POLITECNICO DI MILANO
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Comparison GRASS-LiDAR modules – TerraScan with respect to vegetation filtering

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LiDAR system

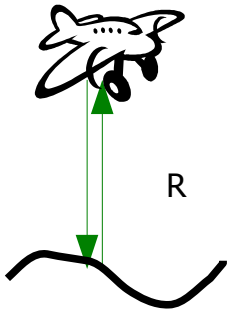
Detection system by a laser telemeter mounted on a aircraft

- Aircraft – terrain distance → indirect measure

- Coordinates obtained thanks to the GPS and INS units installed on the aircraft

$$t_{travel} = \frac{2R}{c}$$

$$R = \frac{t_{travel}}{2} \cdot c$$

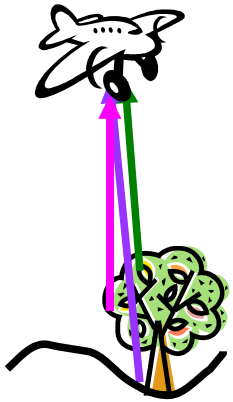


There can be more echoes → the laser has a certain spot diameter and it may be reflected by different surfaces

- First pulse → first reflection

- Last pulse → last reflection

- Possibility of other in-between pulses (usually vegetation)



The scanning path (shape, spot diameter, distance between spots, n° of pulses per scanning line etc...) depends on the instrument used and on the flight height.

GRASS filtering algorithms (still under development)

Filtering → removal of observations that don't correspond to bare earth to obtain thematic maps (vegetation or building maps) and DTM

v.lidar.edgedetection

Purpose: detection of edges (bilinear and bicubic spline interpolations with Tikhonov regularization).

Output: edge and non edge points

Purpose: fill-in the edges using double pulse information (first and last pulse) in the cells obtained from the rasterizing step.

Output: four categories: terrain, terrain with double pulse, object with double pulse, object

v.lidar.growing

v.lidar.correction

Purpose: correction of residual errors from from the growing step

Output: four categories: terrain, terrain with double pulse, object with double pulse, object

TerraScan filtering algorithms

TerraScan by Terrasolid → proprietary software to process airborne data.

Terrascan → Axellson's algorithm: based on a TIN densification.

Step 1: ground/over-ground — Division between ground and over-ground points: terrain points detection

→ Possibility to manually reclassify the result

Step 2: Building detection — Analysis of the over-ground points only to extract hand made features.

→ Possibility to manually reclassify the result

Step 3: Vegetation detection — Analysis of the over-ground points left from the building detection to extract the vegetation

- The filtering process may leave some unclassified points
- Possibility of an additional step to extract linear objects (power lines, electric cable...)

Purpose of the work

Comparison between the automatic filtering results from the two packages.

GRASS	TerraScan
- Cat 1: terrain	- Ground
- Cat 2: terrain with double pulse (low vegetation)	- Vegetation (high+low)
- Cat 3: object with double pulse (high vegetation)	- Building
- Cat 4: object (building)	- Unclassified points

Still problems in the distinction between high vegetation and roofs: impossible to compare with the building class from TerraScan

Comparison extended on the low vegetation class:
- low vegetation is more difficult to be identified
- points could be extracted as ground points

Comparable category

Data description

Data on coastal area of Sardinia region (Italy).

LiDAR dataset: Optech ALTM Gemini LiDAR system + Applanix inertial system; flight height around 1400m. Spatial resolution around 1.5 pts/m^2

Two filtering results provided:

- Completely automatic TerraScan result: used to compare the performance with respect to GRASS
- Semi automatic TerraScan result (manual reclassification by the user)

Orthophoto of the area (global flight: more than 2000 ortophoto)

+ FCIR image (false color infrared image)

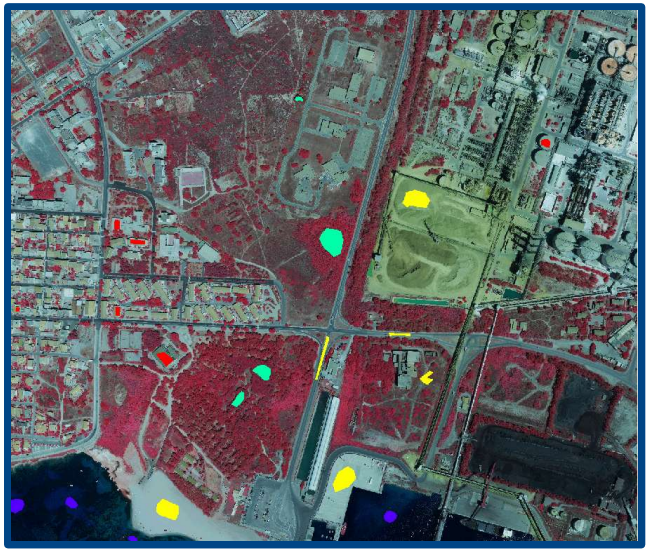
Both used in GRASS to obtain a classified image (maximum likelihood classification after training sample selection: i.maxlik) → purpose: check the filtering result, in particular the vegetation.

In the next slides: Li → points from LiDAR dataset; Cl → classified image

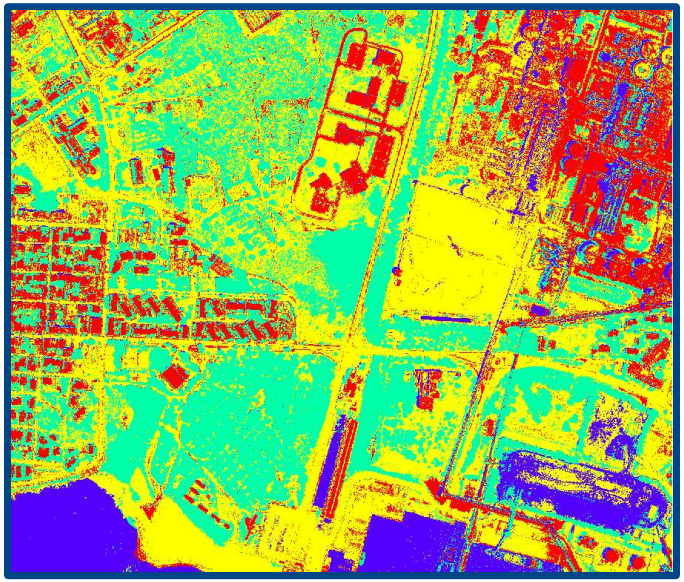
Imagery classification

Orthophoto

FCIR image
+
training
samples



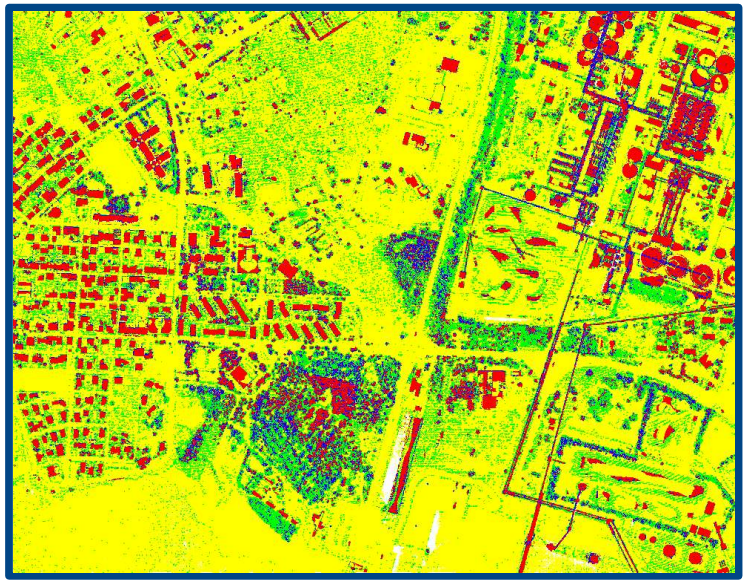
Mostly flat but a morphologically complex area → presence of vegetation, buildings, sea, an industrial area with a quarry (upper right part)



Classified image

- Ground
- Vegetation
- Building
- Sea/shadow

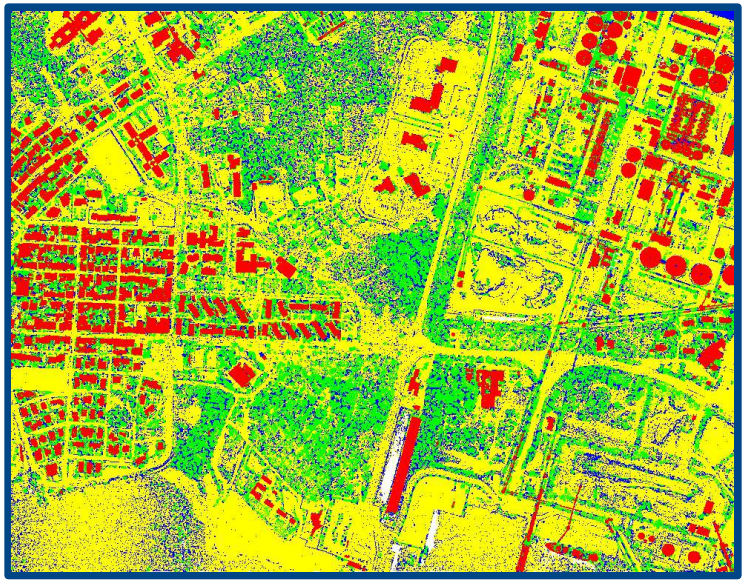
Filtering results



GRASS filtering result

Terrain Terrain with double pulse
Object with double pulse Object

Class	N° points	
Cat 1 - Terrain	1487384	69.99%
Cat 2 – Terrain with double pulse	341702	16.08%
Cat 3 – Object with double pulse	103508	4.87%
Cat 4 - Object	192526	9.06%
	2125120	



Automatic TerraScan filtering result

Ground
Vegetation
Building
Unclassified

Class	N° points	
Ground	1418900	66.77%
Vegetation	356417	16.77%
Building	205748	9.68%
Unclassified	144079	6.78%
	2125144	

Correspondence between ground and terrain points: around 80%

Low vegetation error analysis

Performed on two sub regions of the whole area

- Area near the industrial site

- Area with remarkable presence of vegetation

• Comparison between the points classified as vegetation (Li) (TerraScan) or low vegetation (Li) (terrain with double pulse – GRASS) and the imagery classification result (Cl) → check the presence of misclassified points

• Evaluation of filtering error for the vegetation and ground classes (Li)

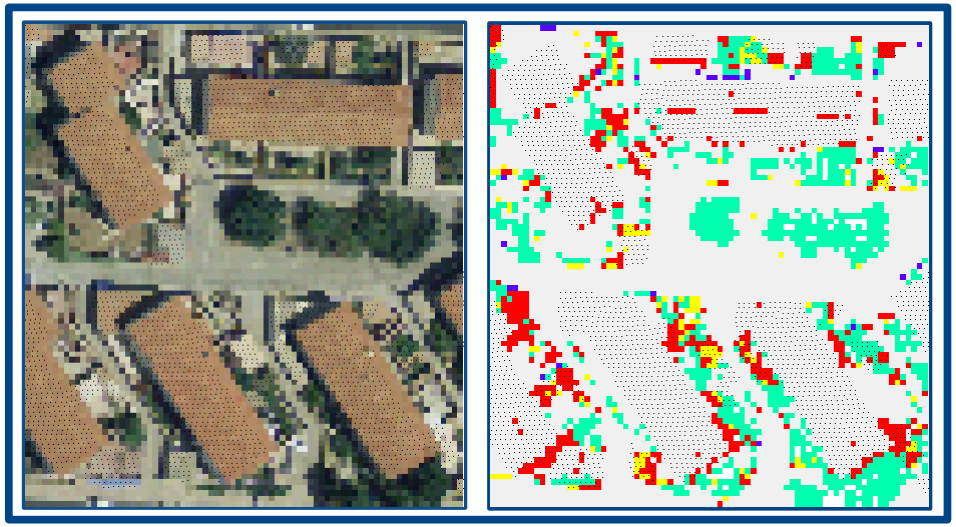
• Evaluation of filtering error height distribution

Comparison with the classified image

Correspondence between points filtered as vegetation (Li) and vegetation class (Cl): around 87%

TerraScan (vegetation class)			GRASS (Low vegetation – category 2)		
Ground	2859	4.63%	Ground	11474	7.20%
Vegetation	54279	87.84%	Vegetation	16214	86.10%
Water/shadow	436	0.71%	Water/shadow	5180	1.12%
Building	4216	6.82%	Building	9014	5.58%
Null	180802	-	Null	225406	-
Total (non null)	61790	100.00%	Total (non null)	41882	100.00%

Points that fall into building class (Cl)→ some of them may derive from errors in the imagery classification, in particular immediately next to buildings.

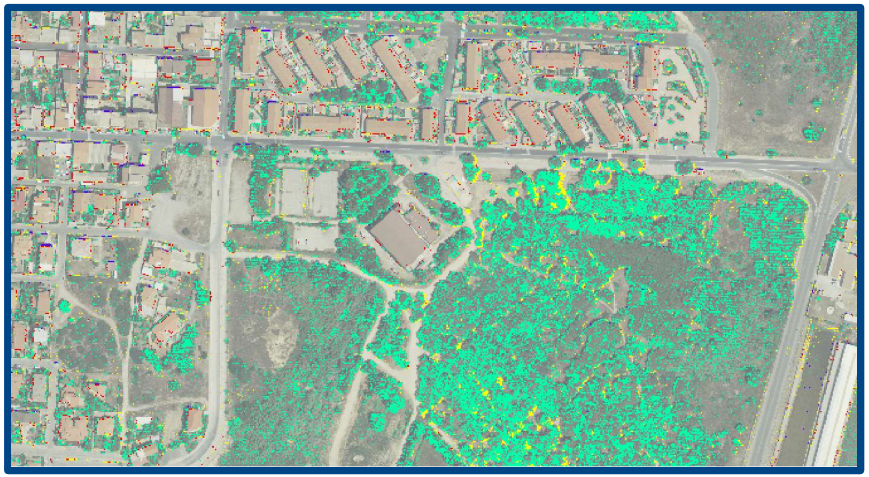


The Orthophoto is generated using a DTM → the building shapes are shifted proportionally to their heights.
(in figures the dotted points (Li) are shifted with respect to the building)

Solution → orthorectification by using a DSM

Ground – vegetation error analysis

TerraScan ground and GRASS category 2 (low vegetation)



GRASS terrain and TerraScan vegetation

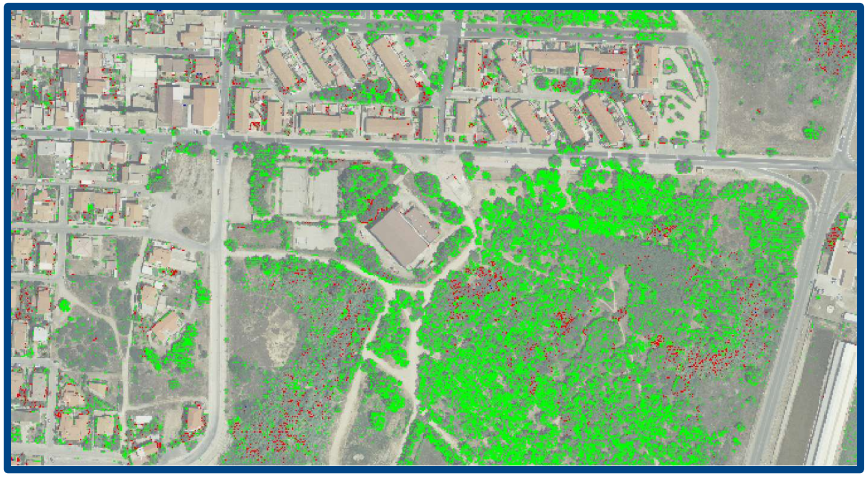
- Ground
- Vegetation
- Building
- Sea/shadow

GRASS (category 2) – TerraScan (ground)			GRASS (terrain) – TerraScan (vegetation)		
Ground	3159	8.63%	Ground	1877	9.17%
Vegetation	31575	86.25%	Vegetation	15845	77.42%
Water/shadow	373	1.02%	Water/shadow	214	1.05%
Building	1503	4.10%	Building	2531	12.36%
Null	205982	-	Null	222125	-
Total (non null)	36610	100.00%	Total (non null)	20467	100.00%

TerraScan classifies as ground the points that should belong to vegetation class; the number of error points in the opposite case is lower.

Height analysis

TerraScan ground and GRASS category 2 (low vegetation)



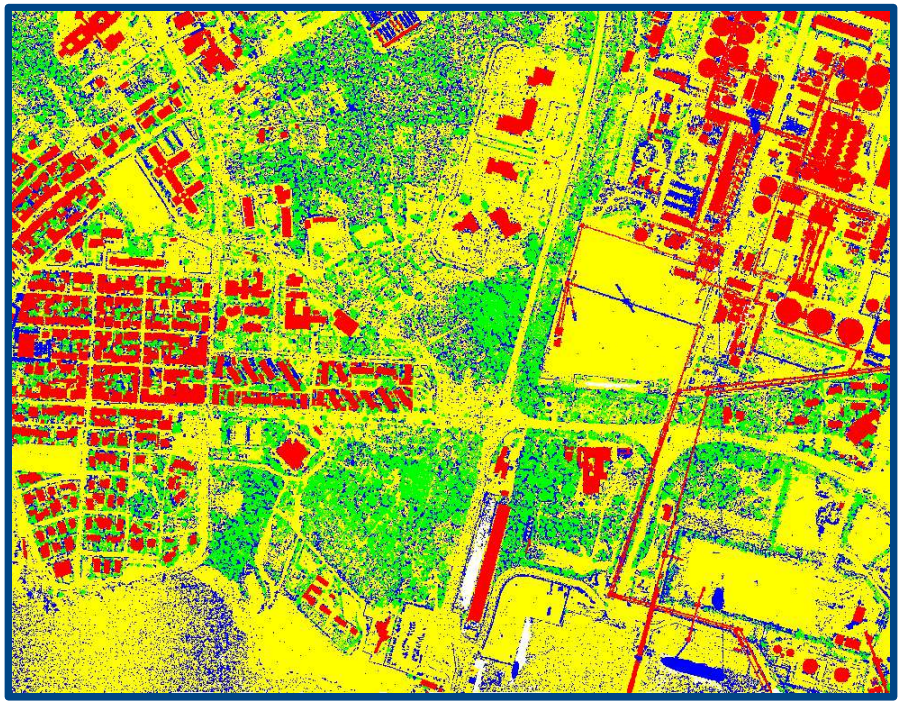
GRASS terrain and TerraScan vegetation

- 0<h<1
- 1<h<3
- 3<h<5
- h>5

GRASS (category 2) – TerraScan (ground)			GRASS (terrain) – TerraScan (vegetation)		
0≤ h ≤1	29012	11.96%	0≤ h ≤1	12587	5.19%
1< h ≤3	2548	1.05%	1< h ≤3	3188	1.31%
3< h ≤5	15	0.01%	3< h ≤5	70	0.03%
h>5	0	0.00%	h>5	0	0.00%
null	211017	86.98%	null	226747	93.47%
Total	242592	100.00%	Total	242592	100.00%

TerraScan has problem in the classification of lower points → they are almost all classified as ground

Semi automatic TerraScan



Ground
Vegetation
Building
Unclassified

Class	N° points	
unclassified	171080	8.06%
ground	1424169	67.09%
vegetation	268750	12.66%
building	258653	12.19%
	2122652	

- Manual intervention of the user after each filtering step

- Time consuming step: average manual editing efficiency is 4-5 Km^2 in 8 hours (depending on the complexity of the area)

- Better ground and hand-made features extraction (very high and very low points)
- Improvement in vegetation detection 89% (more similar to the GRASS one, 86%) even if the user does not modify directly this class; the changes follow other classes modifications.

Conclusion

• Both the two packages have problems in filtering steps: GRASS in the detection of hand made structures and TerraScan in vegetation detection → need of improvements

• At the present no software is able to reach automatically accuracy higher than 95% (5% errors considered as tolerance level) → commercial companies perform some manual time consuming reclassification steps

• After a calibration procedure GRASS is comparable with the automatic TerraScan → GRASS performs better in vegetation areas and TerraScan in hand made ones.

• The main problem in vegetation extraction is that points belonging to vegetation are distributed in a spread range of height classes (from low to high vegetation) and therefore misclassification as ground or buildings is possible. This is still an open problem.

Link and Acknowledgements

GRASS GIS manuals: [last access: 30/08/2010]
http://grass.itc.it/gdp/manuals.php

GRASS LiDAR packages last development: [last access: 30/08/2010]

http://osgeo-org.1803224.n2.nabble.com/lidar-tools-update-in-grass7-td4521505.html

TerraScan by Terrasolid website: [last access: 30/08/2010]

http://www.terrasolid.fi/en/products/terrascan

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