Point Cloud to Raster
LAStools to ArcGIS

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Tutorial notes
Applications of High Resolution Topography to Geologic Hazards in Utah
September, 2017, Salt Lake City, Utah
Find Topography Data

Instructions

Data Sources
- OpenTopography
- Community Contributed
- US Interagency Elevation Inventory

Map | Satellite
--|---
Terrain

SELECT REGION

High Resolution Data

1. State of Utah Acquired LiDAR Data - Wasatch Front

Global Data

Raster Data | Point Cloud Data
1a. Select area of data to download or process

State of Utah Acquired Lidar Data - Wasatch Front

1. Coordinates & Classification

Horizontal Coordinates: UTM Zone 12N, NAD83 (2011) [EPSG: 26912]
Vertical Coordinates: NAVD88 (GEOID12A) [EPSG: 5703]

Data Selection Coordinates:

- Manually enter selection coordinates (in the horizontal coordinate system listed above)

\[ X_{\text{min}} = 414200.283785 \quad Y_{\text{min}} = 4580776.748503 \]
\[ X_{\text{max}} = 414794.803033 \quad Y_{\text{max}} = 4581560.7875 \]

The selection area contains approximately 15,254,000 points.

Choose Return Classification

- Ground
- Unclassified

2. Point Cloud Data Download

- Point cloud data in LAS format
- \( \square \) Point cloud data in LAZ format
- Point cloud data in ASCII format

For now, don’t select anything else

3A. DEM Generation (Streaming TIN)

- Gridding Method
- Calculate TIN
  - Unselect

Job Description

These options allow users to describe and keep track of their jobs. Information entered below is archive accessed via myOpenTopo (available only to registered OpenTopography users).

- Job title (up to 100 characters)
- Job description (up to 500 characters)
- Enter your e-mail address
  - For notification upon completion of processing
  - ramon.arrowsmith@asu.edu

Submit
Point Cloud Job Report

Modify and resubmit this job
Full job metadata report

Job Id | Dataset       | Title                                | Submission         | Completion        | Duration | Num points | Final Status
------|---------------|--------------------------------------|--------------------|-------------------|----------|------------|-------------
pc1505615743550 | UGS_Wasatch | UGS Pearson's Canyon demo | 2017-09-16 19:35:44 | 2017-09-16 19:36:04 | 20 secs | 14,014,140 | Done ✓

Download Job Results

- Point Cloud Results
- Download point cloud data in LAZ format: points.laz (63.3 MB)

Rename it so you can remember

Share These Job Results
LAStools

• Open source and commercial tools for processing and analyzing lidar point cloud data in LAS/LAZ format
• https://rapidlasso.com/lastools/
• Native GUI, command line, ArcGIS, QGIS & ERDAS Imagine toolboxes.
Space bar to change mouse mode

Right click color by... rgb

Right click color by... classification

Right click triangulate

Right click render only... ground
ASPRS LAS(er) Format

- Binary public format for exchange of 3D point cloud data. Owned & maintained by ASPRS.

- .LAZ = LASzip – open source library for lossless compression of LAS lidar data. Developed by Martin Isenburg of LAStools.
Overview
Starting with an LAS/LAZ file, let’s explore the contents of the file, do some manipulation and filtering, and then maybe reproject the file. Next we’ll make elevation and other rasters using Lastools and visualize and examine them in Google Earth and ArcGIS.

Outline
1. LASinfo to see what’s in the file (attributes etc)
2. LAS2txt to look at contents in human readable form
3. LASboundary to make an outline of the file and plot it on a map
4. LASground to classify ground vs vegetation points
5. LAS2LAS for filtering on attributes and reprojection
6. Lasgrid point density
7. Lecture burst on generating DEMs from points
8. Neighborhood approach for DSM and DTM (Lasgrid DEM)
9. Tinning approach with tiling for DSM and DRM (lastile and blast2dem)
10. ArcGIS DEM visualization, manipulation, and simple raster math
LASinfo – reports contents of LAS file

Run button is down here
--collapse the upper choices
LASinfo – reports contents of LAS file

Header summary

Georeferencing information

Summary of file contents - Min/max & histogram – from scan of file
LAS2TXT – points in ascii

LAS version: 1.2
source ID: 0 created: 258/2017
'LAStools (c) by rapidlasso GmbH'
'las2las (version 140403) + OT'
# of points: 14011410
point type: 3 point size: 34
...
LAS2TXT – points in ascii

414248.13,4580776.87,1363.64,134,1,1,1,5,0,6165,67454341.779927,22528,23
414248.04,4580776.97,1363.51,148,1,1,1,5,0,6165,67454341.782320,23040,23
414246.79,4580776.96,1363.12,192,1,1,1,5,0,6165,67454341.800585,27904,28
414247.00,4580777.40,1363.19,185,1,1,1,5,0,6165,67454341.800597,29184,29
414246.90,4580777.54,1363.31,162,1,1,1,5,0,6165,67454341.803013,27904,29
414246.68,4580777.08,1363.20,170,1,1,1,5,0,6165,67454341.803025,31488,32
414245.40,4580776.88,1363.18,199,1,1,1,5,0,6165,67454341.821231,29696,29
414245.62,4580777.35,1363.11,221,1,1,2,5,0,6165,67454341.821243,33024,33
414245.84,4580777.80,1363.14,230,1,1,2,5,0,6165,67454341.821255,31488,31
414246.05,4580778.24,1363.22,205,1,1,1,5,0,6165,67454341.821266,33792,33
414245.98,4580778.42,1363.16,233,1,1,2,5,0,6165,67454341.823683,35072,34
414245.74,4580777.94,1363.15,236,1,1,1,5,0,6165,67454341.823695,31488,30
414245.51,4580777.45,1363.18,231,1,1,1,5,0,6165,67454341.823707,32512,32
414245.27,4580776.96,1363.20,206,1,1,1,5,0,6165,67454341.823718,28416,28
414244.14,4580777.17,1363.16,235,1,1,1,5,0,6165,67454341.841924,26624,24
414244.36,4580777.63,1363.17,202,1,1,2,5,0,6165,67454341.841936,27904,26
414244.58,4580778.09,1363.19,236,1,1,1,5,0,6165,67454341.841948,28672,27
414244.80,4580778.53,1363.25,213,1,1,1,5,0,6165,67454341.841960,28928,27
414245.01,4580778.98,1363.24,236,1,1,1,5,0,6165,67454341.841971,29440,27
414245.23,4580779.44,1363.22,237,1,1,1,5,0,6165,67454341.841983,29184,27
414244.97,4580779.17,1363.20,237,1,1,1,5,0,6165,67454341.844376,28672,27
414244.73,4580778.69,1363.22,215,1,1,1,5,0,6165,67454341.844388,29184,27
LASboundary – generate outline of point data

Filter to use fraction (25%) of points = faster!

Larger the value, the less detailed the outline

Output format

concavity: 100

output: kml
LAS2LAS – filtering, clipping, coordinate transformation

Lots of options for filtering (attribute, coordinates, other...). Can also transform coordinates & rescale values.

Reprojection: set a target. File MUST have CRS set in header to define new output CRS. If not set, use “projection” option at left to define input projection.

```
las2las -i "C:\geospatial\D17_SJER_AOI_points.laz" -keep_classification 2 -target_sp83 CA_IV -olaz
```
Lecture burst:
Point cloud classification
Lidar ground classification

…simplified…

Three assumptions:

1. Ground is smooth
   – Assumption: high curvature is not a point on the ground

2. Ground is continuous (single-valued)

3. Ground is lowest surface in vicinity

Modified from: R. Hagerud, USGS
Start with mixed ground and canopy returns (e.g. last-return data), build TIN
Flag points that define spikes
(strong convexities)
Rebuild TIN
Flag points that define spikes (strong convexities)
Rebuild TIN

R. Hagerud, USGS
Flag points that define spikes (strong convexities)
Rebuild TIN
Despike algorithm

Benefits:

• It works

• It’s automatic
  – Cheap
  – All assumptions explicit

• It can preserve breaklines

• It appears to retain more ground points than other algorithms

R. Hagerud, USGS
Despike algorithm

Problems:
• Removes some corners
• Sensitive to negative blunders
• Computationally intensive
• Makes rough surfaces

Cross-section of highway cut

R. Hagerud, USGS
Point cloud classification

- LASTools LASground
- Other software:
  - Terrascan
  - QT Modeler
  - ENVI lidar
  - Global Mapper
  - MCClidar
  - CANUPO (CloudCompare)
- Still an area of active research
- Based on algorithm in Axellson (2000)*, with some modifications

*Modified from T. Goulden, NEON
LASground – identify bare-earth (ground) points

Input: Unclassified point cloud file

Ground classification settings: Output filename, landcover type, processing level
LASground – identify bare-earth (ground) points

Reclassified point cloud

Original point cloud classification

After point cloud (re)classification
point density

lasgrid - rasters huge LiDAR collections into elevation/intensity/density/... grids

wildcard: *.laz
directory: E:

LAS version: 1.2
source ID: 0 created: 25/08/2017
LASTools (c) by rapidlasso GmbH
las2las (version 140403) + OT
# of points: 14014140
point type: 3 point size: 34

pixel/step size: 1
fill n pixels: 0

1m²

LAS version: 1.2
source ID: 0 created: 25/08/2017
LASTools (c) by rapidlasso GmbH
las2las (version 140403) + OT
# of points: 14014140
point type: 3 point size: 34
Load .tif into ArcMap, change color map, use 3D Analyst to profile density.

Slash of no data is telling us that we have exceeded the license limit.
Digital Elevation Models

- Digital representation of topography / terrain
  - “Raster” format – a grid of squares or “pixels”
  - Continuous surface where Z (elevation) is estimated on a regular X,Y grid
  - “2.5D”

- Grid resolution is defined by the size in the horizontal dimension of the pixel
  - 1 meter DEM has pixels 1 m x 1m assigned a single elevation value.

Source: http://www.ncgia.ucsb.edu/giscc/extra/e001/e001.html
• 1 meter grid

• LiDAR returns from EarthScope data collection

• Example from flat area with little or no vegetation so ground is sampled approx. 5+ times per square meter

• How do we best fit a continuous surface to these points?

• Ultimately wish to represent irregularly sampled data on a regularized grid.
Generating DEMs from LIDAR

- LIDAR points
- triangulating
- temporary TIN
- resampling
- interpolating
- raster DEM

Isenburg, et al., 2006
Interpolation Methods

- Inverse Distance Weighting (IDW)
- Natural Neighbors
- Kriging
- Splines
- TIN
  - linear
  - quintic
- ...

Isenburg, et al., 2006
DEM Generation via TIN Streaming

- Read points from disk
- Streaming Computation of Delaunay Triangulation
- Immediate Rasterization of Streaming TIN
- Store elevation rasters to temporary files (grouped by rows)
- Small buffer in main memory
- Output final DEM to disk

Isenburg, et al., 2006
Example Result

500,141,313 Points
11 GB
(binary, xyz, doubles)

50,394 × 30,500 DEM
3 GB
(binary, BIL, 16 bit, 20 ft)

- on a household laptop with two harddisks
- in 67 minutes
- 64 MB of main memory
- 270 MB temporary disk space

Isenburg, et al., 2006
Measure fault slip at the appropriate scale
B4 LiDAR topography 0.25 m DEM

of the DEM. A common method for determining the cell size of a
DEM has been defined by Hu (2003). The grid size of a DEM can be
estimated by:

\[ s = \sqrt{\frac{A}{n}} \quad \text{Sqrt}(1\text{m}^2/4) = 0.5 \text{ m/pix} \quad (1) \]

where \( s \) is the estimated cell size (typically in m), \( n \) is the number of
sample points and \( A \) is the area containing the sample points. The

Mean ~4 shots/sq. m
LASGRID is a neighborhood approach for DEM computation.

Digital surface model—all points

`lasgrid -i "C:\Users\ramon\Google Drive\+S_Active_Items\2017UGS_OT\PearsonDemopoints.laz" -elevation -average -odix "_DSM" -otif`
Open lasgrid produced 1 m pixel Digital Surface Model and compute hillshade using Spatial Analyst toolbox.
LASGRID is a neighborhood approach for DEM computation.

Digital terrain model—ground points

```
lasgrid -i "C:\Users\ramon\Google Drive\+S_Active_Items\2017UGS_OT\PearsonDemopoints.laz" -keep_classification 2 -elevation -average -odix "_DTM" -otif
```

Under filter, select — keep_classification and number or value 2; ADD
Open lasgrid produced 1 m pixel Digital Terrain Model and view as hillshade. No ground returns under the trees!
BLAST2DEM is TIN approach for DEM computation

Digital surface model—all points (13.4M)

blast2dem -i "C:\Users\ramon\Google Drive\+S_Active_Items\2017UGS_OT\PearsonDemopoints.laz" -elevation -odix "blastDSM" -otif
Looks good but what is that white slash? We exceeded the unlicensed limit for blast2dem of 5M points!
We need to tile the data – be sure to make a folder to capture the tiles

```
lastile -i "C:\Users\ramon\Google Drive\+S_Active_Items\2017UGS_OT\PearsonDemopoints.laz" -o "tile.laz" -tile_size 250 -buffer 10 -faf -cores 3 -odir "C:\Users\ramon\Google Drive\+S_Active_Items\2017UGS_OT\250m_tiles" -olaz
```
Now let’s blast again

blast2dem -lof file_list.8852.txt -cores 3 -elevation -odir "C:\Users\ramon\Google Drive\+S_Active_Items\2017UGS_OT\250m_DSM" -otif
Mosaic the tiles (with their buffers) into a seamless DSM in ArcGIS

Arctoolbox

Load all the tiles with a shift-select

These do matter
Visualize the seamless DSM in ArcGIS as a hillshade
Under filter, select –keep_classification and number or value 2; ADD

blast2dem -lof file_list.3140.txt -cores 3 -keep_classification 2 -elevation -odir "C:\Users\ramon\Google Drive\+S_Active_Items\2017UGS_OT\250m_DTMv2" -otif

Now let's blast again
Visualize the seamless DTM in ArcGIS as a hillshade

(mosaic as we did for the DSM)
DEMs in ArcMap and ArcScene

Basic visualization and colorization
Point and profile measurements
**Raster Math (difference and conditional)**
  - Canopy
3D viewing in ArcScene
Note that is the beginning of other sorts of topographic differencing e.g., Morphological sediment budgeting

http://www.joewheaton.org/
Simple Canopy Height Map
Con: Performs a conditional if/else evaluation on each of the input cells of an input raster. Really powerful!!!
ArcScene Properties tabs:
Symbology—change colormap

Rendering
Shade areal features
High quality enhancement

Visualize it all in ArcScene

1 m cell size
ArcScene Properties tabs:
  Symbology—change colormap

Visualize it all in ArcScene

Drape it on the DSM

Rendering
  Shade areal features
  High quality enhancement

1 m cell size