Snow cover change detection with laser scanning range and brightness measurements

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- Laser scanner intensity calibration
- Laboratory reference measurement
- Terrestrial laser scanner (TLS)
- TLS application to snow monitoring
Laser Scanning research at the Finnish Geodetic Institute

- Change detection, automatic map updating, ...
- Modelling of buildings, cities, forests, ...
- Individual tree height growth
Brightness measurement with ALS: background

- The use of airborne laser scanning (ALS) intensity data has been limited (due to, e.g. calibration problems)
- Systematic calibration method would provide more precise and automatic surface & target characterization + simultaneous/weatherproof reflectance measurement
- Sometimes a major or only source of (brightness) information from a particular area (e.g., glaciers)
- Development of sensors could improve the accuracy
FGI calibration concept for ALS

- Started 2005 using portable reference targets: set of eight 5x5m tarps of 5%-70% reflectance
- New innovation 2006: use of commercial gravels
- Laboratory brightness calibration for gravels/tarps
- First test campaigns show promising results

Tarps at Espoon-lahti boat harbour (2006 ALS campaign)

Gravels in the Nuuksio 2007 and Espoonlahti 2006 ALS flight campaigns
Terrestrial & laboratory reference measurements

- Terrestrial laser scanners: surface topography and intensity at 650/785nm
- Laboratory laser & CCD measurement, e.g. 1064nm & 632.8nm
- Intensity calibration & study of stability for tarps and gravels

Measurements and comparison of gravel intensities from ALS, TLS, and laboratory
LIDAR measurement geometry: backscatter

- Brightness effects take place in ALS because of the geometry (backscatter: reflection in 180° direction w.r.t. source)
- Strong increase in intensity + polarization effects (related to the physical backscatter effects)

Target reflectance (1064 nm) at backscatter (0°) compared to that at the 5° viewing angle, for different gravel & construction targets.
Terrestrial laser scanners

- Applied in digital factory, virtual reality, architecture, civil engineering, archeology and cultural heritage, plant design, space applications and automation systems (robotics)
- Remote sensing applications: construction quality, tree growth/extraction
- Phase shift distance measurement (amplitude modulation)

The FARO terrestrial scanner in field measurements of grain field (left) and snow surface (right).
Technical factors (FARO LS HE80)

- Generally: scanner detectors not optimized for brightness measurement
- Background noise
- Brightness reducer for near distances; distance calibration
- Logarithmic amplifier for small reflectances; reflectance calibration
- Scanner temperature is also critical (+ NO operation below 0°C) and affects the measured counts

Faro LS HE80 terrestrial laser scanner, 785nm
TLS and forest detection

FARO intensity image of mixed trees. The numbers denote the measured reference (ground truth) points, the coloured dots are spherical reference targets.
CAD models of trees combined from several FARO scans

Left: top view. Right: side view of the cropped area (from the left image).
Snow cover monitoring with TLS
Feb-March 2007-Jan 2008

- Three test spots at FGI backyard were scanned with the FARO (785 nm) during Feb-March, 2007 and Jan 2008.

Intensity images: visible changes in snow cover (e.g., snowmelt)

The 3 data collection spots are marked with yellow squares (Low, Middle, High)
Intensity images 2008

Jan 9

Jan 10

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Snow cover depth in range measurements

- Changes in the height of the snowpack can be observed in the TLS range data.
- Agreement with in situ snow depth measurements within a few cm.

Left: the point cloud profiles. Right: comparison of the FARO z-coordinate (Low spot) with ground measurements.
Intensity & distance corrections

- Corrected for the brightness reducer for near distances and the logarithmic amplifier for small reflectances
- Effect of distance corrected with the aid of distance calibration measurements for the Spectralon® reference panel
- Poor accuracy for low reflectance targets

Calibrated FARO intensity vs. distance 0-30m (left) for Spectralon 12%, 25%, 50%, and 99% panels (right).
Intensity calibration

- Spectralon® (Labsphere Inc.) 4-step reference panel
- 12%, 25%, 50%, and 99% reflectances
- Too high counts for the 99% panel -> used 50% in the calibration
- Intensities scaled to the target distance using the FARO distance calibration measurements

Yellow squares are the sampling plots for the 4-step reference target (FARO intensity image)
Corrected snow test spot intensities

- The intensity (counts) for middle and high plots were too low -> reduced accuracy in range and intensity data (distance effect)
- No relation to a single parameter (snow cover thickness, temperature, grain size, etc.) ->
- Intensity is affected by several parameters
- Qualitative search for change effects

Intensity time series for the 3 test spots Feb 2007 – Jan 2008. The intensity counts (raw data) for Middle and Low spots were too low for range & intensity analysis.
Change detection

- Change of (visually) dry to wet conditions in the lowest test spot
- Change (rounding) in grain structure
- In all cases there is a decrease in intensity
- Need more data

Calibrated FARO intensities of the lowest snow test spot

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<thead>
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<th>Date</th>
<th>Temperature Change</th>
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<tr>
<td>Jan 9</td>
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<tr>
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<tr>
<td>Feb 26</td>
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<td>Mar 2</td>
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<td>Mar 9</td>
<td>+3.5°C</td>
</tr>
<tr>
<td>Jan 10</td>
<td>-1°C +2.5°C</td>
</tr>
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</table>
Comparison with earlier results

- Measured with a 1064nm Nd:YAG laser and CCD camera
- Laser intensity around 10° of backscatter (0°)
- Higher reflectance at backscatter for frozen sample (b)
- Large deviation in data -> need more results

Laser backscatter for melting (a) and frozen (b) surface grains measured during the same day at +2.5°C and -3°C. Grain image with a mm scale. Sodankylä March 2, 2005.
Important factors to consider:

- Calibration of laser intensity from snow: strong diffuse radiation inside the layer -> too low reflectance values
- Change detection is possible with relative calibration
- Weather affects the scanning intensity AND the scanner
- Effect of incidence angle visible in all intensity images
Effect of incidence angle

- Effect of incidence angle visible in intensity images ->
- Measurements (Jan 2007) with the FARO TLS, calibrated with 99% reflectance Spectralon standard
- 5cm snow layer on plane (roof) surface, about 0°C.
- We found a strong effect on the measured laser intensity
- The effect of distance to the scanner has been normalized to 1m in the graph
- Also normalized the intensity to be 1.0 at 0° incidence
Conclusions & Outlook

- Changes in snow cover are visible in range and intensity data (e.g., melting, weather effect...)
- Intensity data may not be useful by itself, but could be used in change detection and together with range measurements in data interpretation algorithms
- More measurements are needed to improve the accuracy and search for connections with physical parameters
- Further studies on laser reflection from snow
- More data from the upcoming snow monitoring campaign 2008-2009

THANK YOU!