GRASS GIS for the distinction of vegetation from buildings using LiDAR altimetric data

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Contents

ALS principles

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   - Sensor
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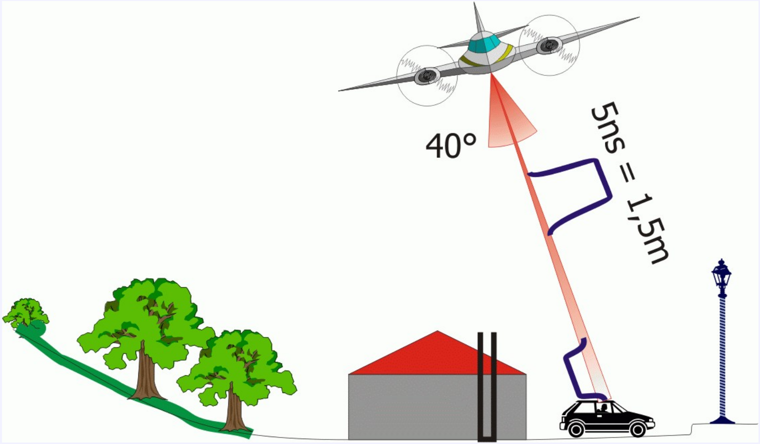
   - The time each pulse takes to reach the ground and return back
   - The angle from the nadir at which it has been emitted
3. The laser data are then combined with the sensor location and orientation to give the coordinates X, Y, Z (WGS84) of the laser footprint on the terrain surface.

ALS principles



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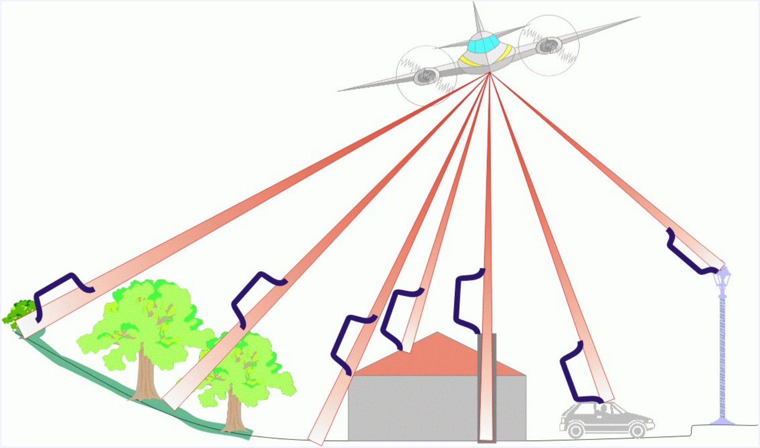
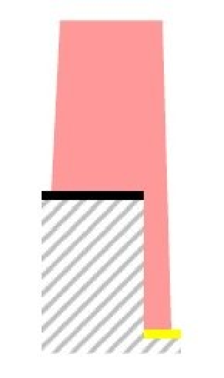


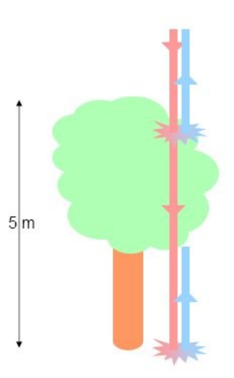
ALS characteristics

1. High accurate measurements in both altimetric and planimetric components
2. Laser pulses are emitted with high repetition rates per second, thus high resolution can be obtained.
3. Monoscopy and almost-nadirality permit to reach the ground or the studied object surface even in highly vegetated zones

First and Last pulses

1. Due to spot size, some pulse may be partially reflected by object at different heights and partially by the terrain.
2. The sensor collects at least two (up to several) returns for a single pulse emitted.





First and Last pulses

1. A considerable difference between first and last pulse can be a clue for the presence of an object with different heights (vegetation or edges of objects, such as buildings, cars, transmission lines, etc.)
2. No chance exists to directly recognize whether the reflecting ray belongs to a point on the bare earth or to a point on an object
3. The data recorded as last pulse (the last return of a single pulse) has the greatest probability to detect the ground

ALS filters

1. A point cloud $V = \left\{ v = (x, a) \,|\, x \in \mathbb{R}^3, a \in \mathbb{N} \right\}$, treated as a set of attributed points in a three-dimensional space, where bare earth labeled points take 0 values and 1 otherwise, is filtered when points labeled as 1 are removed.
2. That is, filtering is the automatic procedure of differencing bare earth from objects in ALS point clouds

Motivation of filters

1. ALS point clouds represent the surveyed surface. Digital Surface Model or DSM
   - Hydrology
   - Topography
   - Cityscapes
   - Coastal engineering
   - Volume computations
   - Power lines
2. Filtering allows to extract attached (buildings and vegetation) and detached objects (bridges, highpasses,...). Digital Terrain Models or DTM
   - Hydrology
   - City modelling
   - Forestry

Geographic Resources Analysis Support System

1. Known as GRASS, it is a GIS software for the geospatial data management and analysis.
2. Since is an open source software with lots of built-in libraries, it is possible to implement embedded analysis algorithms.
3. GRASS 6 vector architecture allows and requires topology (problem to deal with)
4. It is written in C/C++ that allows to implement heavy computational algorithms
5. Portable: Version for GNU/Linux, MS-Windows, Mac-OSX, SUN, etc, thus anyone can use it.
6. More information in: http://grass.osgeo.ogr

Commands in GRASS GIS 6

1. LiDAR filtering tools within GRASS GIS 6:
   - v.outlier
   - v.lidar.edgedetection
   - v.lidar.growing
   - v.lidar.correction
   - v.surf.bspline

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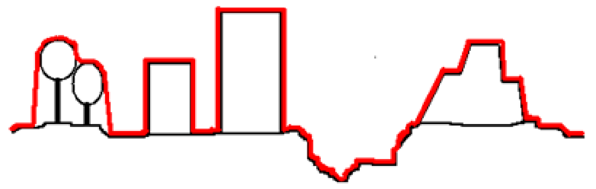
2. Interpolation command v.surf.bspline:
   - Cross validation algorithm (*leave one out*)
3. New vegetation filter:
   - v.lidar.vegetation

Vegetation filter motivations

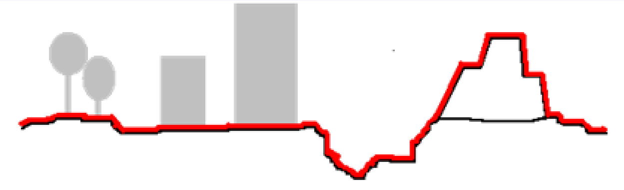
1. Detecting vegetation zones in ALS point clouds is an important task for hydrology, city modelling or forestry studies
2. This filters have been thought to distinguish amongst bare earth, vegetation and buildings.
3. We have developed our vegetation classification from the filter algorithm previously described:
   - There already was a structure which could be used beyond its initial scope
   - There would be an algorithm able to filter vegetation in the open GIS community
   - Only after the participation in the ISPRS filter test [Sithole and Vosselman(2004)], where it was supposed to differentiate between bare earth and object, it was seen that it might be useful to distinguish amongst different types of objects.

1. Digital Surface Model



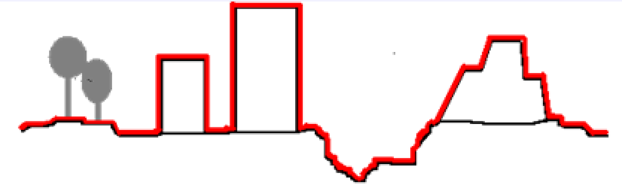
Requested Digital Elevation Models by Adbpo

1. Digital Surface Model
2. Digital Terrain Model



Requested Digital Elevation Models by Adbpo

1. Digital Surface Model
2. Digital Terrain Model
3. Hydrological Digital Model

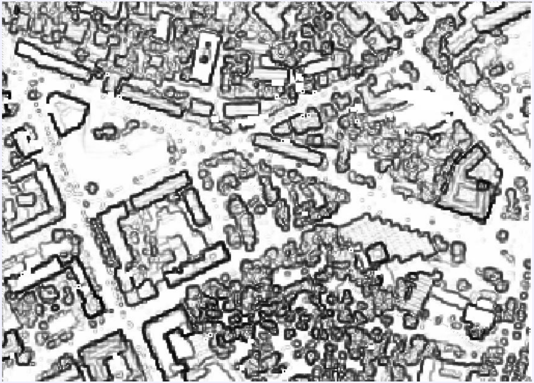


Vegetation filter

1. Input data is the previous object-terrain classification.
2. A segmentation is done by:
   - Rasterization of the pre-classification
   - Region growing
   - Convex-Hull
3. Dimensions and ratio between area and perimeter are used to classify segments:
   - Small or narrow shape objects are not likely to be buildings, thus are vegetation.
   - Single terrain points are always considered as vegetation.
   - Object double pulse outside hull segments are considered as vegetation.
   - Otherwise are buildings.

Csite3 classification

1. Location: Stuttgard
2. 188514 points $\Rightarrow$ 0.9 points/m^2
3. Features: Building with eccentric roof, buildings with vegetation between them, data gaps...



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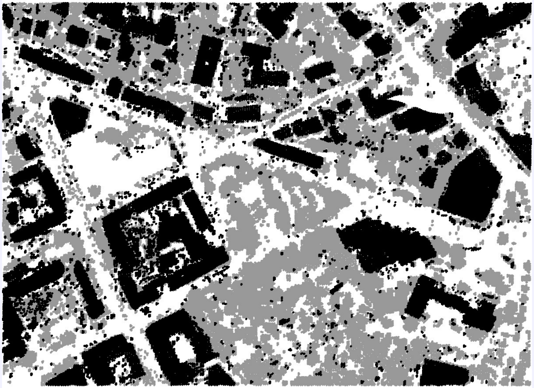


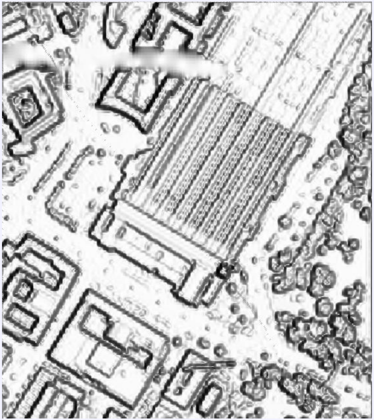
Csite3 confusion matrix

		CLASSIFICATION				Total
		Buildings		Vegetation		
		Points	%	Points	%	
TRUE	**Buildings**	41505	92.2	3520	7.8	45025
	Vegetation	10904	15.3	60442	84.3	71346
	Total	52409	-	63962	-	116371

1. Type I error (Reject building points): 7.8%
2. Type II error (Accepting vegetation as building points): 15.3%
3. Total error: 12.4%

Csite4 classification

1. Location: Stuttgard Railway Station
2. 259030 points $\Rightarrow$ 0.9 points/m^2
3. Features: Large buildings, highpasses, data gaps...



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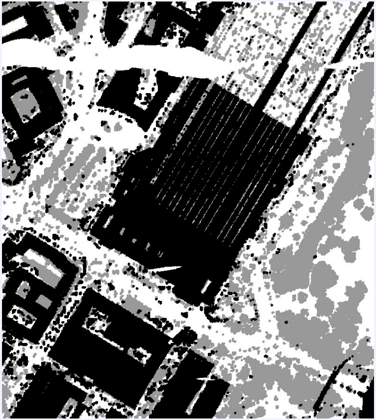

Csite4 confusion matrix

		CLASSIFICATION				Total
		Buildings		Vegetation		
		Points	%	Points	%	
TRUE	Buildings	81479	90.1	8923	9.9	90402
	Vegetation	8920	14.3	53334	15.7	63354
	Total	90399	-	62257	-	152656

1. Type I: 9.9%
2. Type II: 14.3%
3. Total error: 11.7%

Conclusions

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   - High Type I error due to misclassified building edges.
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2. The filter makes use morphological parameters and differences in first and last pulses.
3. Vegetation filtering is strongly affected by the pre-classification into terrain and off-terrain points:
   - High Type `I` error due to misclassified building edges.
   - Type `II` error due to elevated terrain zones misclassified as object and then later misclassfied as buildings.
4. Nevertheless, about the 88% of the points are correctly classified into vegetation and buildings.
   - Wide vegetation regions are always correctly classified as well as the majority of single trees.
   - Most of the building shapes are well defined.

Future work

1. Some efforts have to be done in order to reduce final errors caused by the former classification into terrain and off-terrain points.
2. More tests have to be carried out in such a way to better understand the filter performances.
3. Due to energy different absorption responses in vegetation and buildings, intensity LiDAR data should be considered in order to obtain a better classification.

Final conclusions

1. With the new vegetation filter, able to distinguish vegetation from buildings, the built-in LiDAR filtering tools available in GRASS GIS have been improved.
2. GRASS GIS has been proved to be a perfect software to develope heavy computational analysis algorithms in.
3. With these two filters it has been shown that GFOSS is a feasible way to use LiDAR programs without depending on proprietary software.
4. The community has helped to improve the software in such a way to obtain a solid and reliable filter and interpolation command.

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