Earth Science Lidar Topography Applications

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Featuring work from colleagues:
J Ramón Arrowsmith (ASU); David Phillips (UNAVCO); Mike Oskin (UC Davis), Kurt Frankel (GA Tech)
Introduction:

- Landscape development a combination of many processes:
  - Tectonic
  - Hillslope
  - Fluvial
  - Biologic
  - Anthropogenic

- High-resolution representation of landscape is central to qualitative and quantitative study of process.

- Aerial photography traditional tool for geomorphic studies

- 2D representation

- Qualitative tool

*Crosby, 2006*
Introduction:

- Digital topography provides 2.5D representation of landscape.
- Widely avail. digital topography (digital elevation models - DEMs) are too coarse to provide representation of small geomorphic features / process.
- USGS 30 m DEM = best available national coverage.

*Crosby, 2006*
Introduction:

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- USGS 10 m DEM

Crosby, 2006
Introduction:

• LiDAR / ALSM data

• DEMs at resolutions not previously possible.
  – sub-meter resolution
  – Measure features at the appropriate scale

• Applicable to:
  – Geomorphology
  – Landslide & flood hazards
  – Forestry/Ecology
  – Civil Engineering
  – Urban planning
  – Volcanology

• One of the hottest tools in the Geosciences
3D visualization: DEM + air photo fusion

Crosby, 2006
Airborne Lidar 101

**lidar** = **light detection and ranging** *(aka airborne laser swath mapping)*

- **collected at 10s to 100s of kHz**
- **Vertical accuracy** ~15 cm
- **Beam diameter** 15-20 cm

- **10⁶ to 10⁹ measurements of ground, vegetation, structures**
  - *Point cloud* (*x*,*y*,*z* coordinates) = fundamental lidar data product
- **Earth’s surface > 8 times per meter²**

*Ian Madin DOGAMI*

*Crosby, 2010*
Airborne Laser Swath Mapping (ALSM)

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

-Phillips, UNAVCO
Airborne Lidar Workflow

1. Acquire
   - Laser
   - GPS
   - IMU

2. Process
   - point cloud

3. Classify
   - filter

4. Grid
   - First return
   - Bare earth

5. Generate Derivatives

Crosby, 2010
LiDAR “point cloud”

- $x,y,z$ + attributes
- Filtering algorithms allow classification by return type:
  - Ground, vegetation, building …
Comparisons of Techniques for measuring surfaces and detecting changes in surfaces*

<table>
<thead>
<tr>
<th></th>
<th>GPS</th>
<th>InSAR</th>
<th>ALSM</th>
<th>TLS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample Density</td>
<td>1 site/10 km²</td>
<td>10,000 pixels/km²</td>
<td>1- &gt;14 hits/ m²</td>
<td>1000 hits/ m²</td>
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<tr>
<td>Position Precision</td>
<td>1-20 mm</td>
<td>2-3 m</td>
<td>5-15 cm</td>
<td>0.6-5 cm</td>
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<tr>
<td>Change Detection</td>
<td>1 mm</td>
<td>1-2 cm</td>
<td>10 cm</td>
<td>1 cm</td>
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<tr>
<td>Scale</td>
<td>Global</td>
<td>100 km</td>
<td>10-100 Km</td>
<td>1 km</td>
</tr>
</tbody>
</table>

* Ball park numbers for typical applications

-Phillips, Meertens, and Jackson, UNAVCO
Post earthquake laser scanning and repetition (B4, Hector Mine, Denali)
Post El Mayor-Cucupah EQ Scan

- Oskin, Arrowsmith, Hinojosa, Fletcher (NSF Rapid + SCEC); collected by NCALM
Change Detection with LiDAR Data

- vertical different pre- and post-El Mayor- Cucupah earthquake
- subtract 5 m pre-earthquake INGEGI DEM from 5 m post-earthquake DEM

Arrowsmith, Oskin, Fletcher, Hudnut, in submitted
Red Wall Canyon Offset

- total displacement = 297 ± 9 meters

Frankel et al., 2007, JGR - Solid Earth
Objective Mapping with Roughness

- surficial geologic map
- surface roughness map
- bare-earth DEM (1 m)

Frankel and Dolan, 2007, *JGR - Earth Surface*
Elevation change at Mt St Helens, September 2003 to October 4-5, 2004

Ralph Haugerud (USGS), David Harding (NASA), Vivian Queija (USGS), Linda Mark (USGS)

Port-au-Prince waterfront produced from lidar point cloud data.

Crosby, SDSC
Measuring Landscape Characteristics at the Appropriate Scale

USGS NED 10 m per pixel DEM

B4 LiDAR topography 1 m DEM

meter-scale features

Arrowsmith, ASU
Questions & Comments:

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