Unconventional LiDAR Mapping from Air, Mobile and Terrestrial

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Papers: Google Scholar

Stuttgart, September 11, 2013

Together “what is otherwise impossible”

Pulsed time-of-flight laser radar
Juha Kostamovaara
Univ. Oulu

Mobile and ubiquitous Laser Scanning
Juha Hyyppä
FGI

Laser scanning for precision forestry
Markus Holopainen
Univ. Helsinki

Laser scanning for built environment
Hannu Hyyppä
Aalto Univ.

International benchmarking studies


Unconventional LiDAR Mapping from the air

Anttoni Jaakkola, Yuwei Chen, Juha Hyyppä, Xiaowei Yu

UAV LS – 2nd generation FGI system

UAV-based Laser Scanning SENSEI
UAV LS is usable for multitemporal studies

Use of Individual Tree Features in ABA

<table>
<thead>
<tr>
<th>Feature Index</th>
<th>Volume (m³/ha)</th>
<th>DBH (cm)</th>
<th>Height (m)</th>
<th>R</th>
</tr>
</thead>
<tbody>
<tr>
<td>First - Last Pulse Difference</td>
<td>0.24</td>
<td>0.00</td>
<td>1.20</td>
<td>0.98</td>
</tr>
<tr>
<td>Coniferous</td>
<td>30.16</td>
<td>2.40</td>
<td>15.60</td>
<td>0.96</td>
</tr>
<tr>
<td>Deciduous</td>
<td>37.56</td>
<td>2.00</td>
<td>15.04</td>
<td>0.93</td>
</tr>
<tr>
<td>State-of-the-art of Forest Inventory</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
- Dominant canopy height in large areas with ALS
- Processing level: either microstand or tree level
- Canopy Height of other storeys
- Point cloud metrics (ABA) or ITD
- Reference
  - MLS
  - TLS
  - Field plots
- Tree Species:
  - LS point cloud,
  - aerial image,
  - hyperspectral aerial image,
  - waveform
  - LS time series
- Multispectral ALS in needed (boreal zone, 3-4 tree species needs to be mapped)
Output of UAV TomoRadar

Unconventional LiDAR Mapping from mobile
Antero Kukko, Harri Kaartinen, Anttoni Jaakkola, Yuwei Chen, Xinlian Liang, Juha Hyyppä, Hannu Hyyppä (Aalto), Matti Vaaja (Aalto)

Backpack MLS – 2nd generation

FGI Roamer – 3rd generation

Accuracy of MLS in good GNSS

• Elevation error vs. distance

![Graph showing elevation error vs. distance for different MLS types: MLS A, MLS A recalibrated, MLS B, MLS B recomputed, MLS C, MLS D, MLS E. The x-axis represents distance from trajectory in meters, and the y-axis represents elevation error in meters. The graph shows a trend of increasing elevation error with distance.]
TLS/MLS with harvester

Dbh determination

- SS: only part of the trunk detected, diameter estimation not accurate
- MS: diameter estimated from matched point clouds

Multi-Single-Scan
The results of stem mapping using the MSS method

<table>
<thead>
<tr>
<th>Stem</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density (stems/ha)</td>
<td>60.5</td>
<td>75.2</td>
<td>78.6</td>
<td>76.4</td>
<td>52.0</td>
<td></td>
</tr>
<tr>
<td>Detection (mapped stem/the total)</td>
<td>16/19</td>
<td>15/19</td>
<td>15/15</td>
<td>14/16</td>
<td>9/10</td>
<td></td>
</tr>
<tr>
<td>Bias (cm)</td>
<td>0.78</td>
<td>0.51</td>
<td>0.51</td>
<td>0.78</td>
<td>0.67</td>
<td></td>
</tr>
<tr>
<td>RMSE (cm)</td>
<td>1.23</td>
<td>0.93</td>
<td>0.67</td>
<td>1.90</td>
<td>0.97</td>
<td></td>
</tr>
<tr>
<td>RMSE (%)</td>
<td>5.16</td>
<td>7.72</td>
<td>3.47</td>
<td>9.77</td>
<td>5.26</td>
<td></td>
</tr>
</tbody>
</table>

The volume estimation using automatic TLS measurements and Laasenaho volume models

<table>
<thead>
<tr>
<th>Volume</th>
<th>Species</th>
<th>Bias (dm³)</th>
<th>RMSE (dm³)</th>
<th>RMSE (%)</th>
<th>R</th>
</tr>
</thead>
<tbody>
<tr>
<td>TLS</td>
<td>Pine</td>
<td>-0.91</td>
<td>24.24</td>
<td>8.88</td>
<td>0.98</td>
</tr>
<tr>
<td></td>
<td>Spruce</td>
<td>-12.49</td>
<td>34.90</td>
<td>9.75</td>
<td>0.99</td>
</tr>
<tr>
<td></td>
<td>All</td>
<td>-5.87</td>
<td>29.29</td>
<td>9.47</td>
<td>0.99</td>
</tr>
<tr>
<td>f(d,h)</td>
<td>Pine</td>
<td>-5.37</td>
<td>21.97</td>
<td>8.04</td>
<td>0.99</td>
</tr>
<tr>
<td></td>
<td>Spruce</td>
<td>-12.66</td>
<td>36.17</td>
<td>10.11</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>All</td>
<td>-8.50</td>
<td>28.92</td>
<td>9.35</td>
<td>0.99</td>
</tr>
<tr>
<td>f(d,h)</td>
<td>Pine</td>
<td>-6.85</td>
<td>29.41</td>
<td>10.77</td>
<td>0.98</td>
</tr>
<tr>
<td></td>
<td>Spruce</td>
<td>-6.53</td>
<td>36.66</td>
<td>10.25</td>
<td>0.99</td>
</tr>
<tr>
<td></td>
<td>All</td>
<td>-4.14</td>
<td>32.72</td>
<td>10.57</td>
<td>0.99</td>
</tr>
</tbody>
</table>

Pole-type object derived from mobile mapping point clouds by an automatic process. In the project, we further develop object extraction methods for documenting the road environment.
Unconventional LiDAR Mapping from terrestrial

Yuwei Chen, Teemu Hakala, Anttoni Jaakkola, Xinlian Liang, Sanna Kaasalainen, Juha Hyypää

Defoiliation

- TLS measurement (number of points very high, ab. 1 M hits from one tree)
- Pine tree selected, simulation of the needle loss caused by Large pine sawfly (Diprion pini)
- Manual destructive removal of needles in six consecutive steps, weight of removed needles measured with accuracy of 2g. The original weight of the tree measured. TLS was recording the pine tree after each step
- Voxel model created
- Additionally, features calculated such as
  1. Number of points coming from the tree above a threshold
  2. Number of points below a threshold (in the surrounding area)
  3. Number of ground hits

Use of TLS

- Single scan/Multi Scan
- Trunk location
- Trunk diameters and trunk curves
- Tree Species
- ALS + TLS integration

Total biomass

Branch and needle biomass

Crop Inventory

Kemira’s test site in Vihti

R²=0.92 linear model

R²=0.98
Hyperspectral Lidar
• Supercontinuum laser & laser scanning
• Hyperspectral LiDAR prototype
• Data example & processing
• Environmental applications

Example of Measurement Data
• Apple tree
• 3.5m high
• 4.5m distance
• 375,000 points with spectra
• 15 minutes scan time

Data

FULL WAVEFORM DATA (8Ch)

3D POINT CLOUD

REFLECTANCE SPECTRA

Teemu Hakala, Sanna Kaasalainen, Juha Suomalainen
Applications

Target classification example

Technology and applications of virtual 3D models using mobile mapping and 3D games engines

Juha Hyppä, Anttoni Jaakkola and Lingli Zhu

Automatic generation of virtual reality

Summary

• Unconventional usage of LS actually means that you can use laser scanning/LiDAR in a wide range of problems, applications and phenomena.