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Comparison of CSF Ground Filtering Method by Using Airborne LiDAR Data

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Abstract

Airborne LiDAR System (ALS) is a common use of rapid data gathering technologies in a variety of fields, such as cultural heritage, Geography Information Systems (GIS), 3D city modeling, and the production of Digital Terrain Models (DTM). Geomatics experts must use Light Detection and Ranging (LiDAR) to filter out the bare ground from point cloud data. So, the Cloth Simulation Filtering (CSF) ground filtering technique is discussed in this study. The ground and non-ground point clouds of the airborne LiDAR point cloud data were separated for assessment. All point cloud data must be compared for an accurate appraisal of filtering accuracy. However, the data is so massive; this seems implausible. Data manually identified as ground and non-ground were used as a reference to measure classification success adequately. Our findings show that the CSF approach's performance is sufficient but depends on the kind of point cloud, the slope, and the vegetation type.

1. Introduction

In geomatics applications, airborne LiDAR techniques are utilized for rapid data collection on various topographic land surveys. Additionally, many applications have used elevation and geomorphological data from digital elevation models (DEMs) produced by these methods (Erol S. et al., 2020). Large high-resolution regions may be quickly and accurately mapped using LiDAR technology, progressively replacing other methods as the primary way to create Digital Terrain Models (DTMs). On the other hand, DTMs are used to represent the bare soil and validate the actual surface. As a result, point clouds produced by these measurement techniques are increasingly used to create DTMs. DTMs are created by filtering aerial LiDAR point cloud data into the ground and non-ground point clouds. However, point cloud filtering (removing bare soil from point cloud data) remains a significant problem when creating DTMs.

Different ground filtering algorithms have been used in GIS or LiDAR software solutions over the past 20 years (for example, Global Mapper, LASTools, and ALDPAT). However, the advantages of these filtering algorithms differ from terrain to terrain, and each technique employed to cope with various terrains has advantages and disadvantages. In order to choose the best filters, it is advantageous to compare the performance of different filtering algorithms (Chen, C., 2021). However, most algorithms (Klápt, P. et al., 2021; Meng, X., Currit, & Zhao, 2010; Susaki, J., 2012; Rashidi, P., & Rastiveis, H., 2017) are made to filter ALS data. Multiple laser pulse returns are recorded sequentially by the ALS. The ALS records the sequence of multiple laser pulse returns. The values obtained from bare-earth topography that make up the ground points in LiDAR data are typically the lowest surface characteristics in a given locality. Non-ground points are measurements taken from trees, buildings, bridges, and bushes above bare soil. Understanding the physical traits of ground points that set them apart from non-ground points is crucial for correctly identifying them (Xuelian Meng., et al., 2010). As a result, the ground filter algorithm represents the ground using these attributes.

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In post-processing light detection and ranging (LiDAR) data, it is critical to classify the initial point clouds into ground and non-ground points. The cloth simulation filtering (CSF) algorithm is generally used to validate ground points based on physical processes. Cloth simulation is also known as cloth modeling in computer programming. CSF algorithm is an accurate, automatic, easy-to-use LiDAR point cloud algorithm. Particularly, this algorithm's accuracy is similar to the majority of modern ground filtering algorithms. Due to the fact that it has few parameters to process, the users can rapidly implement them with little experience.

Accuracy assessment is essential in ground and non-ground filtering algorithms and its application enhancement. The same test areas are used to evaluate the accuracy of ground filtering algorithms. The accuracy assessment methods of this application have three primary categories, including visual inspection, random sampling of ground-filtered data, and cross tabulation with classified ground truth data (Xuelian Meng., et al., 2010). This study evaluates the CSF algorithm's performance on two LiDAR point cloud data. In addition, it is used to analyze the effects of filtering methods applied to various cloth resolutions. Cloth resolution relates to the grid size of cloth implemented for masking the surface (Zhang et al., 2016).

2. Method

In this study, LiDAR point cloud data were obtained by test flights from 1200 m heights with the Riegl LMS-Q1560 and Optech LiDAR system provided by the general directorate of mapping of Turkey. A manual accuracy assessment approach was preferred for the performance of filtering. The primary purpose of this study is to evaluate the performance of CSF method in different point clouds and different cloth resolutions in the same area.

2.1. Study Area

The case study area for aerial LiDAR data is located in the Bergama test site in Turkey (Figure 1). The land size is 150 m in length and 100 m in width. After obtaining the point cloud data with two different airborne LiDAR systems, the data were processed, and the DTMs were gained with the CSF algorithm's different cloth resolutions for this study area. Furthermore, the accomplishment of the filter algorithms in DTM generation was evaluated and examined.

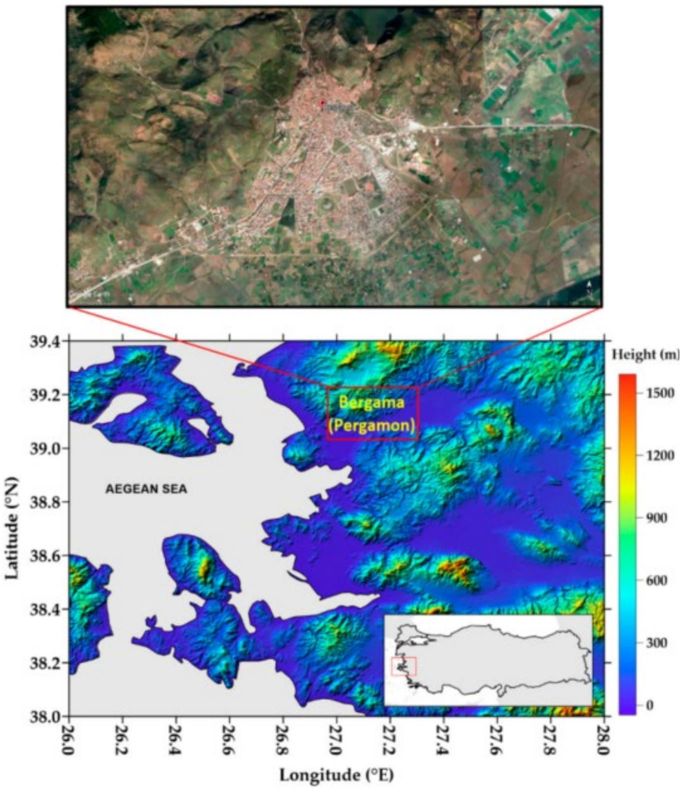

Figure 1. Google Earth image (top) and SRTM DTM (bottom) of Bergama test area (Erol, S. et al., 2021)

2.2. Filtering

In order to create a digital terrain model, filtering is the process of deciding whether data relates to the ground or non-ground surface. Numerous filtering algorithms fall into one of five categories [Buján, S., 2020; Štular, B., & Lozić, E., 2020; Pfeifer, N. and G. Mandlburger, 2018; Süleymanoğlu, B. and Soycan, M., 2019, Kuçak, R. A., 2022):

- Morphological filtering (PMF, SBF, SMRF),
- Surface-based filtering (WLS, CSF),
- Segmentation-based filtering (SegBF),
- Progressive densification (PTIN),
- Other (MCC), and Hybrid (BMHF).

According to Zhang et al. (2016), the CSF algorithm divides point clouds into the ground and non-ground points using a cloth simulation approach. CSF is a cloth simulation-based airborne LiDAR filtering technique. It only attempts to replicate how cloth nodes and accompanying LiDAR points interact. An approximate representation of the ground surface may be created by determining the positions of the cloth nodes. By comparing the original LiDAR points with the produced surface, the ground points may be retrieved from the LiDAR point cloud. Thus, cloth simulation filtering (CSF) could refer to the filtering algorithm (W. Zhang et al., 2016). Figure 2 illustrates the overview of the CSF algorithm.

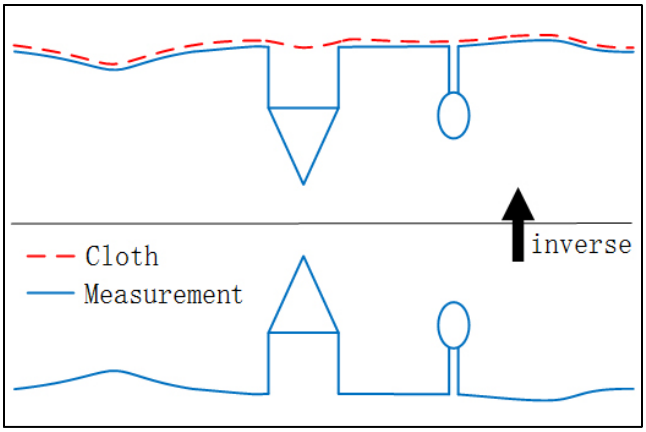

Figure 2. Overview of the CSF algorithm (Zhang et al., 2016).

The point cloud data were filtered using the CSF method in this case study, and DTMs were produced. CSF is built on surface-based filtering methodologies. All points are first acknowledged as ground points; then, all non-ground points are gradually removed. The surface is generally defined using all of the points from the first step using simple kriging. The distance between the ground and non-ground places is an average surface. The separation from the mean surface determines the residual value (Pingel, T. J., 2013; Süleymanoğlu, B. and Soycan, M., 2019, Kuçak, R. A., 2022).

The efficiency of filtering methods was investigated in this study utilizing ground and non-ground data using a manually edited process (Visual inspection). Visual inspection is a widely used manual accuracy evaluation technique when unavailable ground truth data. Error type I, II, and accuracy were three additional indices based on an employed confusion matrix (Table 1), (Susaki, J., 2012). How equations (1), (2), and (3) are represented (Kuçak, R. A., 2022).

$$\text{error type I} = b/(a+b), \quad (1)$$

$$\text{error type II} = c/(c+d), \quad (2)$$

$$\text{accuracy} = (a+d)/(a+b+c+d), \quad (3)$$

Table 1. Structure of Confusion Matrix

		Classified Points	
		Ground Points	Non-ground Points
Reference Points	Ground Points	a	b
	Non-Ground Points	c	d

3. Results

DTM filtering (CSF method) was applied to two aerial LiDAR data sets using Cloud Compare open-source software. The filtering algorithm's correctness was manually examined using reference data. This case study applied the CSF algorithm to Optech and Riegl LiDAR point clouds and filtered ground and non-ground points with both 0.1 and 0.05 cloth resolution.

3.1. CSF Algorithm with 0.1 Cloth Resolution

Firstly, LiDAR point clouds and filtered ground and non-ground points with 0.1 cloth resolution in this case study. Approximately 173.600 points were filtered as ground points for the Optech point cloud. Also, approximately 98.600 points were filtered as non-ground points (Figure 3a). Approximately 134.400 points were filtered as ground points for the Riegl point cloud. Also, approximately 51.000 points were filtered as non-ground points (Figure 3b).

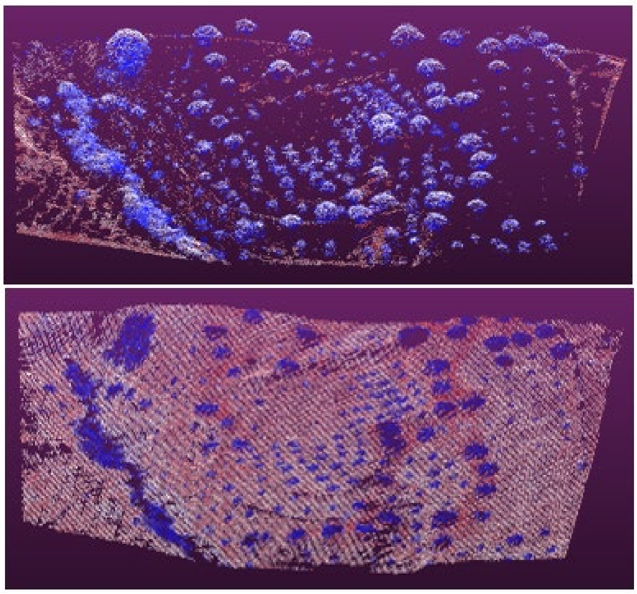

Figure 3a. The ground (bottom) and the non-ground (top) points of Optech Data with CSF 0.1

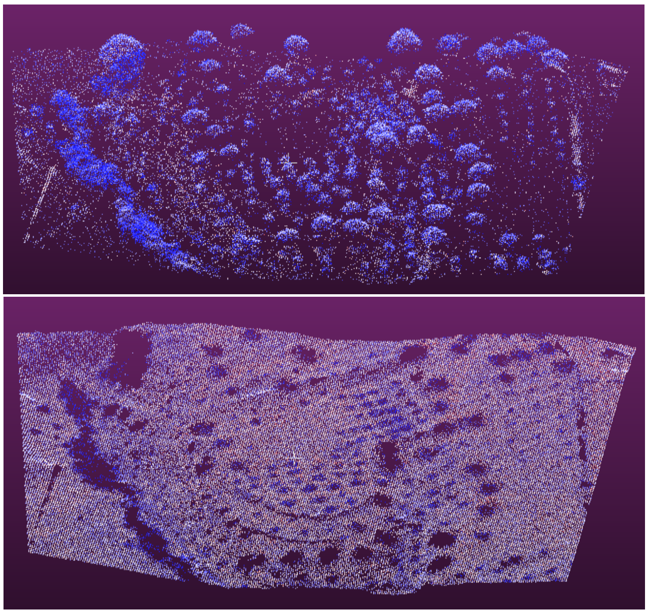

Figure 3b. The ground (bottom) and the non-ground (top) points of Riegl Data with CSF 0.1

3.2. CSF Algorithm 0.05 Cloth Resolution

This case study shows filtered ground and non-ground points with 0.05 cloth resolution. For the Optech Data, approximately 164.300 points were filtered as ground points. Also, approximately 107.800 points were filtered as non-ground points (Figure 4a). Approximately 108.000 points were filtered as ground points for the Riegl point cloud. Also, approximately 77.500 points were filtered as non-ground points (Figure 4b).

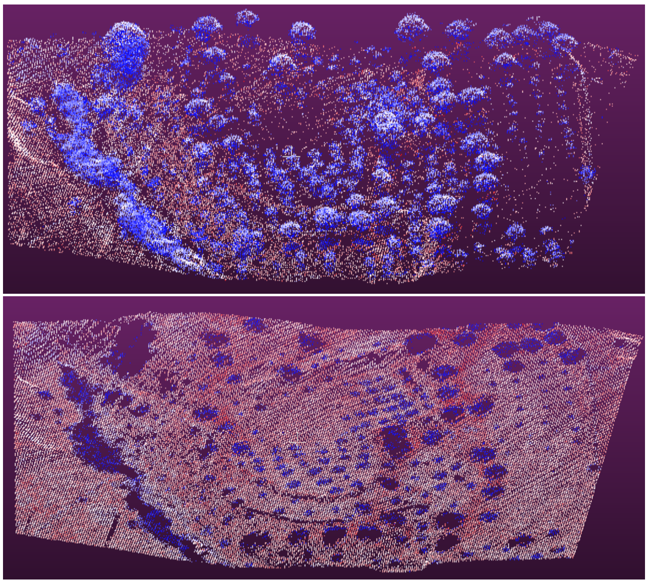

Figure 4a. The ground (**bottom**) and the non-ground (**top**) points of Optech Data with CSF 0.05

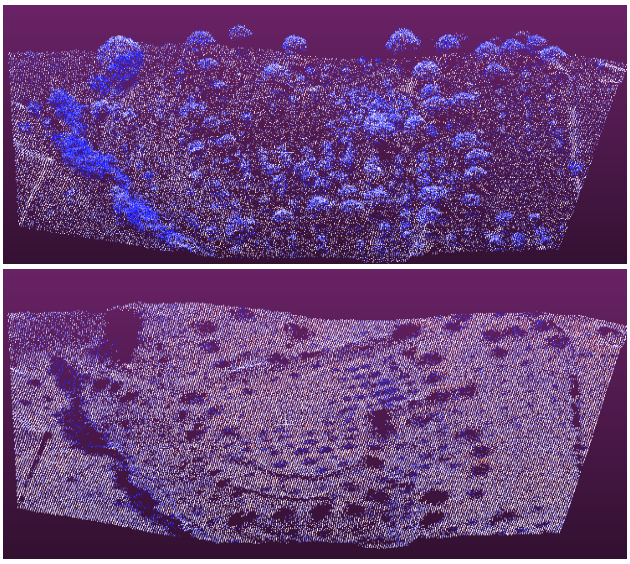

Figure 4b. The ground (**bottom**) and the non-ground (**top**) points of Riegl Data with CSF 0.05

3.3. Evaluation of Filtered Data

Accuracy assessment is essential in ground and non-ground filtering applications and algorithm development. The same test sites are selected to compare and evaluate ground filtering algorithms. Three primary categories of accuracy assessment methods, including visual inspection, random sampling of ground-filtered data, and cross tabulation with classified ground truth data can be used (Xuelian Meng., et al., 2010).

Cloud Compare software was preferred for DTM filtering. The filtering methods were carried out using manually altered reference data, and ground and non-ground data were used as references (Table 1).

The computed type I, type II, and accuracy for the test samples are shown in Table 2. Confusion Matrix has performed with Visual inspection approach. The CSF 0.05 approach has produced the most reliable findings compared to the CSF 0.1 approach. Riegl Lidar CSF 0.05 has the best results with %99 accuracy value for filtering. This case study obtained the most accurate results with CSF 0.05 cloth resolution. This means 0.05 cloth resolution is a more suitable approach for Riegl data. This value needs to be changed to get better results with Optech. This result does not mean the CSF algorithm is inadequate for Optech data. This is a problem for users choosing inappropriate values. As a result, this study also showed that the cloth resolution value in CSF filtering is significant for ground filtering, and the appropriate value should be determined according to the resolution of the point cloud. If care is not taken, ground filtering can cause many errors.

Table 2. The Confusion Matrix of the filtering methods

Sample Dataset	Type I Error (%)	Type II Error (%)	Accuracy
Riegl CSF 0.1	35	17	77
Riegl CSF 0.05	1	1	99
Optech CSF 0.1	48	33	61
Optech CSF 0.05	43	31	63

4. Discussion

Ground and non-ground data were included in the reference data that was performed using the filtering methodologies using the manually filtering approach. The size of the cloth grid used to cover the ground is called the "cloth resolution". The bigger the cloth resolution has set, the coarser DTM will get. On the other hand, different data types cannot use the same cloth resolution. When using the CSF algorithm, the most appropriate value should be chosen by each data because each data's resolution varies. The following factors when selecting workspaces for testing the reliability of ground and non-ground filters should be considered; the difference in slope and elevation, the size and density of objects, the size of the working area, and surface properties. They also affect filtering as they are factors that affect resolution. As a result, this study also demonstrated the importance of the cloth resolution value for ground filtering in CSF filtering and the need to choose the correct value based on the point cloud's resolution. Ground filtering can lead to several mistakes if caution is not applied.

Another factor affecting the comparison of filtering methods is that two different data taken from the same height have a topographic feature in a rural area, that is, without buildings. Natural objects belonging to the earth always provide the best results. Finally, the better result of the Riegl CSF approach can be interpreted differently depending on the parameter changes. However, these results will serve as a reference for future studies.

5. Conclusion

In this study, existing techniques for ground filtering on point clouds are experimentally investigated. These tests highlighted numerous aspects of the methodology by comparing two separate aerial LiDAR datasets with various cloth resolutions. The case study location for aerial LiDAR data is Bergama. The accuracy values for the two datasets and the cloth resolution levels can be adjusted for ground filtering, demonstrating the efficacy of the suggested method for filtering LiDAR data. Shortly, correct filtering can be achieved in both data with correct cloth resolution. These filtering results demonstrated that the suggested strategy might effectively remove non-ground points from LiDAR point clouds.

In future LiDAR filtering applications, novel filtering algorithms for broad fields will be evaluated. The impact of UAV and mobile LiDAR point cloud quality on filtering results will be investigated. The suitable methods for ground filtering will be searched by trying the same algorithms on different data for accurate filtering.

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Author contributions

The authors declare that they have contributed equally to the article.

Conflicts of interest

There is no conflict of interest between the authors.

Statement of Research and Publication Ethics

Research and publication ethics were complied with in the study.

References

Buján, S., Cordero, M., & Miranda, D. (2020). Hybrid overlap filter for LiDAR point clouds using free software. *Remote Sensing*, *12*(7), 1051.

Chen, C., Guo, J., Wu, H., Li, Y. & Shi, B. (2021). Performance Comparison of Filtering Algorithms for High-Density Airborne LiDAR Point Clouds over Complex LandScapes. *Remote Sensing*, *13*(14), 2663.

Erol, S., Özögel, E., Kuçak, R. A. & Erol, B. (2020). Utilizing Airborne LiDAR and UAV Photogrammetry Techniques in Local Geoid Model Determination and Validation. *ISPRS International Journal of Geo-Information*, *9*(9), 528.

Klápště, P., Fogl, M., Barták, V., Gdulová, K., Urban, R. & Moudrý, V. (2021). Sensitivity analysis of parameters and contrasting performance of ground filtering algorithms with UAV photogrammetry-based and LiDAR point clouds. *International Journal of Digital Earth*, *13*(12), 1672-1694.

Meng, X., Currit, N. & Zhao, K. (2010). Ground filtering algorithms for airborne LiDAR data: A review of critical issues. *Remote Sensing*, *2*(3), 833-860.

Pfeifer, N. & G. Mandlburger. (2018). LiDAR data filtering and digital terrain model generation, in Topographic Laser Ranging and Scanning. CRC Press. p. 349-378.

Pingel, T. J., Clarke, K. C. & McBride, W. A. (2013). An improved simple morphological filter for the terrain classification of airborne LIDAR data. *ISPRS Journal of Photogrammetry and Remote Sensing*, *77*, 21-30.

Rashidi, P. & Rastiveis, H. (2017). Ground filtering lidar data based on multi-scale analysis of height difference threshold. *Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci*, 225-229.

Štular, B. & Lozić, E. (2020). Comparison of Filters for Archaeology-Specific Ground Extraction from Airborne LiDAR Point Clouds. *Remote Sensing*, *12*(18), 3025.

Süleymanoğlu, B., & Soycan, M. (2019). Comparison of filtering algorithms used for DTM production from airborne lidar data: A case study in Bergama, Turkey. *Geodetski Vestnik*, *63*(3).

Susaki, J. (2012). Adaptive slope filtering of airborne LiDAR data in urban areas for digital terrain model (DTM) generation. *Remote Sensing*, *4*(6), 1804-1819.

Zhang, W., Qi, J., Wan, P., Wang, H., Xie, D., Wang, X., & Yan, G. (2016). An easy-to-use airborne LiDAR data filtering method based on cloth simulation. *Remote sensing*, *8*(6), 501.

Meng, X., Currit, N., & Zhao, K. (2010). Ground filtering algorithms for airborne LiDAR data: A review of critical issues. *Remote Sensing*, *2*(3), 833-860.