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Filtering airborne LiDAR data

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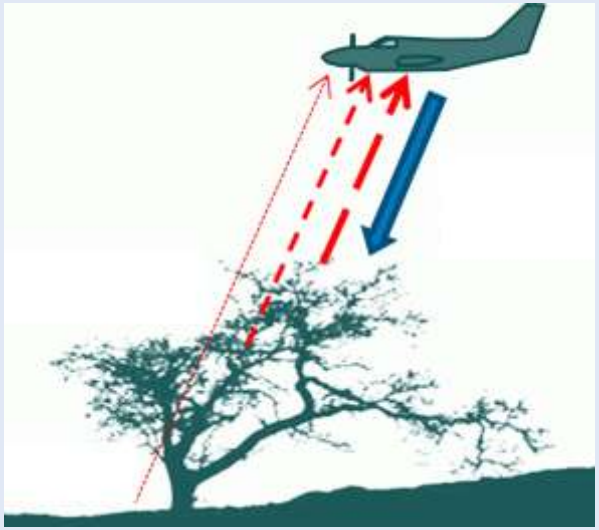
Outline

1. Geospatial Research Group
2. LiDAR Technology
3. Digital Models
4. General Ground Filtering Procedures
5. Ground Filtering Methods
6. Test Sites and Method Evaluation
7. Results and Conclusion

Geospatial Research Group

Centro de Desarrollo Aeroespacial

LiDAR Technology



Multiple Return LIDAR

- Quick source of three-dimensional accurate data.
- Returns: possibility of extracting the surface of the ground under dense vegetation.

Data: Point Cloud.

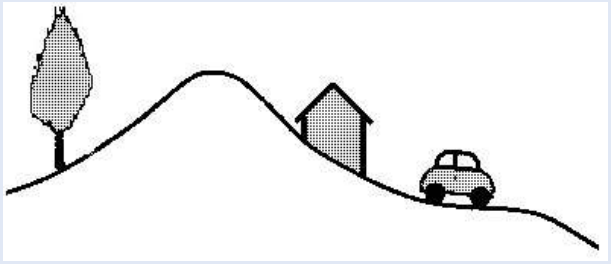
Application fields:

- ✓ Forest management
- ✓ Urban planning
- ✓ Natural disasters prevention
- ✓ Etc…

Digital Models

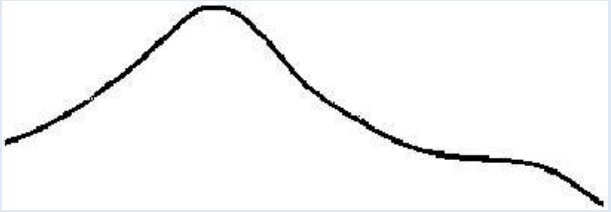
Three components of LiDAR point measurements:

$$Msensor = E_{ground} + E_{objects} + M_{noise}$$



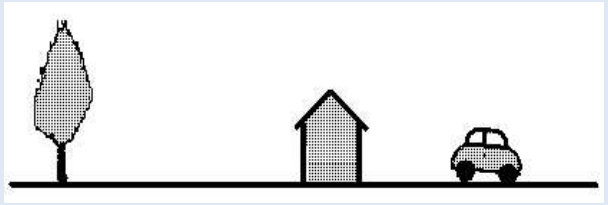
Digital Surface Model (DSM): Bare ground + objects (trees, buildings, etc.).

Filtering ↓



Digital Terrain Model (DTM): Bare ground.

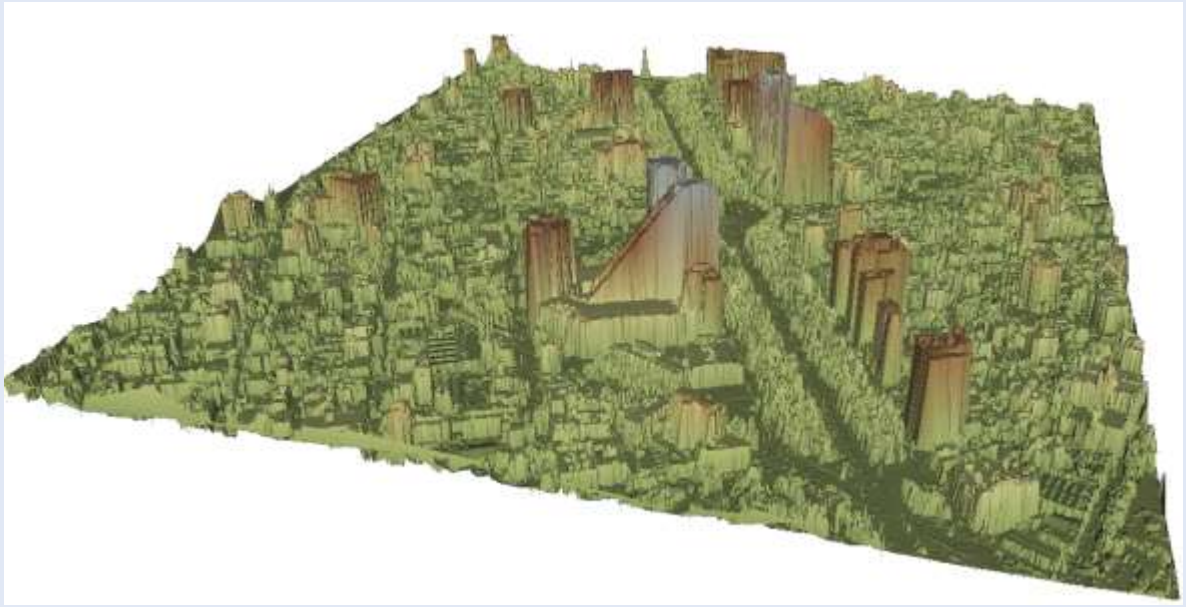
nDSM=DSM-DTM ↓



Normalized Digital Surface Model (nDSM): Objects on elevation height zero.

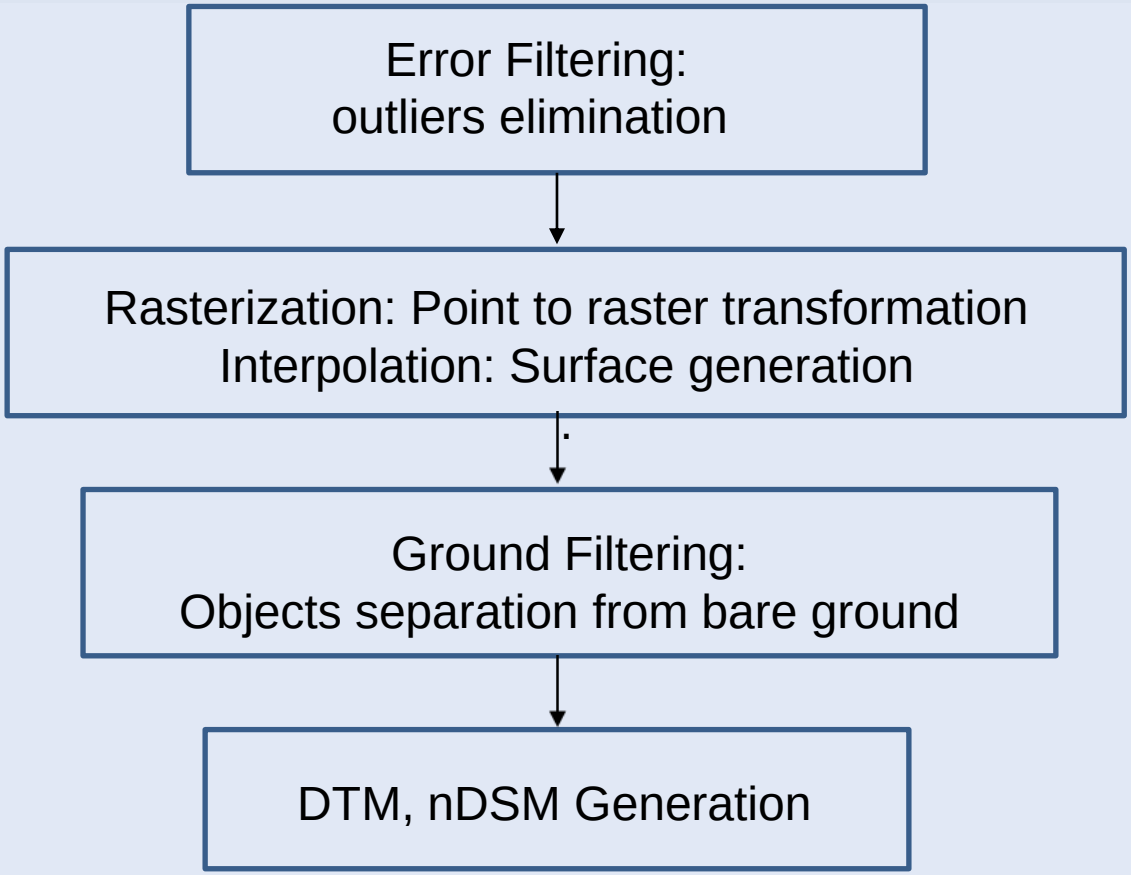
Digital Models

LiDAR point cloud



DSM

General Ground Filtering Procedures



Ground Filtering Methods

- Morphological based methods: opening, closing, top-hat transform.
- Segmentation: growing regions, active contours.
- Clustering: k-means and mean-shift.
- Directional scanning-based methods: N - S, E – W (*).
- Interpolation-based methods: spline, TIN triangulation, etc..
- Fourier, Wavelet, and Hermit transform (*).

(*) Jose Luis Silvan Cardenas, CentroGeo

Ground Filtering Methods

Morphological based method

Progressive morphological filter: iterative top-hat transform.

top-hat transform : original image - opening image

opening = erosion + dilation

Local information involved by kernel operator o structuring element.

In grayscale Morphology:

- Erosion is the minimum value in the kernel.
- Dilation is the maximum value in the kernel.

Various parameters: Cell size c, maximum window size, terrain slope s, initial elevation difference threshold dh_0, maximum elevation difference dh_{max}, …

$$dh = s\,(w_k - w_{k-1})c + dh_0$$

Ground Filtering Methods

Local segmentation based method

Local segmentation: thresholding with kernel operator.

Local information involved by kernel operator (min, max)

Parameter: kernel size.

Automatic threshold: T= F(min,max)

Test sites

Datasets: International Society for Photogrammetry and Remote Sensing (ISPRS) Benchmark
http://www.itc.nl/isprswgIII-3/filtertest/Reference.zip

Site	Region	Point Spacing	Special features
1	Urban	1 - 1.5m 2 - 3.5m 4 - 6m	Steep slopes, mixture of vegetation and buildings on hillside, buildings on hillside, data gaps
2	Urban	1 - 1.5m	Large buildings, irregularly shaped buildings, road with bridge and small tunnel, data gaps
3	Urban	1 - 1.5m	Densely packed buildings with vegetation between them, building with eccentric roof, open space with mixture of low and high features, data gaps
4	Urban	1 - 1.5m	Railway station with trains (low density of terrain points), data gaps
5	Rural	2 - 3.5m	Steep slopes with vegetation, quarry, vegetation on river bank, data gaps
6	Rural	2 - 3.5m	Large buildings, road with embankment, data gaps
7	Rural	2 - 3.5m	Bridge, underpass, road with embankments, data gaps
8	Rural	2 - 3.5m 4 - 5.5m 7 - 10m	High bridge, break-line, vegetation on river bank, data gaps

Characteristics of the test sites

Method evaluation

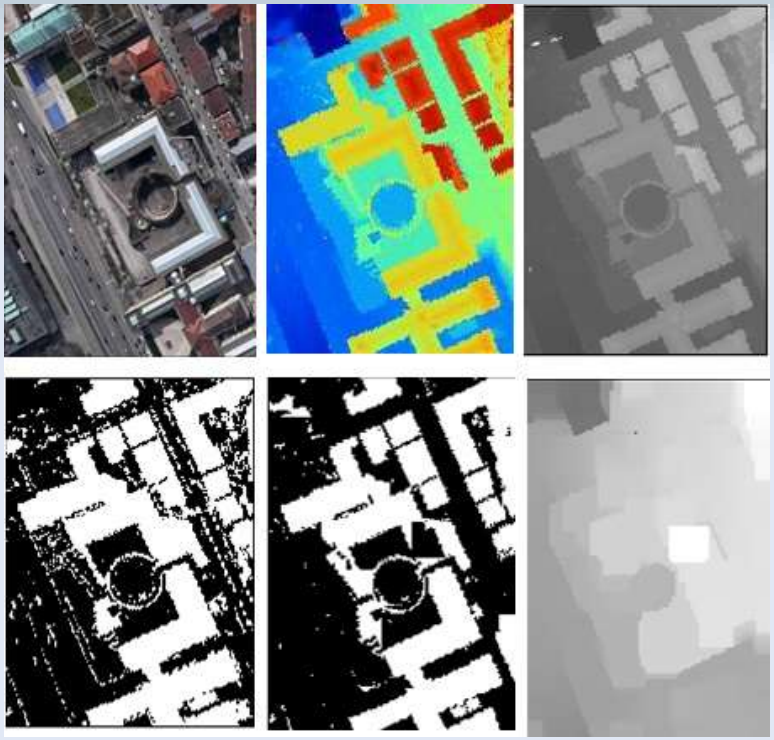
		Filtered			
		Bare Earth	Object		
Reference	Bare Earth	a	b	$a+b$	$f=\frac{a+b}{a+b+c+d}$
	Object	c	d	$c+d$	$g=\frac{c+d}{a+b+c+d}$
		$a+c$	$b+d$	$e=a+b+c+d$	
		$h=\frac{a+c}{a+b+c+d}$	$i=\frac{b+d}{a+b+c+d}$		

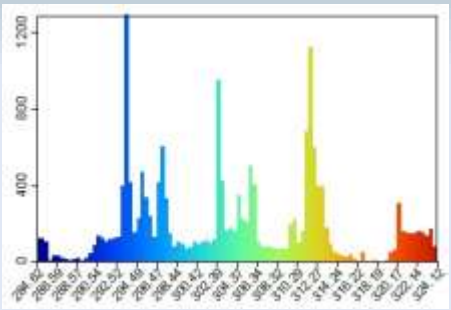
Confusion matrix

Error types

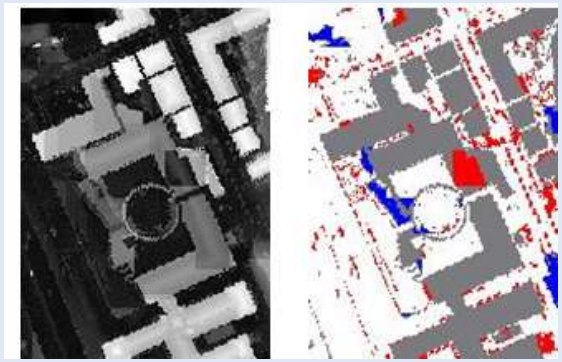
Type I	$\frac{b}{a+b}$
Type II	$\frac{c}{c+d}$
Total	$\frac{b+c}{e}$

Results: Sample 23





Pixel size: 1 m × 1 m.
Image size: 147 × 207pixels.
Window size : 20 pixels.
Threshol d: 3 m.
Density: 0.83 points/m^2.



Satellite image, DSM in color and gray level, reference image, classified image, DTM.

nDSM, Error total

Results:

	ATIN*%	PMM%	LSM%
Sample 11	10.76	17.4	12.5
Sample 12	3.25	8.60	10.3
Sample 21	4.25	7.70	8.65
Sample 22	3.36	8.70	11.5
Sample 23	4.00	9.87	10.6
Sample 24	4.42	11.12	10.12
Sample 31	4.78	7.80	4.02
Sample 41	13.91	7.36	6.80
Sample 42	1.62	3.01	1.98
Sample 51	2.72	7.67	5.2
Sample 52	3.07	6.29	8.5
Sample 53	8.91	3.25	3.02
Sample 54	3.23	3.38	4.03
Sample 61	2.08	1.01	1.78
Sample 71	1.63	3.86	4.50

Comparison of total errors for test samples

ATIN: Adaptive Triangulated Irregular Network (TIN) model
SMM: Progressive morphological method
LSM: Local segmentation method

*Q. Chen, P. Gong, D. Baldocchi, and G. Xie, “Filtering airborne laser scanning data with morphological methods,” *Photogrammetric Engineering and Remote Sensing*, vol. 73, pp. 175–185, Febrero 2007.

Conclusion

- A new approach based in Local Segmentation Method is developed.
- It is a viable tool to address the filtering problem with only one parameter.
- Further research should explore the optimality of the filter performance.