Towards Multispectral, Multi-Sensor Indoor Positioning and Target Identification

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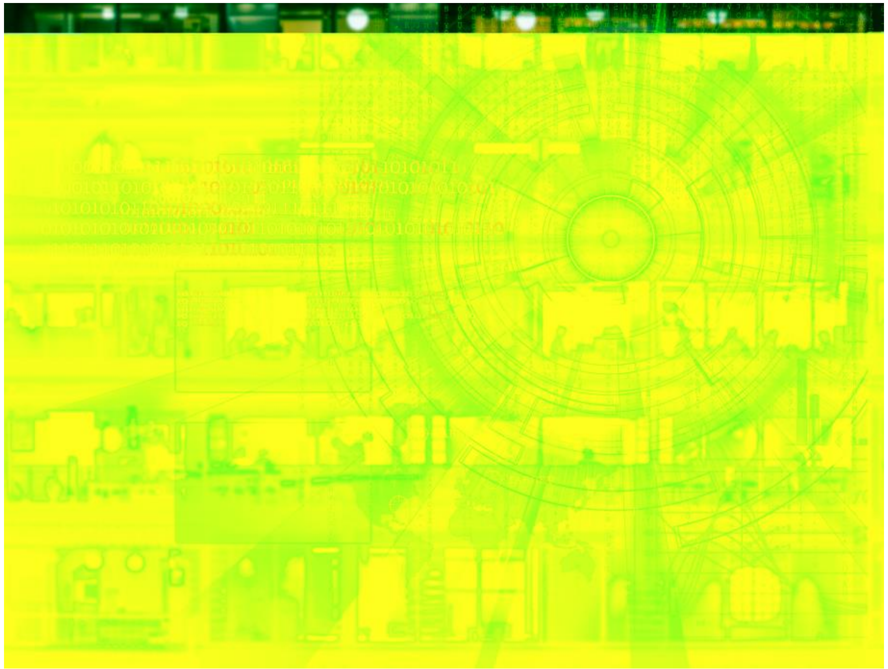

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Motivation

- Growing need for mobile mapping and surveillance in buildings
- Combining Light Detection and Ranging (lidar) and positioning sensors => simultaneous localization and mapping (SLAM)
- Multispectral lidar => target identification
- Multisensor fusion => infrastructure-free position solution

➢ Spatially resolved target identification in unknown indoor environment

Multispectral lidar

- Laser scanning => multiwavelength lidar
- Output of a multispectral lidar is the pointcloud (x,y,z,I)
- I is the intensity containing multiple values of wavelength
- Used for target identification and e.g. vegetation studies


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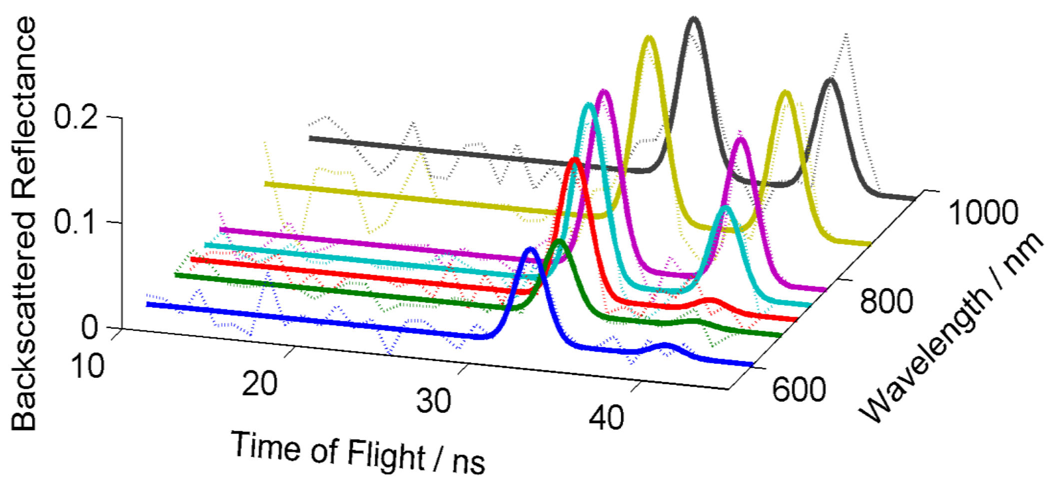
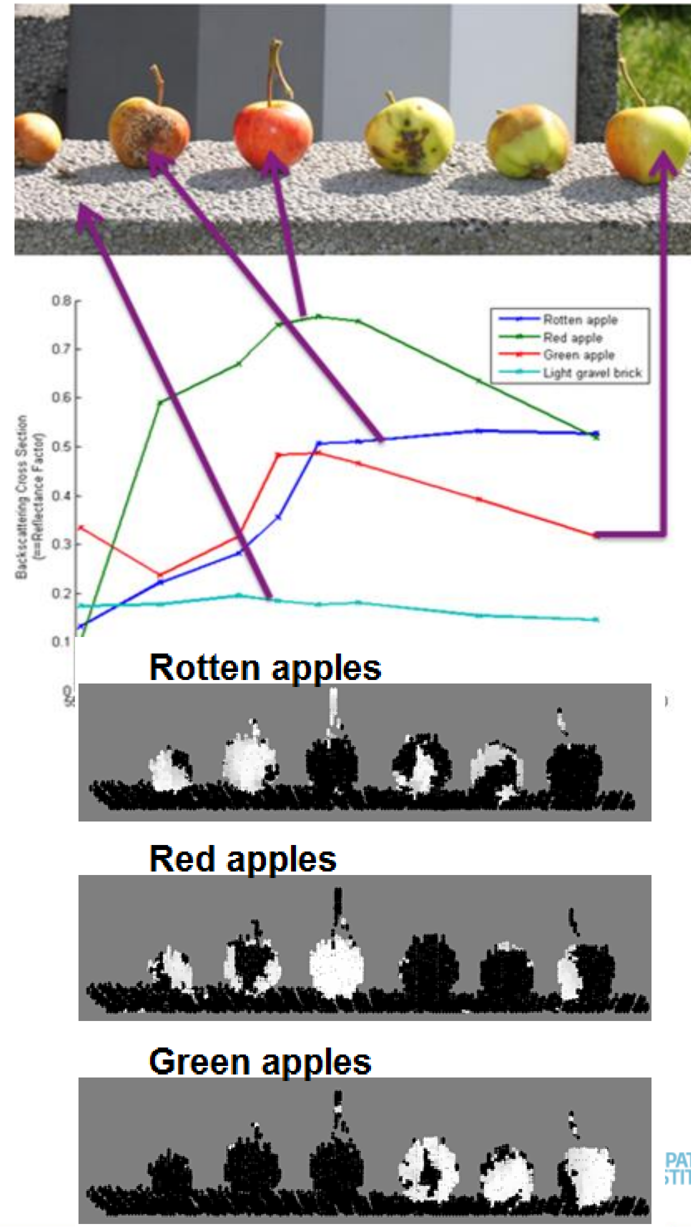
The FGI hyperspectral lidar (HSL) prototype

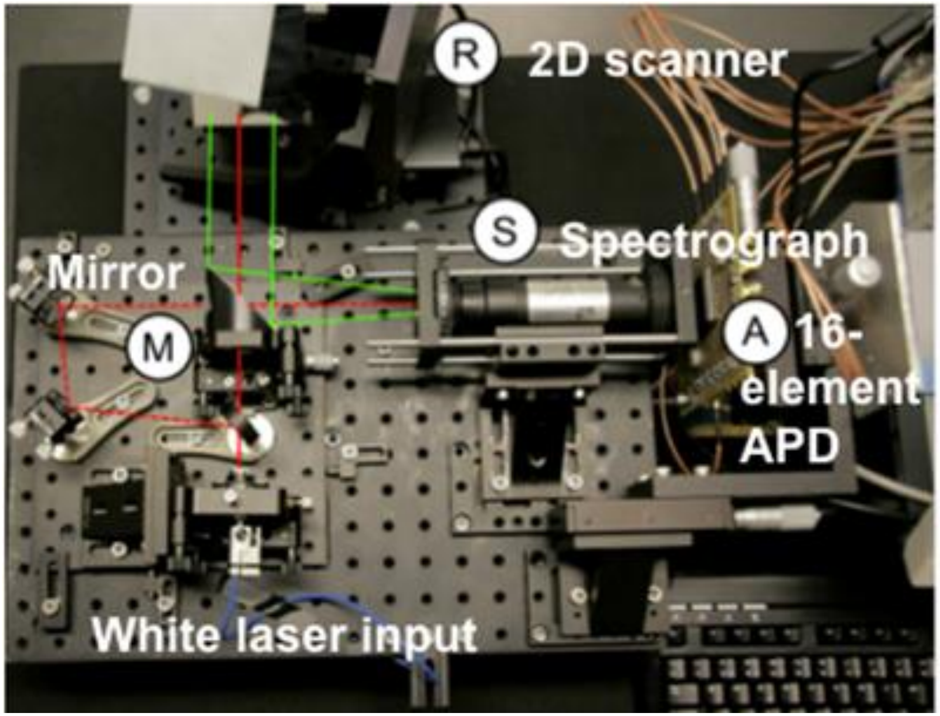
- Automatic 3D target identification
- One-shot topography & active hyperspectral imaging
- Spectrum directly available for each point in the laser scanning point cloud
- Algorithms for automatic classification of targets with spectral and spatial features





FGI HSL

- Supercontinuum laser light source
- 8 channel spectrum, 500-1000 nm for each point
- Parabolic mirror to gather returning laser pulses
- Detector
  - Spectrograph
  - 16-element avalanche photodiode
- 1 ns digitizer for data storage
- Wavelength channels selected by adjusting the spectrograph position



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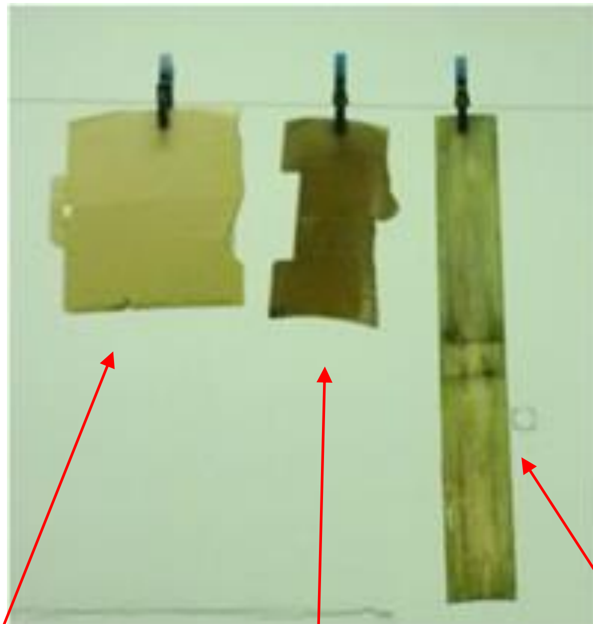
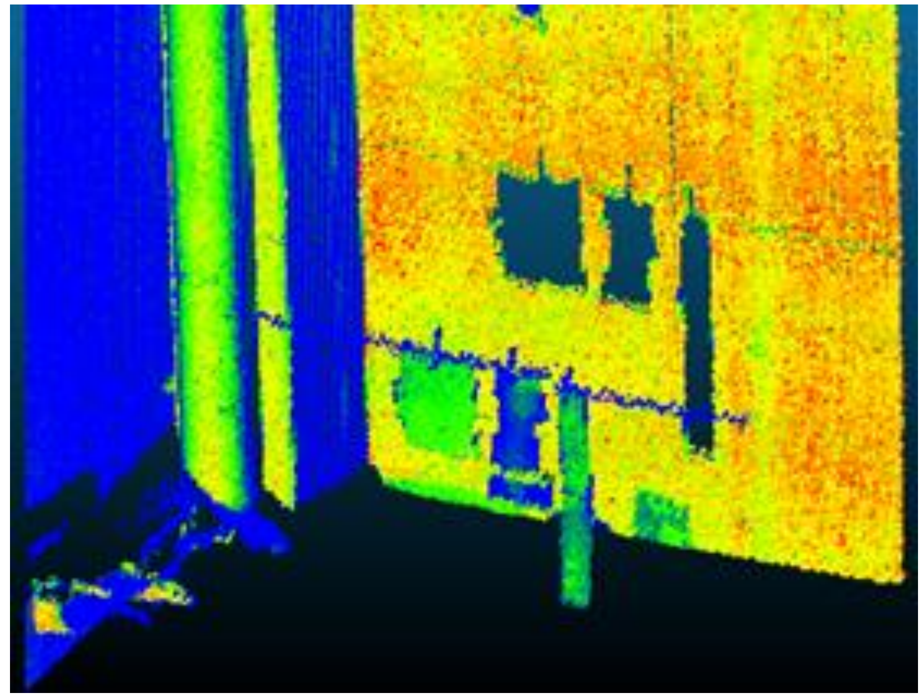
Target identification 1/3

- Identifying targets with different moisture levels





Cardboard

Cardboard with water

Wood with mold

Pointcloud of the room showing the targets

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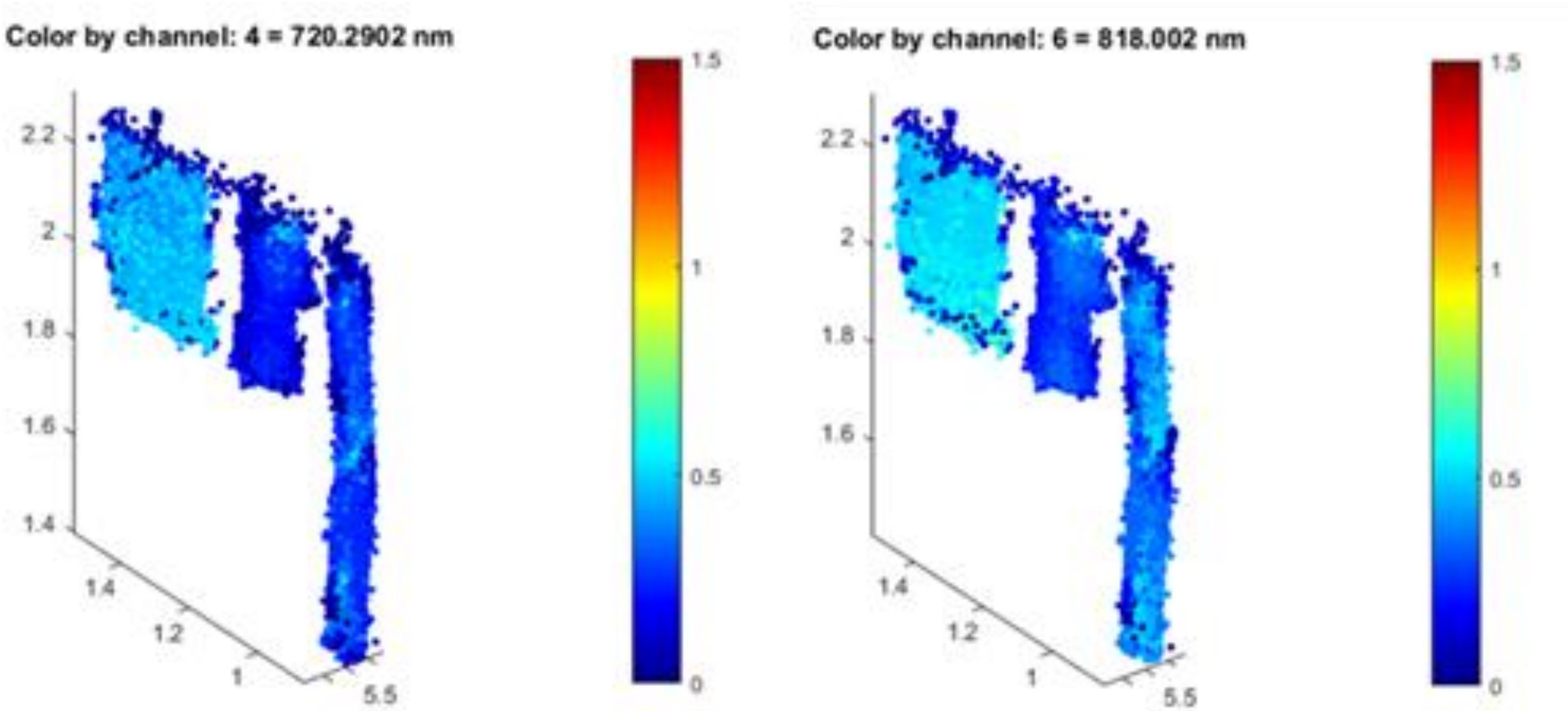
Target identification 2/3

- Targets were cropped from the point cloud => mean backscattered reflectance of all echos
- Intensity of channels 4 (720 nm) and 8 (818 nm)



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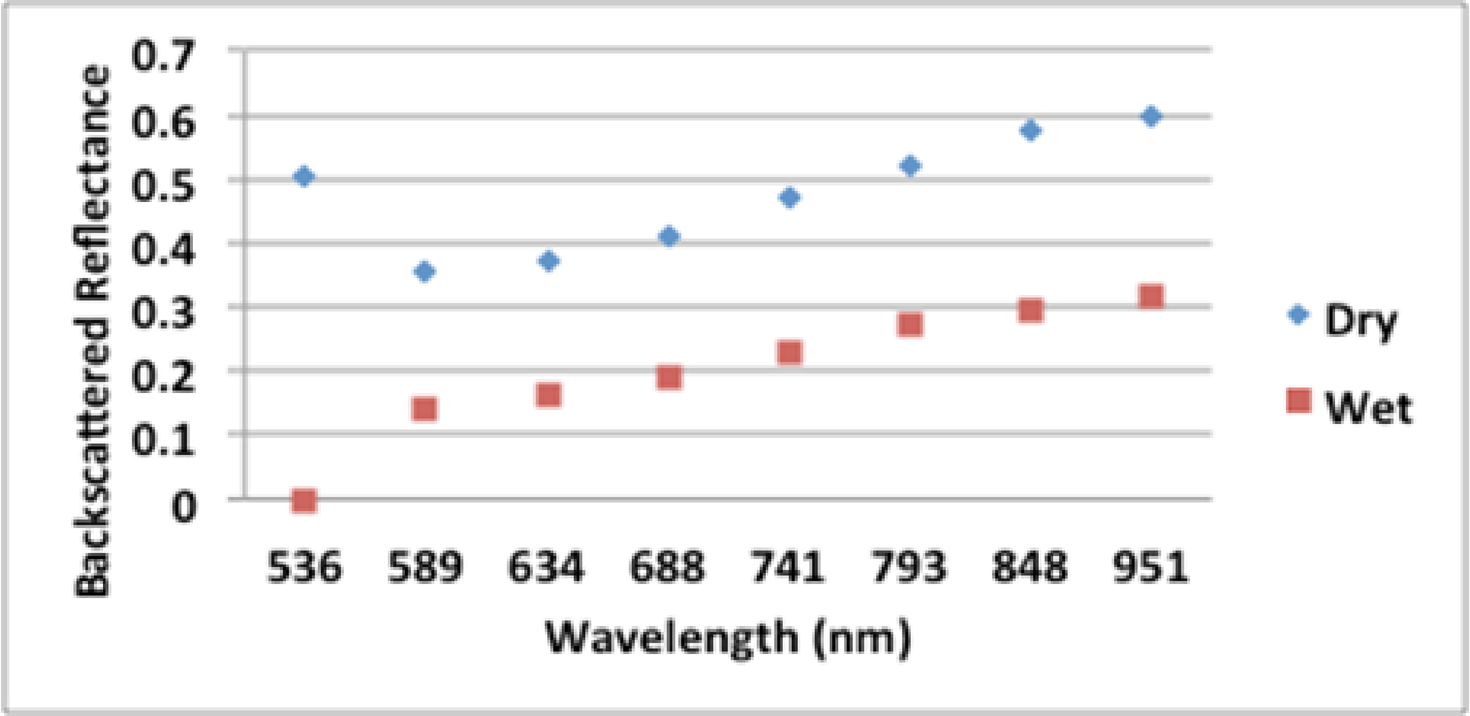
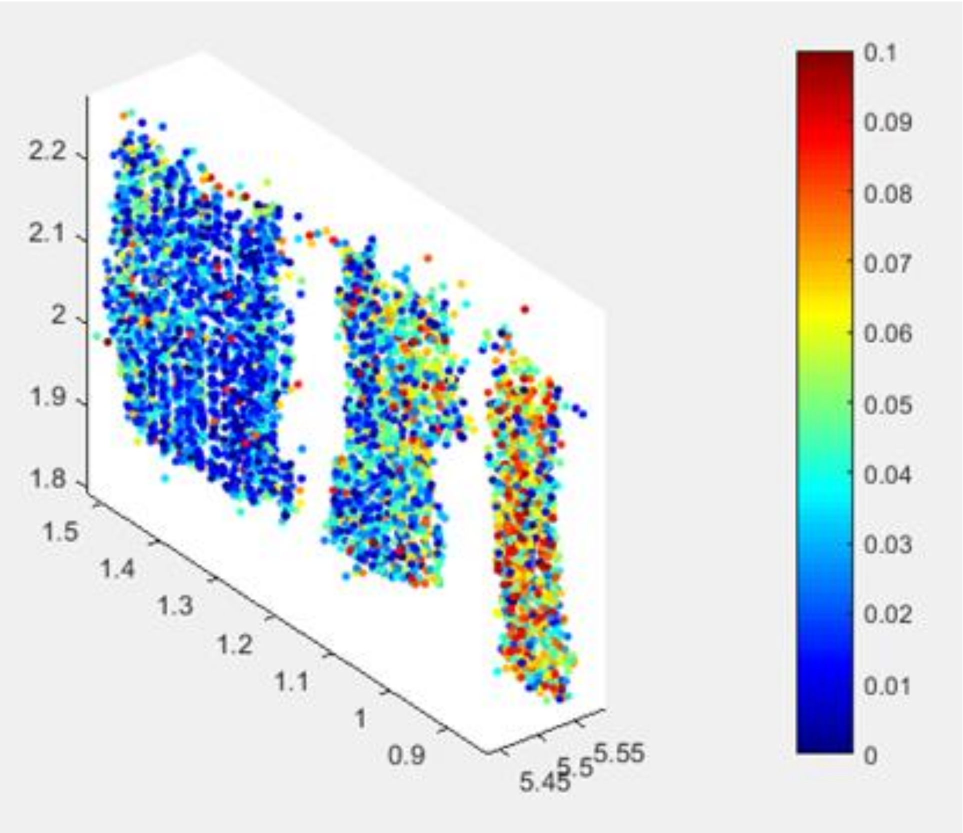
Target identification 3/3



- Spectra of the wet and dry carboard panels
- Averaging the intensity of all points at each wavelength channel
- 6 % error in reflectance measurement
- Difference in the intensity visible at all wavelengths

Automatizing target identification



Normalized Water Index (NWI)

- Spectral identification using spectral indices
  - Water concentration index WI
  - Normalized water index NWI
  - Both use
    - Water absorption band 970 nm
    - Reference wavelength
  - WI(dry)= 0.96, WI(wet)= 0.94
  - NWI(dry) = 0.02, NWI(wet) = 0.33

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Infrastructure-free positioning

- GNSS positioning is unavailable indoors
- Other radio positioning requires infrastructure and preparation
- Self-contained sensors provide motion measurements
  - Inertial sensors, magnetometers, odometers, …
  - Measurement errors deteriorate the solution

➢ Multisensor fusion

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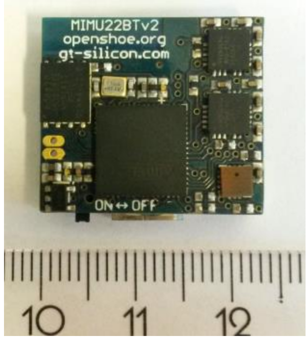
Multisensor position solution

- Sensors in our system:
  - 3 Inertial Measurement Units (IMUs)
    - one in foot (positioning),
      body and helmet (motion recognition)
  - A camera
  - Sonar
  - Barometer for vertical position



- Measurements fused using Particle filtering
- **INTACT-** a project funded by the Ministry of Defence in Finland 1.1.2015-30.11.2017

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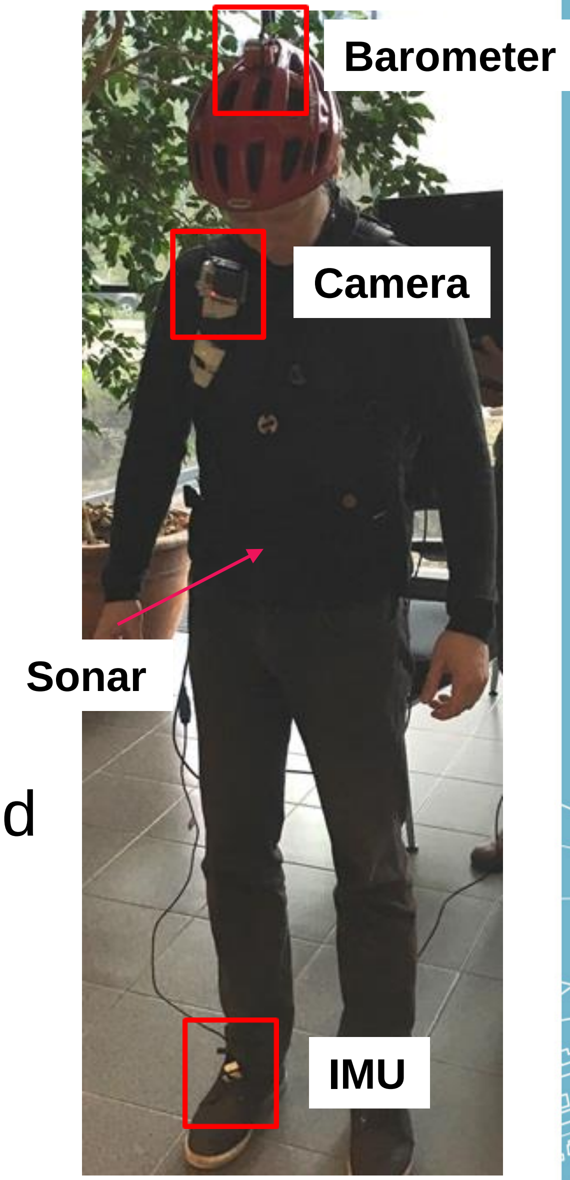
Measurement models

- Inertial sensors mounted to the foot for horizontal positioning
    - Zero velocity updates improve the result
    - Calibrated using vision-aiding
- Barometer for vertical positioning
    - Computes height using pressure and temperature
    - Calibrated using sonar



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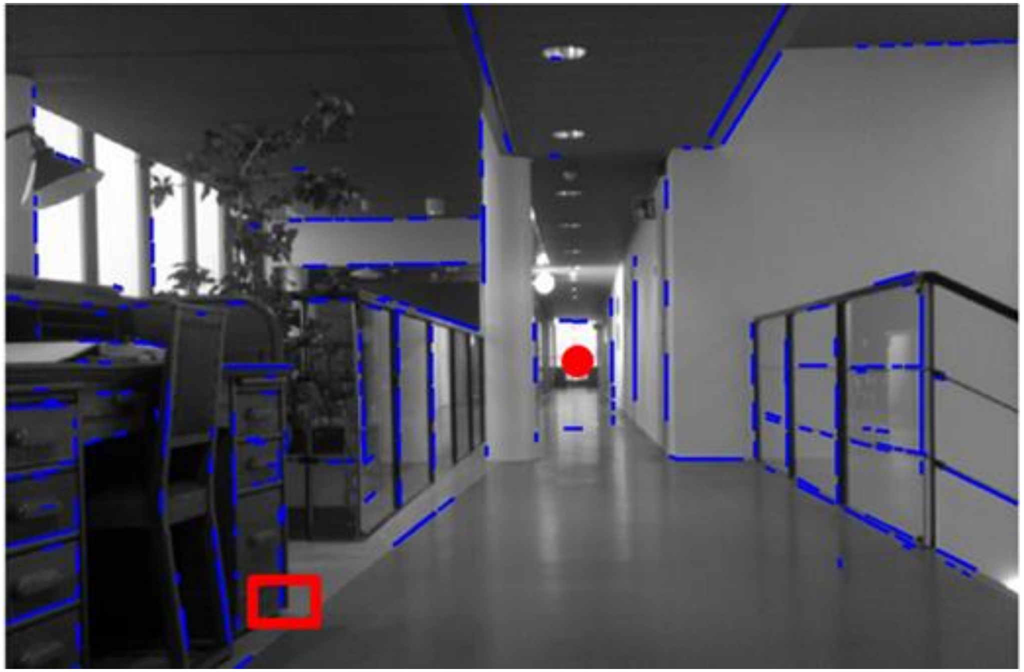
Vision-aided positioning

- Tracking features in consecutive images => motion of the camera may be computed
- Used as additional gyroscope and accelerometer
- Different error sources => complete inertial sensors



Ruotsalainen I., Vision-Aided Pedestrian Navigation for Challenging GNSS Environments,
Doctoral Dissertation, 2013, TUT

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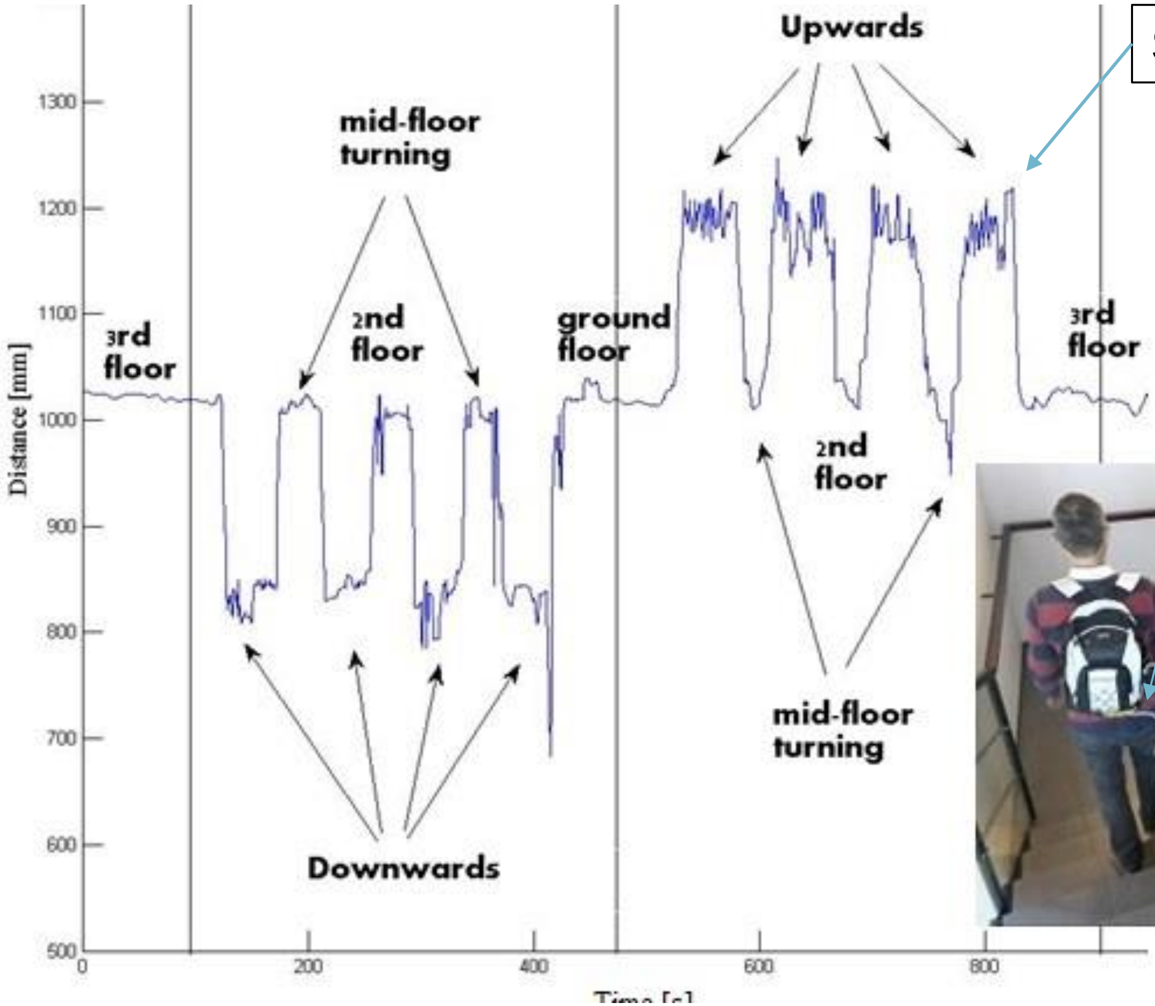
Sonar and barometer integrated for robust vertical positioning



Step detection

Sonar pointing downwards

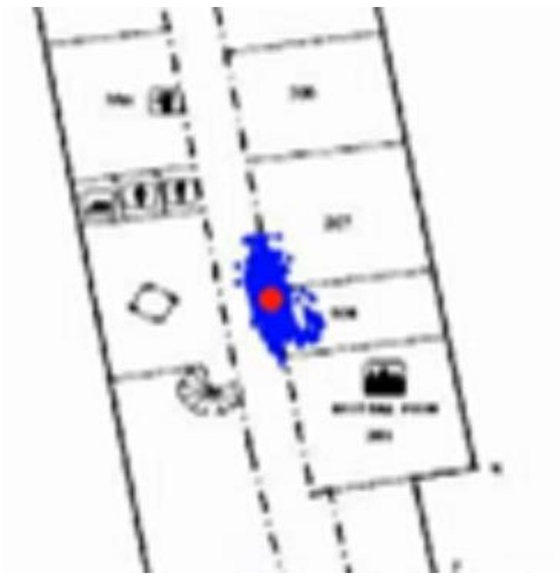
Fusing measurements using Particle filtering

$$\mathbf{x}_k = [E \;\; N \;\; H \;\; \dot{\psi} \;\; \psi \;\; S]_k$$

State vector

$$z_k = [\dot{\psi}_{footIMU} \;\; \dot{\psi}_{visual} \;\; S_{footIMU} \;\; S_{visual}, H_{baro}, H_{ultrasonar}]$$

Measurement vector



- Particle filtering is Bayesian estimation method for non-linear and non-Gaussian measurements
- Resampling of particles based on weights
- State at each epoch k is the weighted mean of particles

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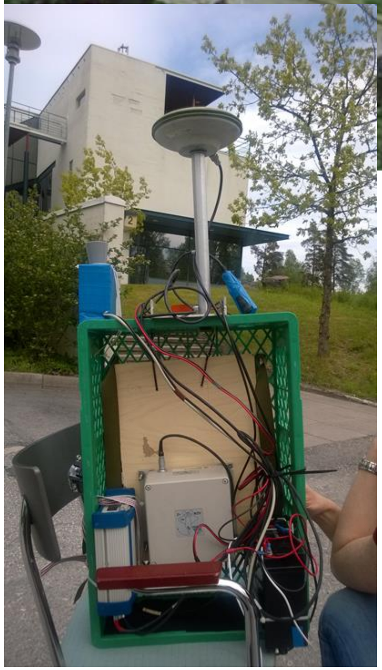
Positioning results



- Position solution from outdoors to the HSL location
- Route 200m
- Challenging environments including spiral stairs etc
- Equipment:
  - GoPro camera
  - Osmium MIMU22BT IMU
  - XSENS Mti-G-700 barometer
  - HRUSB-MaxSonar
  - Novatel SPAN for reference

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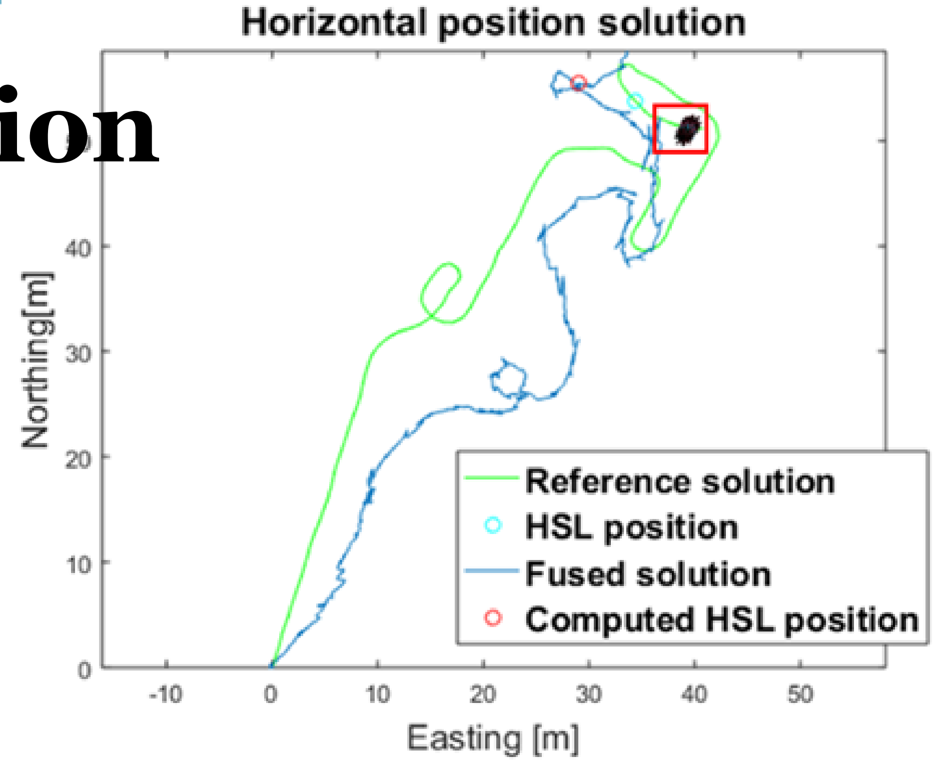
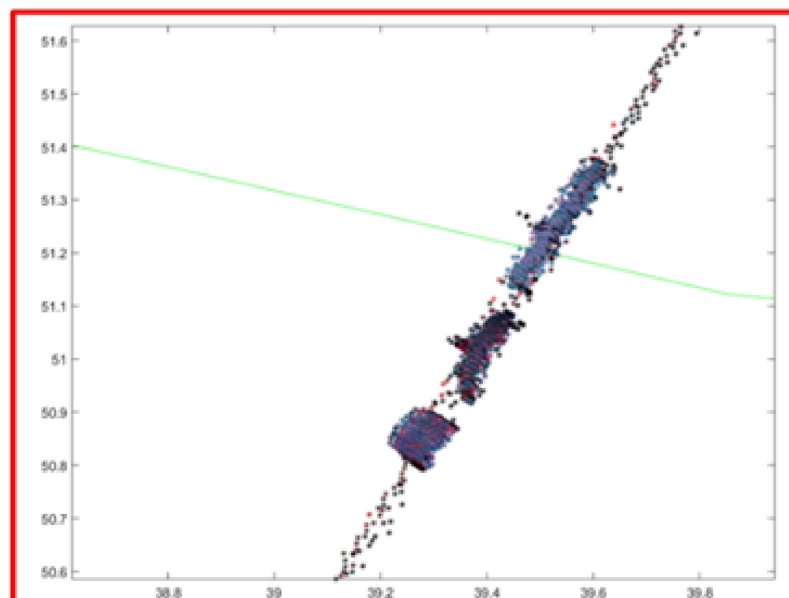
Horizontal position solution

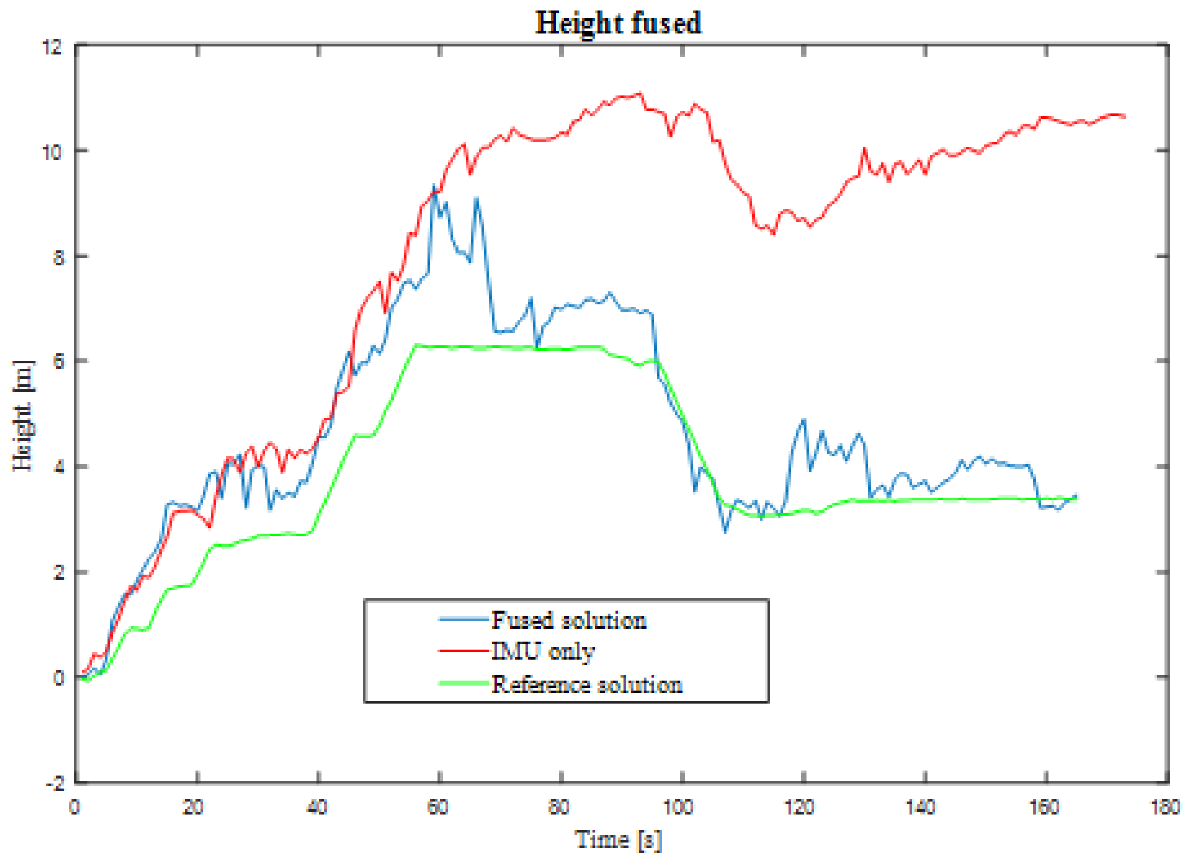
- Distance Root Mean Squared (DRMS) error was 3.4 m
- IMU only DRMS 6 m
- Below close-up showing the target



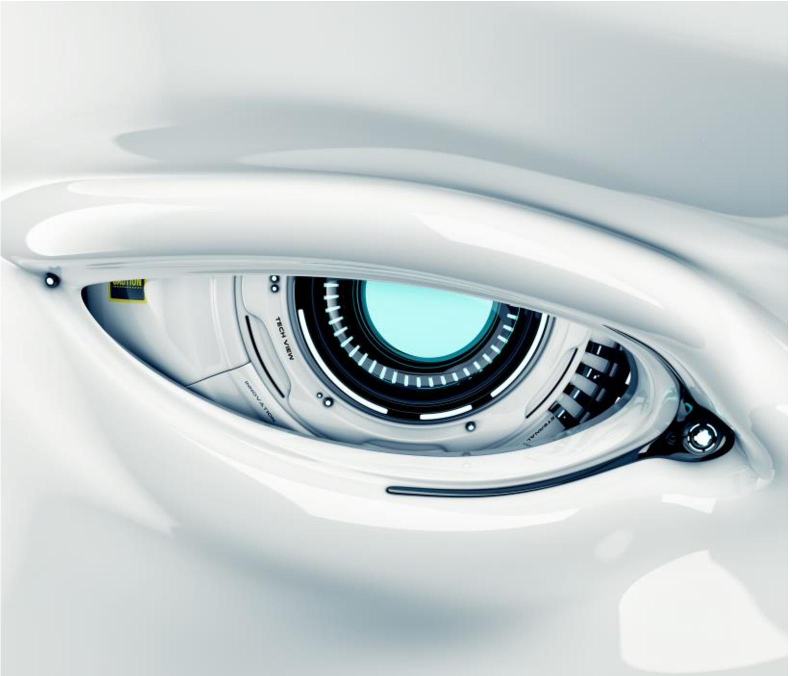


Vertical Position Solution

- Mean error for fused solution 1 m, std 0.6 m
- Mean error for IMU only 4.2 m, std 2.1 m



Conclusions



- Normalized Water Index is feasible for automatic target detection
- Accuracy of the fused position solution seems feasible for indoor positioning for many applications
- In future these two will be fused for more accurate and target identification enhanced SLAM solution
- Long term goal is to obtain a method for autonomous surveillance for e.g. tactical and security applications

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Thank you!