A description of the Master Thesis at ifp

Filtering terrestrial LiDAR point cloud in forest areas

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Introduction and motivation

As a method to provide a primary database for multidisciplinary research, filtering is a preliminary and important process to extract digital elevation model (DEM) from non-ground objects in wooded forest areas. In the past years, airborne LiDAR used to provide large areas of point clouds for forest investigations but with numbers of noise under canopies that influence to the applications which rely on detail features. Different from the airborne LiDAR, the terrestrial LiDAR point cloud represents high accessibility to details in forest areas that allows studies for the ecological and archaeological purposes, such as LoD3 tree modeling and archaeological sites surveying. However, filtering in such detailed point cloud is complicated. Many of the current filter methods still have outliers and tree stumps problems, and need tremendous modification of parameters for an optimal result. Based on the 3D Forest[2], this thesis promotes the voxel-based filter with an improvement by developing profile clustering optimizing method (PCOM), mitigating the outliers and tree stump problems with a few easy-determined parameters.

Contribution

Filtering vegetation in forest areas is the aim of the thesis has done by the voxel-based filter with the developed profile clustering optimizing method (PCOM). Firstly, the raw data was structured by octree and represented by the calculated voxel centroids. As the provisional DEM, the lowest centroid points were then searched. There were remain some points representing outliers and other non-ground objects. Thus, analyses were implemented with clustering by Euclidean distance in each level of horizontal profiles which depended on the given resolution of the octree structure. After eliminating non-ground voxel centroids, the ground was extracted by an expansion of the rest lowest voxels.

For a robust result, the voxel-based filter also invokes data hierarchies with different scales of the predefined resolution. The first extracted ground was applied to the same process but with a smaller resolution that offers a relatively precise ground (coarse-to-fine), which then made a comparison to the third result with the original resolution.

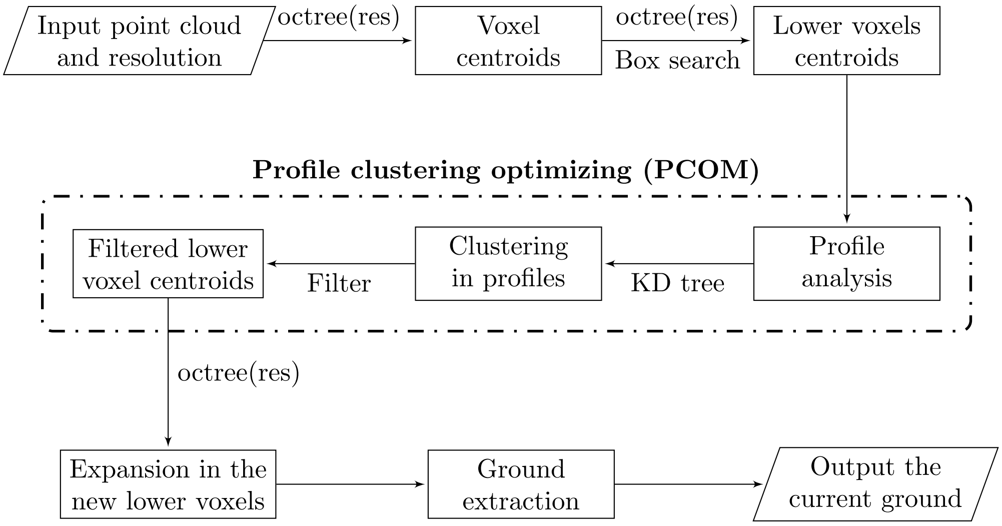

Figure 1: Flowchart of the voxel-based filter with PCOM

In many cases, the bare-earth hide under dense vegetation that is hard to inspect, such as the large-scale samples of the forest area shown in figure 2(a). Attributed to the sufficient ground point providing by terrestrial laser scanning, the voxel-based filter extracts the bare-earth though its lower voxels in an octree structure. Simultaneously, the profile clustering optimizing method retains features of the terrain and eliminates misclassified points that allows the extraction (as shown in figure 2(c)) to be close to the ground truth.

(a) (b) (c)

Figure 2: (a) A section of raw forest point cloud data with Max.height: 31.11 m and width: 118.89 m; (b) Filtering result of the forest area without PCOM; (c) Filtering result of the forest area with PCOM (Max.height: 20.06 m, width: 100.63 m);

For evaluating the performance of proposed PCOM optimizing method, Type.I (misclassification of bare-Earth points in the object), Type.II (proportion of object points being misclassified as bare-Earth), Total (rate of erroneous points to the entire set) errors , Cohens kappa coefficient (κ) [1] and the precision rate P were invoked. With the difference from airborne LiDAR data, it is deficient in offering benchmarks to the terrestrial LiDAR point cloud by an official organization. Therefore, relatively correct references of the test data were manually produced for a comparison purpose.

Table 1: Comparison of the result from each dataset with and without PCOM in the voxel-based filter algorithm. Comp. represents small (width $<$ 100 m) complex sample. Grp_{K1} and Grp_{K2} are large (width $>$ 100 m) forest areas

Data	PCOM (optimized)					3D Forest (optimized)				
	P	$T.I$	$T.II$ (%)	$T.E.$	κ	P	$T.I$	$T.II$ (%)	$T.E.$	κ
Flat	98.49	0.00	0.75	0.50	98.86	95.55	0.00	2.23	1.51	96.60
Slope	73.44	0.00	4.77	4.22	82.31	72.40	0.00	5.02	4.43	81.49
Comp.	87.16	12.84	3.70	5.74	83.47	88.13	11.87	3.39	5.28	84.74
Grp_{K1}	83.83	0.00	3.61	3.04	89.38	80.03	0.00	4.62	3.90	86.57
Grp_{K2}	87.21	12.79	4.48	6.64	82.73	82.55	17.45	6.34	9.30	76.21
Avg.	86.03	5.13	3.46	4.03	87.35	83.73	5.86	4.32	4.88	85.12
Std.	8.96	7.02	1.60	2.41	7.05	8.70	8.27	1.57	2.84	7.53

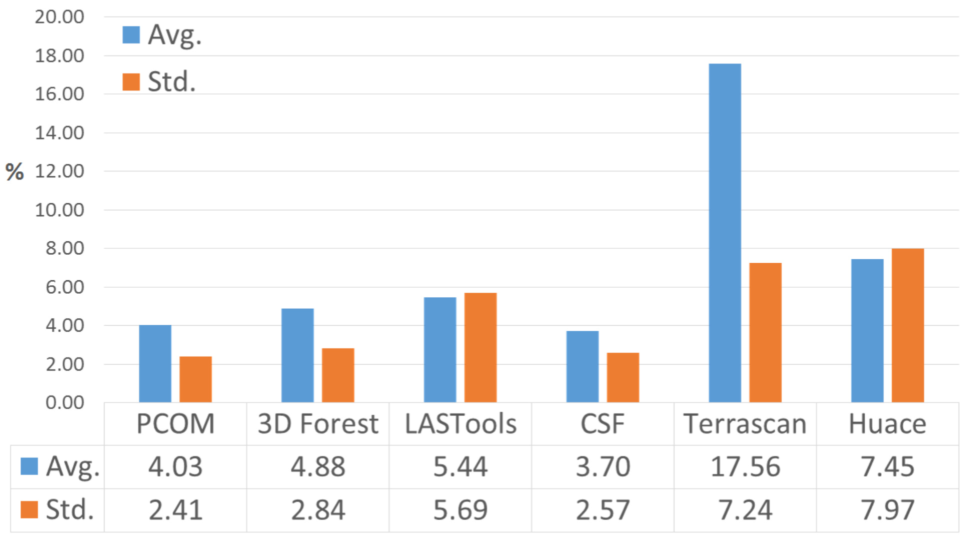

Figure 3: Total error comparison to other methods

Each software has its profits in different applications. The above comparison was based on the test data and manual benchmarks from the thesis. It is possible to be different with other raw data, such as airborne and mobile-terrestrial laser scanning point clouds.

Conclusion

This paper proposes an optimizing method, named PCOM, to the voxel-based filter. For filtering terrestrial LiDAR point cloud in forest areas, the voxel-based filter uses the coarse-to-fine approach with a comparison of the terrains by higher and lower resolutions based on data pyramids. It increases the robustness but still has noises and gross errors. The PCOM exploits characteristics of octree data structure and surmounts the noise problem with easy-determined parameters. It utilizes horizontal profiles in DEMs generated by voxel centers to gauge the ground and off-terrain points by cluster analyses, where the interior threshold is related to the given resolution. By this optimizing method, the outliers and tree stump problems mitigated. The accuracy of the voxel-based filter, therefore, has an improvement among 0.73% - 6.52%.

However, there are some limitations to the voxel-based filter with PCOM. Due to the search of low voxels in space, some small steps or terraces will be filtered. Additionally, filter algorithms can hardly get rid of specific parameters in various cases, neither the voxel-based filter with PCOM. If the point cloud is with low density or discontinuity, misclassification will happen by the restriction of minimum cluster size and cluster tolerance.

In the future, an adaptive method to differentiate ground and non-ground points for profiles analyses or invoke other information, such as colors or corresponding images, could enhance the reliability of filtering. Moreover, further research on filtering in specific applications, such as filtering the vegetation and retain some specific objects (e.g. ancient architectures or tree species), is also worth to consider.

Reference

[1] George Sithole and George Vosselman. Experimental comparison of filter algorithms for bare-earth extraction from airborne laser scanning point clouds. *ISPRS Journal of Photogrammetry and Remote Sensing*, 59(12):85 – 101, 2004. Advanced Techniques for Analysis of Geo-spatial Data.

[2] Jan TROCHTA. *The use and processing of TLS data for purposes of forestry and forest ecology [online]*. Disertan prce, Mendelova univerzita v Brn, Lesnick a devask fakulta, Brno, 2016.