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Obtaining ground points using CSF Filter algorithm in various airborne LIDAR point cloud data

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Abstract

Airborne laser scanning (ALS) is a remote sensing method widely recognized for its efficiency in acquiring data quickly and delivering accurate results. To ensure the reliability of ALS data, effective decontamination is crucial. This study aims to enhance the data quality of three distinct LIDAR datasets representing urban, rural, and forest environments by applying the CSF Filter algorithm in the CloudCompare software, an open-source tool widely used in point cloud processing. The impact of various data characteristics and input parameters on the filtering results was assessed through a series of comprehensive tests. The results of our analysis revealed a notable relationship between the selected parameters and the quality of the filtered data. Specifically, when the cover value within the CSF Filter parameters was increased, a corresponding increase in data loss was observed, leading to significantly flawed outcomes. These findings emphasize the importance of carefully selecting and fine-tuning the input parameters to avoid undesirable consequences. The findings underscore the importance of combining automated filtering algorithms with manual cleaning to achieve high-quality and reliable point cloud data for various geospatial analyses and applications.

1. Introduction

Modern remote sensing technologies have revolutionized the way we monitor and map large-scale regions, gradually replacing traditional measurement methods. Aerial laser scanning, a prominent laser scanning technology, has emerged as one of the most effective remote sensing methods (Uray, 2022). This technique involves transmitting lasers from scanning devices mounted on aircraft or helicopters, which reflect off objects. The distance between the scanning device and the scanned object is then calculated based on the pulse's return time. Aerial LIDAR systems typically comprise three components: GPS, IMU, and a scanner. The scanner records the reflection values, GPS captures location information of the point cloud, and the IMU-derived orientation parameters of the aircraft assist in calibrating the point cloud (Civelekoğlu, 2015).

Remote sensing methods, such as LIDAR, facilitate the creation of numerical elevation models that encompass comprehensive elevation information of the Earth's surface. Models containing three-dimensional information about various structures on the Earth's surface are known as numerical elevation models, while those representing only the bare land surface are referred to as numerical terrain models (Uray, 2022).

LIDAR technology enables the collection of raw data on both natural and man-made objects present on the Earth's surface (Kostrikov, 2019). It allows for rapid and precise acquisition of physical data in a non-contact manner, facilitating the creation of accurate 3D models (Fidan and Fidan 2021).

This study aims to investigate the performance of different filtering algorithms, specifically focusing on the CSF filter algorithm, in determining ground points for classification in point clouds obtained using LIDAR technology. The research examines various point clouds with distinct properties and compares the accuracy rates of different classification and filtering algorithms. The objective is to determine which algorithm delivers more successful filtering results for specific feature-bearing point clouds.

Previous studies in the literature have employed the CSF filtering algorithm for filtering ground points, such as the study titled "Performance Analysis of the CSF Algorithm for Filtering Ground Points." This research focused on an area characterized by challenging terrain with steep slopes and dense forest cover. Orthophotos

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obtained simultaneously with the LIDAR data served as reference data for the study. Point cloud data were processed using the CloudCompare software, with specific parameter values selected for filtering operations. The study employed a classification threshold value of 0.5, a repetition time of 1000, and varied grid resolutions of 0.2, 0.3, 0.4, 0.5, 1, and 2. The results demonstrated distortions in the surface model with increasing grid resolution values, resulting in a reduced number of ground-class points. Consequently, manual filtering was deemed necessary to eliminate non-ground points.

By conducting an in-depth analysis of different filtering algorithms, this study contributes to the field of current research topics in LIDAR technology. The findings offer insights into the most effective filtering algorithms for specific types of feature-bearing point clouds, facilitating accurate data analysis and interpretation for various applications (Karasaka and Keleş, 2020).

2. Materials and Methods

2.1. Point Cloud Filtering

In order to create a SAM with LIDAR, the points belonging to the ground class must be cleared of objects that do not belong to the ground class, such as trees and buildings. This process in question is called filtering (Soycan et al., 2011b).

When the physical properties of the ground points are taken into consideration, they are grouped in four different ways (Süleymanoğlu and Soycan, 2017; Meng et al., 2010):

- **The lowest height:** Ground points are points located at an additional low altitude in the available October LIDAR data.
- **The steepness of the floor surface:** When looking at the Declivity between the ground and points that do not belong to the ground, it is steeper than the Declivity between neighboring ground points.
- **The height difference between the decking points:** The high elevation differences of the points between each other indicate the points belonging to objects such as buildings and trees, while the low elevation differences indicate that it is the declivity point.
- **Homogeneity of the floor surface:** The points belonging to the ground are partly smoother and more continuous than the points belonging to other objects.

2.2. Method

In this study, we investigate the effectiveness of the CSF Filter algorithm, implemented in the CloudCompare software, for filtering LIDAR point cloud data with urban, rural, and forest characteristics. By varying the input parameter values, we aim to determine which parameter values yield more accurate ground point classification. The study involves the creation of Surface Models (SAM) for each parameter value applied in the filtering algorithm, followed by an accuracy analysis of the resulting SAMs.

During the acquisition of LIDAR point clouds, atmospheric conditions like fog or rain can lead to the formation of noise points. Manual cleaning methods using the CloudCompare software are employed to remove these noise points. Subsequently, the CSF Filter algorithm, available in CloudCompare, is utilized for ground point classification. The cover value parameter is assessed using different combinations to determine its impact on the filtering results.

Through this research, we aim to identify the most effective parameter values for accurate ground point classification in LIDAR point cloud data. The findings will contribute to enhancing the data quality and reliability of LIDAR-based applications in urban, rural, and forest environments. Additionally, the study highlights the importance of pre-processing steps, such as manual noise removal, and provides insights into the optimization of the CSF Filter algorithm for improved point cloud filtering.

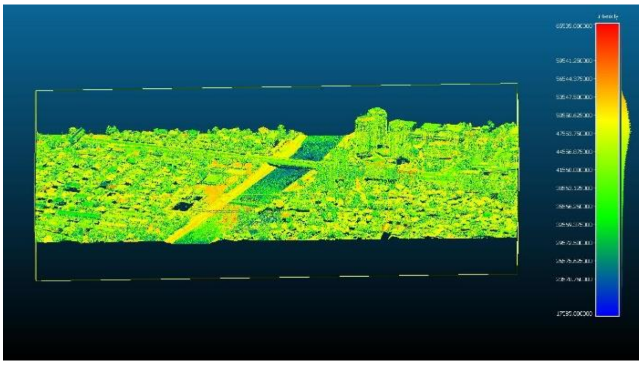

Figure 1. Display of urban area LIDAR data in CloudCompare software

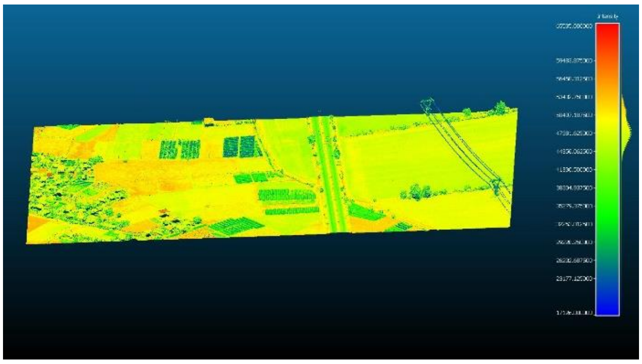

Figure 2. Displaying rural area LIDAR data in CloudCompare software

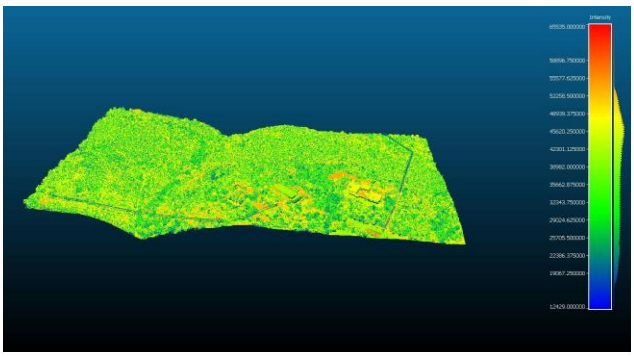

Figure 3. Displaying forest area LIDAR data in CloudCompare software

2.3. Filtering of LIDAR data – urban area

The urban area with a total of 312 buildings, is a part in the western part of Skopje, the capital of North Macedonia (Figure 1). The study area is divided into two parts by the Vardar river, which is about 60 m wide, while there are dense and low residential grid-like buildings with a maximum height of 10 m on the left side of the study area, and there are taller residential and commercial buildings on the right side. The maximum height is 70 m. The working area is generally flat, and the surface height of the working area varies between 250-327, while the terrain height is between 25 Dec-Dec 325. Besides the buildings, there are many trees, bridges and a river bank 20 m wide on both sides in the study area (Kaplan et al. 2022).

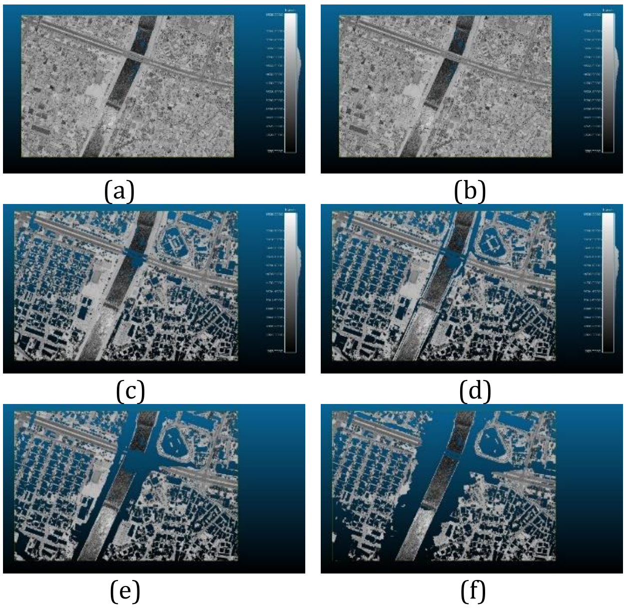

Figure 4. For an urban LIDAR point cloud; (a) The Original Point Cloud, (b) Data Obtained As a Result of Entering the CSF Filter Algorithm Cover Value as 0.1, (c) Data Obtained as a Result of Entering the CSF Filter Algorithm Cover Value as 0.5, (d) Data Obtained As a Result of Entering the CSF Filter Algorithm Cover Value as 1, (e) Data Obtained as a Result of Entering the CSF Filter Algorithm Cover Value as 2, (f) Data Obtained as a Result of Entering the CSF Filter Algorithm Cover Value as 5.

2.4. Filtering of LIDAR data – rural areas

The agricultural study area is flat and consists of corp fields, divided with a road. The main part of the crops is empty, while smaller part of the area consists of green crop lands (Figure 5).

2.5. Filtering of LIDAR data – forest area

The forest area is characterized by its abundant growth of dense and towering trees, which create a captivating and enchanting environment. The natural landscape is further enhanced by the presence of rugged mountains.

The terrain within the forest area is undulating, with varying altitudes and steep slopes that add a sense of adventure and challenge to exploring the region (Figure 6).

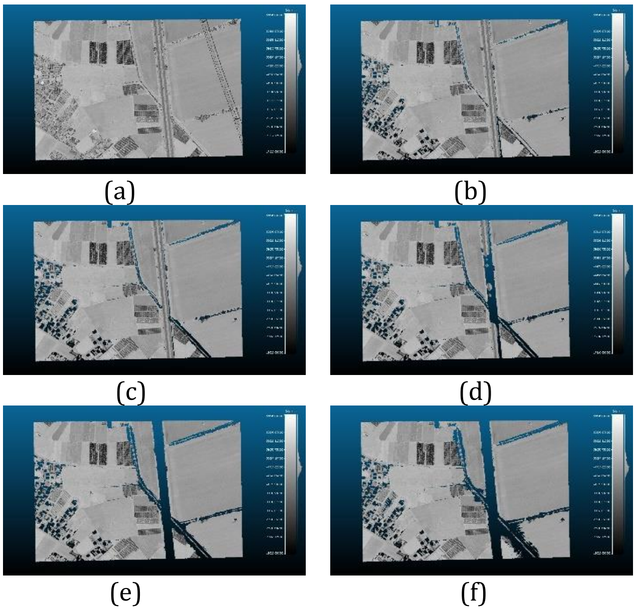

Figure 5. For rural LIDAR point cloud; (a)The Original Point Cloud, (b)The Data Obtained As a Result of Entering the CSF Filter Algorithm Cover Value as 0.1, (c) The Data Obtained as a Result of Entering the CSF Filter Algorithm Cover Value as 0.5, (d) The Data Obtained as a Result of Entering the CSF Filter Algorithm Cover Value as 1, (e) The Data Obtained as a Result of Entering the CSF Filter Algorithm Cover Value as 2, (f)The Data Obtained as a Result of Entering the CSF Filter Algorithm Cover Value as 5.

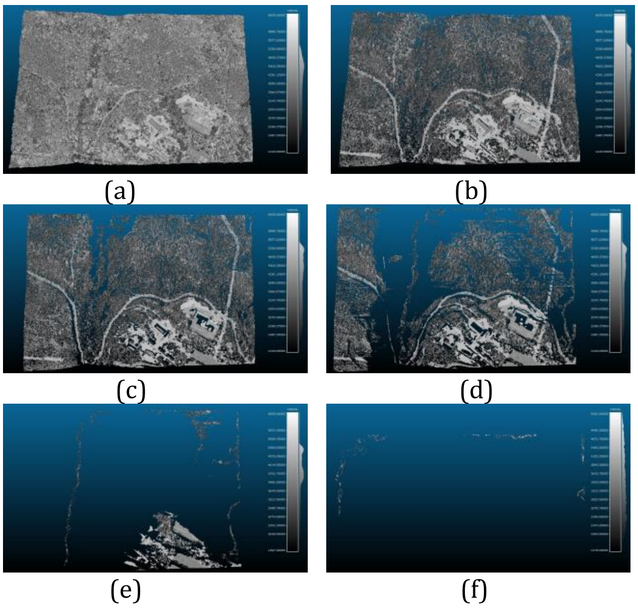

Figure 6. For Forest LIDAR point cloud; (a)The Original Point Cloud, (b)The Data Obtained As a Result of Entering the CSF Filter Algorithm Cover Value as 0.1, (c) The Data Obtained as a Result of Entering the CSF Filter Algorithm Cover Value as 0.5, (d) The Data Obtained as a Result of Entering the CSF Filter Algorithm Cover Value as 1, (e) The Data Obtained as a Result of Entering the CSF Filter Algorithm Cover Value as 2, (f) The Data Obtained as a Result of Entering the CSF Filter Algorithm Cover Value as 5.

3. Results

When examining the ground points classified by the CSF Filter algorithm, it becomes evident that there is a loss of data in the ground points as the cover value increases, leading to noticeably incorrect classifications. While it was initially assumed that the decrease in the cover value would accurately determine the actual ground points, it is observed that planar areas such as building roofs are mistakenly classified as ground points.

In assessing the urban, rural, and forest characteristics of the data, it becomes apparent that the most successful results are achieved in rural areas. However, this assessment has been primarily based on visual analysis. In future studies, it is crucial to perform a statistical accuracy assessment to obtain more reliable and objective results. By conducting such an assessment, the outcomes can be quantitatively compared and analyzed to validate the algorithm's performance across different landscapes.

This statistical accuracy assessment would involve rigorous data analysis and comparison of ground truth data with the algorithm's classifications. Furthermore, the assessment should consider factors like the complexity of urban and forest environments, as they pose additional challenges for accurate ground point classification.

By conducting a thorough statistical accuracy assessment, it will be possible to gain a deeper understanding of the algorithm's limitations and strengths across various landscape types. This assessment will provide more robust evidence to evaluate the algorithm's effectiveness and guide future improvements and optimizations.

In conclusion, while the CSF Filter algorithm exhibits data loss and incorrect classifications in ground points with increasing cover values, a more comprehensive and statistically rigorous accuracy assessment is required to assess its performance accurately. By conducting such an assessment and comparing the results across different urban, rural, and forest landscapes, a clearer understanding of the algorithm's performance can be obtained, leading to further improvements and advancements in the future.

4. Discussion

In the process of removing ground points, which is being performed using the CSF Filter algorithm, manual cleaning operation is required in the remaining parts due to the fact that planar areas are considered as ground. In this way, the process of obtaining ground points will reach a more accurate result.

5. Conclusion

In order for the accuracy analysis to be performed with more precise results, reference SAM data are needed. As a result of comparing the obtained data with the reference data, the accuracy rates of the parameters will be determined more accurately.

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