

Infrastructure free navigation and target identification

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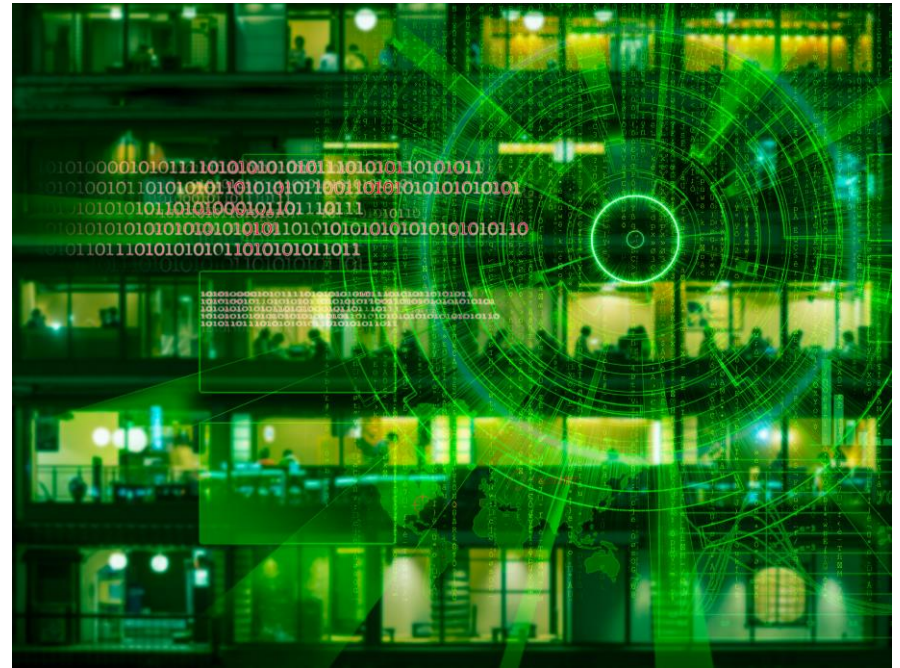
Finnish Geospatial Research Institute (FGI)



Nordic Institute of Navigation – Norwegian Forum for Autonomous Ships
15 June 2017, Trondheim

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Motivation

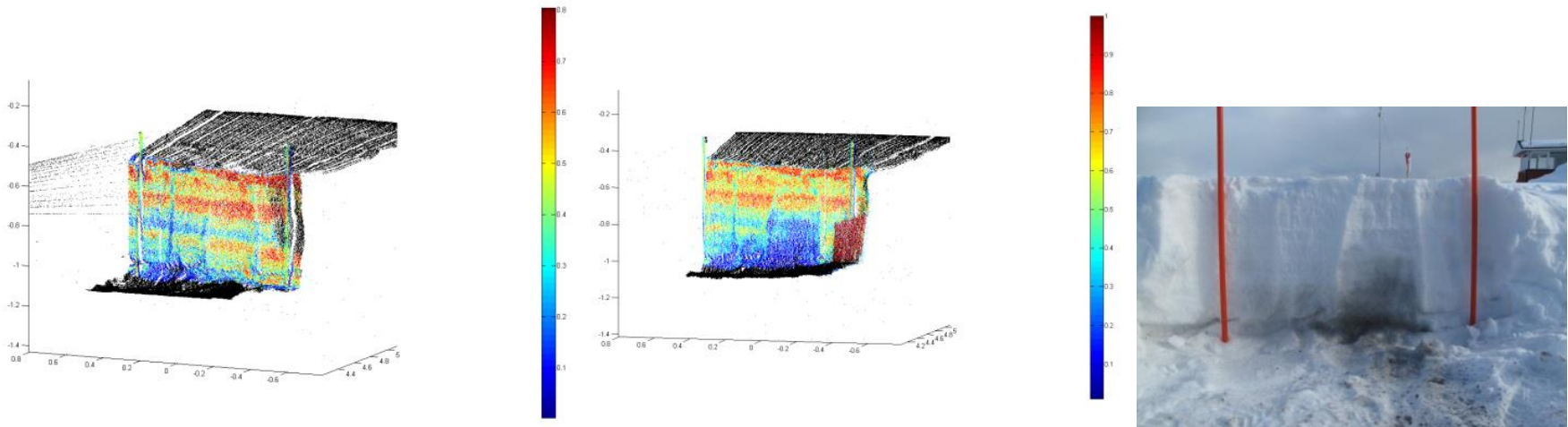
- Growing need for mobile mapping and surveillance in buildings or GNSS denied environment
- Autonomous ships: augment/backup GNSS
- Combining Light Detection and Ranging (lidar) and positioning sensors → simultaneous localization and mapping (SLAM)
- Multispectral lidar → target identification
- Multisensor fusion → infrastructure-free position solution
- Spatially resolved target identification in unknown indoor environment

Multispectral lidar

- Laser scanning → multiwavelength lidar
- Output of a multispectral lidar: pointcloud (x,y,z,I)
- I is the intensity containing multiple values of wavelength
- Used for target identification and, e.g., snow or vegetation studies
- Detection of e.g., pollution or ice in maritime conditions



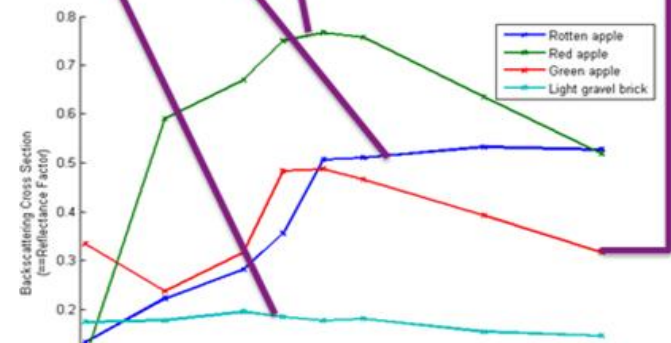
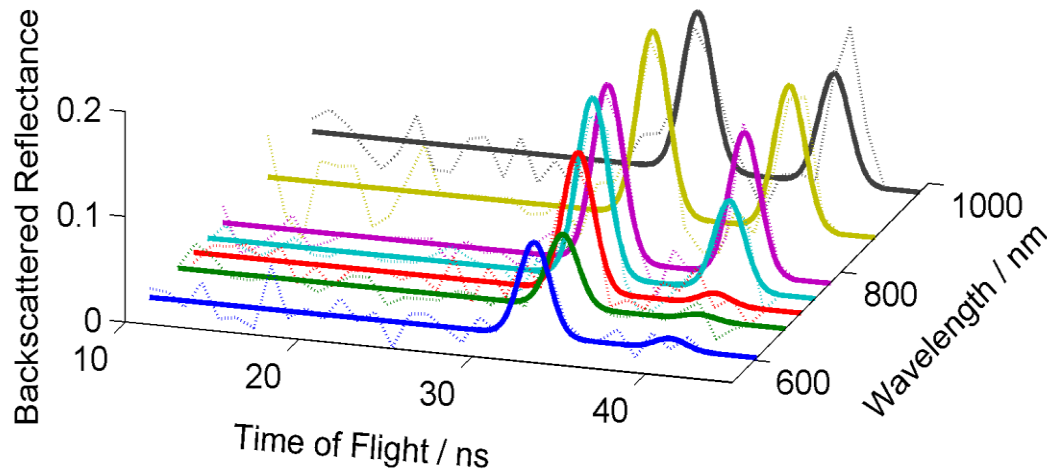
Snow/Ice & pollution



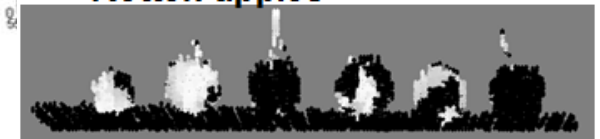
3D detection of exhaust gas on snow cover with the FGI hyperspectral lidar.
Images by Teemu Hakala, FGI

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



Rotten apples



Red apples

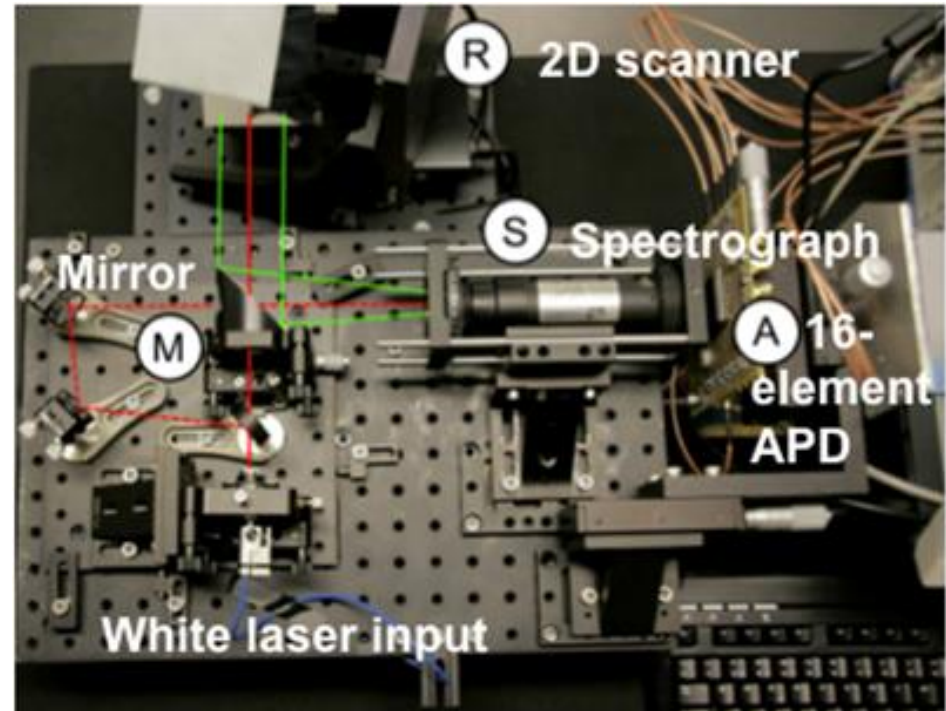


Green apples



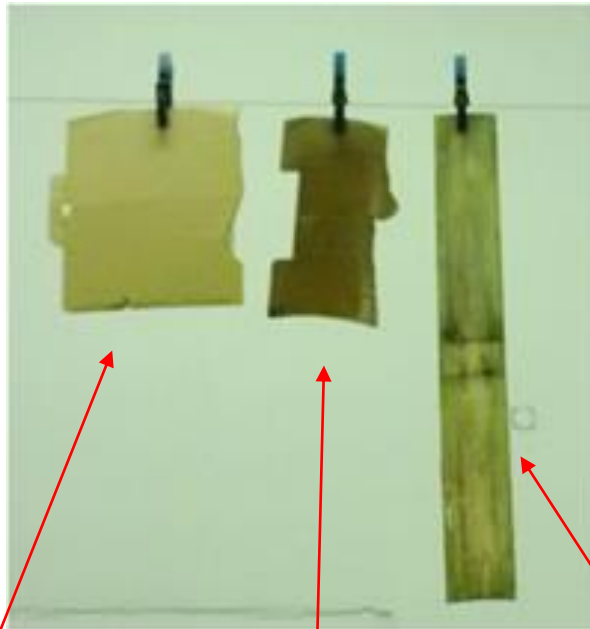
FGI HSL

- 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 GHz digitizer for data storage
- Wavelength channels selected by adjusting the spectrograph position



Target identification 1/3

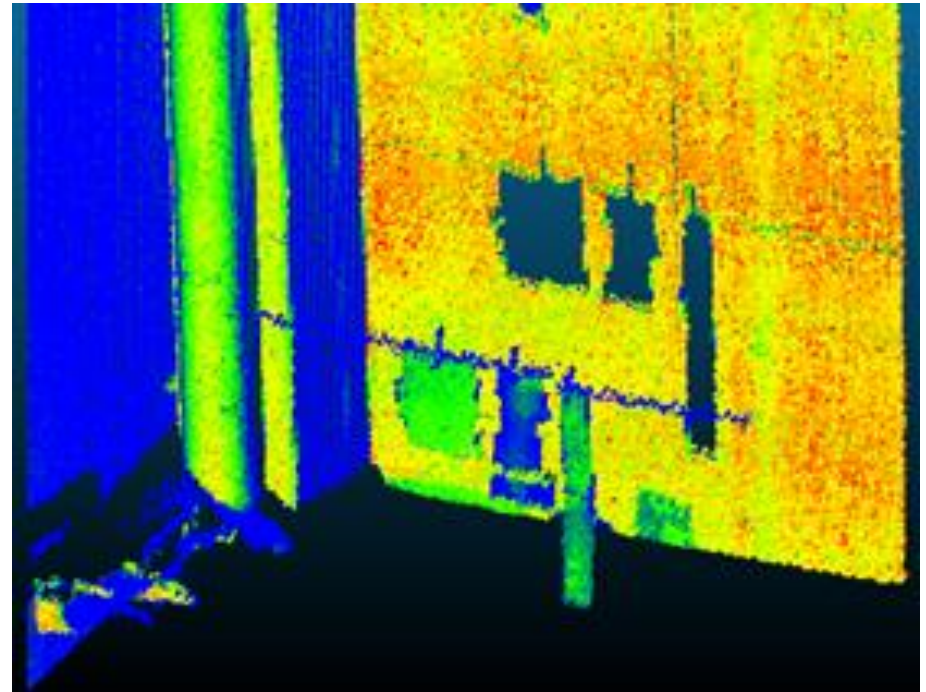
- Identifying targets with different moisture levels



Cardboard

**Cardboard
with water**

**Wood
with mold**

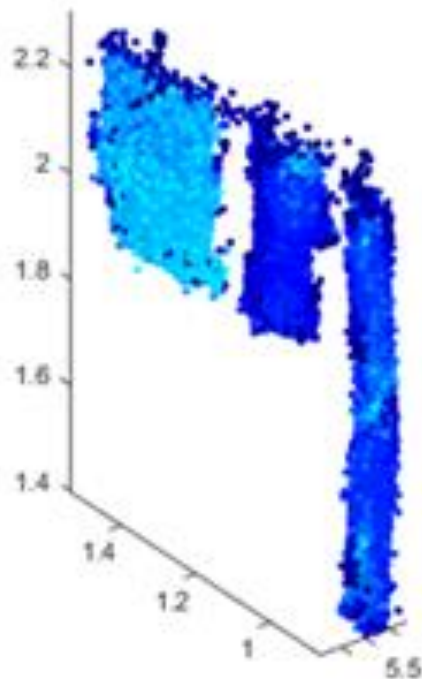


**Pointcloud of the room
showing the targets**

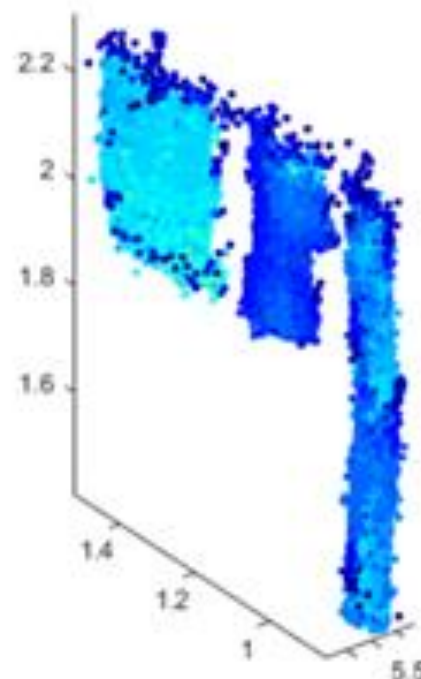
Target identification 2/3

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

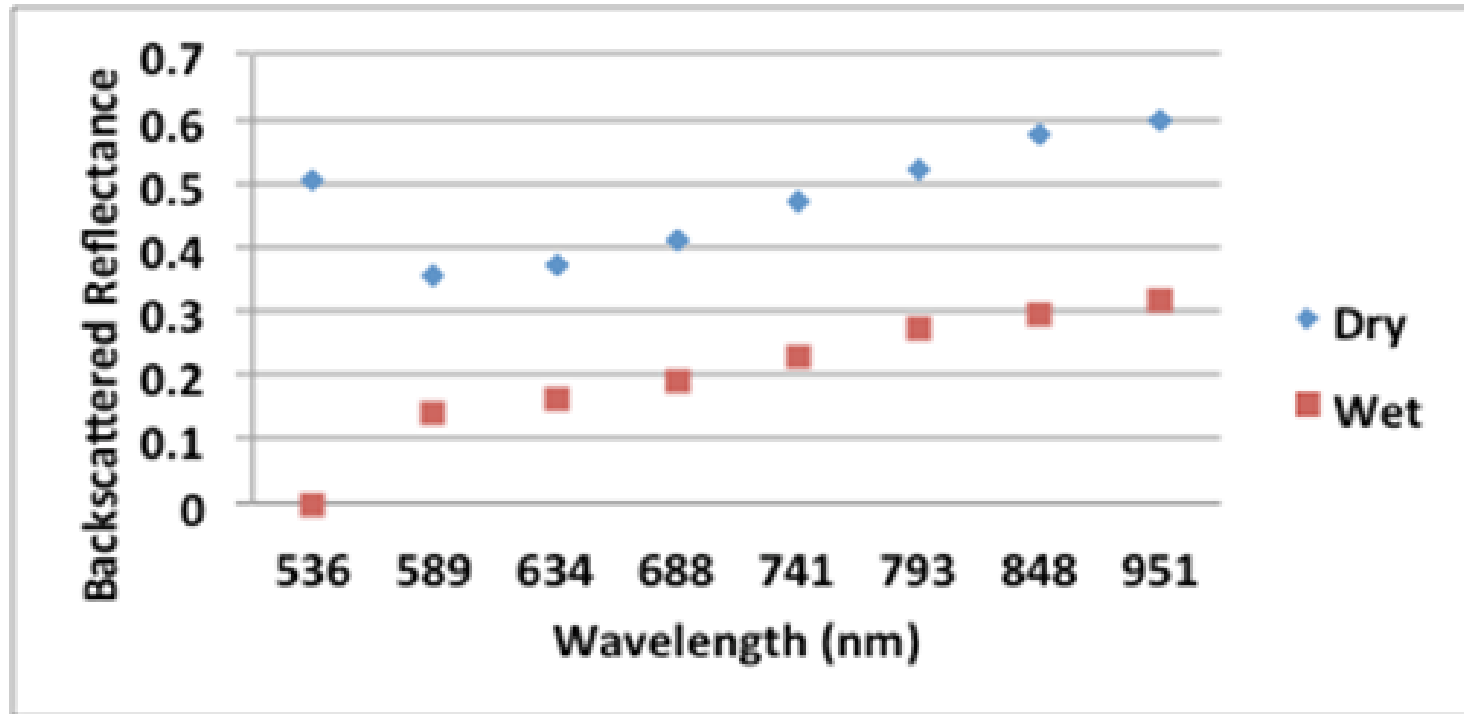
Color by channel: 4 = 720.2902 nm



Color by channel: 6 = 818.002 nm

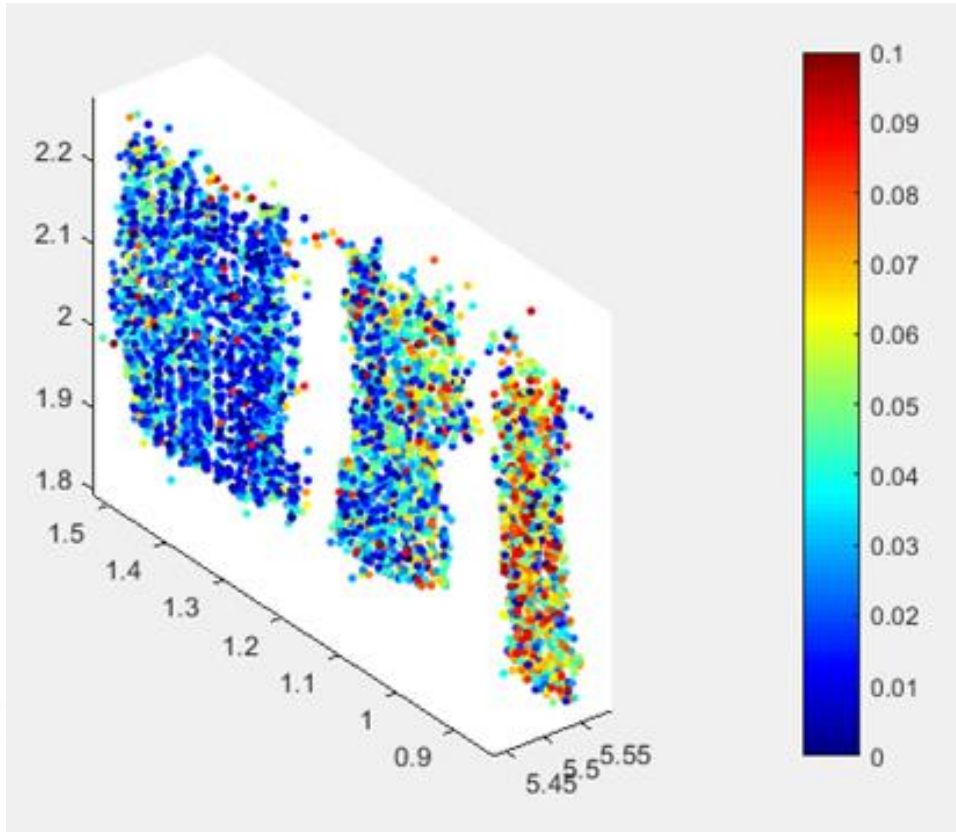


Target identification 3/3



- Spectra of the wet and dry cardboard 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
 - $WI(\text{dry}) = 0.96$, $WI(\text{wet}) = 0.94$
 - $NWI(\text{dry}) = 0.02$, $NWI(\text{wet}) = 0.33$

Infrastructure-free positioning

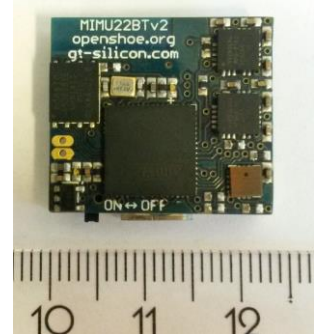
- GNSS positioning is unavailable indoors or under interference
 - Other radio positioning requires infrastructure & preparation
 - Self-contained sensors provide motion measurements
 - Inertial sensors, magnetometers, odometers, ...
 - Measurement errors deteriorate the solution
- Multisensor fusion



Image: Optech

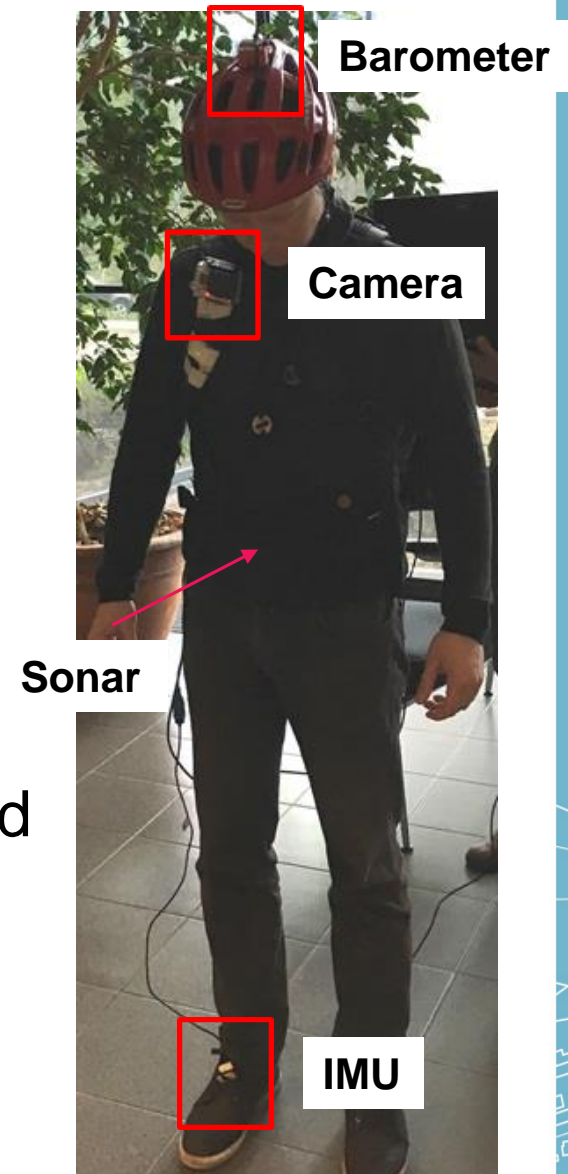
Multisensor position solution

- 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



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



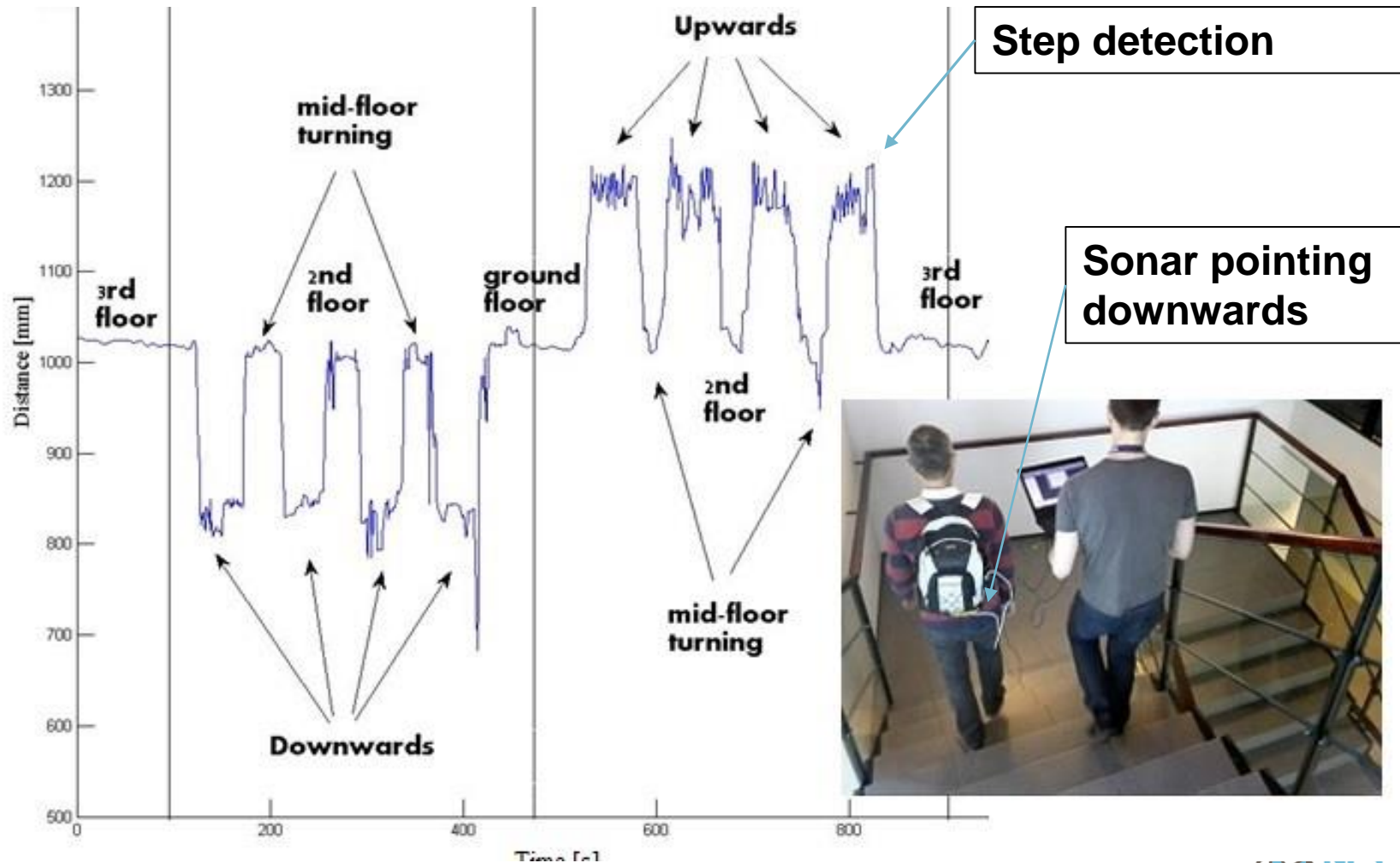
Vision-aided positioning

- 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

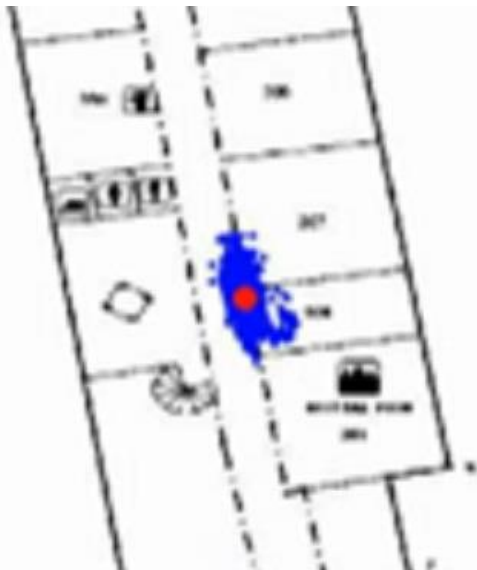
Sonar and barometer integrated for robust vertical positioning



Fusing measurements using Particle filtering

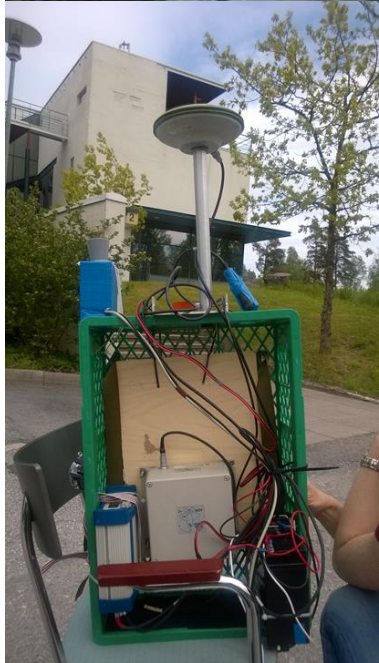
$\mathbf{x}_k = [E \ N \ H \ \dot{\psi} \ \psi \ S]_k$ State vector

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

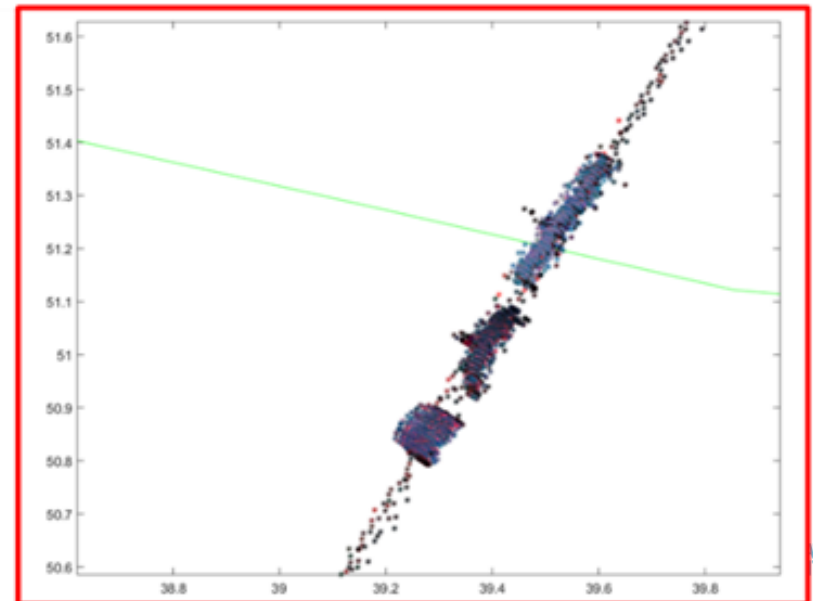
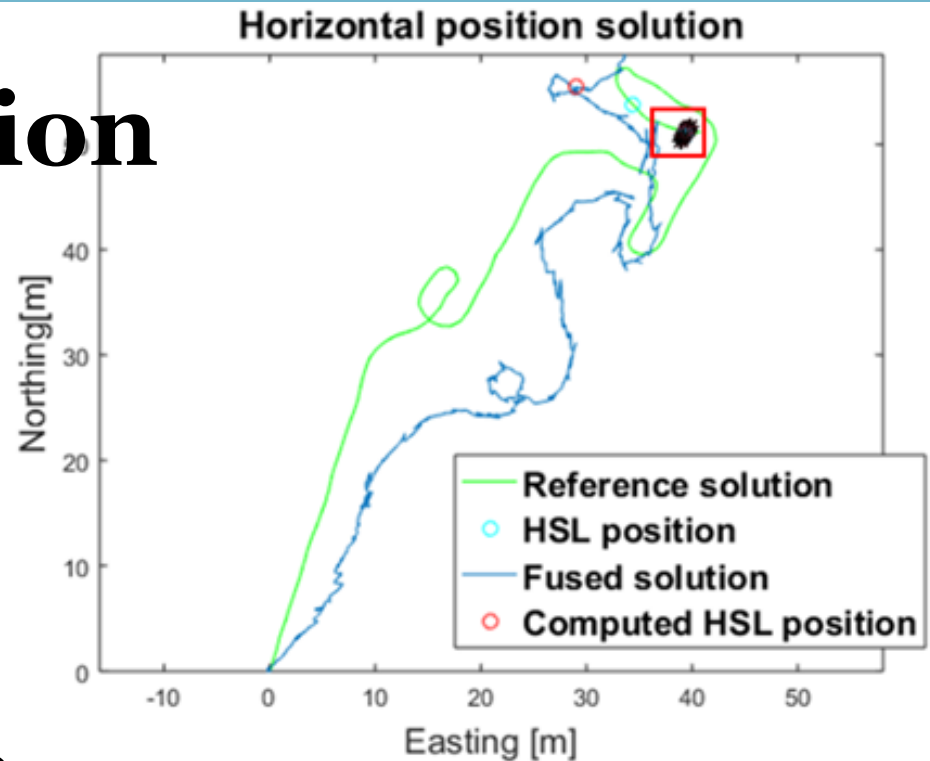
Positioning results



- 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

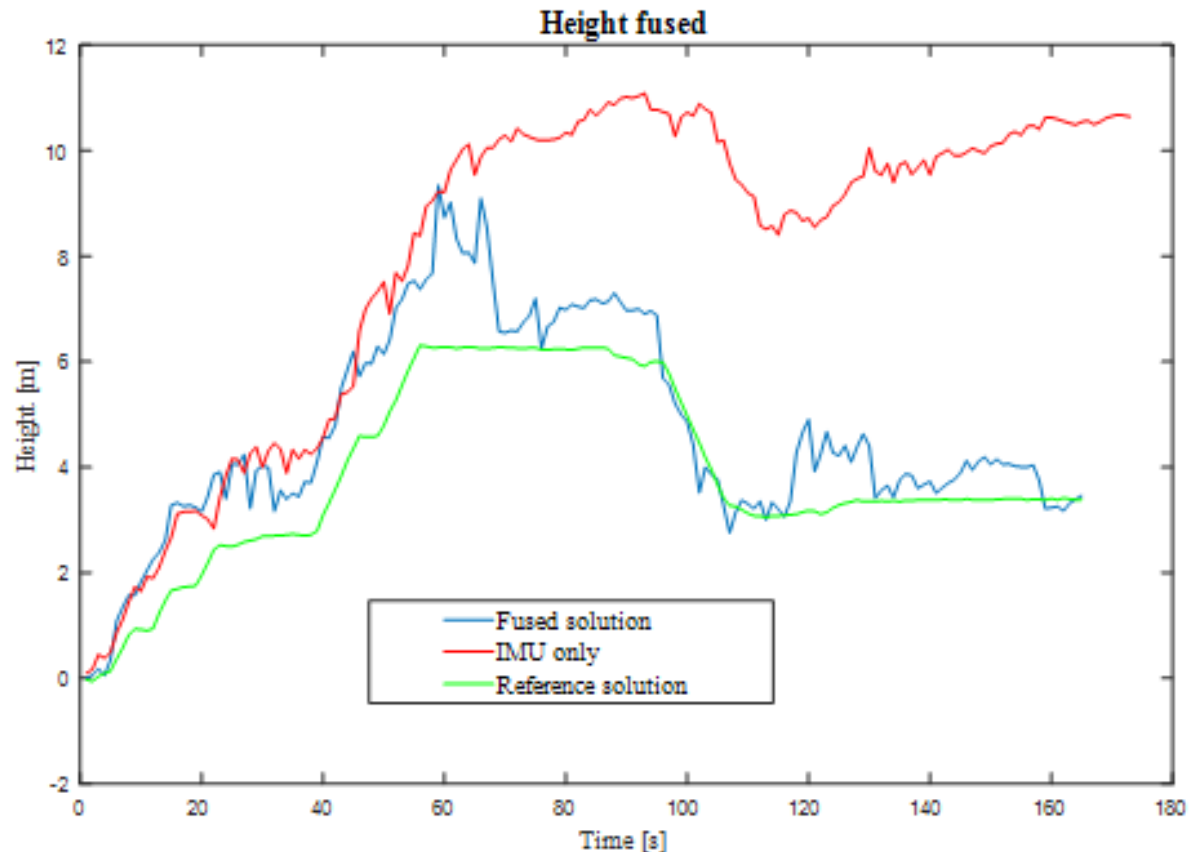
Horizontal position solution

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



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

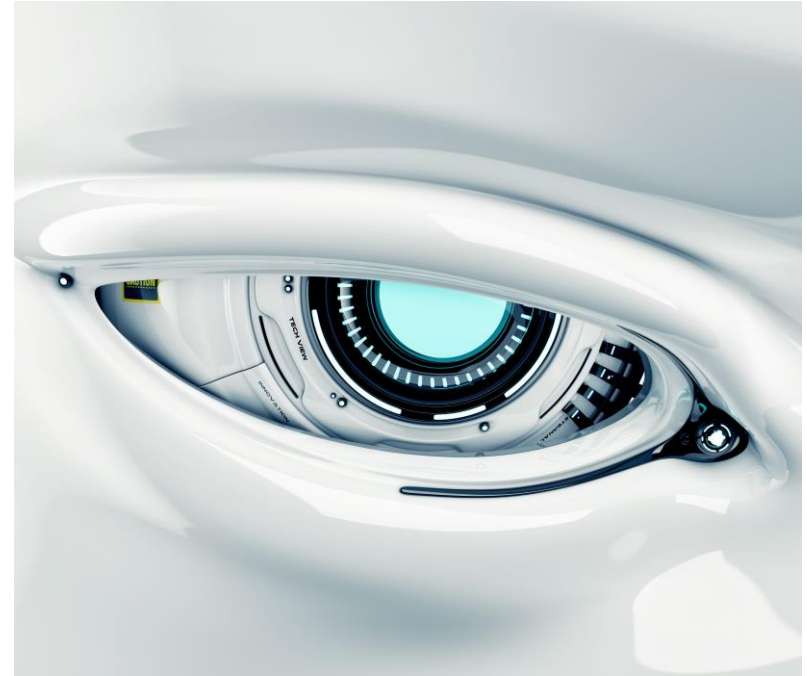


New paper in Electronics Letters: Towards Multispectral, Multi-Sensor Indoor Positioning and Target Identification

By S. Kaasalainen; L. Ruotsalainen; M. Kirkko-Jaakkola; O. Nevalainen; T. Hakala. http://ietdl.org/t/59_v9b

Conclusions

- Automatic target detection is feasible with spectral indices
- 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!