Airborne mapping LIDAR data collection and processing for archaeological research

Juan Carlos Fernandez-Diaz (jfern4@central.uh.edu) Michael Sartori, Abhinav Singhania, William Carter and Ramesh Shrestha

SAA 79th Annual Meeting—April 27th, 2014, Austin, TX
Behind the scenes on going… from an impervious canopy to measuring the canopy and ground in 3D.
Behind the scenes on going…

from an impervious canopy
to measuring the canopy and ground in 3D
to developing the DEM
or whatever product that enables your research
Points to take home

• Not all LiDAR products are created equal
  – 10 shots/m² ≠ 10 shots/m² (under canopy)
  – No one-size-fits-all
• LiDAR processing is both an art and a science
  – Not necessarily a linear process
  – Many more options than “standard processing”…and no “ONE BEST WAY”
  – If not happy go back and talk to provider
• Have to go further from DEMs/DSMs
• Not a magic bullet, it has its limitations!

It all starts with…

• Archaeologist: “I want LiDAR for my study area!”
• Provider: “How much money you have?”
• The PI’s requirements for the project:
  – Area to be covered
  – Desired collection window
  – Special considerations
  – Desired point density (~resolution)*
    • Shot, Return, GROUND POINT Densities
You can create a grid at whatever resolution you want, but that does not mean you will see small features if you don't have the returns to support them.
Mission Planning 1

- Determining best system configuration and flying parameters to meet PI requirements:
  - Pulse Repetition Frequency (PRF)
  - Scan Angle / Frequency
  - Beam divergence
  - Flying height AGL
  - Flying speed

- Other considerations:
  - Safety
  - Airspace regulations
  - Efficiency
  - CANOPY PENETRATION

Canopy Penetration

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Counts</th>
<th>Density [1/m²]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Laser Shots</td>
<td>Total Returns</td>
</tr>
<tr>
<td>125 kHz, Wide</td>
<td>4,325,637</td>
<td>7,179,745</td>
</tr>
<tr>
<td>142 kHz, Wide</td>
<td>5,106,135</td>
<td>7,410,600</td>
</tr>
<tr>
<td>125 kHz, Narrow</td>
<td>4,405,288</td>
<td>6,503,826</td>
</tr>
</tbody>
</table>

10 shots/m² ≠ 10 shots/m²
Mission Planning 2

- Logistics:
  - Suitable, secure airport & support facilities
  - Locating GPS base stations
    - 100 km max baselines
  - Hotels, roads, phone, internet

- Permits:
  - US DOS – Export License for IMU
  - Foreign government permits (equivalent to the US FAA – Department of Interior)
  - Temporary import of equipment into country

PI Requirements - Caracol
Mission Planning – Caracol

Data Collection
Data Collection

What is Collected

- Up in the air:
  - IMU and GPS data
  - Discrete range data
  - Waveform data
  - Weather
- On the ground:
  - Lever arms
  - GPS base station data
  - Ground truth data
The goodies to be delivered

- Standard Deliverables:
  - Raw unclassified point cloud strips
  - Classified LAS tiles
  - ARCGIS 1 km x 1km tile grids
    - Bare Earth DEMs & First Surface DSMs
    - Bare Earth & First Surface Hillshades
  - Surfer Grids 1 km x 1km tile grids
    - Bare Earth & First Surface
  - ARCGIS or Surfer Mosaics
  - Project report

Processing Art/Science
GPS Trajectory

GPS reference stations:
- Coordinates through NGS OPUS tied to the international CORS network.

Airplane GPS:
- Differential trajectories derived using KARS software (Kinematic and Rapid Static) or POS GPS to each reference station.
- the solutions are differenced and compared for consistency
- individual solutions are combined using an unweighted averaging algorithm

IMU data:
- GPS and IMU data is blended into an INS through a Kalman filter yielding a Smoothed Best Estimate Trajectory (SBET)

Calibration

The objective is to account for sensors systematic errors so that observations for overlapping strips match:
- Errors in laser distance measurement
- Scanning mirror errors
- Errors in position (GPS)
- Errors in orientation (INS)
Raw point cloud generation

- The SBET, Range File (or waveform NDF) and the Calibration files are processed through DASHMAP
- The output are the raw point cloud files, usually:
  - ASPRS LAS format (Classified by Echo)
  - 1 File per strip
    - Due to planned overlap data from a given area will be contained in several strips.
    - Strips are too big for further processing

Raw LAS files per strip
Raw LAS files per strip

Breaking the project into tiles
Classification (Filtering)

- AKA Filtering, but this is not correct, because it is not about eliminating data
- ASPRS LAS Classes:
  - 1 Unclassified
  - 2 Ground
  - 3-5 Vegetation
  - 6 Building
  - ...
- Terrascan has several routines:
  - Low points
  - Isolated points
  - By echo, echo difference
  - By absolute elevation
  - **Ground**

Ground Classification

- Iterative process which builds a triangulated model and molds it upwards as long as it finds new points matching iteration parameters
  - Location becomes ground if the application finds a smooth route to the top
  - Location becomes ground if you can drive a bicycle onto it from a previously established ground point
Ground Classification

- Initial Logic: No building covers an area of given dimensions
- A grid is created using that maximum building dimension
  - Lowest point in any such grid cell is ground
Classification (Filtering)

All Points

Quasi Uniform Distribution

Non-uniform Distribution

Only Ground Points

Gridding

• Point clouds are irregularly spaced 3D datasets
  – Full information (6-40 returns/m²)
  – Hard to Manipulate
• Grids are regularly spaced 2.5D datasets
  – Easier to manipulate
  – Resampled info (1 or 4 pts/m²)
• Grids are displayed in a variety of ways
  – Shaded Relief Maps, Image Maps, Contours
• Creating a grid (out of the tiles)
  – Create equally spaced horizontal mesh (nodes)
  – Interpolate elevation for each node
    • Nearest neighbor, WID, TLI, Kriging
Interpolation Methods

- Kriging
- Inverse Distance to a Power
- Triangulation With Linear Interpolation
- Minimum Curvature

Grid Mosaics – Hillshade
Moving Beyond the DEMs
Limitations

• Mapping LiDAR is a spatial sampling technology – not full illumination
  – Random illumination of target
    • Resolution of an Image ≠ Resolution of DEM (Cell Size)

• There is uncertainty (accuracy/precision) in the measurements
  – GPS, attitude, ranging, footprint size
  – Mixed return signal
    – 20-50 cm horizontal, 5-15 cm vertical

• Not X-ray vision, line-of-sight, see thru gaps

• Return classification is probabilistic in nature
  – False positives, false negatives

• Hard to identify the point of diminishing returns