Laser scanner simulator for system analysis and algorithm development: a Case with forest measurements

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Introduction - 1

- Empirical data have a mixture of errors
- Comparison of system performance difficult
- Mapping algorithm development not always easy
- Sensor information not usually available
Introduction - 2

- Simulation provides
  - Known objects,
  - Component analysis,
  - Flexible platform for various sensor models,
  - Verification of future laser instruments
  - a tool for analyzing systematic properties of scanning LIDAR systems, and factors affecting the quality of the LIDAR end products
Ideas for the simulation - 1

- Sensor models
  - TopoSys Falcon II (line)
  - Riegl LMSQ560 (line)
  - Optech ALTM3100, ALTM2033 (Oscillating)
  - TopEye MkII (conic)
  - Other general sensors
    - Mobile mapping
    - Traffic flow and vehicle detection
    - etc.

Scan patterns of a line, conic and oscillating scanners
Ideas for the simulation - 2

- Palmer scanner video
  - TopEyeMkII_400m_100fps.avi

Laser Scanning 2007 and SilviLaser 2007
Espoo 13.9.2007

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Ideas for the simulation - 3

- Pulse transmission
  - Multi ray model
  - Pulse shape and length
    - Ideal Gaussian pulse
    - Any shape
  - Intensity model
    - $\text{TEM}_{\infty}$
    - Any pattern
Ideas for the simulation - 4

- Intensity pattern video
  - 3DPulseInt_1J_1mrad_5ns_400m.avi
  - 1 J Gaussian pulse
  - 1 mrad
  - 5 ns
  - 400 m

![Intensity pattern video graph](image-url)
Ideas for the simulation - 5

- **Waveform and detection**
  - Each sub beam reflects from the target
  - The location of a scatterer in a beam area
  - Incidence angle effect reduces the back scattered energy
  - Summing the sub echoes to a high resolution prototype depending on the arrival time
Implementations

- Simulator runs in Matlab, most of the computing done in mex (dll).
- **Output:** $X_s, Y_s, Z_s, V_{dir}, X_f, Y_f, Z_f, \text{Waveform}_n$
  - Position of the sensor at the end (data split, batch)
  - first echo data
- **High resolution raster models used for surfaces**
  - Suitable for buildings and ground
  - Tree modeling if scanning angles are moderate (top view)
Cases - Forest

- Artificial forest model
  - 150x150 m²
  - 100 trees at random location

- Mean height 25.97 m, STD 0.58 m
- Mean crown diameter 10.31 m, STD 1.40 m
- Modeled by means of a sinusoidal surface with 5.0 cm grid spacing, 1.0 cm height resolution
Cases - Forest

- Simulation parameters
  - TopEye MK-II laser scanner
  - Altitude of 200 m, three flight directions
  - Flight speed of 25 m/s
  - Pulse repetition frequency 30kHz
  - Scanning angle 20 degrees
  - Sub-sampling of the 1.0 mrad laser beam with 53 rays within the footprint area of 20 cm in diameter
Cases - Forest
Cases - Forest

- Tree extraction
  - 0.5 m radius from the model data tree tops
  - 0.33 m underestimation to known ground
  - 0.02 m underestimation achieved if the simulated ground data considered
Cases - Forest

- Relatively good results are due to
  - Dense point cloud
  - Relatively flat tree tops
  - Small footprint size
  - Same reflectance for ground and tree

- Simulation and simulated data can be used

- For trees more realistic models need to be introduced
Cases – Comparison to real data

- Point cloud presentation of the simulated data (left) and the original laser scanning data of TopoSys Falcon II (right).

- Comparison of the original data (blue) with the simulated TopoSys Falcon II (red) and Optech ALTM 3100 (green).
Summary

- Simulator combines both spatial and radiometric components to produce realistic point cloud and waveform data
- Simulation is a significant adjunct in understanding of the error sources and their effects on data
- Simulation provides artificial data on known targets for algorithm development purposes in many fields of application without expensive data and time delays
Questions?