Feature Extraction from KYAPED LiDAR Point Clouds: Challenges and Opportunities

D. Scott Stepro, GISP
Demetrio P. Zourarakis, Ph.D., GISP, CMS, CGP-G

Kentucky Division of Geographic Information
Office of Application Development
Commonwealth Office of Technology

LEVEL UP
In Louisville
KAMP 2017
GIS Conference

Sept. 5-7, 2017
Extracting Building Footprints From Unclassified LiDAR Elevation models or Reclassification?

D. Scott Stepro, GISP
Kentucky Division of Geographic Information (DGI)
Scott.Stepro@ky.gov
Approach and Method

• esri’s*“3D Mapping with Lidar Point Clouds“ in an ArcPro 2.0 environment

  • as presented during Esri’s 2017 Imaging and Mapping Forum. Extracts outlines from unclassified LiDAR using surface and terrain models.

• LP360 LiDAR (Qcoherent) processing software in an ArcGIS 10.5 environment.

  • LP360 searches for points that fit user defined planes and classifies those points to a specified class. Outlines are then extracted from the newly reclassified LiDAR.

*http://esriurl.com/3DMappingWithLidar
Methodology – Raster Extraction

• *esri’s ArcPRO tool* “3D Mapping with Lidar Point Clouds”
Esri’s Terrain Modeling (continued)

Above ground features

Bare Earth
Esri’s Terrain Modeling (continued)

Composite Normalized DSM
Normalized DEM (anything taller than 10’)

Esri’s Terrain Modeling (continued)
Esri’s Terrain Modeling (continued)

Rough Buildings Extracted from Normalized DSM
Esri’s Terrain Modeling (continued)

Rough Building Footprints Regularized (squared)
Methodology – Reclassifying with LP360

LP360 (Qcoherent)
LP360 Reclassification Variables (continued) – Source and Return Combinations

- Use Height Filter
  - Minimum Height: 0
  - Maximum Height: 95

- Destination Class:
  - Units: Feet

- Min. Plane Edge: 10,0000
- Maximum Grow Window Area: 5000
- N Threshold: 0.4000
- Plane Fit: 0.2000
- Min Slope (Deg): 0
- Max Slope (Deg): 45

- Clean-Up Percent (0 to 100%)

- Point Filter
  - Intensity
  - Flags
  - Point Source IDs
  - Scan Angle

- Return Combinations
  - All Returns
  - 1 Return
  - 2 Returns
  - 3 Returns
  - 4 Returns

- Elevation Range
**Minimum Height**
Lowest vertical distance from ground considered. Using a Height Filter during the execution of the planar filter uses the minimum and maximum object height parameters to eliminate points above a ground surface from consideration.

**Maximum Height**
Maximum vertical distance from ground considered. Using a Height Filter during the execution of the planar filter uses the minimum and maximum object height parameters to eliminate points above a ground surface from consideration.

**Destination Class**
Defines the class value that points are set to when the points fit a defined plane.
LP360 Reclassification variables (continued) – Point inclusion/exclusion

Minimum Plane Edge
The Min. Plane Length value is best input as the maximum point spacing or ground sample distance found in point cloud data. This distance is used to construct a moving window where the moving window will have a length and width of twice the Min. Plane Length value.

Maximum Grow Window Area
The *maximum grow window area parameter is used as a limit to the surface growing. When the area of the grow window exceeds this value, it is terminated but points are still classified.
*Increasing the maximum grow window area results in more points being classified.
*Decreasing the maximum grow window increases the possibility certain portions of the building might be missed.

Modify Z threshold
The Z threshold parameter represents the maximum orthogonal distance to the plane under consideration required for a point to be classified. If the plane is a good fit, based on the plane fit parameter, new points are added to the plane during the surface growing if the points are less than the Z threshold value.
*Increasing the Z threshold area results in more points being classified.
*Decreasing the Z threshold increases the possibility certain portions of the building might be missed.

Plane Fit
The plane fit value represents the variance of the residuals of the fitted plane. This value is used to determine if the fitted plane is a good fit where planes with values above the plane fit value would not be classified. The plane fit value is linear and the default value for this parameter is appropriate for most cases.
*Increasing the Plane Fit results in more points being classified.
*Decreasing the Plane Fit increases the possibility certain portions of the building might be missed.
**Minimum Object Slope**
The minimum object slope is in degrees. Planes with slopes less than the value will not be classified.
*Increasing the Minimum Object Slope area results in more points being classified.*
*Decreasing the Minimum Object Slope increases the possibility certain portions of the building might be missed.*

**Maximum Object Slope**
The maximum object slope is in degrees. Planes with slopes greater than the value will not be classified.
*Increasing the Maximum Object Slope threshold area results in more points being classified.*
*Decreasing the Maximum Object Slope increases the possibility certain portions of the building might be missed.*

**Clean up percentage**
This is used to clean up missed points. For a planar filter locating buildings, these missed points are typically some roof feature, such as, a vent or points that hit the building side or the edge. A value of 0 will not perform any cleanup and a value of 100 will perform a maximum amount of cleanup.
*Increasing the Clean up percentage results in more points being classified.*
*Decreasing the Clean up percentage increases the possibility certain portions of the building might be missed.*
LP360 Reclassification Variables (continued) – Preview Results
LP360 Extraction variables – Building Outlines

**Boundary Trace Class**
The Boundary Trace Classification defines the set of points that the outlines will be drawn around. If no points exist on that class, no outlines will be produced.

**Units**
The unit of measure for all applicable parameters for the point group tracing and squaring task. Note: the parameter values for the task do not have to match the units of the point cloud data.

**Grow Window**
A moving window size used to group points based on the Boundary Trace Class. The moving window will be a square with length and width twice the value. This moving window is fit around an initial point and a surface growing process occurs grouping points with the same classification and within a distance specified by grow window parameters.

*Increasing the grow window value above the point spacing could result in grouping adjacent objects into single objects*

*Decreasing the grow window value below the maximum point spacing could result in splitting of a single object into multiple objects (e.g., a single building into more than one building). There is a trade-off between grouping adjacent objects into one object and splitting one object into multiple objects that is a function of the point density of the point cloud data.*

**Trace Window**
parameter is the moving window size used to trace a grouped set of points. This parameter is also dependent on the ground sample distance. Typically, the value would not be less than the ground sample distance and the value set for the Grow Window parameter. Also, the type of objects would affect this parameter where objects with a lot of nooks and crannies might require a smaller value

* Increasing the trace window value above the maximum point spacing will generally result in more objects being traced and squared. In addition, the traced and squared objects will tend to be somewhat smoother the larger the value. Additionally, increasing the trace window value will result in losing some of the nooks and crannies that might be present in a particular object
Minimum Area:
The Minimum Object Area parameter allows you to filter small objects from the extracted output. Traced outlines with areas smaller than the minimum object area are not included in the extracted file.

Reclassify Minimum Points:
Point groups that are too small to trace outlines around are defined as groups of three or less point counts. As these point groups are encountered, the task will reclassify those points onto a specified classification.

Perform Squaring:
When extracting appropriate objects such as buildings, the traced outlines may be squared using an orthogonal squaring algorithm. The extent of the squaring is determined by the squaring angle.

Squaring Angle:
The squaring angle parameter represents the angle between traced boundary edges (i.e., point to point) where boundary edges with angles less than the value will be merged into a single edge. Thresholds between thirty and forty-five degrees appear to work well with the default value of 30 seeming to be most appropriate for point cloud data.
LP360 Extraction Variables (continued) – Preview Results
Misclassification – LP360
Unclassified as Ground

Sept. 6, 2017 - S. Stepro – D. Zourarakis
Misclassification (Continued) – LP360

Before Reclassification
Misclassification (Continued) – LP360

After Reclassification
Misclassification (Continued) – LP360

Building Outlines Extracted after Reclassification
Misclassification (Continued) – Raster Extraction

Building Outline extracted from DSM
Common Building Extraction Result

Building with Open spaces/Complex Geometry
Common Building Extraction Result (Continued)

Structures without angles (Silo) and Artifacts
Common Building Extraction Result (Continued)

Vegetation or structure? Missing Structures?
LP360 Specific Building Extraction Result

Angles +/- 90° and Dark rooftops
LP360 Specific Building Extraction Result (Continued)

Height and Grow/Trace Filters
Conclusion – That’s fascinating but....

Which do I use??
Extraction from Raster - The Pro’s…

• *Esri’s zlas compression increases performance within ArcPRO*

• **Powerful Building Extraction tools are now available as a downloadable add-on (esri)**

• **LAS Dataset indifferent to differences in LAS version (e.g. 1.2, 1.4) or projection.**

• **Picks up unusually shaped/angled structures.**

• **Tends to pick up less vegetation/artifacts.**

• **Maintains the native point classification.**

• **Can be accomplished out of the box in ArcMap without Esri add-on.**
Extraction from Raster - The Con’s...

• *Requires advanced ArcGIS as well as Spatial and 3d Analyst. Add-in toolset must be run in 64-bit ArcPro.
  • Without Add-in raster extraction is a multi-step, time consuming process using out of the box ArcGIS

• Limited parameter changes available (e.g., Elevation range, Plane Edge, Grow Window, roof slope, clean up % etc.). Editing the original model is cumbersome and not recommended.

• No online support available for ESRI tools.

• Raster’s with or without tool creates big data and require significant space and resources.

• WYSIWYG. Quality of both the input and output can be suspect. Classification of points and extraction variable settings set the initial quality of the extraction.

• No process is full proof; post extraction clean-up is inevitable!!
Point Reclassification... The Pro’s

- Building filter/extraction an out of the box tool in LP360.

- Able to tweak parameters to filter/preview output prior to run (e.g., Elevation range, Plane Edge, Grow Window, roof slope, clean up % etc.).

- Parameter modifications can be exported and used in other projects.

- Option to simultaneously reclassify point areas to another class (e.g., vegetation) if smaller than minimum area specified in the filter.

- DSM/DTM raster's not necessary to produce building outline.

- Tends to pick up more structures compared to raster extraction.

- Software is available as an extension to ArcGIS (32bit) or stand alone (64bit).
Point Reclassification... The Con’s

• Requires advanced LP360.

• Point cloud classifications are permanently changed. LAS file must be duplicated to maintain delivered condition.

• LP360 makes distinction between LAS version and projections. Point Clouds written in different versions (e.g., 1.2 and 1.4) or in different coordinate systems are split into two datasets. Thus requiring filtering/extraction on TWO datasets in instead of one.

• WYSIWYG. Quality of both the input and output can be suspect. Classification of points and extraction variable settings set the initial quality of the extraction.

• Tends to pick up more vegetation/artifacts than Raster Extraction.

• No process is full proof; post extraction clean-up is inevitable!!
Conclusion

• Best single method approach to accurate building outline extraction is to correct classifications in profile view after automated reclassification. X and Y location of a point may suggest it’s on a roof plane however the truth is in the profile. You must verify X, Y AND Z location before reclassifying. THIS however it is often price prohibitive as it’s a time consuming and therefore expensive process.

• Both methods have equal merit and a “tag team” approach is best if possible. Buildings extracted from both methods blended together based on heads-up observation achieve the “second” best result.

• No process is full proof; post extraction clean-up is inevitable!! When obscured by vegetation neither method can easily differentiate between vegetation and structures and overlap will occur. Error instances noted previously in presentation will happened and will be widespread.

• Can use NDVI polygons extracted from Raster and working with esri to create appropriate methodology. Esri is considering incorporating this functionality in the future.
NOTE!! DGI is looking for county support during clean up processes. If interested, please see me after the session for questions or contact me...

• D. Scott Stepro, GISP
  Scott.Stepro@ky.gov
  Kentucky Division of Geographic Information
Feature Extraction from KYAPED LiDAR Point Clouds

Challenges and Opportunities...

Part II

Demetrio P. Zourarakis, Ph.D., GISP, URISA, CMS, ASPRS, CGP-G, USGIF

GIS and Remote Sensing Analyst
Kentucky Division of Geographic Information
Office of Application Development
Commonwealth Office of Technology
Vegetation “Feature” extraction from LiDAR point clouds

**BIG QUESTION**...

.... What is the *feature* we are extracting?

• a feature is *usually* understood as vector-format object*
  a. Tree crowns? (polygons)
  b. Vegetative canopy? (polygons) << think spatial variability in 3D>>
  c. Tree points? (points)

• can/should we extend this notion to other models in 2D, 3D, 4D, etc.*
  a. pixel-based: i.e. elevation/height based Digital Surface Models (DSM)
     b. canopy structure (i.e. **voxel**-based)?
        (NOTE: Minecraft used to do just this...)

• LiDAR vegetation classes are BY HEIGHT (0-2 m, >2-6m, >6 m).
  a. WHICH height?
     i. Tallest canopy?
     ii. ??
"On seeing the wood from the leaves and the role of voxel size in determining leaf area distribution of forests with terrestrial LiDAR"
Martin Bélanda, Dennis D.Baldocchia, Jean-Luc Widlowski, Richard A.Fournier and Michel M.Verstraete
Agricultural and Forest Meteorology, Volume 184, 15 January 2014, Pages 82-97
REMINDER #2: Forest type and structure matter!
KYAPED deals with Kentucky Woodlands and Forests.

“A voxel-based LiDAR method for estimating crown base height for deciduous and pine trees”
Sorin C. Popescu and Kaiguan Zhao

“3D terrestrial LiDAR classifications with super-voxels and multi-scale Conditional Random Fields”
Ed Hui Lim and David Suter
Computer-Aided Design, Volume 41, Issue 10, October 2009, Pages 701-710

http://www.americanforests.org/magazine/article/venerable-trees-of-the-bluegrass/
“Lidar for Biomass Estimation”
Yashar Fallah Vazirabad and Mahmut Onur Karslioglu
Biomass – Detection, Production and Usage.
Edited by Darko Matovic, ISBN 978-953-307-492-4, 443 pages, Publisher:
InTech, Chapters published September 09, 2011 under CC BY-NC-SA 3.0 license
REMINDER #4: About vegetation filters...

1- Vegetation filters are the toughest to design
2- Automation can be tricky – if filter are too aggressive, for example, can result in loss of information
   “...vegetation classification tends to be the most difficult...”
   page 179; Chapter 6 – Data Processing. Jamie Young and Qassim Abdullah.
   Michael S. Renslow, Editor
   2012 – ASPRS pub.

3- No “off the shelf” morphological filters – just height filters >>> veg. classes
4- Point density is a key parameter for good results
5- ** Unlike structures, no geometric primitives can be easily applied **
   - plane geometry (line, polygon, circle, etc.)
   - solid geometry (sphere, parallelepiped, cone, etc.)

** depending on type of vegetation, forest ecosystem, etc.
Digital Surface Models - - what/how.

Digital Surface Model (i.e. a raster or image) – a DSM
(NOTE: a Digital Elevation Model is a type of DSM)

Characteristics/Considerations:

a. Elevation DSM (geodetic – above a vertical datum)
b. Height DSM (above ‘ground’ - - i.e. above a ‘bare earth’ DEM)
c- Based on ‘binning’ (several methods)
d- Creates ‘no data’ pixels as a natural product
e. Pulse returns chosen result in a VARIETY of DSMs
f. Ground sampling distance (GSD) – i.e. center-of-pixel to center-of-pixel x/y distance determines the SPATIAL RESOLUTION of the DSM
Data fusion - - kind of...

*** We all do it naturally, even subconsciously (some may even say unconsciously) when using GIS ***

“... GIS ... no single point of verification!”

(Ken Bates, personal communication, ca.1998)

**EXAMPLES:**

a- Data compilation
b- Data conflation
c- Merging, mosaicking of imagery, datasets
d- Compositing spectral bands in multispectral imagery (e.g. Landsat)

e- VISUAL INTERPRETATION (digital image interpretation or photointerpretation)
  i. Google Earth, Esri’s Unlock Earth’s Secrets, etc.
  ii. Using high resolution imagery to check LiDAR work... classical imagery: NAIP
  iii. Normalized Difference Vegetation Index (NDVI)
      \[ NDVI = \frac{NIR - R}{NIR + R} \]
KyFromAbove Program Status
- LiDAR -

- 2012 – “Golden Triangle”
- 2013 – “Purchase”
- 2014 – “Western Kentucky”
- 2015 – “Central Kentucky”
- 2016 – “South Central Kentucky”
- 2017 – “Daniel Boone National Forest”

The 2017 KyFromAbove LiDAR acquisition is complete and Kentucky now has 100% coverage.

Data is currently being processed and should be available to Partners and available for download by December, 2017.

New RFP to be released in Fall of 2017.
... Meet KYAPED Tile N116E310...
Anatomy of a Digital Surface Model (DSM) – (…pseudo 3D)

- High Vegetation (Maximum) DSM – <class 3 if available>>
- Medium Vegetation (Maximum) DSM – <class 4 if available>>
- Low Vegetation (Maximum) DSM – <class 5 if available>>
- DEM (Average) *just another DSM* – <class 2 (or 8 if available)>>

Normalized DSM (nDSM) = DSM - DEM
LAS Dataset to Raster Conversion (Sli cells - Maximum - Simple Void Fill)

ELEVATION (i.e. above NVD88)
HEIGHT (i.e. above ‘ground’)
PD = 8,761,432 pts/25,000,000 ft$^2$ = 0.35 pts/ft$^2$ (3.8 pts/m$^2$)
NPS = $\sqrt{1/PD}$ = 1.68 feet (0.51 m)
Bare Earth (class 2) – point cloud
First Return ALL Classes
DSM
First of Many Returns

<Ground+Noise+Water: Classes excluded>
First of Many Returns

*Ground+Noise+Water: Classes excluded*
LAS Dataset to Raster

<Binning, Nearest Neighbor, Simple Fill, 5-foot cells>
**NEXT STEPS**
1. Reclass by height
2. Raster to Polygon
3. Edit
Useful tools available in ArcGIS Desktop 10.5.1

Extraction w/o re-classification of LiDAR points (uses Class 1: UNCLASSIFIED, mostly)

1- LAS Dataset creation and manipulation
2- DSM and nDSM raster creation (from specific *classes* and *returns*)
3- Reclass by height
4- Raster to polygon mask
5- etc. etc.

Extraction reclassifying LiDAR points

More yet to come in ArcPro!
Many tools are available in LP360 v. 2017.1.54.0 – a LiDAR-specific software from GeoCue

1. Point Cloud Tasks (no morphology filter!)
2. Highly intuitive and interactive re-classification workflow in 2D and 3D via profile view
3. **SELECTION BY ORDER OF RETURN** (i.e. First of 2, Second of 3, etc.)
4. Model Key point generation
5. etc. etc.
Conclusions

• LiDAR point clouds are available ubiquitously

• Software is widely available:
  • COTS: Esri, GeoCue (LP360), Erdas IMAGINE, ENVI, etc.
  • Open source: LASTools (M. Isenburg) in QGIS, NOAA Digital Coast, etc.

• Analyst attention/work is required to:
  • Discern which returns and classes to use for reclassification/extraction
  • The highest quality input (CLASS/SPATIAL ACCURACY) in order to provide highest quality output

• “Future” opportunities (... here already):
  • “new” technologies: Geiger mode (GmAPD), Flash LiDAR
  • Minecraft modeling
Acknowledgements

Kent Anness, DGI
GIS Manager
KYAPED Program Manager

Kim Anness, DGI
Geoprocessing Specialist
Contact Information

Demetrio P. Zourarakis

demetrio.zourarakis@ky.gov
502-564-6246

http://gis.ky.gov