Introduction to LiDAR
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How do we get the Topography?
- Ground Survey
  - Leveling
  - Total Station
  - GPS
- Photogrammetric Compilation
  - Stereo Plotters
  - Softcopy Photogrammetry
- LiDAR – Light Detection And Ranging
  - Just another tool in the box to obtain topographic detail

What is LiDAR?
- Acronym for Light Detection And Ranging
- Basic laser ranging technology has been available for 20 years – eg. Distance measuring devices for surveying
- Can operate in the ultraviolet, visible or infrared regions of the electromagnetic spectrum
- Combines information from Physics, Engineering, Geodesy and GIS

LiDAR Basics
1. The position of the laser is provided by GPS
2. The orientation of the laser is provided by an IMU
3. The scan angles and ranges of the laser are provided by the sensor
   - 1+3+3 data combined in post-flight processing to accurately determine the position of each point
   - Acquires up to 200,000 points per second
   - 2-8 raw points every square metre is now common

Rotating Polygon Mirror
- Laser is directed at mirror
- Mirror rotates
- Pulses are spread out in a line perpendicular to the flight path
- Provides regular grid of points on the ground

LiDAR Flight Simulation
- Missions contain a series of parallel flight lines
- Adjacent flight lines overlap to avoid gaps
- Data from all flight lines are merged
- Merged raw data set is processed to generate desired deliverables
Why all the Hype?

- High resolution 3D surface
- “Point Cloud of Data”
- Millions of points per square km
- Fast & accurate
- Up to 100 square km per hour
- 5 cm accuracy possible on hard surfaces
- Cost effective
- Flexible collection
- Maps through canopy
- Independent of sun angle
- Day or night
- Diverse data products
  - Full-feature, Bare Earth
  - Contours, Building Footprints
  - Land Usage
  - Transportation/Utility Corridors etc.

Can LiDAR see Everything?

- Infrared lasers do not penetrate water
- Some surfaces are poor reflectors
  - Still water
  - Asphalt, coal and other dark materials
  - Wet surfaces or mud
  - Naturally dark or freshly turned soils
  - Surfaces at obtuse angle to incident laser pulse
- These targets are not invisible to infrared LiDAR, but are more difficult to detect
- Non-reflective targets are a limitation of optical physics, not the LiDAR instrument itself

Save the Key LiDAR Points

Cross Sections Anywhere

High Range LiDAR Systems

- 3 Optech 5100’s
- 2000 to 9000 feet collection altitude
- Large area surveys
**Helicopter LiDAR Systems**

- Portable/modular design
- Easy to install and operate
- Fly low and slow for high survey point density
- 2 to 20 pts per m²
- Higher accuracy than fixed winged systems
- Integrated with a digital camera and a digital video

**Low Range Systems**

- From ASTAR-350’s, Hughes 500’s, Robinson R44’s, Bell 206 Jet Rangers

**Mobile Ground Based**

**LiDAR Accuracy**

**System Comparison**

<table>
<thead>
<tr>
<th></th>
<th>High</th>
<th>Low</th>
<th>TITAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input platform</td>
<td>Fixed Wing</td>
<td>Helicopter</td>
<td>Vehicle</td>
</tr>
<tr>
<td>Operating Altitude</td>
<td>600m - 3000m</td>
<td>2 - 3000m</td>
<td>N/A</td>
</tr>
<tr>
<td>Vertical Agility</td>
<td>10 deg</td>
<td>10 deg</td>
<td>30 deg</td>
</tr>
<tr>
<td>swath width</td>
<td>69% of range</td>
<td>100% of range</td>
<td>Variab*</td>
</tr>
<tr>
<td>Returns per pulse</td>
<td>1 to 4</td>
<td>1 (No, No, alternating)</td>
<td>1 (No, No, alternating)</td>
</tr>
<tr>
<td>Interferable pulse</td>
<td>4</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Vertical Accuracy</td>
<td>15 - 30cm RMS</td>
<td>15 - 30cm RMS</td>
<td>15 - 30cm RMS</td>
</tr>
<tr>
<td>Horizontal Accuracy</td>
<td>15cm RMS</td>
<td>25cm RMS</td>
<td>25cm RMS</td>
</tr>
</tbody>
</table>

**How Do We Check?**

LiDAR with GPS Check Cross-sections 8 pts/m²
Accuracy: 300ft versus 450ft AGL

<table>
<thead>
<tr>
<th>Site</th>
<th>Sample Size</th>
<th>RMSE 300 ft AGL</th>
<th>RMSE 450 ft AGL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ditch</td>
<td>47</td>
<td>0.67</td>
<td>1.88</td>
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<tr>
<td>Edge of Pavement</td>
<td>68</td>
<td>1.10</td>
<td></td>
</tr>
<tr>
<td>Edge of Shoulder</td>
<td>45</td>
<td>1.27</td>
<td></td>
</tr>
<tr>
<td>Guard Rail</td>
<td>26</td>
<td>1.51</td>
<td></td>
</tr>
<tr>
<td>Property Line</td>
<td>36</td>
<td>1.95</td>
<td></td>
</tr>
<tr>
<td>Toe Slope</td>
<td>44</td>
<td>1.88</td>
<td></td>
</tr>
<tr>
<td>Sidewalk</td>
<td>36</td>
<td>1.83</td>
<td></td>
</tr>
</tbody>
</table>

LiDAR points vs. total station cross sections (data shows 450 ft AGL numbers)

LiDAR Filtering to Bare Earth

- Also referred to as Classification or Vegetation Removal
- Classification is the process whereby the laser points are filtered to obtain a DEM that represents the ground, and it allows for the extraction of above ground objects and features
- i.e. Trees, Buildings, Towers, Hydro Lines, Overpasses, etc. are separated from the bare earth points

QC and Editing

- Automated "devegging" software and routines used to remove non-ground points
- Manual QC of all tiles to remove other anomalies or non-ground points and to ensure valid ground points have not been removed
- More detailed QC against grounds checks to ensure overall accuracy

After the Automatic Classification

- Our experience shows that the process removes 99% of the non-ground, but it also erroneously removes ground features
- Manually identify the final 1% of erroneous classification points

All Points or Raw Data
Standard Deliverables

- Digital Elevation Model (DEM) / Digital Canopy Model (DCM)
  - Points at regular intervals showing ground or vegetation elevations
  - Can insert breaklines from LiDAR or photo
  - ASCII text, ArcView / ArcInfo grids, GeoTIFF, Surfer, etc...
- LiDAR points
  - ASCII text or LAS / TerraScan binary files, no interpolation / gridding, showing ground, non-ground or other classified LiDAR returns
- Keypoints
  - Intelligently thinned un-interpolated points with tolerances for both horizontal distance and vertical elevation change
- Contours
- LiDAR Hill-Shade imagery in GeoTIFF format

Products: X, Y, Z Points, Key Points

Products: All Points Hill-Shade

Products: Bare Earth Hill-Shade
Products: Raw Contours (25cm to 2m)

GeoTIFF format

Products: Orthophoto

GeoTIFF format

Custom Deliverables

- Feature Extraction
- 3D Visualisations
- Powerline Mapping and derivatives
- Erosion analysis
- Relative Flood Height Maps
- Projection / Datum Transformations
- Posters
- Vegetation Height Maps
- Point Density Maps
- Volume Calculations

Thank You