluetooth antenna
- Microprocessor STM32



Processing Unit / User Interface

- Lenovo X1 Yoga
- Intel i7-7500U (2.7GHz)
- 16GB DDR3-RAM

Outline

Model Based Navigation

Zero Velocity Update (ZUPT)

Challenges of MEMS sensors for INS:

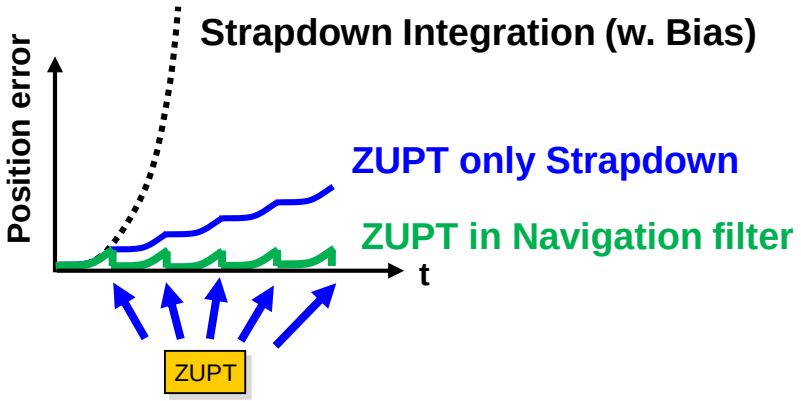
- Accumulation of biased ACC+GYRO values → increasing drift

Solutions:

- Additional aiding sensors (Laser, camera,…) → increasing cost, weight and size
- Physical or model-based knowledge

Zero Velocity Update (ZUPT):

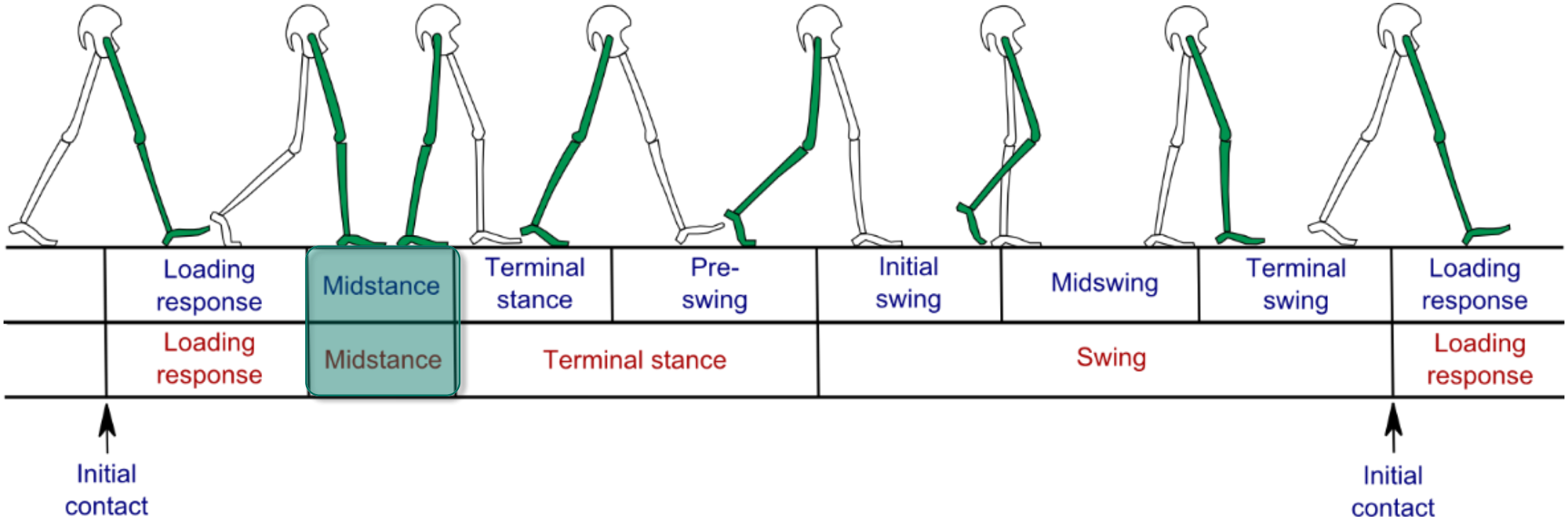
- σ^2- based technique → imprecise
- New: model-based technique → high-precision



Model Based Navigation

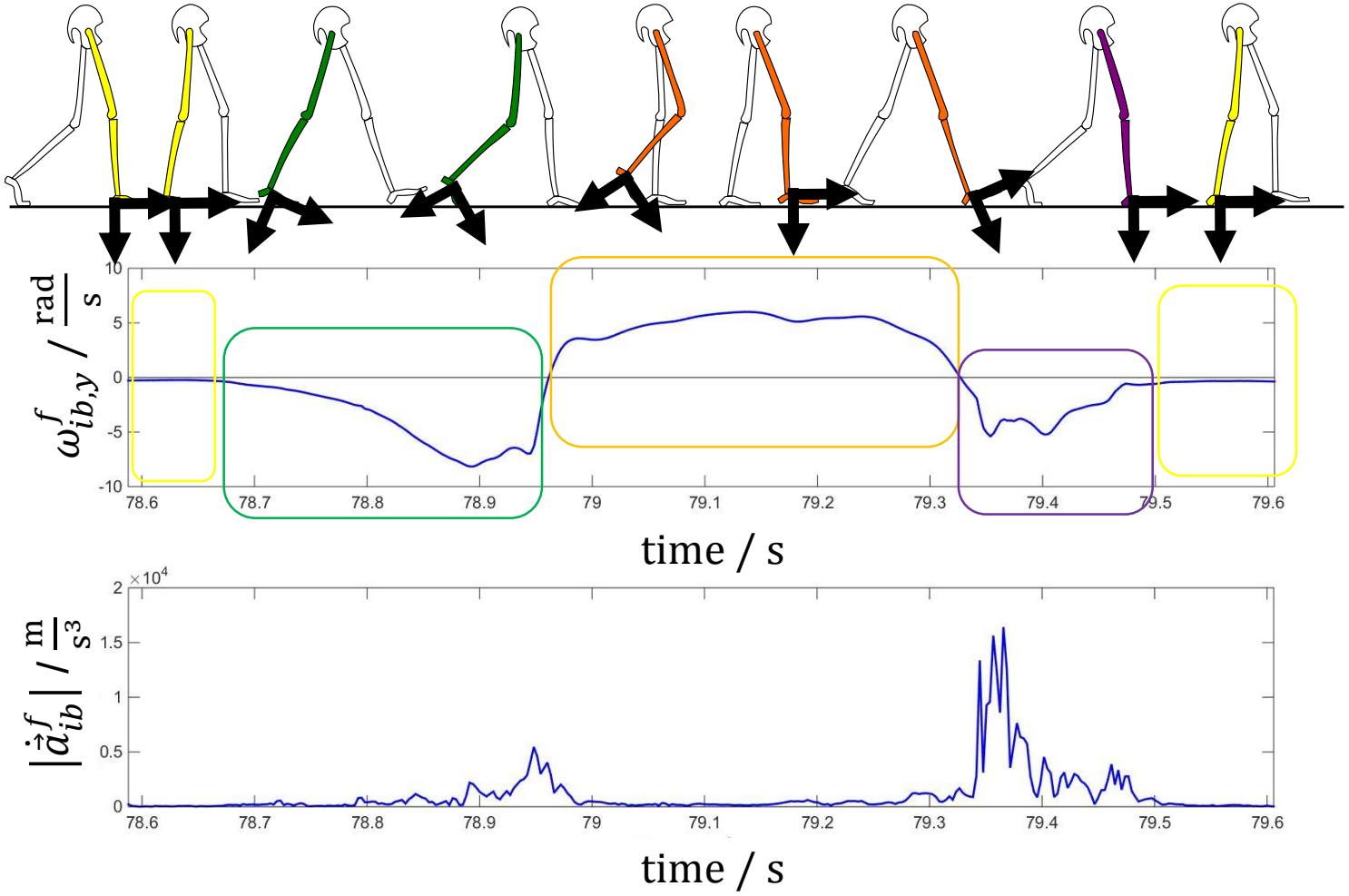
Finite State Machine (FSM) - Idea

Goal: Robust and accurate detection of the Midstance phase



Model Based Navigation

Finite State Machine (FSM) - Step Detection

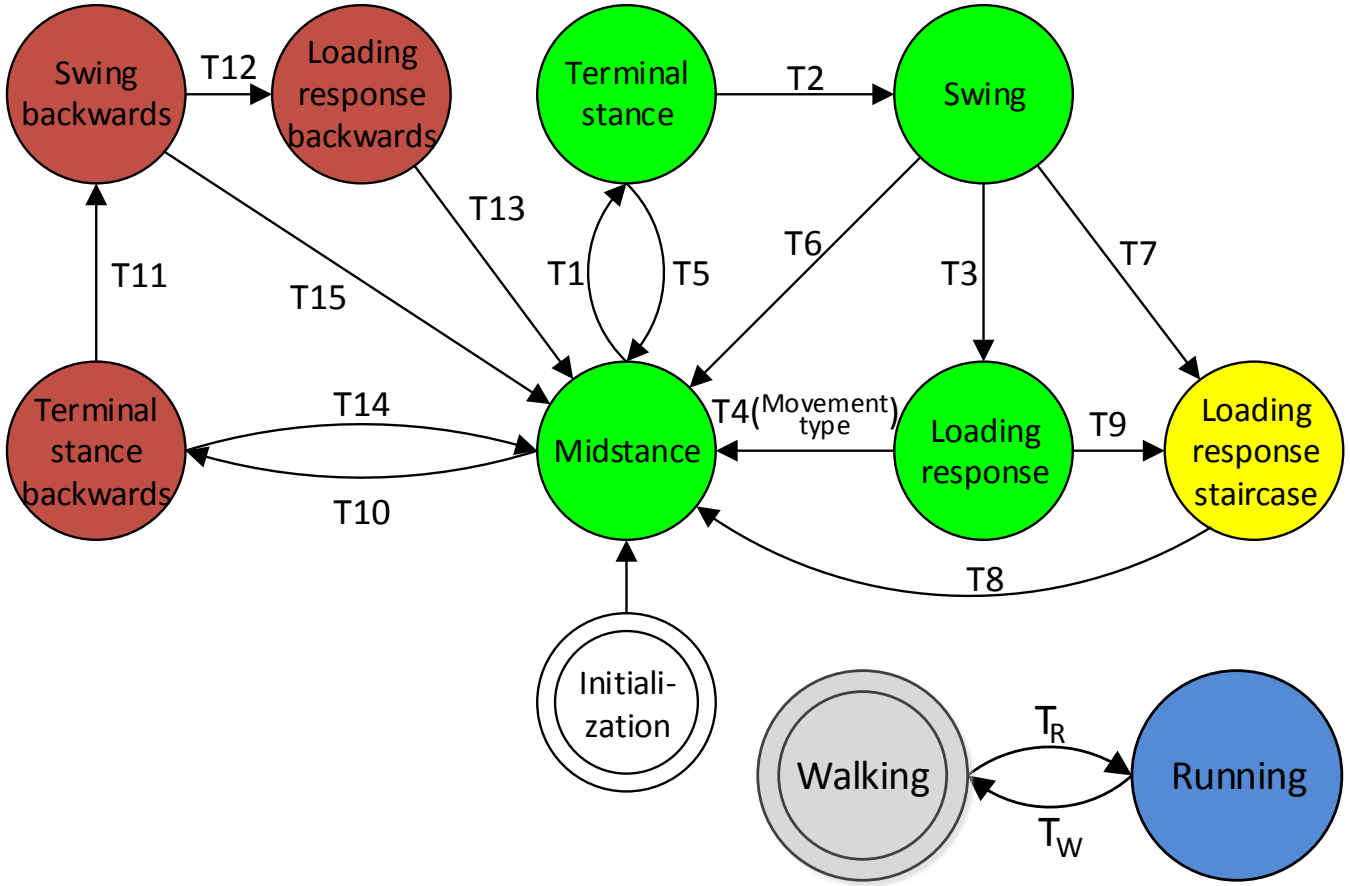


Model Based Navigation

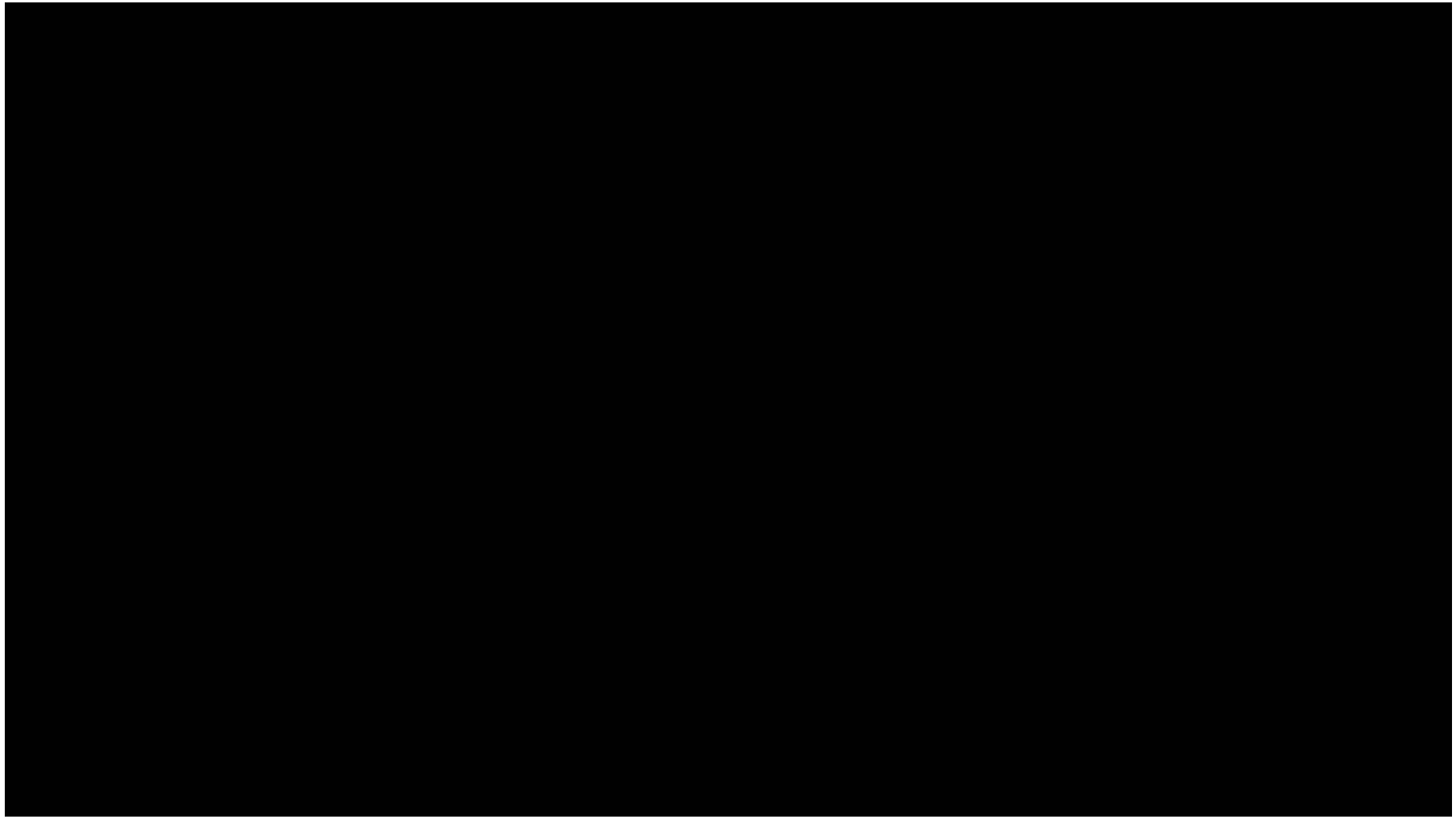
Finite State Machine (FSM) - Step Detection

Decision Signals:

- Angular rate $\omega_{ib,y}^{f}$
- Derivation $\dot{\omega}_{ib,y}^{f}$
- Magnitude $\left|\vec{\omega}_{ib}^{f}\right|$
- Magnitude $\left|\vec{a}_{ib}^{b}\right|$
- Variance σ_{ω}^{2}, σ_{a}^{2}
- Magnitude of $\left|\dot{\vec{a}}_{ib}^{f}\right|$

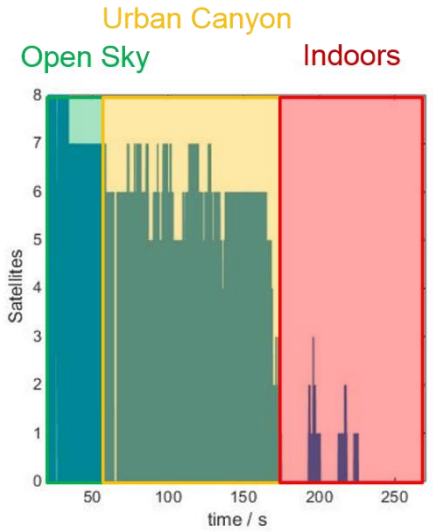


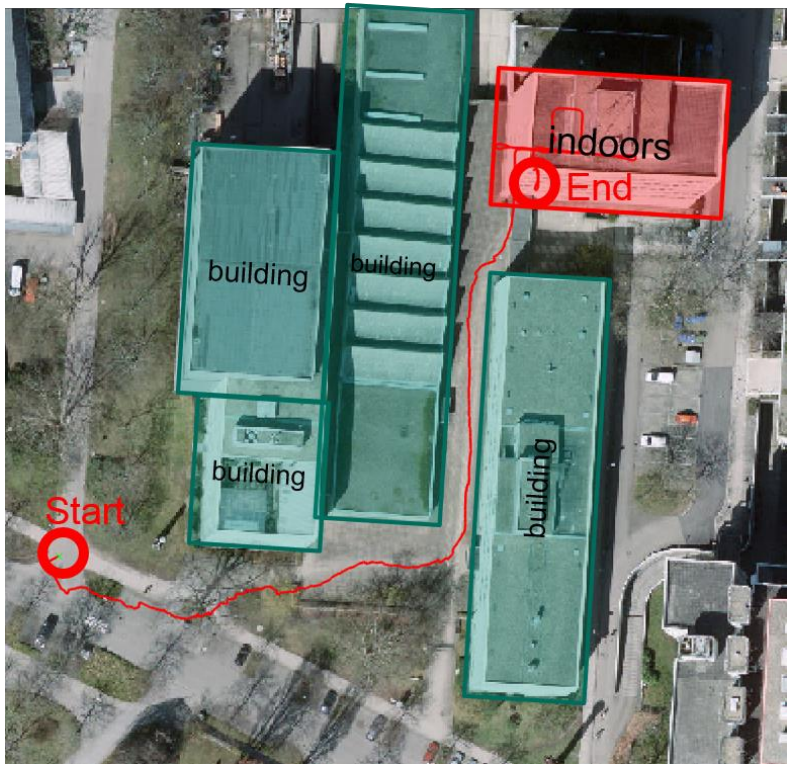
Experimental Results



Model Based Navigation

- Absolute position and attitude estimation with GNSS signals
- Tightly Coupled GNSS/INS Integration
- Indoor/Outdoor transitions possible
- Time delay correction between GNSS and IMU data
- GPS support (GLONASS in future)
- Detection and exclusion of GNSS satellites with multipath errors





Model Based Navigation

Check Elevation

- $\phi > \delta_{\phi}$
- Satellites with low elevation angles have a high probability of multipath errors especially in urban envirnoments

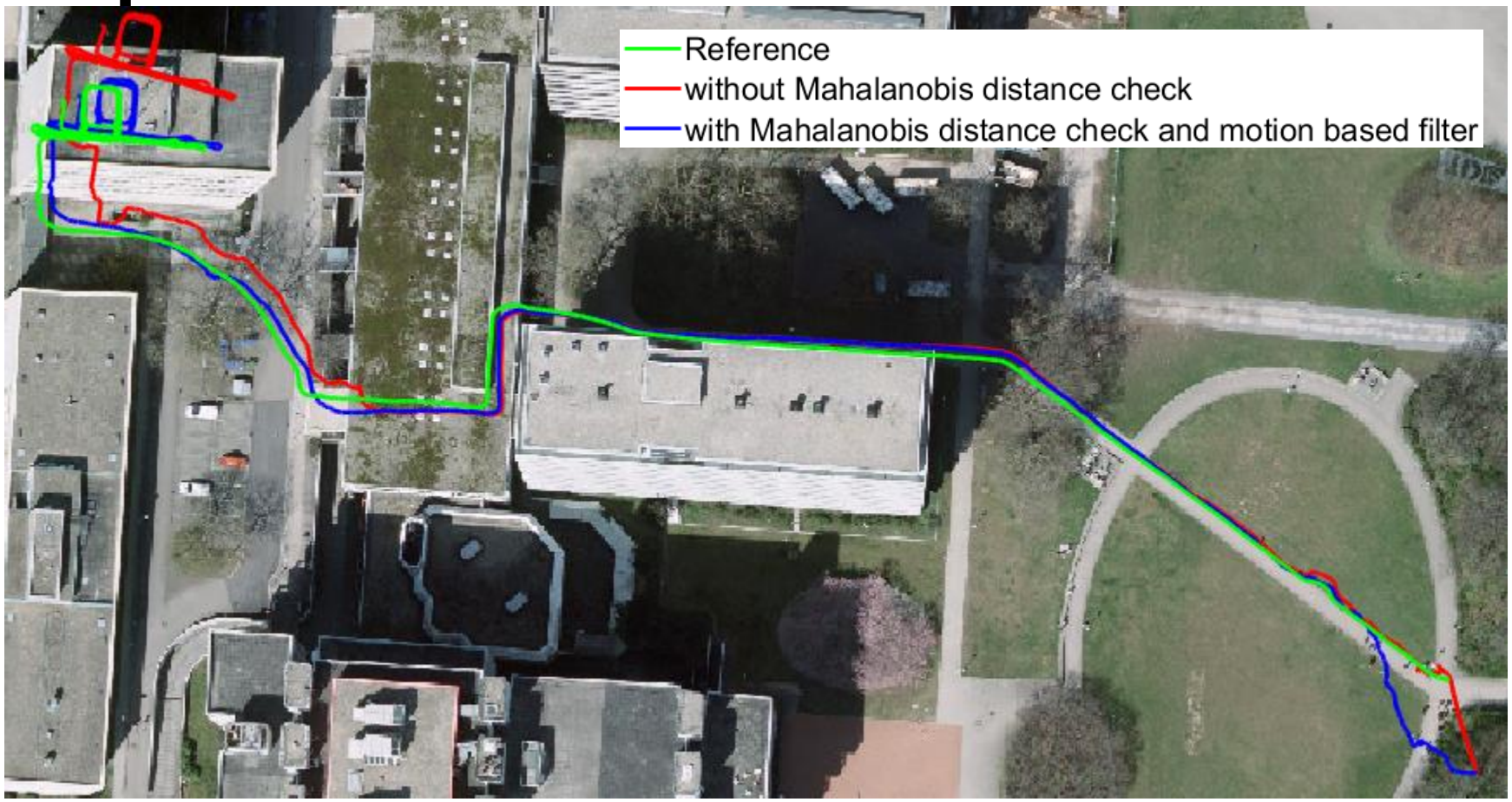
Check SNR

- $SNR > \delta_{SNR}$
- Reduction of the signal power by reflection, deflection or scattering

Mahalanobis Distance

- $m < \delta_{mahal}$ $\quad m = \sqrt{\frac{r^2}{\sigma_S^2}}$ $\quad r = H\hat{\vec{x}} - \tilde{y}$ $\quad \sigma_S^2 = HPH^T + \sigma_R^2$
- Adaptive outlier detection depending on P
- Check if there is a big gap between predicted and received measurement respect to their covariances

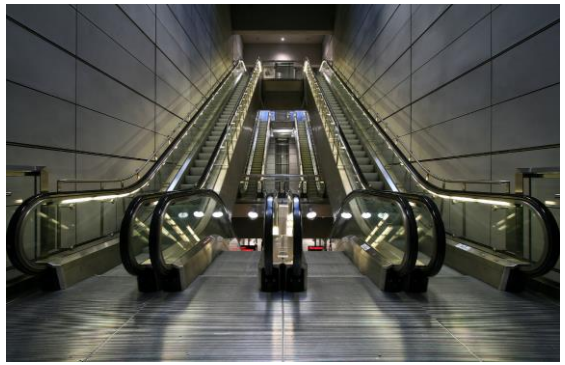
Experimental Results



- ADIS 16448 IMU
- GPS only with 10Hz

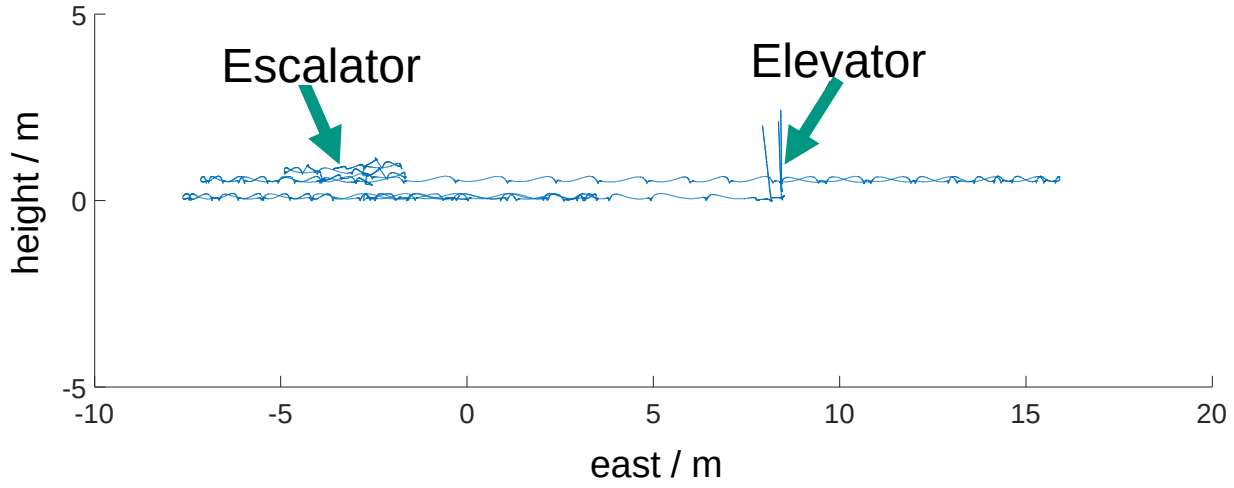
Model Based Navigation

[1]



[2]

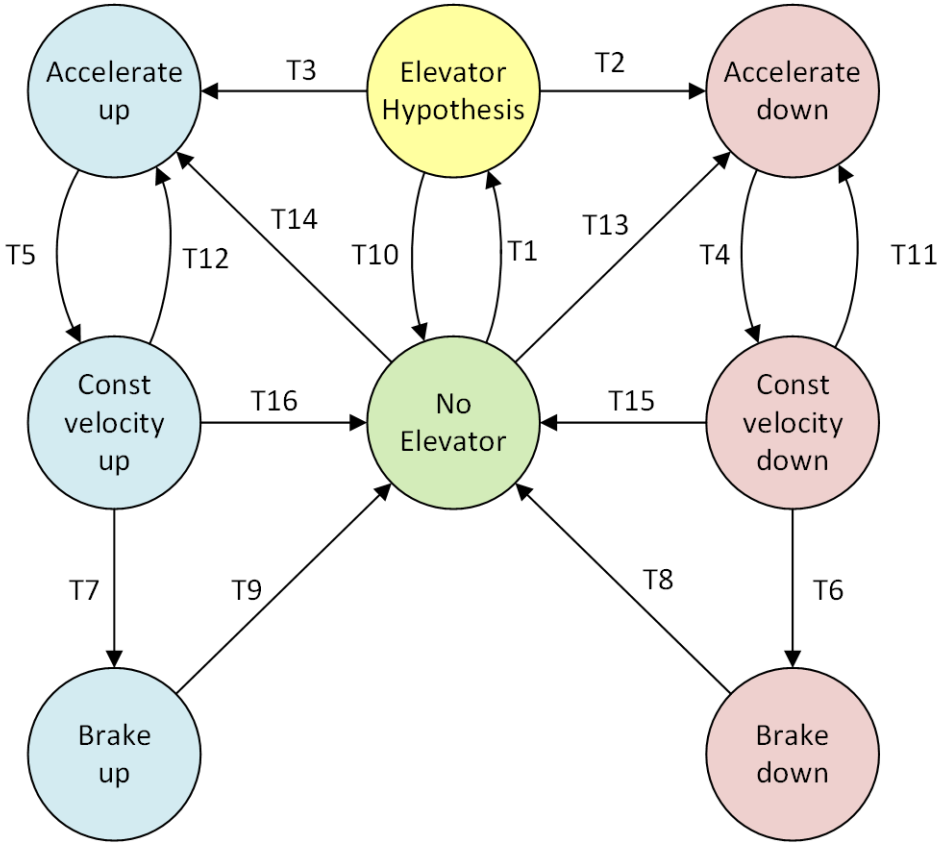
- ZUPT not always indoors

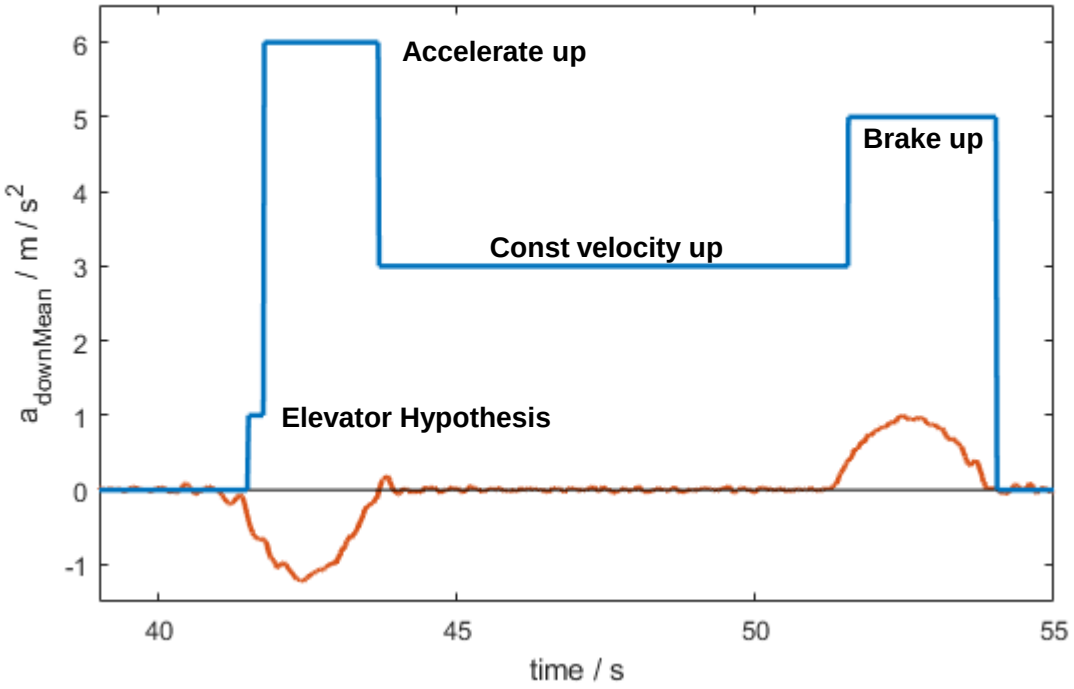


→ Robust and exact detection of moving platforms

Source of [1]: https://ozoneelevators.co.in/images/backgrounds/bg-main-2.jpg
Source of [2]: https://upload.wikimedia.org/wikipedia/commons/thumb/4/42/Copenhag en_Metro_escalators.jpg/1920px-Copenhagen_Metro_escalators.jpg

Model Based Navigation





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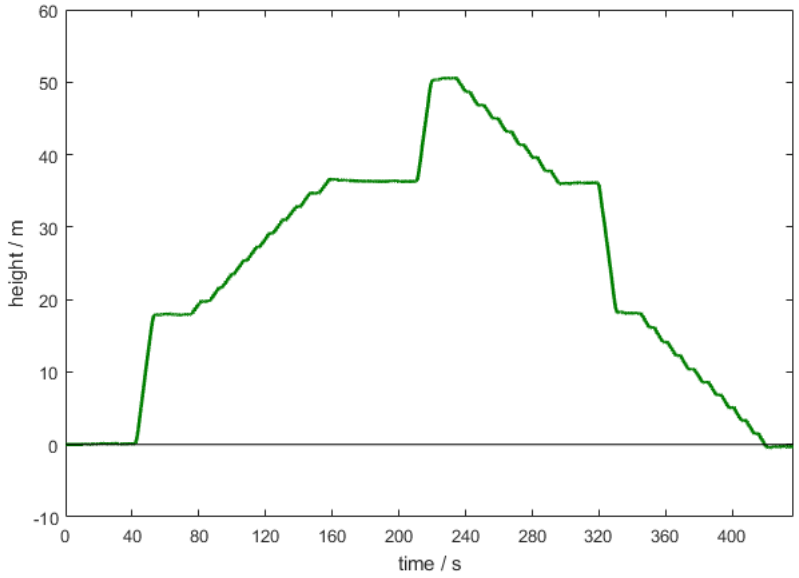
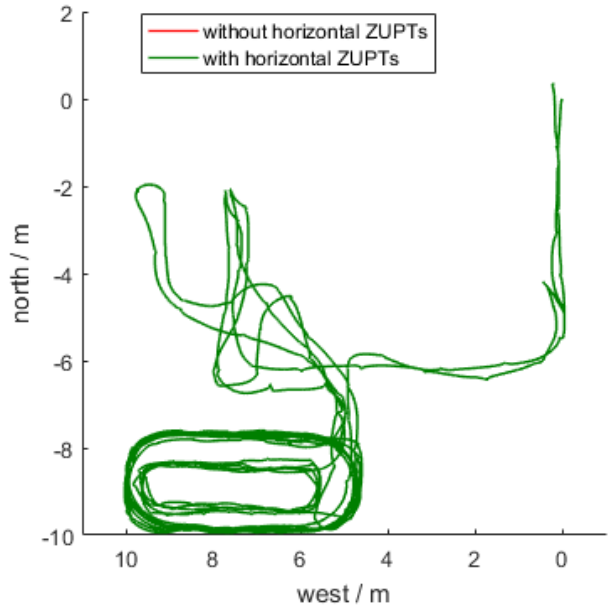
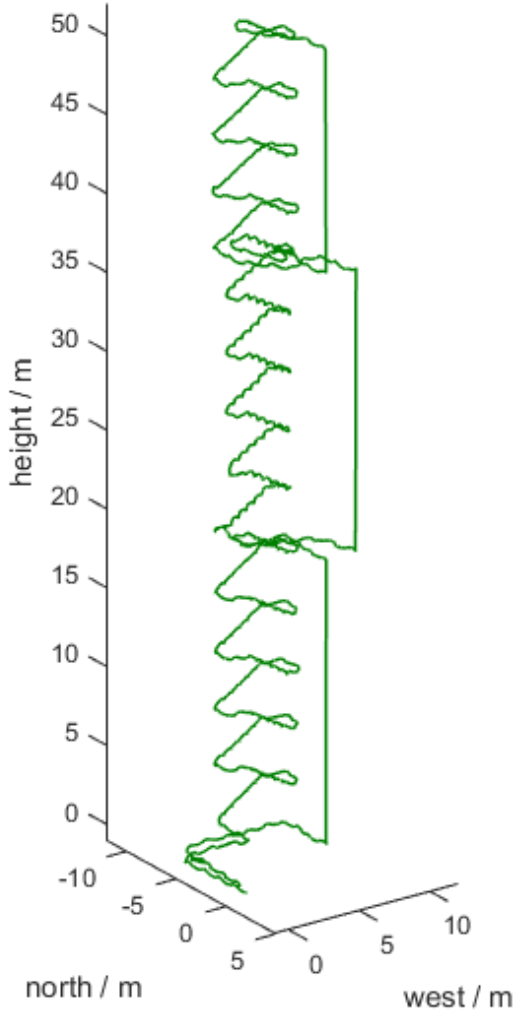


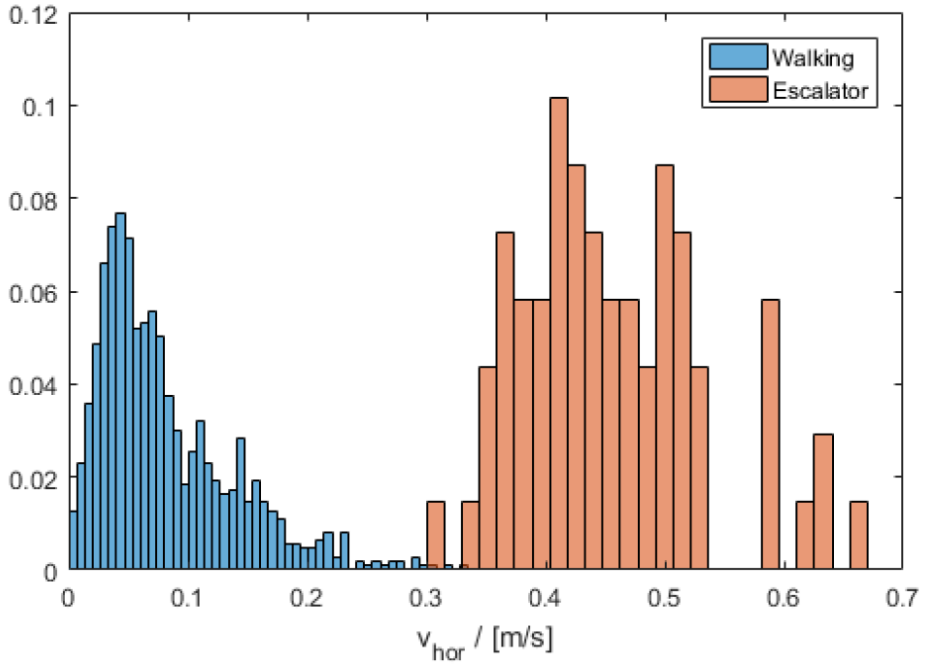


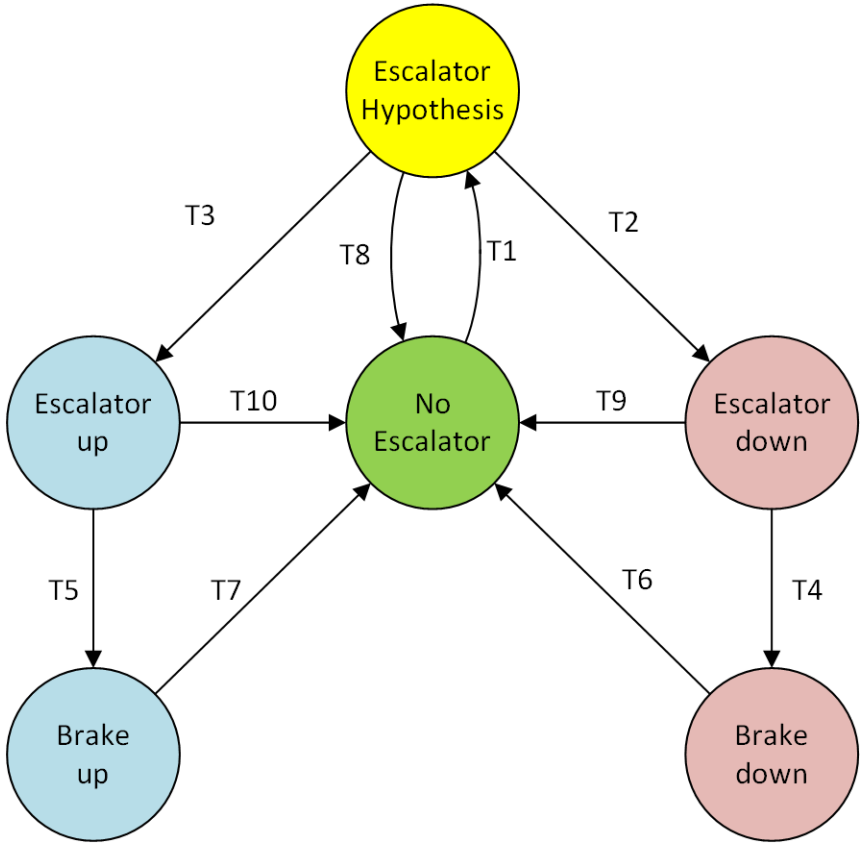


	vert. distance	hor. distance	Δh	Δ2D	Δ3D
Test 1	**105.23m**	**240.00m**	**0.33m**	**0.40m**	**0.52m**
Test 2	63.52m	140.07m	0.89m	0.57m	1.05m
Test 3	124.03m	153.79m	0.98m	0.62m	1.16m

Model Based Navigation

$$v_{hor} = \sqrt{v_{north}^2 + v_{east}^2}$$





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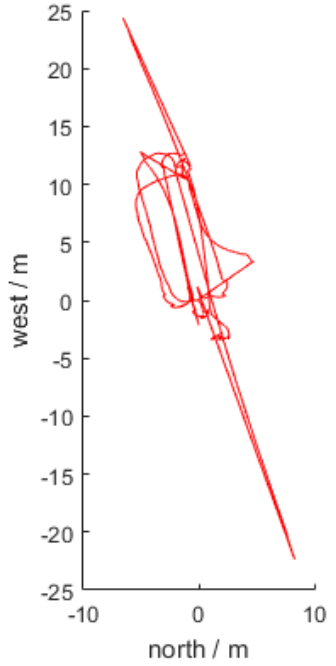
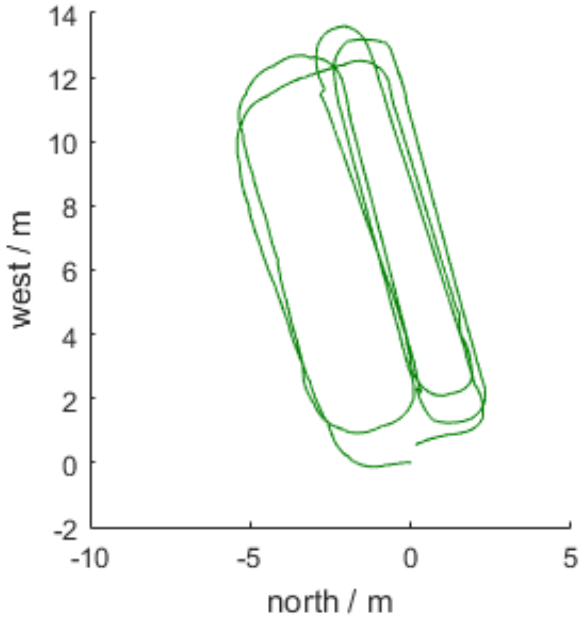
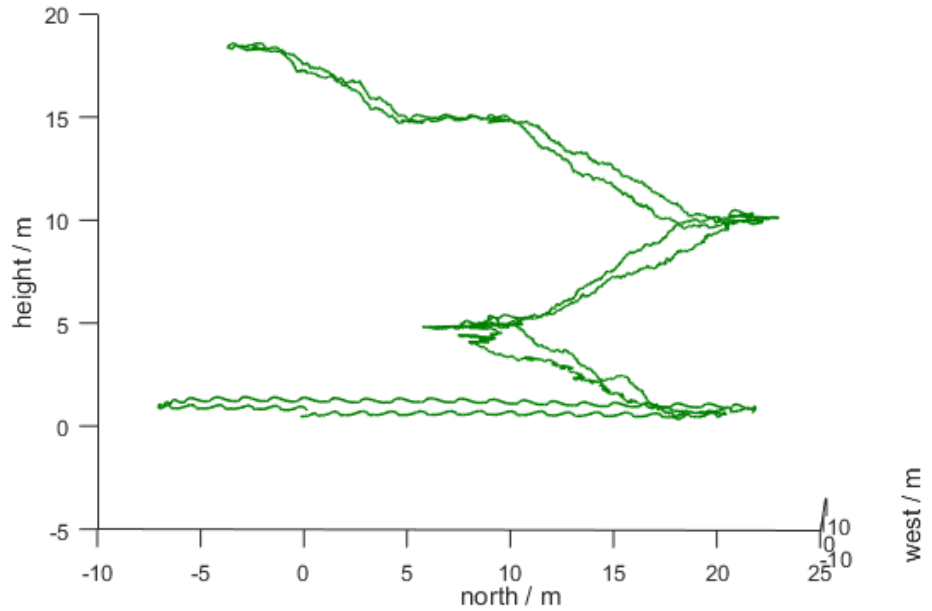


Without constraints



With constraints



With constraints and steps on the escalator

	vert. distance	hor. distance	Δh	Δ2D	Δ3D
Test 1	28.95m	111.53m	0.49m	0.82m	0.97m
Test 2	**36.90m**	**168.37m**	**0.06m**	**2.38m**	**2.38m**
Test 3	25.99m	123.34m	0.11m	0.57m	0.58m
Test 4	20.46m	324.99m	0.05m	1.37m	1.37m

Outline

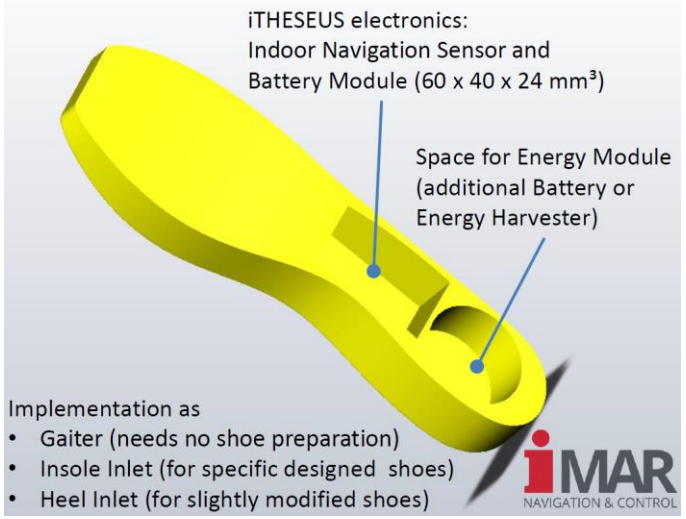
Conclusion & Outlook

Conclusion

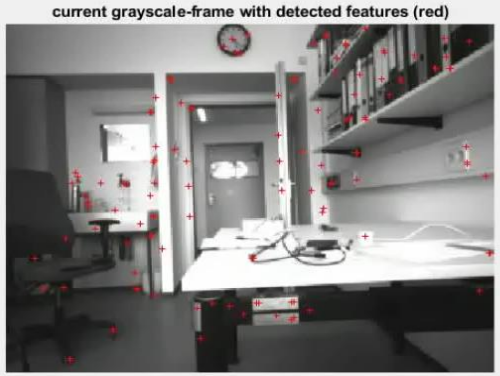
- High accurate relative positioning system
- Tightly integration of GNSS/IMU data for absolute localization
- Detection of elevators and escalators
- Real-time localization in outdoor and indoor scenarios

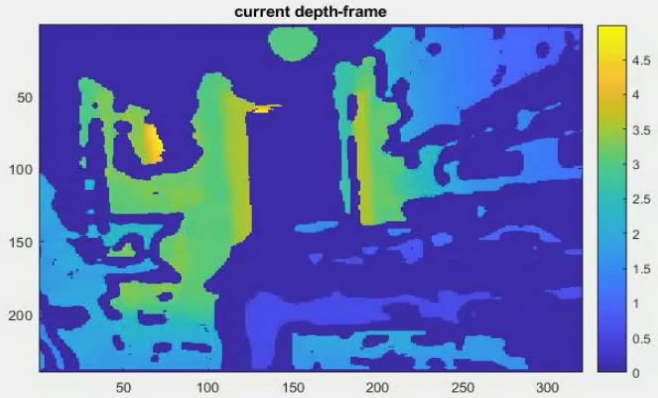
Outlook

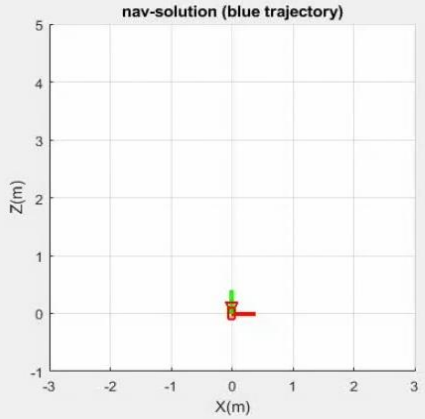
- Mounting electronics in heel
- Body camera with RGBD sensor for reconstruction of 3D map

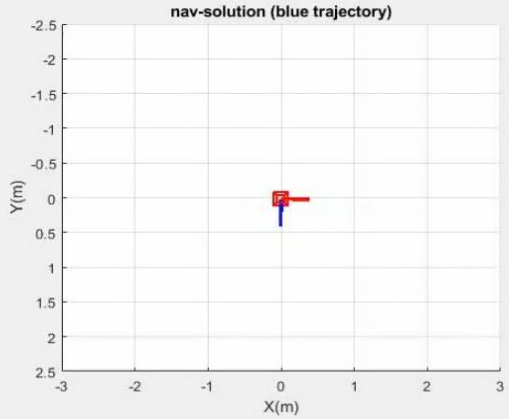


Conclusion & Outlook



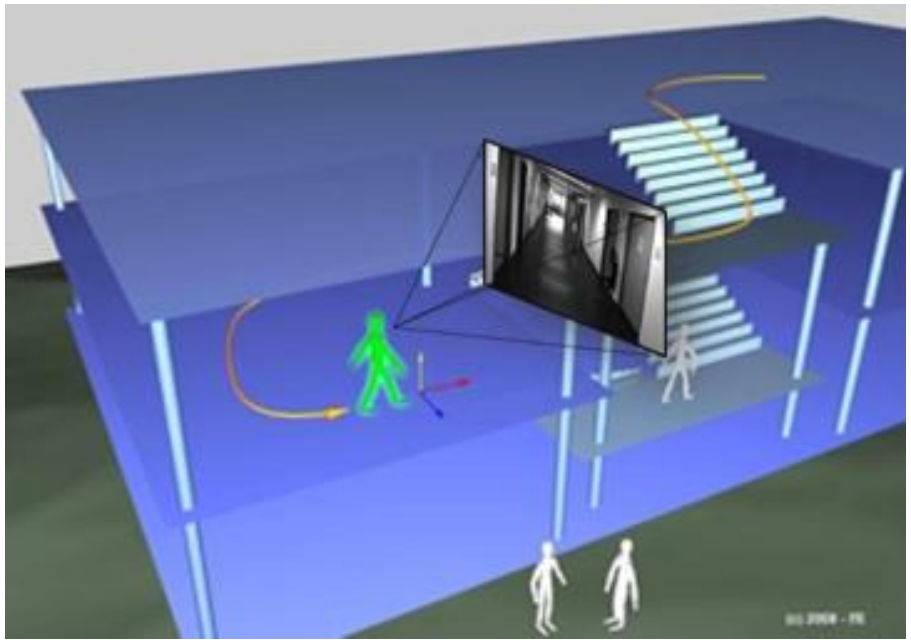






- Realsense D435
- (IMU Integration)

Thank you!



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