HSG-IMIT

Locating and supervising relief forces in buildings without the use of infrastructure

Tracking of position with low-cost inertial sensors

innBW INNOVATIONSALLIANZ BADEN-WÜRTTEMBERG

HSG-IMIT

Key data (2013)

- Place of business: Villingen-Schwenningen, Freiburg
- Staff: 120 FTE
- Budget: 13,3 M€

Business areas

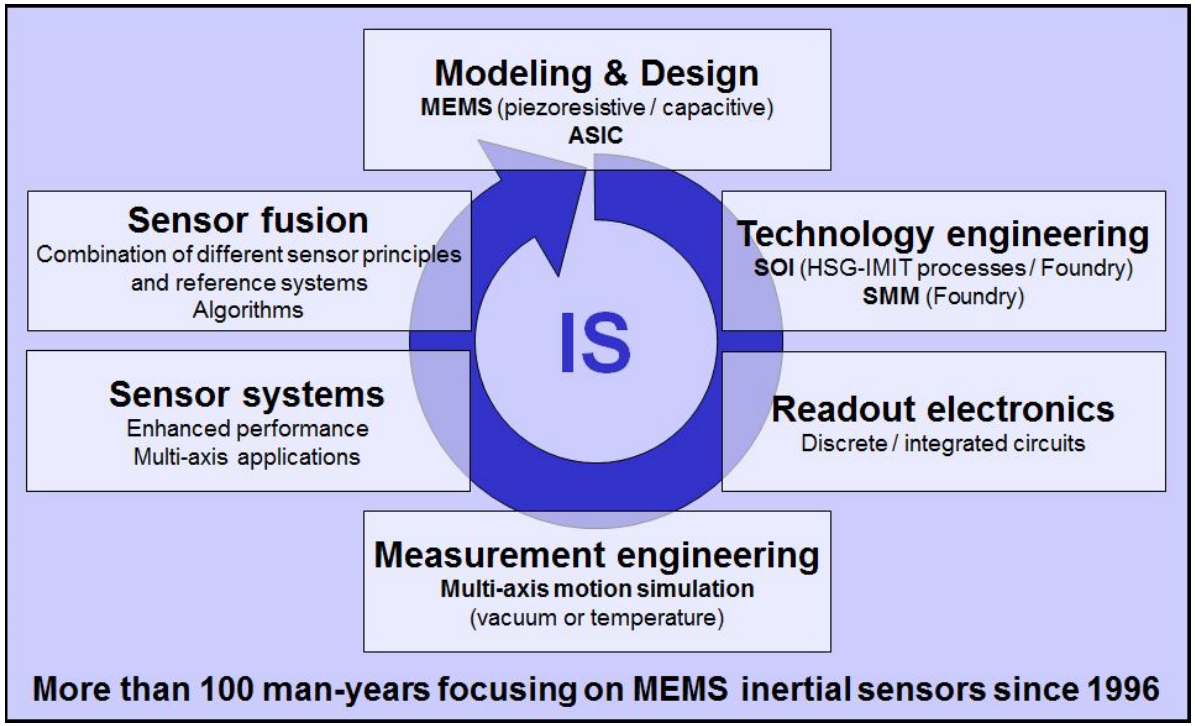
- Sensors & Systems
- Microfluidics
- Prototyping & Production
- Lab-on-a-Chip

Quality management

- DIN EN ISO 9001:2008 certified

HSG-IMIT: Inertial Sensor Systems

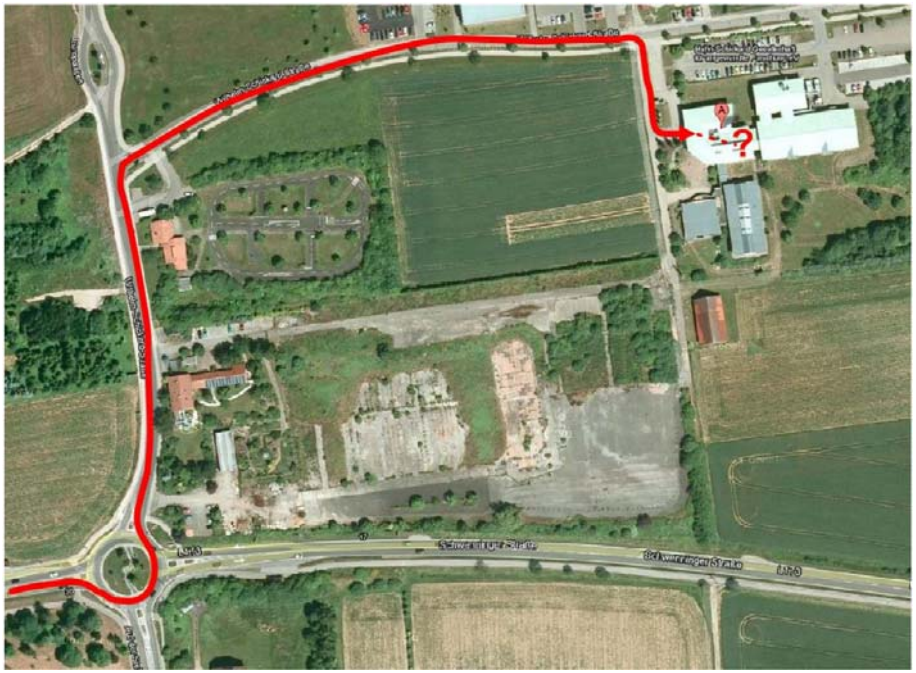
Competencies:



Motivation

Challenges of the (Indoor)-Localization

- Absence of GPS signals in houses, woods, between high rows of houses,…
- No area-wide infrastructure of triangulation technologies
  - WLAN
  - GSM
  - Bluetooth
- Lighting conditions, reflections, textures, resolution limits …. of optical methods
  - 2D, 3D-cameras (passive methods)
  - Depth-sensors (active methods – mutual interferences)
  - Laser

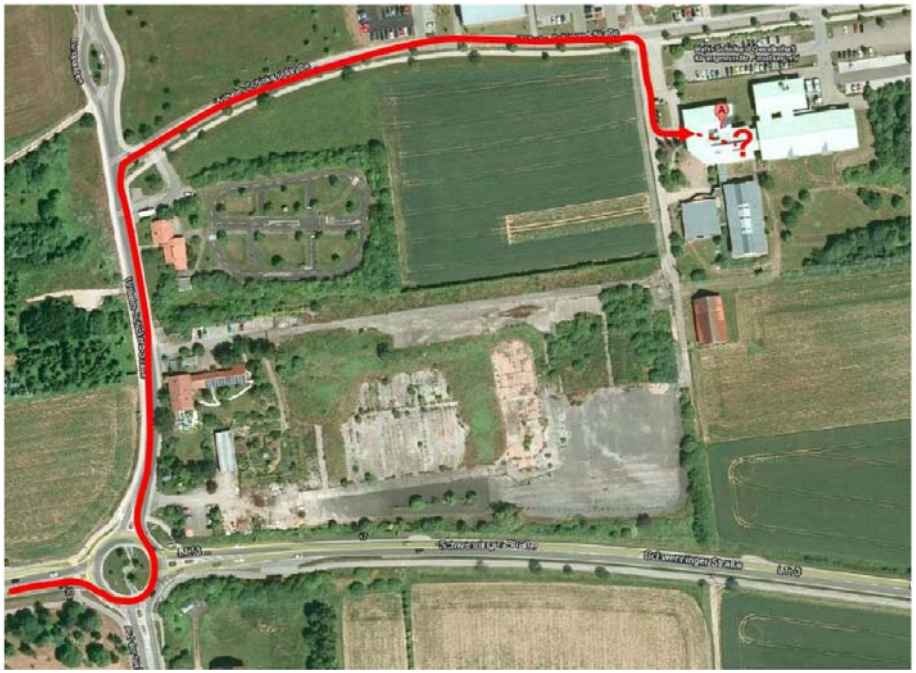


Motivation

Challenges of the (Indoor)-Localization

- Environmental interferences by using acoustic methods
  - Microphone array
  - Ultrasonic sound
- Requirements regarding size, weight and costs

➔ **Inertial Navigation !**

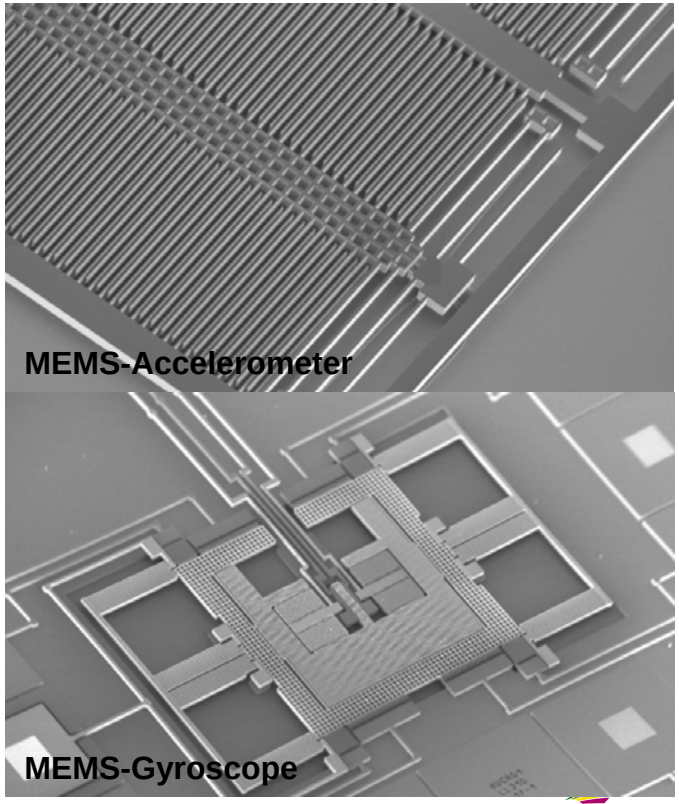


Inertial Navigation - Theory

Inertial Sensors measure relative movements

- MEMS-Accelerometer
  - Small, cheap, low power
  - measures the acceleration of a body
- MEMS-Gyroscope
  - Small, close to cheap, close to low power
  - measures the angular rate of a body

NICE!



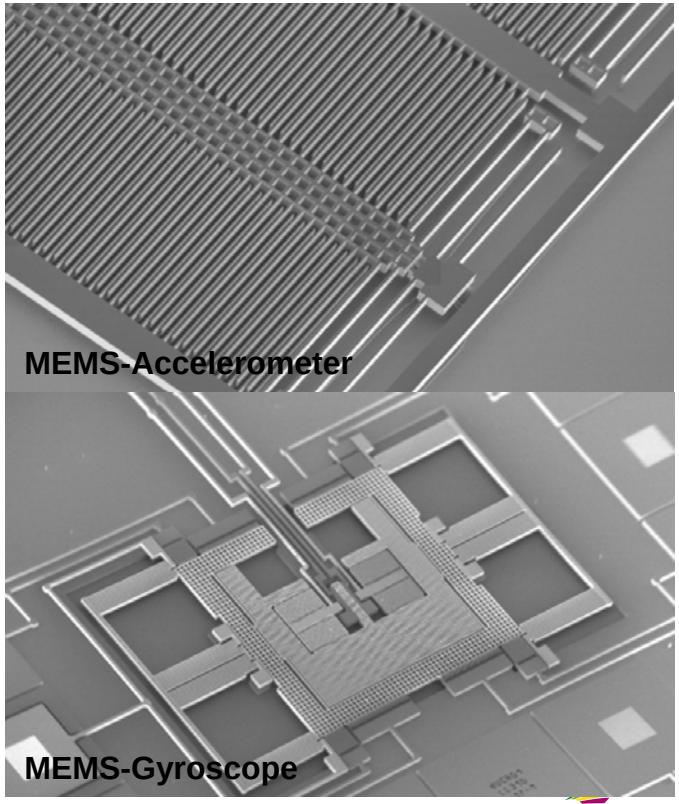
Inertial Navigation - Theory

Inertial Sensors measure relative movements

- Simple integration of angular rate
  - orientation of an object
- Double integration of acceleration
  - position of an object
- No external system needed

PROBLEM SOLVED!

… so far the theory…



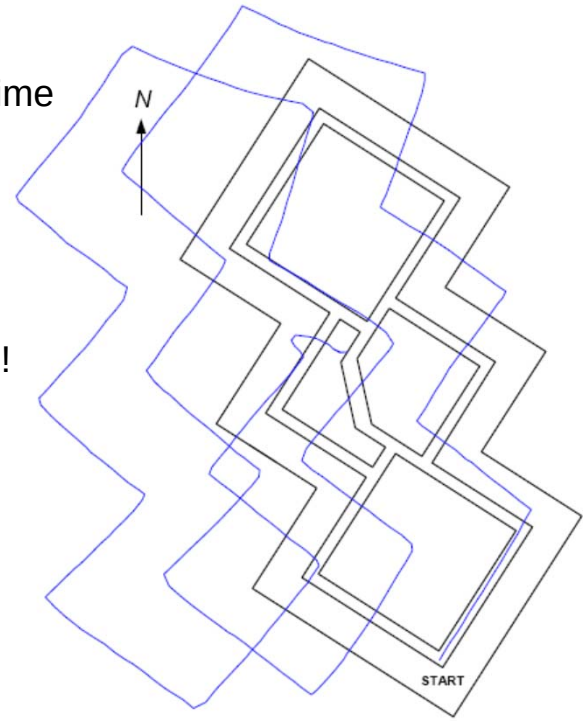
Inertial Navigation – Practice

It works

- with very (!) expensive and large sensor systems over a limited time
  - FOG, RLG, mechanical gyros → hours
    (used in planes, satellites, rockets, missiles,…)

It does not work

- with low cost sensors, especially when they are worn by persons!
  - Drift due to integration
  - Superimposed movement information



Inertial Navigation – with MEMS sensors

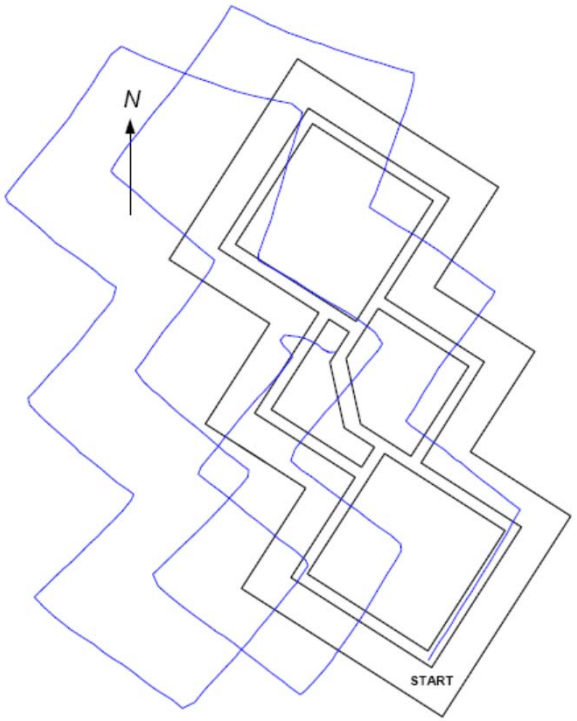
Advantages of inertial navigation

- Independent of external infrastructure
- Low-cost hardware
- Seamless indoor-/outdoor navigation

Disadvantage

- Conventional inertial navigation does not work with low-cost MEMS sensors
  - Drift due to integration

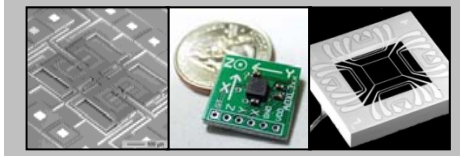
Solution: Sensor Fusion !



Sensor and Information-Fusion

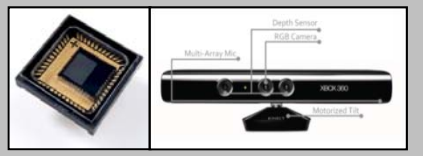
(extract of competencies of HSG-IMIT)

Sensor and Reference systems



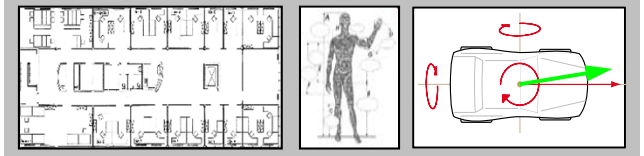
Acceleration, angular rate, magnetic field, distance,…

Bluetooth, GPS, WLAN, …



Mono, Stereo, Depth-camera, Laser

Knowledge about the system



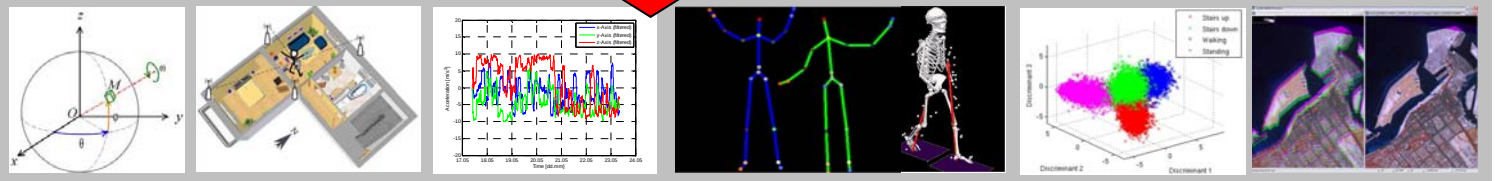
Maps, motion models, environment

Preprocessing (Signalprocessing, Image/Videoprocessing, …)

Constraints

Fusions algorithms (Bayesian Filters)

System state

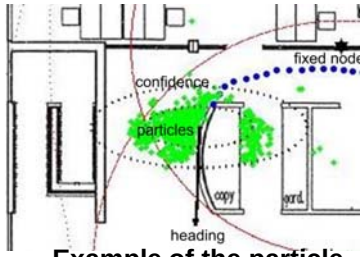


Orientation, Localization, motion tracking, motion analysis, motion classification, computer vision

Sensor Fusion: Indoor Localization

Body attached sensor unit

- Accelerometer for step detection and step length scaling;
- Gyro/magnetometer for heading estimation;
- CSS (NanoLOC) range measurements to anchors;



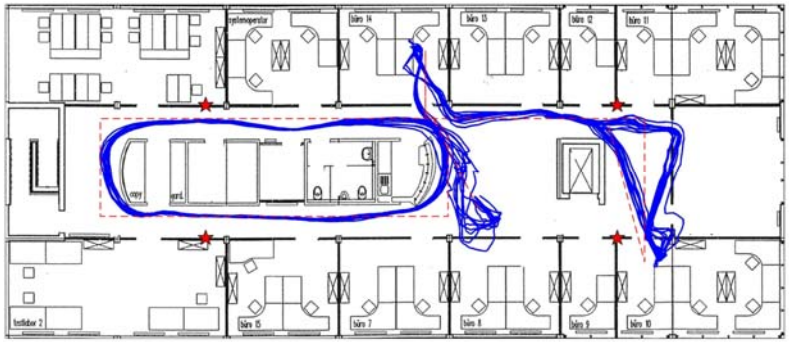
Example of the particle cloud in the particle filter

Information of application

- Implementation of map constraints to limit the motion

Advanced Particle Filter for position estimation

- Disadvantages:
  - external reference system
  - Computing time



Particle Filter (10 iterations) on the same data using the map constraints

Sensor Fusion: Combined Indoor/Outdoor Localisation using ZUPT

Sensor unit mounted on foot

- 3axis gyroscope
- 3axis accelerometer
- 3axis magnetometer
- Microcontroller (MSP430)
- Low power Bluetooth for communication with handheld

UKF-based estimation algorithm

“Zero Velocity Update” – based measurement model

- Considering the movement phases for the position calculation
- „Generation of references“ (no step counting!)

1st Demonstrator: Realtime visualization of the position on a tablet

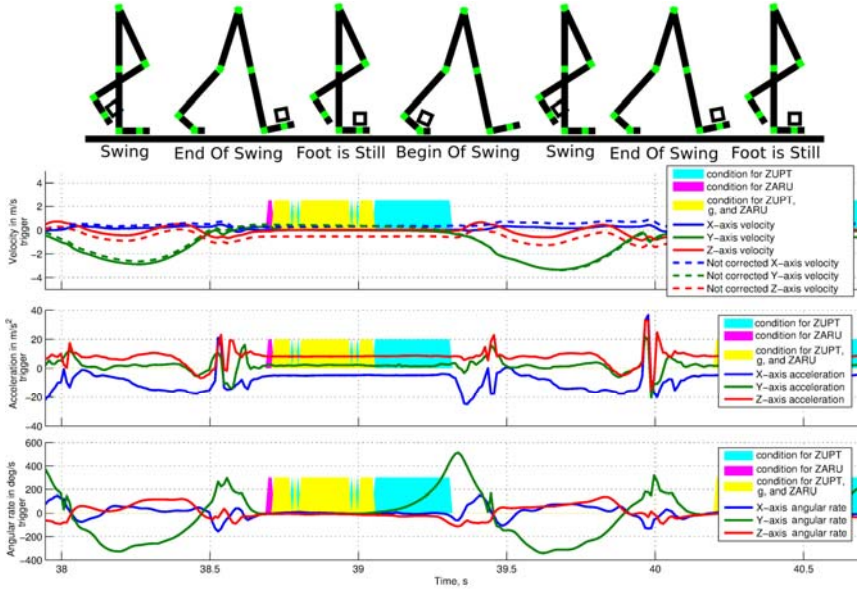
Movement phases – Trigger mechanism

Virtual measurements at the still phase of the foot

- Zero Velocity Update (ZUPT)
  - No velocity
- Zero Angular Rate Update (ZARU)
  - No rotation
- Measurement of gravity acceleration
  - Correction of pitch and roll

Detection of still phase heuristic

- Parameter tunable
  - Thresholds, Delays,…



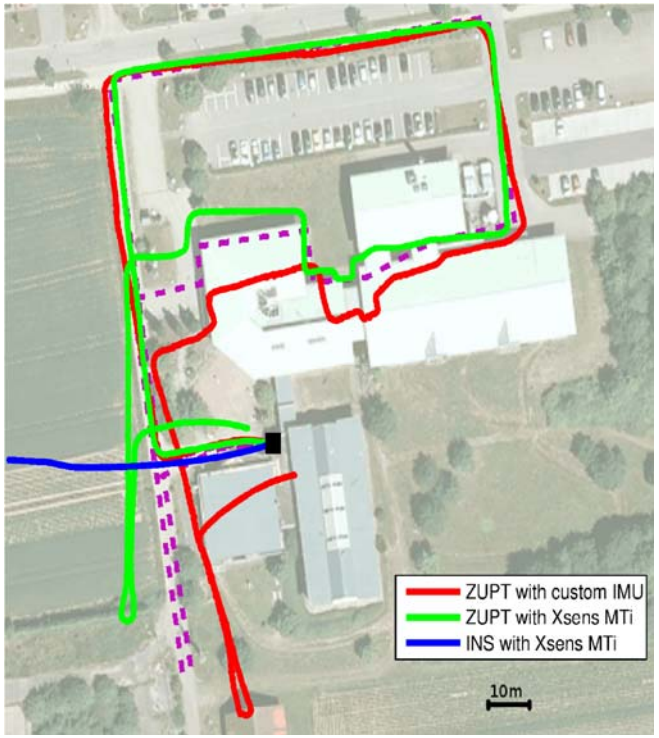
Results: Pure Inertial Navigation

Comparison: highly calibrated IMU (Xsens) vs. low-cost IMU

- Only gyroscopes and accelerometers
  - No heading correction with magnetometers
  - Basic calibration, no orthogonality compensation

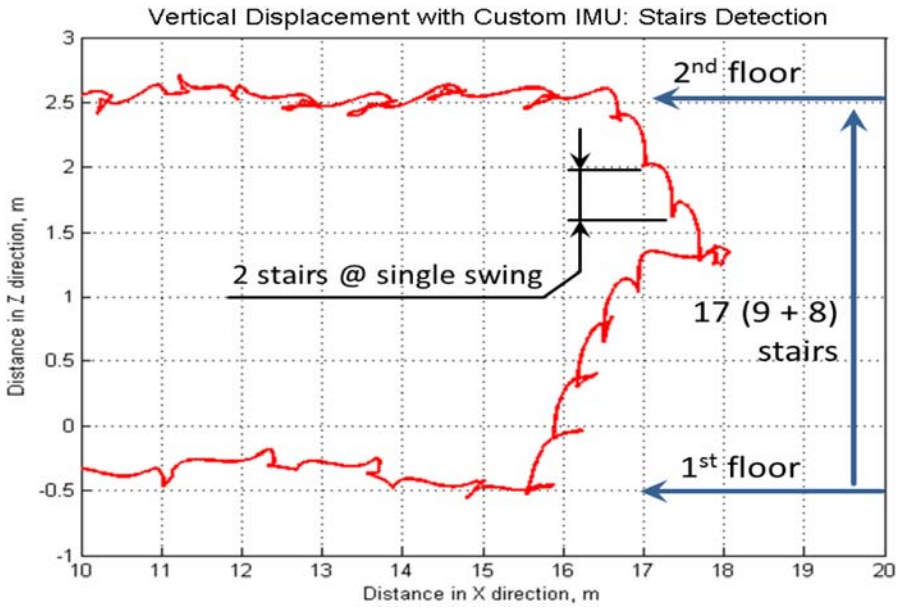
Results:

- Only slight drift over several minutes
- Comparable performance
- (blue line: Inertial Navigation without ZUPT)

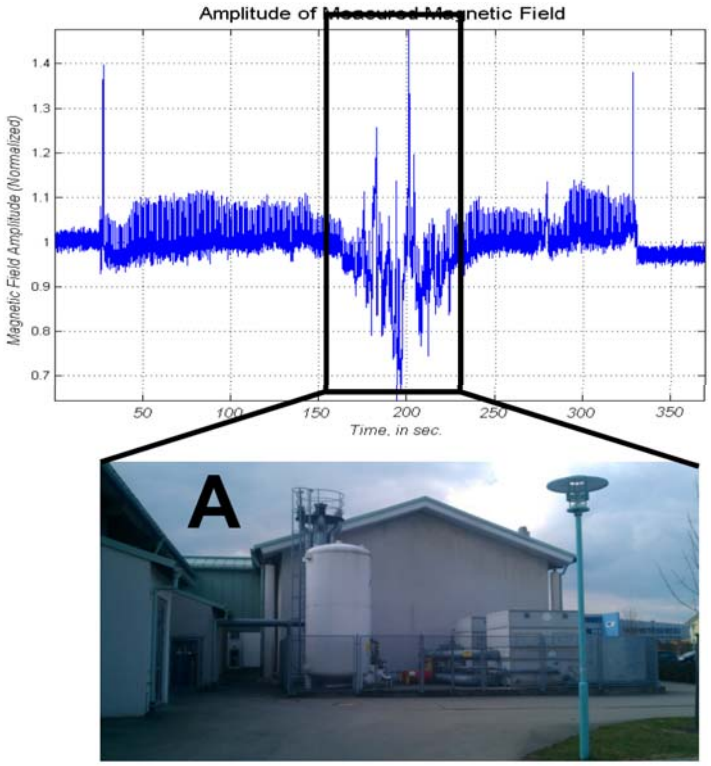


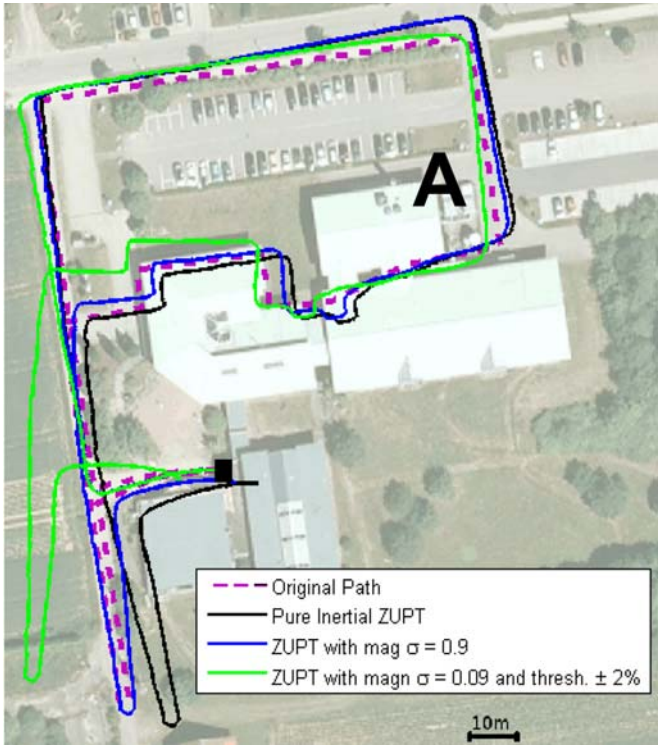
Results: Pure Inertial Navigation (vertically)

- Sufficient accuracy to resolve the steps of a staircase (2x)
- Chances of floor levels can be detected
  - Only short-time
  - Without barometer not possible in systems using step counting/step length estimation



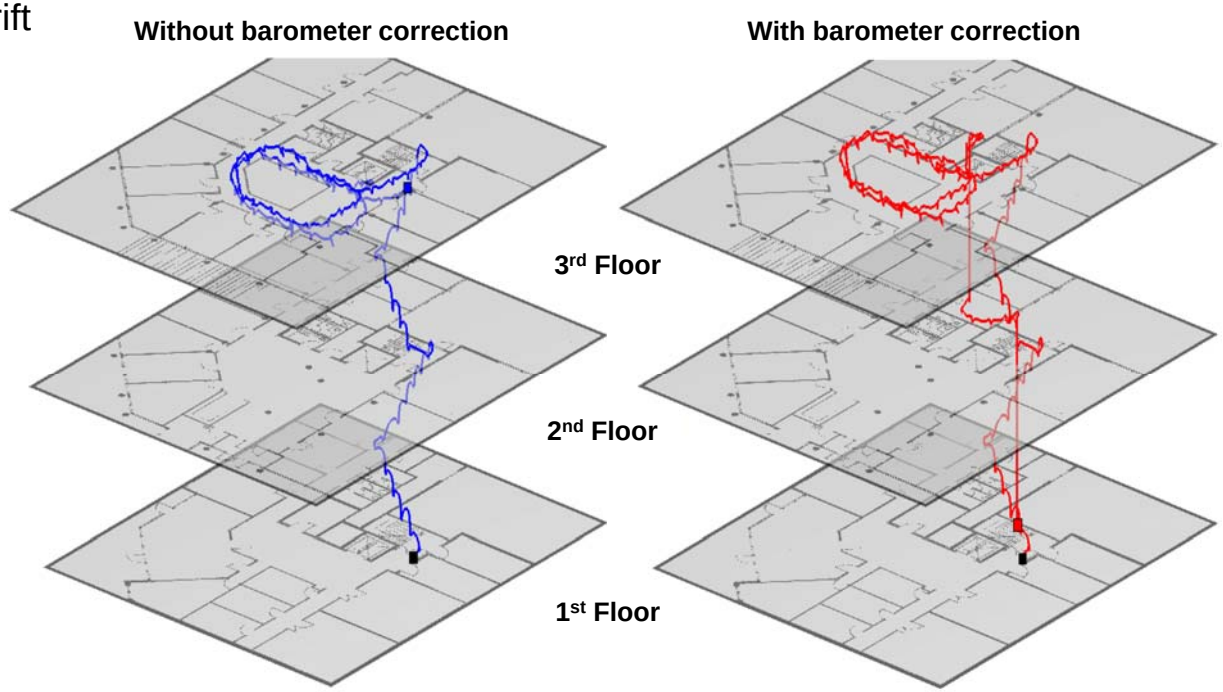
Results: Extension with a magnetometer





Results: Extension with a barometer

- Compensation of vertical drift
- Correct height also when using an elevator



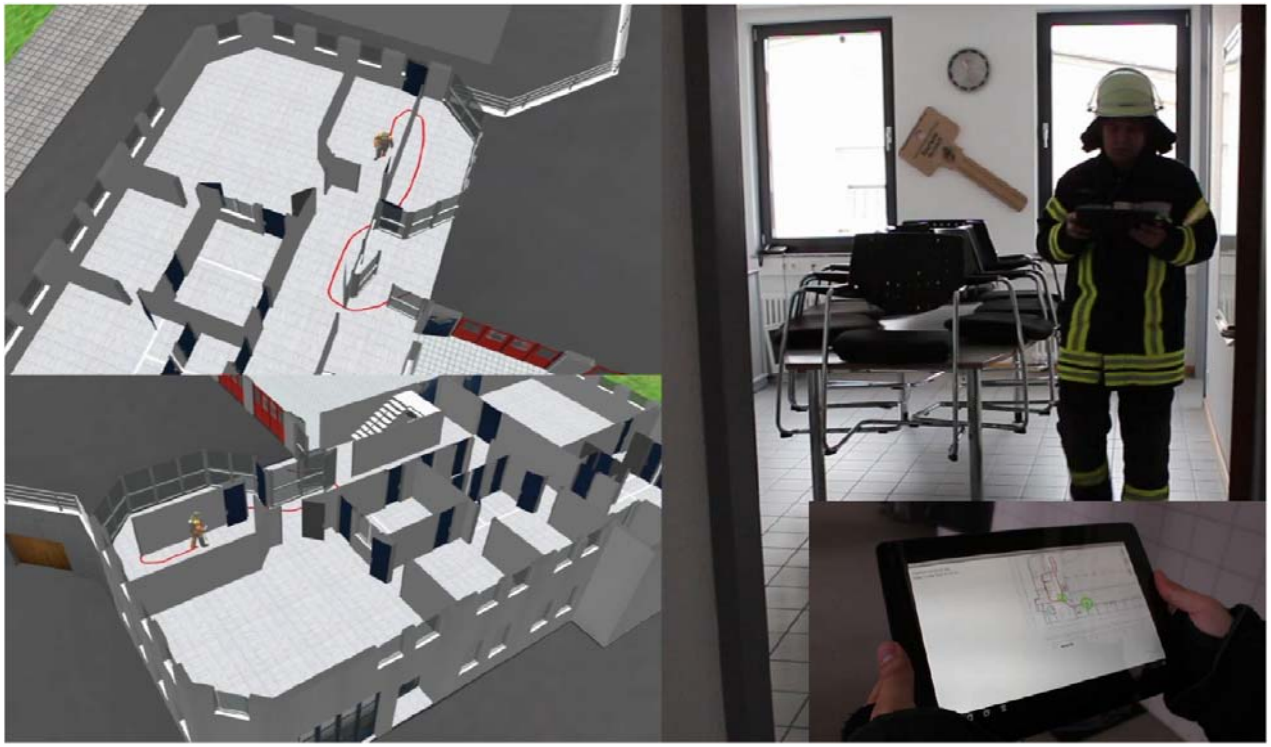
Visualization in „Real-Time“

On-site:

- 2D map material

Outside (@ operation control):

- 3D visualization of the building with trajectory of the fire fighter



Summary and outlook

Summary:

- Suitable tracking of persons even with low-cost sensors possible
- Considerable improvement due to filter tuning expected
- Inherent disadvantages of the ZUPT-method only solvable by extension with additional reference systems
  - Snow, escalator, rocky ground,…

Outlook:

- Automatic involvement of WiFi/GPS if available
  - Absolute reference
  - On tablet/smartphone available without additional costs
- Incorporation of floor plans
- Sensor network for communication