KIG-C1010 Introduction to geoinformatics 2023

Lecture 6, part I: **Laser scanning**

Matti Vaaja (*matti.t.vaaja@aalto.fi*)

Aalto-yliopisto

Learning objectives

- To understand general principles of laser scanning
  - Props and cons of laser scanning technology
  - Main platforms for laser scanning
- To recognize potential of laser scanning for applications
- To know the most important laser scanning data products

Questions, comments or feedback:
presemo.aalto.fi/c1010lecture6

Aalto-yliopisto

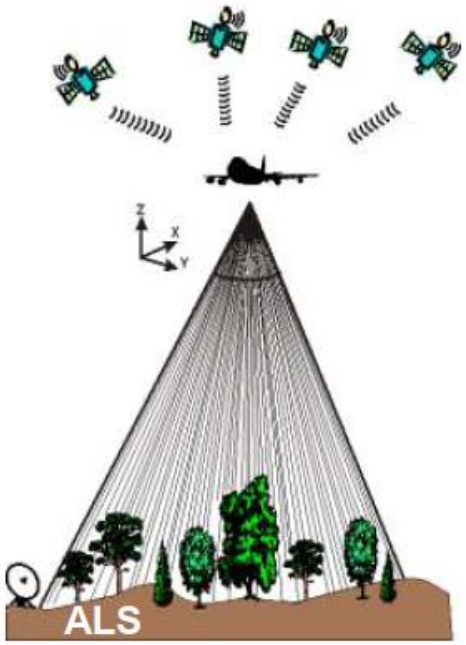
Development of Mobile Laser Scanning platforms and applications

>10 years ago near the river Pulmankijoki (Lapland)

MOBILE MAPPING SYSTEMS

Kukko, A, Kaartinen, H, Hyyppä, J & Chen, Y 2012, 'Multiplatform Mobile Laser Scanning: Usability and Performance' SENSORS, vol 12, no. 9, pp. 11712-11733. DOI: 10.3390/s120911712

Various platforms for laser scanning



Airborne Laser Scanning

Terrestrial Laser Scanning

Mobile Laser Scanning

Personal Laser Scanning (PLS)

- The idea first appeared as a backpack-type MLS system, where the scanning and positioning systems were on the operator's back rather than on a vehicle platform.
- The last years have witnessed rapid progress in sensor miniaturization. This has enabled to develop **personal wearable laser scanning systems**.
- The main advantage of PLS lies in its high mobility in various terrain conditions and rapid data collection.
- The main systems have been **backpack and handheld laser scanning devices**.
- Significantly faster data collection than TLS

Image: M. Vaaja,
AhkaR3 backpack system developed by Antero Kukko FGI

Leica Pegasus Backpack system, Kaarta Stencil, GeoSLAM ZEB-REVO

General principles in laser scanning

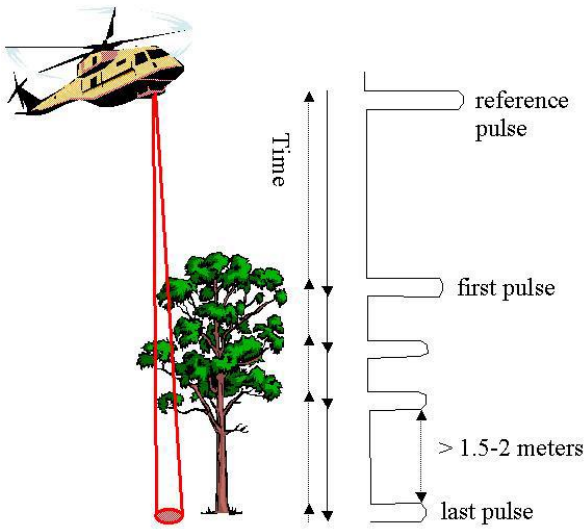
Aalto-yliopisto

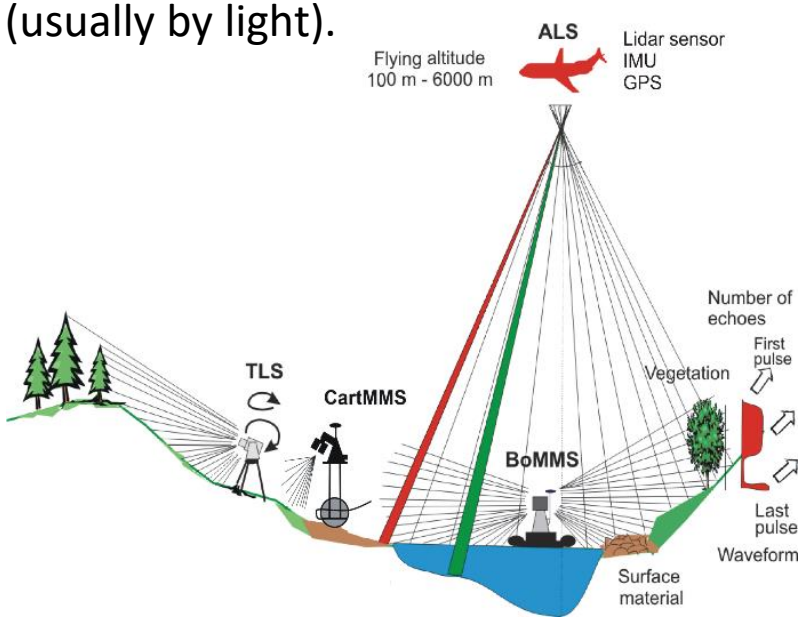
LASER SCANNING / LiDAR

- LASER – (“Light Amplification by Stimulated Emission of Radiation”) or LiDAR – (“Light Detection and Ranging”)

- Technology for measuring ranges and producing 3D information

- Active distance measurement
  - **The active** methods are measuring the distance by sending some signals to the object (e.g. laser beam, radio signals, ultra-sound, etc.) while **passive** ones only receive information about object’s position (usually by light).



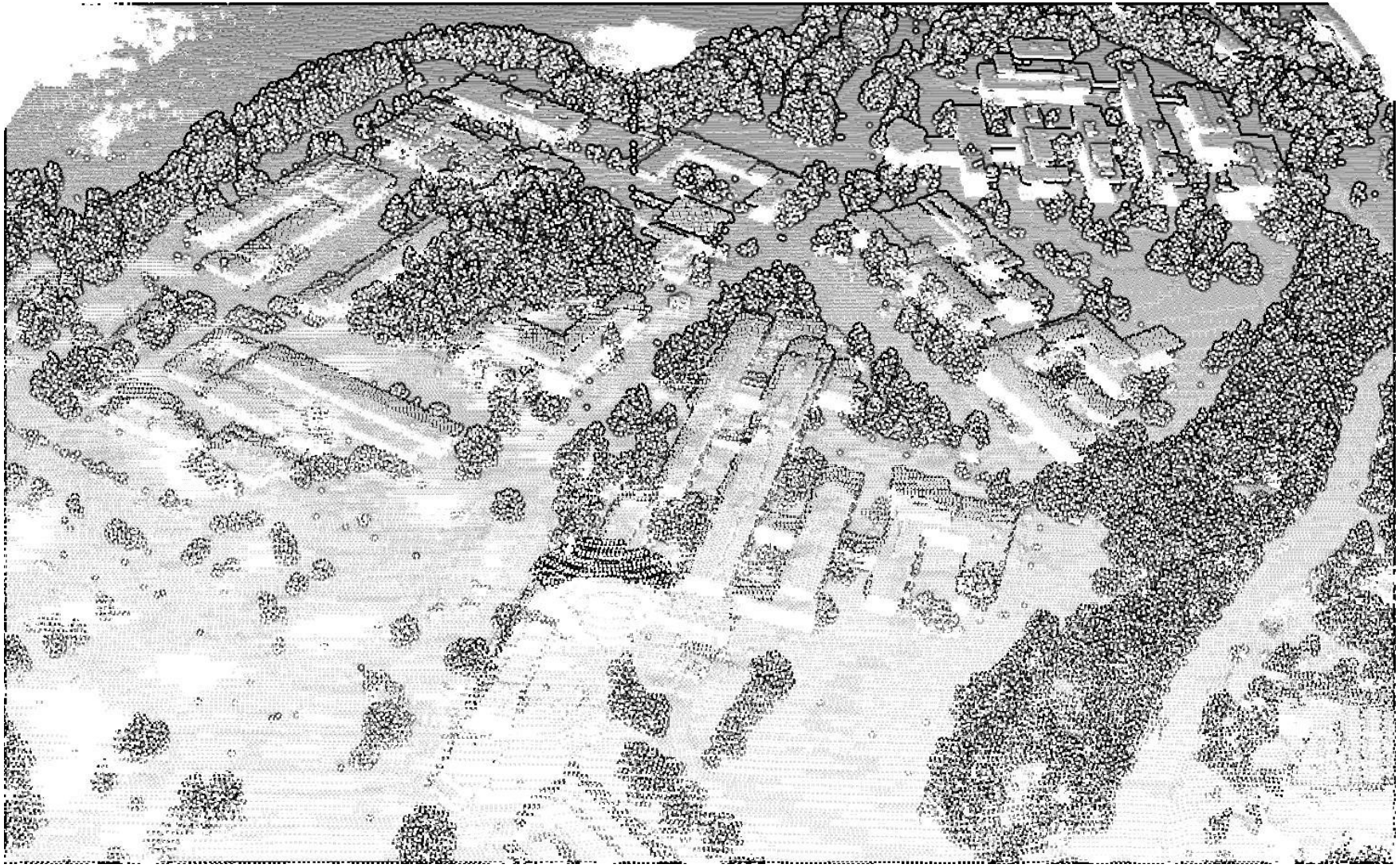


LASER SCANNING / LiDAR

- **Properties of the laser**
  - Direct 3D measurements (vs. camera with two or more image)
  - Extremely accurate depth/range information
  - ≤ 360 degrees of field-of-view
  - Active measurements (sends and returns the laser beam)
    - Independent on external light source (vs. imaging)
    - Works in dark and bright conditions (vs. imaging)
  - Measurements of objects under/behind vegetation with multi echo detection

  - **What limitations are present?**
    - Monochromatic light (consisting of a single wavelength) -> no color information for texturing and classification
    - Inhomogeneous point distribution due to the platform movement

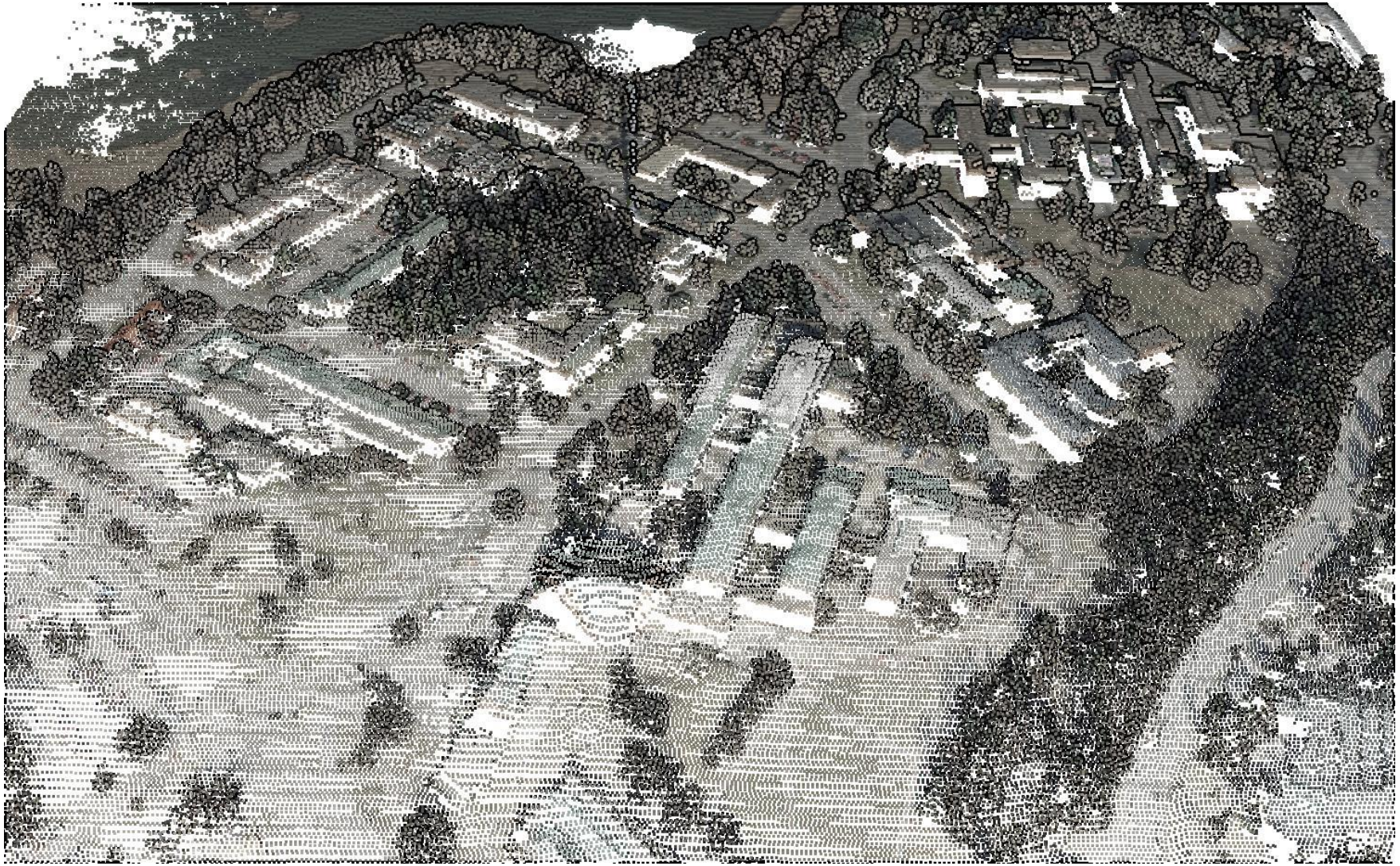
Airborne laser scanning point cloud data



Aalto University
School of Engineering

Point cloud © National Land Survey of Finland

Coloured airborne laser scanning point cloud data

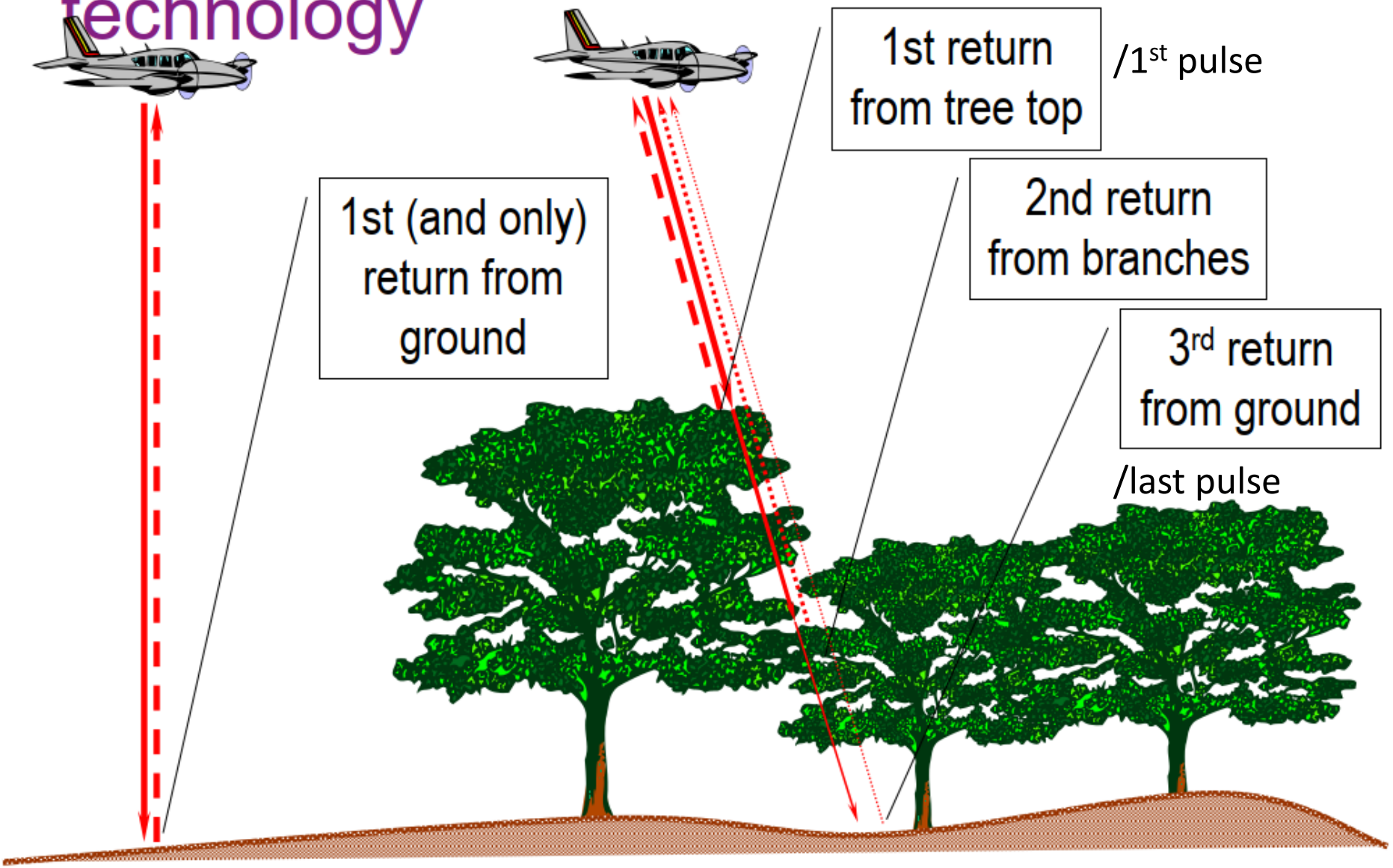


Point cloud © National Land Survey of Finland

Classified airborne laser scanning point cloud data

Point cloud © National Land Survey of Finland

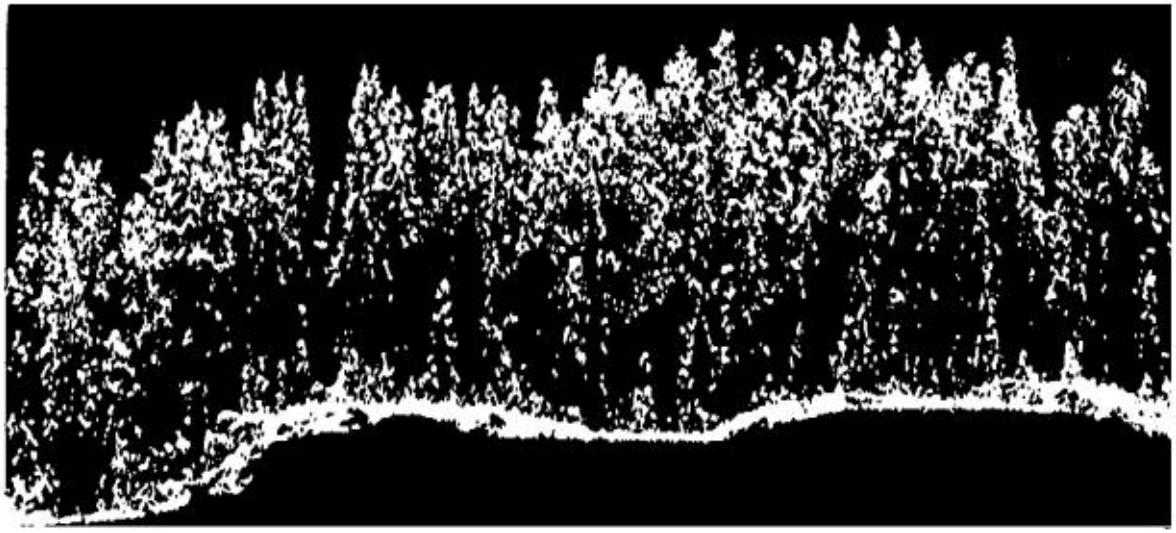
Fundamentals of multiple discrete return technology



Example of airborne laser scanning output

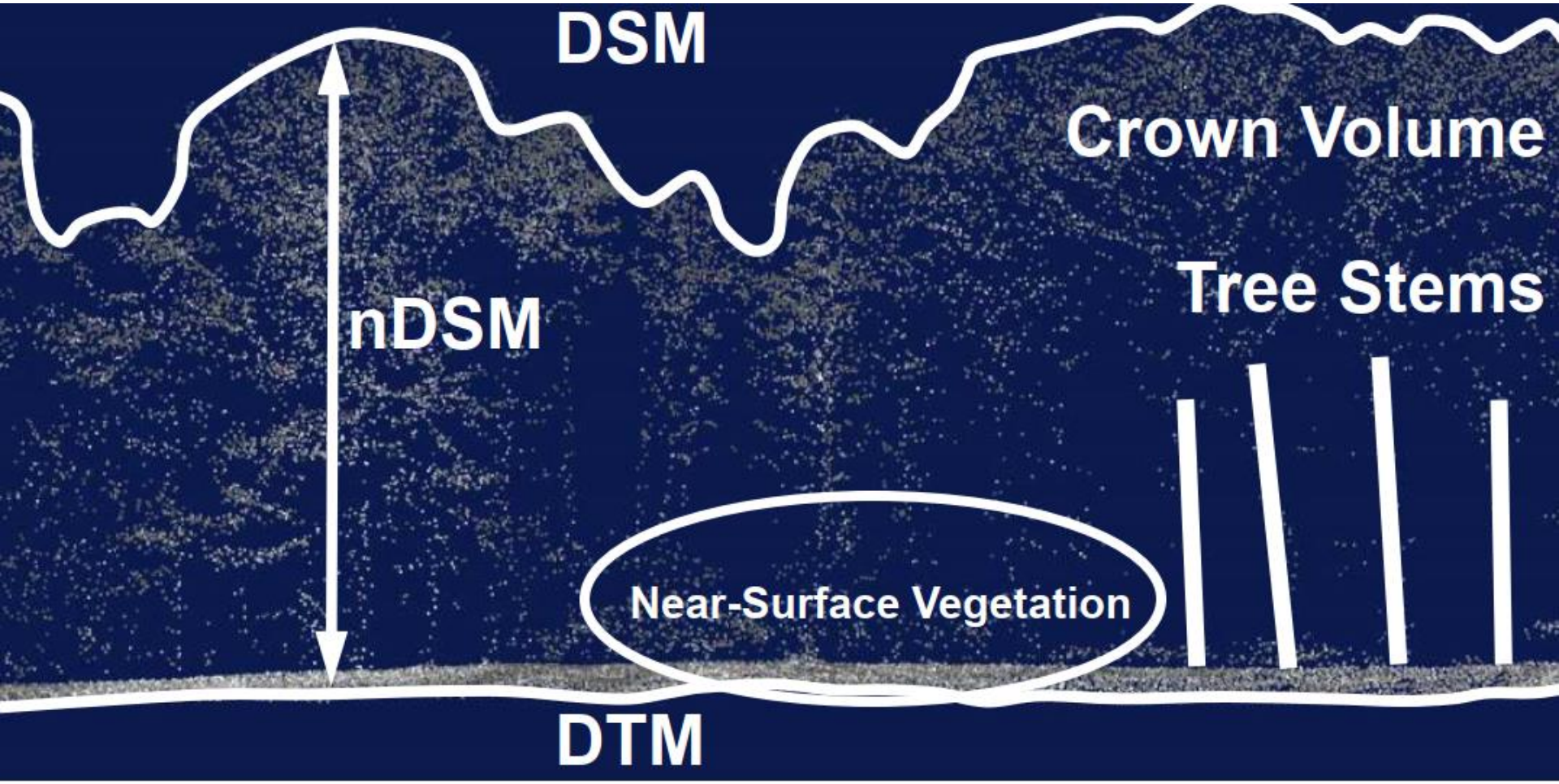
- **A set of points *p* in 3D space (x, y, z)**
- Laser scanning **intensity** as additional attribute

Output: x,y,z, intensity !



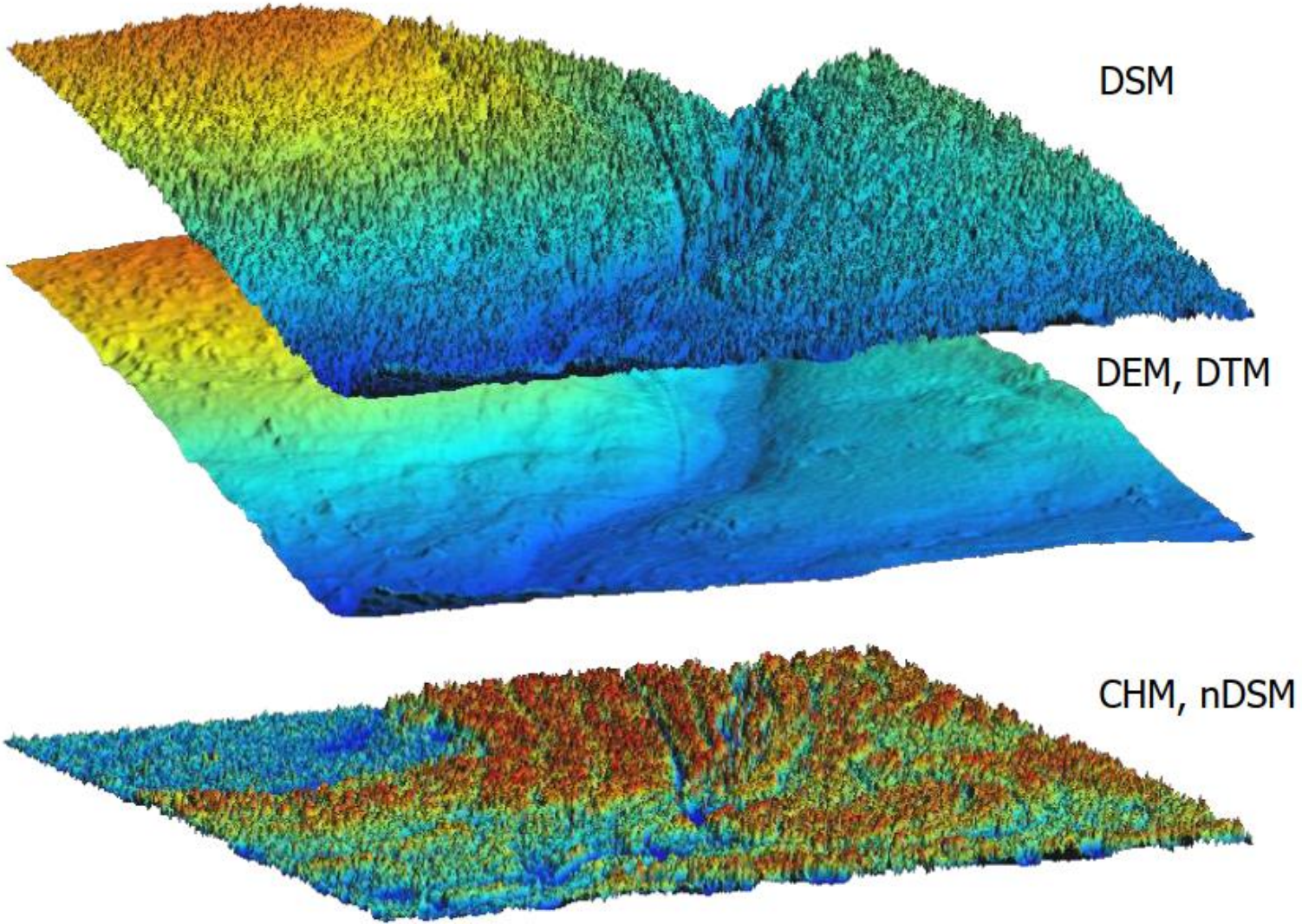
C. Hannu Hyyppä, Petri Rönnholm

Interpreting ALS point cloud data

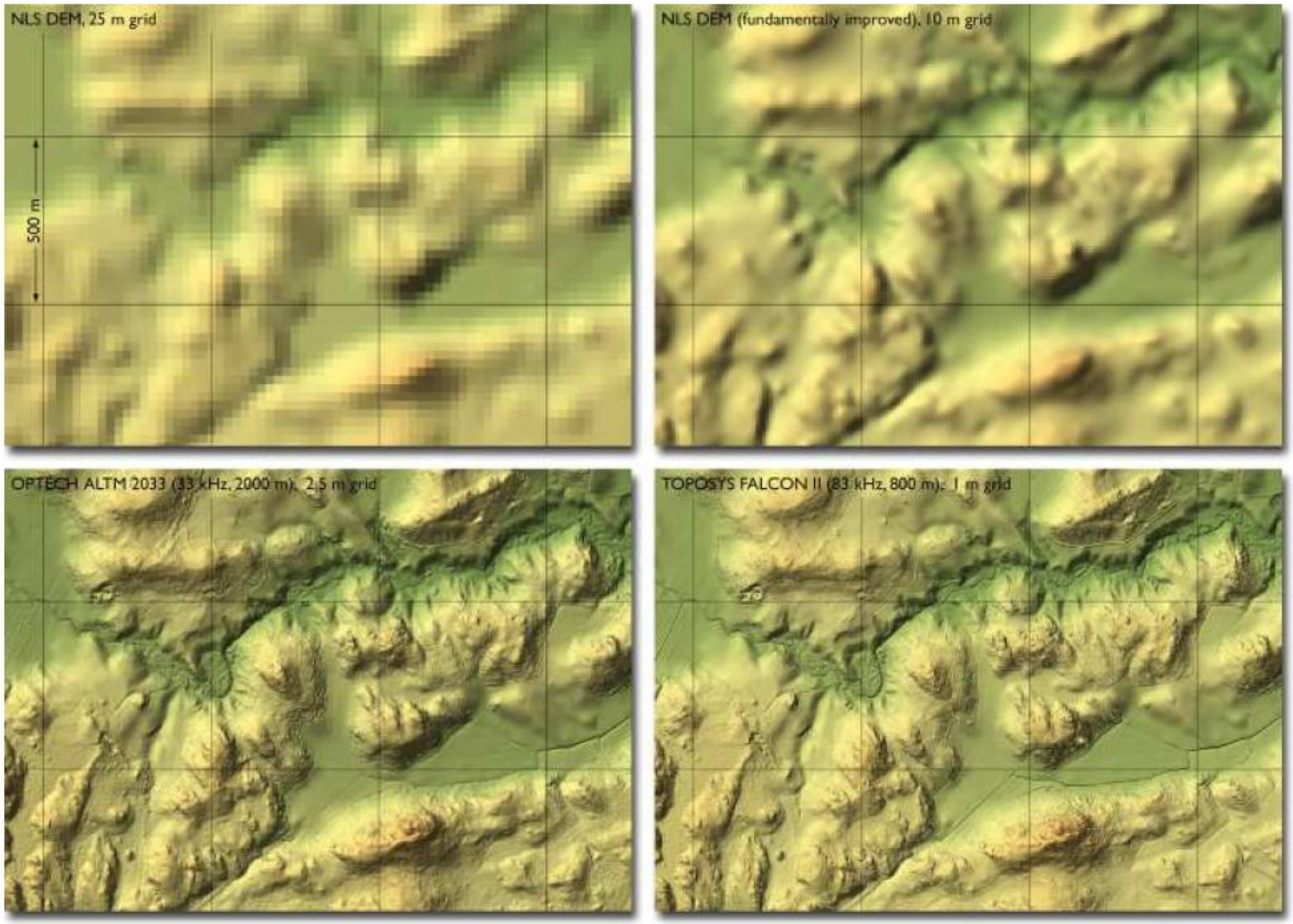


DSM, digital surface model
DTM, digital terrain model
nDSM, normalized digital surface model (= DSM – DTM), also called as Canopy height model (CHM) in case of forests

DTM, DSM, nDSM



Comparison of DTM/DEM resolutions: 25m-10m-2,5m-1m



Autonomous driving and laser scanning

Aalto-yliopisto

LIDAR for Autonomous Vehicles

- The expected function from automotive lidar sensors is to ensure reliable and safe automated driving such as **collision detection, blind spot monitoring, object and pedestrian recognition, terrain mapping**.

- At the same, the autonomous vehicles are able to produce huge amount of 3D data of its environment.

Aalto University

Sensors in Autonomous vehicles

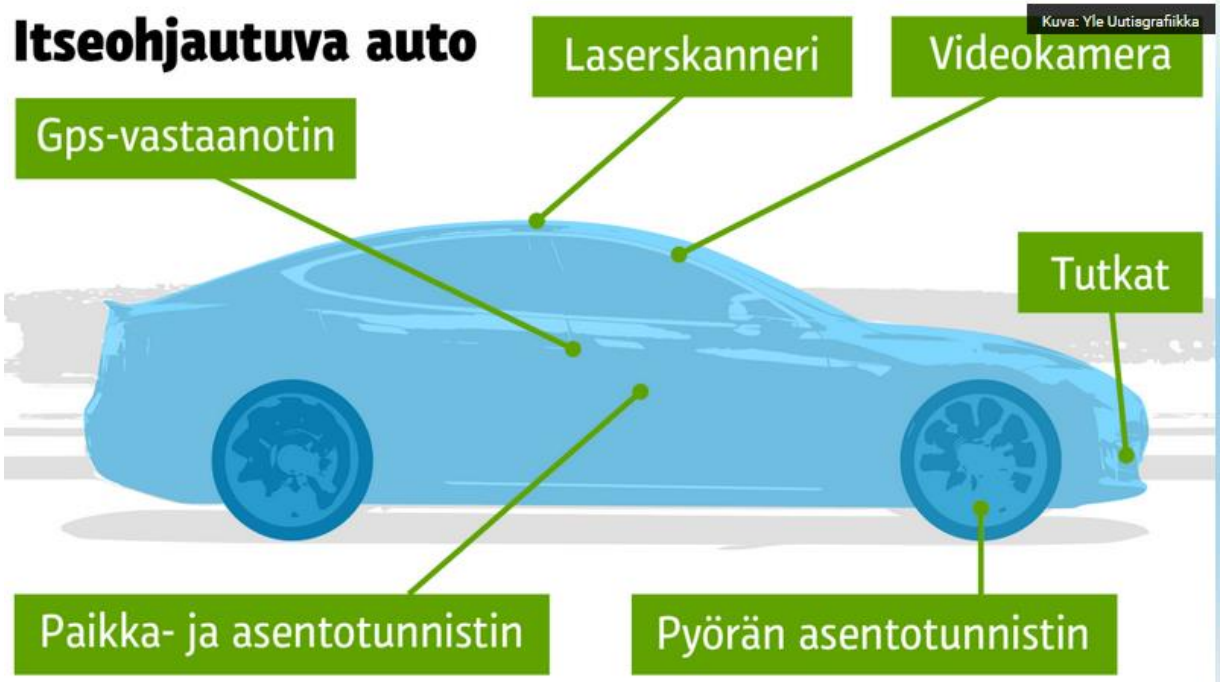
yle Uutiset

UUTISET

Itseohjautuvaa autoa voi ajaa vaikka sokea – Tällaiseen tekniikkaan se perustuu

Tekniikka, jolla auto pystyy kulkemaan haluttuun paikkaan ilman kuljettajaa, ei ole Googlen tai Applen yksinoikeus, vaan sitä tutkitaan ja kehitetään huipputasolla myös Suomessa.

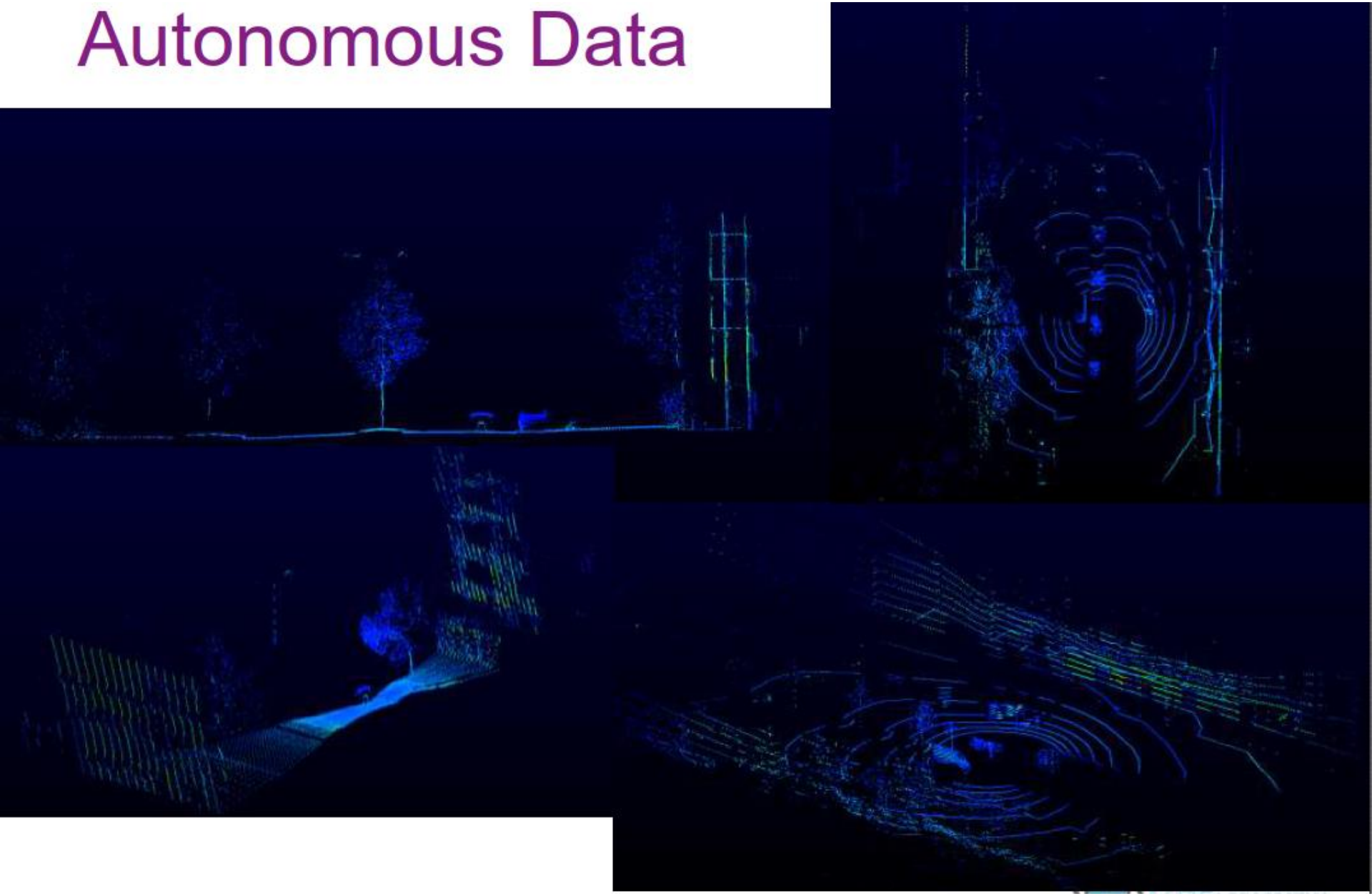
Tiede 11.9.2016 klo 17:04 | päivitetty 27.10.2016 klo 17:40



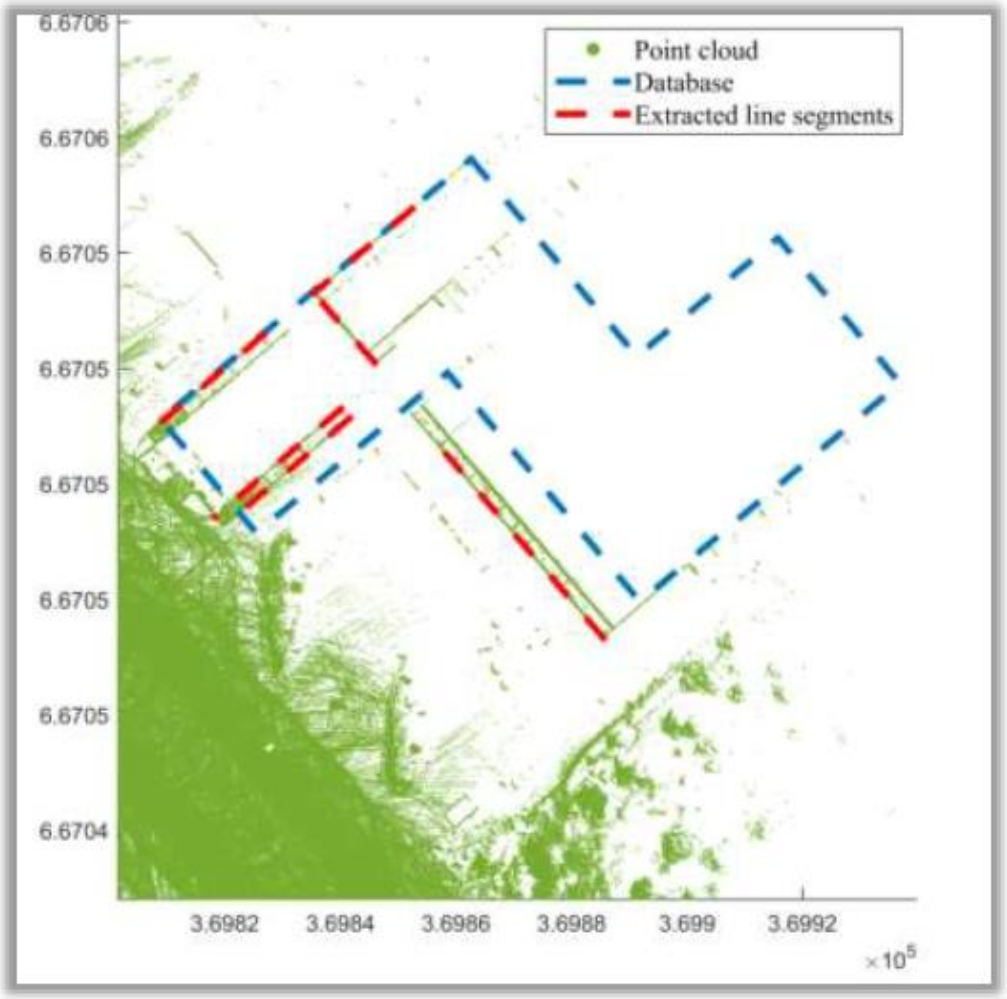
- https://yle.fi/uutiset/3-9153345

Autonomous Driving

Autonomous Data



Surveying level data



The Demolished and New Buildings

The algorithm has detected (part of) the walls of the new building (red dashed lines) that was built in the place of the old demolished building (blue dashed lines).

Car parkings

Figure. a) Part of the street Espoonlahdenkatu as recorded on the reference video during data acquisition Drive 1. b) Raster representation of the car-based laser scanner data. The pixel value of each 0.3 m × 0.3 m cell corresponds to the number of laser points inside the cell. Parked cars appear as L shaped clusters of bright pixels.

NLS FINNISH GEOSPATIAL RESEARCH INSTITUTE FGI

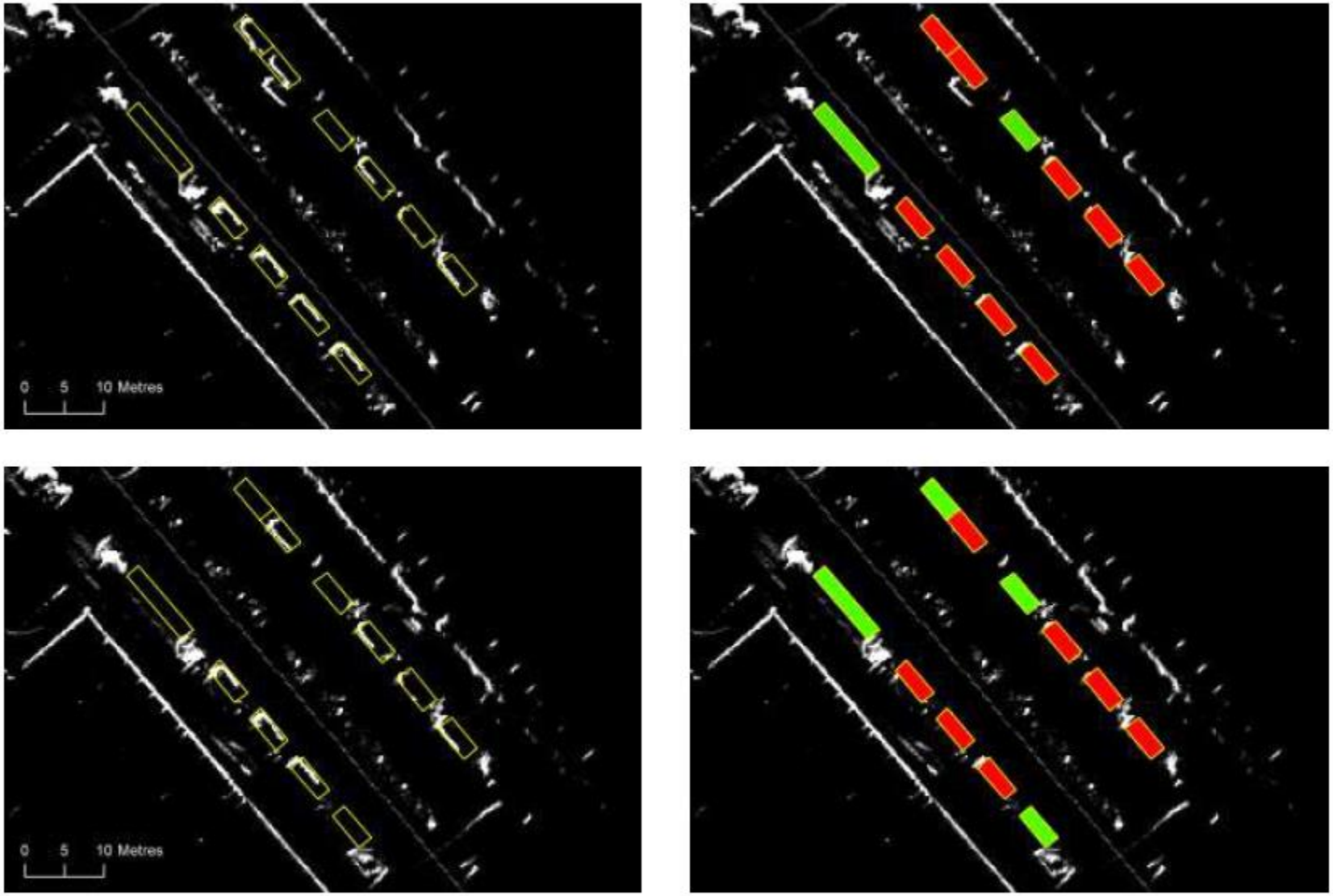


Figure x. Data (left) and classification results (right) for Drives 1 (upper row) and 2 (lower row). Parking places classified as free are shown in green and parking places classified as occupied are shown in red. Digitized boundaries of the parking places are shown in yellow.

Road inventory

Aalto-yliopisto

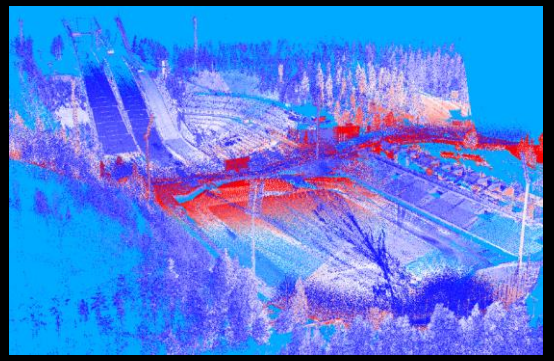
Inventory and modeling of roadside

Road distress detection and monitoring

More applications…

Case: FIS Nordic Ski Championships 2017

Utilization of virtual 3D model in sport application



4.3.2017. https://yle.fi/urheilu/3-9491840

Aalto University
School of Engineering

MML
PAIKKA-
TIETO-
KESKUS FGI

Centre of Excellence
in Laser Scanning Research

LAHTI
2017

yle

Case: FIS Nordic Ski Championships 2017
Utilization of virtual 3D model in sport application

General list of LS applications

- Topographic mapping (DTM, DSM etc.)
- Forests inventories and determination of vegetation parameters, stem diameter, tree height, density, biomass estimation etc.
- 3D city modeling and automated building detection and reconstruction
- Map updating, urban planning, indoor modeling
- Corridor mapping of roads, railroads, power lines and waterways
- Coastal area mapping (flood risk areas, erosion etc.)
- Volume estimation and change detection on open pit mines
- Industrial planning
- Rapid response applications, damage assessments for nature catastrophies etc.
- Mapping of snow and ice cover
- 3D modelling for cultural heritage
- 3D visualization, animations, simulations
- …

Read and learn more

Point Clouds as the Future Topographic Core Data - 05/02/2019

Technologies and Means towards a Paradigm Shift

Antero Kukko, Juho-Pekka Virtanen, Hannu Hyyppä

Could 3D point cloud data be used as the framework for topographic information in the future? Point clouds can be captured with an ever-increasing number of means from ground-based, airborne and spaceborne platforms to understand the surrounding reality and detect critical developments. What are the future technologies and processes that will build the capability for high-density 3D data? This article explores the possibilities based on the latest developments in the industry.

GIM magazine

Read it now!

https://www.gim-international.com/content/article/point-clouds-as-the-future-topographic-core-data

Aalto University

Other application examples and videos:

- Application examples in Finland: https://esrifinland.maps.arcgis.com/apps/Cascade/index.html?appid=342246f914bd4fbe93591ca39ddf9043
- What is LIDAR: How it Works & Why Important for Self-driving Car? https://medium.com/vsinghbisen/what-is-lidar-how-it-works-why-important-for-self-driving-car-dc750bdc679
- Apple iPad Pro with LiDAR Scanner: https://www.geospatialworld.net/blogs/apples-lidar-scanner/
- How Does LiDAR Work? Light Detection and Ranging: https://www.youtube.com/watch?v=EYbhNSUnIdU&feature=youtu.be
- What is lidar? How does lidar work? How does lidar keep us safe?: https://www.youtube.com/watch?v=NZKvf1cXe8s
- How scientists try to weigh some of the fattest bears on Earth: https://www.popsci.com/story/technology/fat-bear-week-laser-scanning-weight-estimates/

Aalto-yliopisto

Characteristics of LS

Airborne Laser Scanning

- Point density 0.5-40 pts/m^2
- Homogenous point density
- Elevation accuracy 5-30 cm
- Planimetric accuracy 20-80 cm
- Few hundred m to several km
- Transfer costs
- Cost-effective for areas larger than 50km^2
- Multitemporal ALS applications studied relatively little (Murakami et al. 1999, Yu et al. 2004)
- Reference book Shan and Toth (2009), Vosselman and Maas (2009)

Airborne mini-UAV scanning

- New research area (idea in Zhao et al., 2006, first demo for mapping Jaakkola et al. 2010)
- Point density 10-several hundred pts/m^2
- Elevation accuracy 5-30 cm
- Altitude tens of m
- Usable for research and multitemporal studies
- Presently commercial applications
- Reduces CO_2 consumption of research

Description by prof. Juha Hyyppä

Characteristics of LS

Mobile laser scanning

- Point density in the range of 100 to several thousands pts/m^2
- More homogeneous (TLS) point density
- Point accuracy of few centimeters (egg) when collected with good GNSS coverage
- Applicable range of few tens of m
- Viewing angle different from ALS
- Higher variation in the range data (e.g. round traffic poles are not round in the data)
- Vast data sets when data collection is done continuously
- Need for automatic and interactive algorithms

Terrestrial Laser Scanning

- Point density in the range of 10000 pts/m^2 at the 10 m distance
- Distance accuracy of few mm to 1-2 cm
- Operational scanning range from 1 to several hundred m
- Feasible for small areas less than few tens of m distance
- Processing time challenging: image processing technigues applied
- Small variation in data, e.g. Distance variation low -> surface normal etc can be calculated
- Reference book: Vosselman and Maas (2009)

Description by prof. Juha Hyyppä