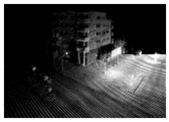


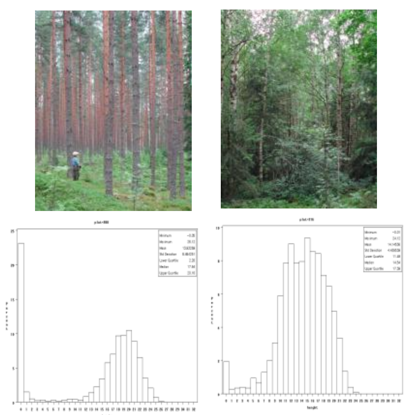
State of the Art in Laser Scanning

Juha Hyyppä, Anttoni Jaakkola, Antero Kukko, Harri Kaartinen, Sanna Kaasalainen, Eetu Puttonen, Xiaowei Yu, Hannu Hyyppä*, Lingli Zhu, Matti Lehtomäki, Yi Lin, Paula Litkey, Xinlian Liang, Matti Vaaja*, JP Virtanen*, M. Kurkela*, M. Ahlavuo*

Finnish Geodetic Institute
*Aalto University

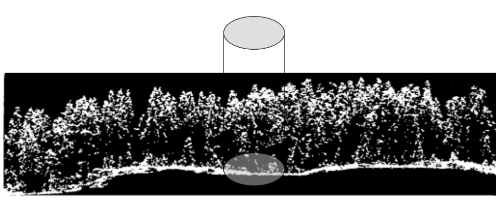
Contents

Forest Inventory



C. Erik Næsset, NLH

What do the laser data express?

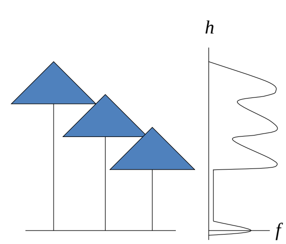


Forest canopy profile using view depth of 6 m and width of 200 m. Conical shape of trees can be recognized visually. Approx. 5 pulses per m^2

Source: Hyyppä et al. 1999.

C. Erik Næsset, NLH

Which properties may be extracted from the laser data?



Height-related

variables

h_{90}

h_{70}

h_{mean}

h_{10}

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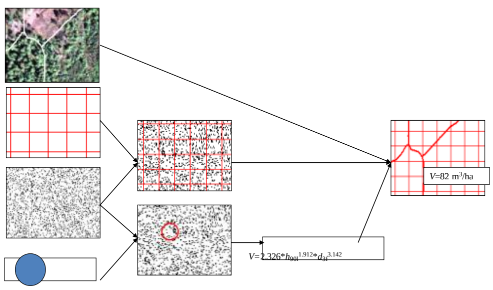
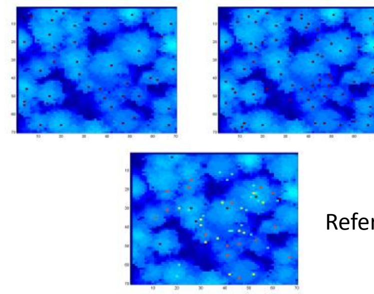


C. Erik Næsset, NLH

Individual Tree Detection

State-of-the-art

Developed



Reference

C. J. Hyyppä, FGI

Trunk detection algorithms with TLS

two-dimensional (2D) layer searching

- a slice with certain thickness is cut from the original point cloud. Points inside the slice are projected onto the layer. Trunks are identified by point clustering or circle finding

point cloud processing method,

- the attributes of the individual point are estimated in a local neighbourhood and the tree is identified by semantic interpretations

range image clustering method,

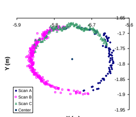
- points, or pixels in the range image, are grouped according to local properties, e.g. the distance or surface curvature. This technique is designed for single-scan data processing. There has not been a solution for merged multi-scan TLS data

the detection accuracy

- from single- and multi-scan data is 22% and 52% in a plot with 556 pc/ha (Thies and Spiecker, 2004);

97% in plots with average density 321 pc/ha and 100% in a plot with 310 pc/ha (Maas et al., 2008).

In (Litkey et al., 2009), 85% trees, which can be manually identified from TLS data



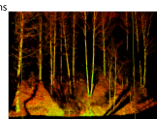
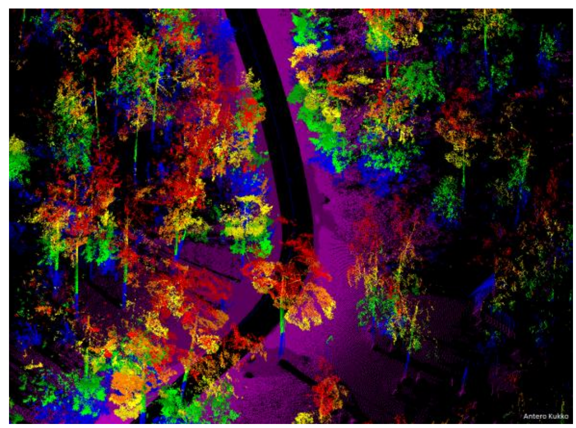


Table 2: Summery of maps produced by field and TLS measurement

Plot	Reference trees	Mapped trees	Type I error	Type II error
1	16	11	5	2
2	17	11	6	9
3	21	17	4	2
4	32	26	6	3
5	34	21	13	1
6	40	21	19	4
7	41	32	9	7
8	43	25	18	11
9	45	40	5	4

C. Harri Kaartinen, Xinlian Liang, FGI



Forest Inventory Outlook

- Area-based techniques are operationally applied in Scandinavian standwise forest inventory, Wallenberg Prize
- Currently better results obtained using individual tree approach, which however require calibration at stand level and tree level calibration helps.
- EuroSDR/ISPRS comparison at tree level 2005-2008
- Both methods currently use non-parametric estimation techniques (main difference between features used)
- FWF LS is expected to improve e.g. tree finding and tree species classification
- Tree species classification is currently the major lack in operative systems
- Integration of TLS/MLS and ALS

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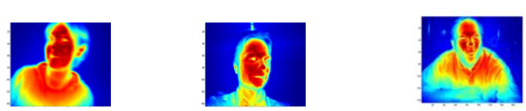
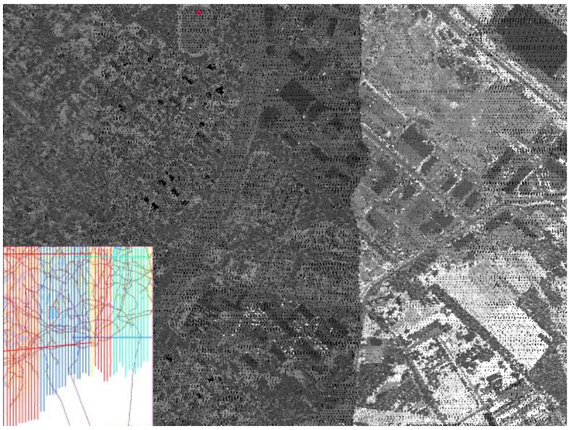


Radiometric Calibration of Intensity – Brief summary

Juha Hyyppä, Wolfgang Wagner, Hannu Hyyppä, Sanna Kaasalainen, Antero Kukko, Harri Kaartinen, Anssi Krooks, Ants Vain, Ulla Pyysalo, Paula Litkey

Finnish Geodetic Institute
TKK – Institute of Modelling and Measuring for the Built Environment
TU Wien



Absolute and relative calibration

- Relative calibration of ALS intensity means that measurements from different altitudes, incidence angles and dates are comparable for the same system.
- Absolute calibration of ALS intensity means that the obtained corrected value of intensity describes the target properties and corresponding values obtained from various sensors are directly comparable.

C. J. Hyyppä, FGI

Relative calibration

Moving parameters

- Spreading loss
- Backscattering properties versus incidence angle (all materials rough)
- Transmitter power changes (when PRF is changed)
- Atmospheric properties

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Absolute calibration

- To link the obtained corrected intensities to absolute value
  - Reflectance/gamma values of the target should be known, laboratory measurements may be needed
  - High accuracy techniques
    - Tarps
    - Gravels, other natural materials
    - Calibrated NIR camera
    - Use of calibrated reflectometer
  - Low-cost, practical methods
    - Use of natural targets with roughly known reflectance (based on a library)

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Examples of Recommendations

- In discrete return LS
  - The momentary return recorded as intensity is assumed to correspond to backscatter power
  - This is roughly valid only with flat surfaces where beam is fully filled with the surface, therefore, this type of calibration can be made with ”*only pulses*” (first of many, last of many, intermediate returns are obtained with beams partly seeing multiple targets and even range correction is not correct (see Korpela et al. 2010)
- Radiometrically calibrated products are
  - Cross-section σ (vs. radar cross-section [m^2]) with full-waveform system
  - Backscattering coefficient γ *or* σ^0 (area-normalized cross-section values), σ is also sometimes related to the cross-section of the incoming beam, $A_i \cos\theta$, instead of the illuminated target area A_i
  - Backscattering coefficient only approximated in discrete return system
  - See Wagner 2010 for details.

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Examples of Recommendations

- Meta data should be saved for each flight track
  - System, system properties (transmitter power statistics, e.g. versus PRF/PRR changes)
  - GPS, IMU tracks (range, indicende angle)
  - AGC, traceable AGC (allowing original intensity calculated from AGC information)
  - Atmosphere, presently it seems that standard atmospheric value are adequate
- Processing
  - Radiometric strip adjustment (parallel information in overlapping strip should be used to enchance intensity)
  - So-called model based correction (based on lidar equation, overlapping information may be used to minimize variation in the data and to determine constants in the correction formula)
  - See e.g. Wagner 2010, Höfle and Pfeifer 2007 and Gatziolis 2011

C. J. Hyyppä, FGI

Examples of Recommendations

- Future improvement in absolute calibration
  - Better documentation of systems for system changes allowing more robust calibration (now it seems very flight is different)
  - Calibration in e.g. tests fields after mounting the system to the aircraft
    - Range calibration (LUT updating) with gray scale
    - Same gray scale measurement used for absolute calibration
- Relative calibration, Effect of incidence angle
  - Incidence angle effect small until 20 degrees off nadir
  - In MLS and TLS, spread loss and incidence angle effects are mixed and incidence angle has to be taken into account
- Absolute calibration
  - Use of simultaneous calibration targets can be easily accomplished with TLS and MLS,

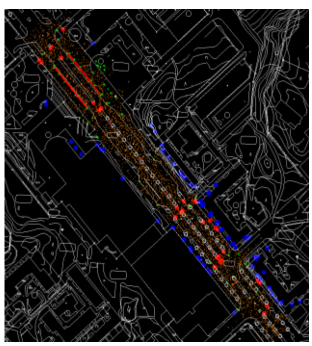
C. J. Hyyppä, FGI

EuroSDR Mobile Laser Scanning-a benchmarking study on MLS

Juha Hyyppä
Harri Kaartinen and Matti Lehtomäki

Reference data

- Test plot
  - Length 350 m
  - 3282 height points (orange)
  - 273 planimetric targets



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Reference for planimetric accuracy

- Targets include poles, building corners and curbs
- Point clouds were cut into two sections for measuremets
  - Points below 50 cm above ground
    - Pole and curb targets
  - 1 m section from 5 m above ground
    - Building corners

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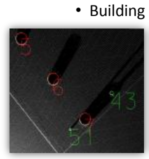
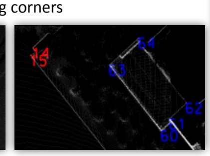
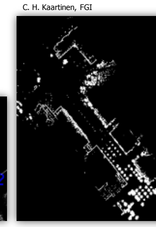
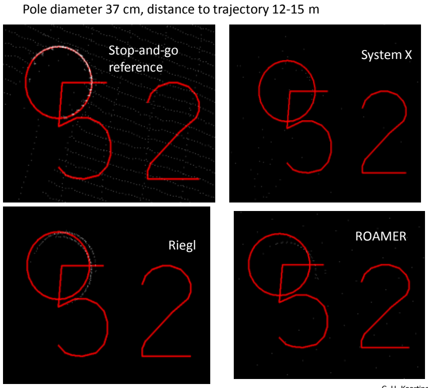






Points <50 cm above ground, top view
Pole diameter 37 cm, distance to trajectory 12-15 m



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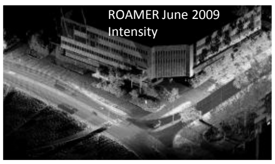
Mobile mapping systems

- The Espoonlahti test site has been mapped by three systems
  - FGI ROAMER
    - Operational since summer 2007
  - Riegl VMX-250
    - Introduced beginning of 2010
    - Data provided to us by Riegl
  - System X
    - Operational since 2009
  - (FGI Sensei low-cost system)
    - See ISPRS J. 100 years special issue
  - (Optech Lynx, tbd)
  - (StreetMapper) ()= coming

- Most sparse data
- Vegetation causes shadows (full leafs)
- Limited range

- Very dense data
- No shadows from vegetation (leafless)
- Very few ground points outside the road due to wet asphalt and snow



- Dense data
- Vegetation causes shadows (small leafs)

C. H. Kaartinen, FGI

Mobile mapping systems

- With all systems the test site was driven in both clockwise (run 1) and counter-clockwise (run 2) direction
- Point densities in Espoonlahti while driving in one direction at speed of about 20-30 km/h

Points on the road / m²	Along trajectory	8-10 m from traj.
System X	320	25
Riegl	6000	500
ROAMER	700	100

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Results

- Planimetric accuracy, average of two runs, systematic errors removed

	MMS A	MMS B	MMS C
STD [cm]	2.0	1.5	2.9
RMSE [cm]	4.1	2.4	4.2

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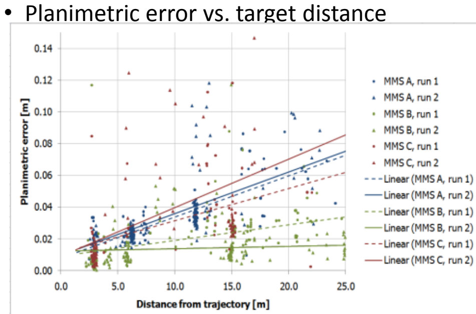
Results

- Planimetric error vs. target distance



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Results

- Height accuracy, average of two runs, systematic errors removed

	MMS A	MMS B	MMS C
STD [cm]	3.9	1.3	2.0

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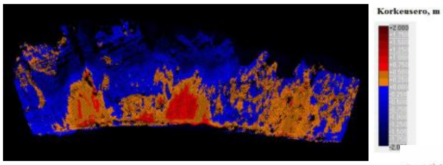
MLS for Change Detection

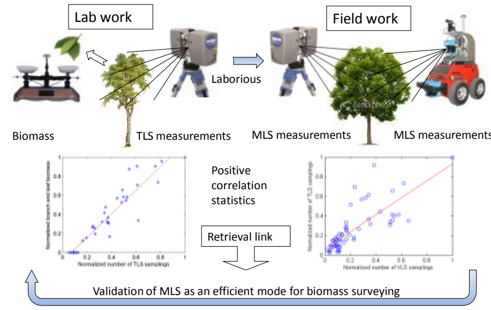
Erosion Change Detection

- Sand bar: 2008-2009



C. M. Vaaja, Aalto Univ.

Biomass Change Estimation



C. Y. Lin, FGI

Work published by ***Remote Sensing***

Use of Mini-UAV for LS

FGI Sensei

- NovAtel SPAN-CPT
- Ibeo Lux
- AVT Pike F-421C
- Specim V10H

C. A. Jaakkola, FGI

FGI mini-UAV LS

Jaakkola et al. 2010, ISPRS Journal, 100 years special issue.
Terrasolid käyttäpäivät 2/2010, 2 esitystä

C. A. Jaakkola, FGI

DTM and tree accuracy

Method	n	Horizontal mean	Horiz. StDev	Height mean	Height StDev
Manual	17	40 cm	14 cm	**-15 cm**	**30 cm**
Automatic	55	110 cm	56 cm	**2 cm**	**34 cm**

DTM Height
Mean 3.1 cm
Std 9.2 cm

Repeatability
Std 5.9 ± 1.7 cm

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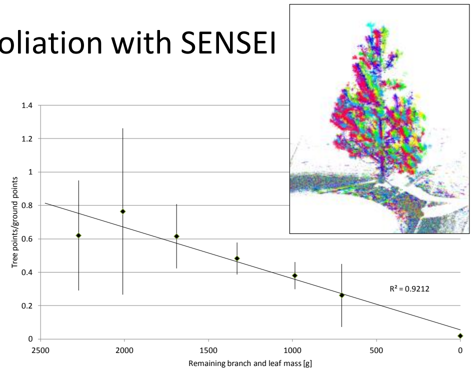
Defoliation with SENSEI



C. A. Jaakkola, FGI

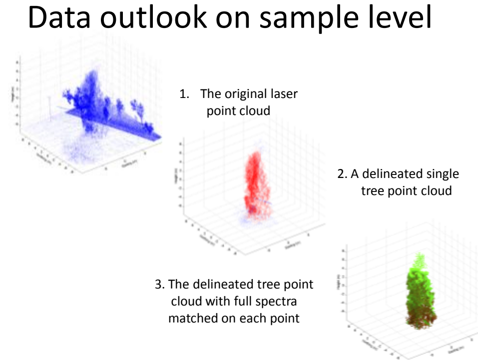
Integrated Use of LS and Hyperspectral Data

'Sensei' Mobile Mapping System

- A) Laser scanner
  - Ibeo Lux
- B) IMU
  - NovaTel Span-CPT
- C) Spectrometer
  - Specim V10H

C. E. Puttonen, FGI

Data outlook on sample level

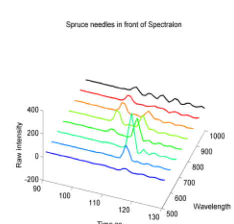


C. E. Puttonen, FGI

Study results

- Tree species classification was studied with 133 trees representing 10 different species
- Four classification parameters were used
  - Two point cloud shape features and two spectral features
- The best obtained classification result was 83.5% overall classification accuracy

Active Lidar Spectrometer

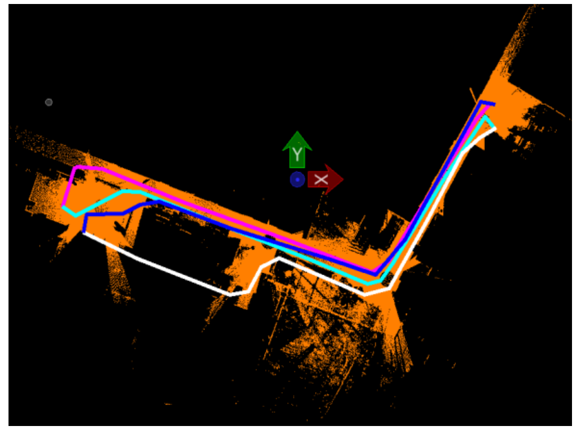


Example: spruce target in front of a Spectralon panel.

- Fully selectable wavelengths
- Spectrograph & avalanche photodiode array (16 channels)
- Data collection with analog-to-digital converters (1 GHz sampling)
- Full waveform → range sampling at 15 cm resolution

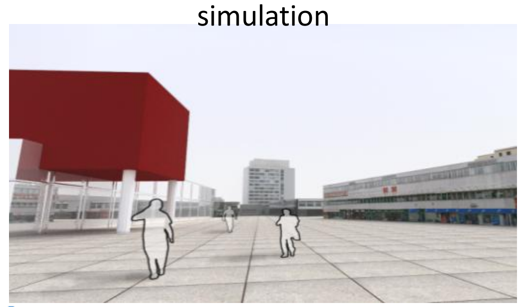
C. S. Kaasalainen, T. Hakala, FGI

Indoor MLS



Full textured 3D Model

General construction work for buildings – renovation, planning, simulation



Energy performance of buildings

We are extremely interested in co-operation, please contact.

Juha.hyyppa@fgi.fi