INTRODUCTION TO LIDAR

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(with content adapted from Ralph Hagerud; Ian Madin, DOGAMI; Jason Stoker, USGS; Tristan Goulden, NEON; Quantum Spatial)
LIGHT DETECTION AND RANGING (LIDAR)

• Accurate distance measurements with a laser rangefinder
• Distance is calculated by measuring the two-way travel time of a laser pulse.
• Near IR (1550nm) or green (532nm)

Modified from Ian Madin, DOGAMI
LIDAR PLATFORMS

J. Stoker,
USGS
Similar technology, different platforms:

Terrestrial Laser Scanning (TLS)

- Also called ground based lidar or T-lidar.

Laser scanning moving ground based platform = Mobile Laser Scanning (MLS).

Laser scanning from airborne platform = Airborne Laser Scanning (ALS).
<table>
<thead>
<tr>
<th>System:</th>
<th>Spaceborne (e.g. GLAS)</th>
<th>High Altitude (e.g. LVIS)</th>
<th>Airborne (ALS)</th>
<th>Terrestrial (TLS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Altitude:</td>
<td>600 km</td>
<td>10 km</td>
<td>1 km</td>
<td>1 m</td>
</tr>
<tr>
<td>Footprint:</td>
<td>60 m</td>
<td>15 m</td>
<td>25 cm</td>
<td>1–10 cm</td>
</tr>
<tr>
<td>Vertical Accuracy</td>
<td>15cm to 10m depends on slope</td>
<td>50/100 cm bare ground/vegetation</td>
<td>20 cm</td>
<td>1–10 cm Depends on range, which is few meters to 2 km or more</td>
</tr>
</tbody>
</table>
How is range measured?

**Time of flight**

Time it takes for emitted pulse to reflect off object and return to scanner.

\[
\text{Distance} = \frac{\text{Speed of Light} \times \text{Time of Flight}}{2}
\]

**Phase Shift**

Distance is calculated along a sinusoidally modulated laser pulse.

\[
\text{Time of Flight} = \frac{\text{Phase Shift}}{2\pi \times \text{Modulation Frequency}}
\]
LIDAR & AUTONOMOUS VEHICLES
LIDAR & AUTONOMOUS VEHICLES

Sight Lines, ScanLAB: https://vimeo.com/145248208
LIDAR DATA COLLECTION

Ian Madin, DOGAMI
LIDAR DATA COLLECTION

1. Laser scanner
2. Inertial Measurement Unit (IMU)
3. GPS

Laser

Direction of Flight

GPS Reference Base Station

Laser Pulse

Scan Line

Laser Spot Size

15 - 20 cm
Scan line spacing, swath width, spot size and overlap can all be defined as necessary to achieve target data to specification.
**Typical Lidar Data Collection Parameters**

- **Aircraft:** Cessna 337 Skymaster
  - One pilot, one operator in plane
  - GPS ground crew (2 to 10+ people)

- **Scanner:** Optech near-IR

- **PRF:** 33-900 KHz

- **Pulse width:** 10 ns

- **Flying:** 600 – 1,000m AGL, 120mph

- **Swath overlap:** 50% nominal

- **Ground truthing:** GPS (campaign & CORS)

- **Pulse spacing:** sub-meter

**Nominal Accuracy (on open hard and flat surface):**

- Vertical: 3 – 6 cm.
- Horizontal: 20 – 30 cm.
Discrete pulse = binary yes or no return. Only location of return is saved.

Full waveform = digitized backscatter waveform. Saves the full return energy signature.

Data size / processing time vs. enhanced information.

T. Goulden, NEON
DISCRETE PULSE AND FULL WAVEFORM LIDAR
Left = point cloud view of the tree in the photo on the right. Each point is colored by which return it was from a particular pulse:

- Red = 1\textsuperscript{st}
- Yellow = 2\textsuperscript{nd}
- Green = 3\textsuperscript{rd}
Lidar Data Quality

Not all lidar is created equal – huge range in quality, resolution, accuracy of data publicly available.

Typical metric is pulse density / shot ("post") spacing:
- Describes sampling density of data and potential grid resolution.
- Shot density highly heterogeneous.
- Ground point density typically far lower than total pulse density.

Evaluate lidar data quality by:
- Testing against ground control
- Looking at big images
- Quantifying swath to swath reproducibility

Read the metadata & survey report

Modified from R. Hagerud, USGS
Lidar data collection

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Laser Spot Size
15 - 20 cm
Lidar Data Error Sources

Two major sources of uncertainty

• Geolocation (GPS, INS, ranging) uncertainty
• Processing uncertainty

Vegetation and terrain conditions affect uncertainty

Error budget = 

+/- 5 to 15 cm (vertical)
In the PNW:
14% of points classified as ground

Minimum LiDAR Considerations in the Pacific Northwest
Watershed Sciences, Inc.
Heterogeneity of surface sampling: B4 shot density maps and profiles
LIDAR ARTIFACTS

“Seam line” between swaths where the corduroy artifacts will not line up due to Vertical Swath Offset.

Red Arrows – features attributed to artifacts  Green Arrows – “natural” features (aligned drainages, scarplets)

Ante Perez, CGS
Figure 7a. LiDAR artifact (arrows) in the Yucaipa study area. The artifact appears as a linear highlight suggestive of an east-facing scarp. However, the evident “corduroy” texture on one side versus the other alerts one to the likelihood that this is an artifact. Indeed, it corresponds to the overlap margin between LiDAR swaths.

Treiman, Perez, & Bryant, 2010, USGS Award No. 08HQGR0096 Final Tech. Report
Lidar data deliverables

Classified point cloud
- Ground, vegetation, buildings, water, blunders etc.
- Intensity, return number & number of returns, GPS time, RGB…
- Tiled or swath LAS/LAZ

Raster data derivatives
- DTM ("bare earth"), DSM ("highest hit")
- Hillshades of DTM, DSM; intensity; RGB
- Tiled GeoTIFF, IMG, Arc Binary

Metadata & survey report
LIDAR DATA DELIVERABLES

A **point cloud** is the fundamental lidar dataset – discrete x,y,z points with attributes (Intensity, return number & number of returns, classification, gps time, RGB...):
LIDAR DATA DELIVERABLES

National Geospatial Program
Lidar Base Specification

Chapter 4 of
Section B, U.S. Geological Survey Standards
Book 11, Collection and Delineation of Spatial Data

Techniques and Methods 11-B4
Version 1.0, August 2012
Version 1.1, October 2014
Version 1.2, November 2014

U.S. Department of the Interior
U.S. Geological Survey

J. Stoker, USGS

LPC and Breaklines

Hydro enforced DEM
THANKS!
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