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Ground Point Removal From 3D Point Cloud Using 3d Ransac Based on Normal Vector

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ABSTRACT

Capturing objects in the real world using Light Detection and Ranging (LiDAR) is challenging due to the existence of ground points. The ground point tends to reduce the performance of computer vision-related tasks such as object recognition, detection, segmentation, and classification. This paper proposes a ground removal method for 3D Point Cloud using Random Sample Consensus (RANSAC). RANSAC algorithm effectively removes ground points on normal vector-based 3D points cloud objects. RANSAC fits data models containing significant inliers. By selecting the coordinate points, followed by calculating plane equation coefficients using normal vectors, removal is done by calculating each point's distance from the ground plane and identifying inliers based on a specified threshold. This analysis shows that the RANSAC algorithm effectively removes ground points.

INTRODUCTION

Light Detection and Ranging (LiDAR) technology has become popular in remote sensing, where it utilizes laser light to measure the height and topography of the ground surface [1]. LiDAR produces data as a point cloud, a collection of points in three-dimensional space with x, y, and z coordinates that visually represent objects and surface features through scanning the LiDAR sensor. The use of LiDAR, especially in autonomous vehicle navigation, has undergone significant development [2].

LiDAR is usually used to track and estimate the driver of a vehicle on the road. However, capturing data from real-world objects using LiDAR is often challenging due to the presence of ground points, which

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are collection of points representing the ground [3]. These ground points tend to reduce the performance of computer vision-related tasks, such as object recognition, detection, segmentation, and classification [3].

This research introduces a highly effective method to deal with ground points in LiDAR data. Random Sampling Consensus (RANSAC) is a robust modeling algorithm, and its performance is often compared to linear regression algorithms so that outliers are rejected [4]. This is in contrast to previously used approaches, such as the tornado algorithm, which is inspired by nature and can destroy buildings and uproot trees [5]. This algorithm is suitable for modeling data that contains significant outliers. By selecting coordinate points, followed by calculating the plane equation coefficients using normal vectors, the removal is done by calculating the distance of each point from the ground plane and identifying the inliers based on the specified threshold. The analysis shows that the RANSAC algorithm can effectively remove LiDAR data ground points.

This research is expected to contribute to other studies that conduct 3D object processing research related to computer vision. Thus, this research not only provides a better understanding of the ground point problem in LiDAR data but also provides an effective solution to improve the image processing performance of LiDAR data.

EXPERIMENTAL

This research aims to remove ground points on 3D point cloud objects going through several stages. Several stages will be carried out, including datasets, pre-processing, processing, and results. The research stages to be carried out can be seen in Fig. 1.

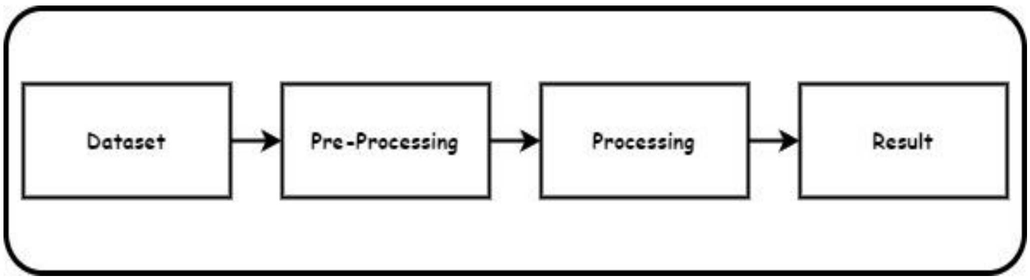

Fig. 1. The flow of research stages for ground point removal.

In this research, the authors collect data that will be used to carry out an analysis. To obtain this data, the authors used LiDAR type OS1-32 from OUSTER [6]. This sensor has specifications equipped with 32-line scanning, 2048 points in one column, a field of view (FOV) of 45°, precision of up to 0.5 cm, and a range of up to 90 meters. The LiDAR sensor is positioned in the top corner of the room, measuring 4x6 meters, and then oriented 45° downwards towards the center point.

The object used is a human pose placed in the middle position with a 50:50 ratio. The sensor is performed by posing in various ways, including lying, standing, bending, sitting, squatting, and side hands. Each session is taken for 20 seconds, covering an area between 90° and 270°, and the output produced via LiDAR capture is in Packet Capture (PCAP) format, which is then converted into Point Cloud (PCD) format [7]. Human pose data after conversion can be seen in Fig. 2.

However, data converted into PCD format cannot be executed directly because it requires cropping. The minimum and maximum measurements and calculations for the data cropping process at x, y, and z coordinates are required. The minimum and maximum cropping data values can be seen in the

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table 1. After the data cropping, the results leave ground points and 3D point cloud human poses. By cropping this data, the research performance process in removing ground points will be more effective and accurate. The cropped data can be seen in Fig. 3.

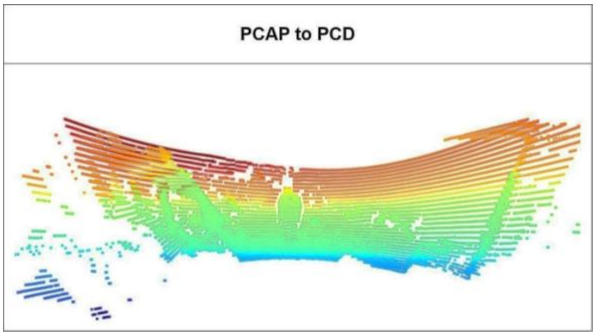

Fig. 2. The human pose data after conversion.

Table 1. The minimum and maximum cropping data values.

No.	Coordinates	min	max
1	X	2.1	3.5
2	Y	-0.6	1.1
3	Z	-1.2	1.1

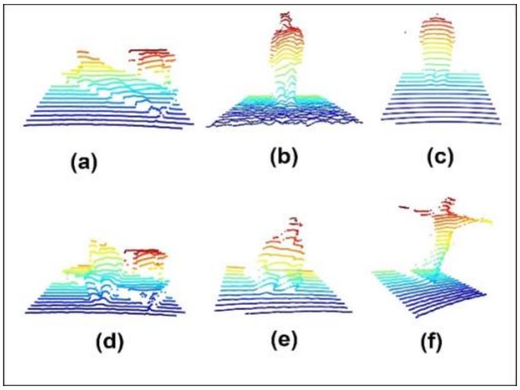

Fig. 3. This figure is cropped data from various poses: (a) lying, (b) standing, (c) bending, (d) sitting, (e) squatting, and (f) side arms.

Pre-processing

After data collection preparation, data conversion into PCD format and cropping is complete. Authors prepare supporting libraries for further analysis. The libraries authors use in this research are NumPy and open3D. The NumPy library is used for numerical processing in Python, while the open3D library is used for 3D point cloud data visualization processes. Then, the data was imported into the Jupiter Notebook platform to create a dataset to carry out analysis for the research.

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Processing

After preparing the dataset and importing data into the platform, the following analysis is in the processing stage. This stage is the stage of deleting ground points in the data. This process will go through normal vector calculations to determine plane equation coefficients and ground point elimination using the RANSAC method by calculating the distance of each point from the ground plane and identifying inliers based on the specified threshold.

After processing the results using the normal vector estimation stages, the RANSAC method, and ground point removal, the researchers visualized them. Examples of visualization results of 3D point cloud objects (human poses) before and after can be seen in Fig. 4.

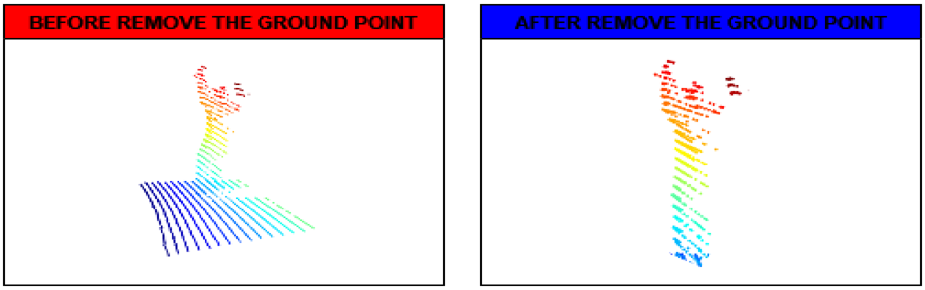

Fig. 4. (left) This figure is taken before removing the ground point; (right) This figure is taken after removing the ground point. Human pose visualization results.

RESULTS AND DISCUSSION

In this stage, the RANSAC method removes ground points on 3D point cloud objects using data captured by LiDAR sensors. Deletion is carried out by selecting coordinate points, followed by calculating the plane equation coefficients using a normal vector by calculating the distance of each point from the ground plane and identifying inliers based on the specified threshold.

Calculate *Normal Vector*

Before determining the coefficients of the plane equation in 3D space, authors first determine the normal vector. The steps that must be taken are to determine three coordinate points randomly. The authors implemented the three coordinate points to determine the normal vector, including P, Q, and R. Next, from these three coordinate points, the authors connected P and Q to become $\overrightarrow{PQ}$, and then P and R became $\overrightarrow{PR}$[8]. Because $\overrightarrow{PQ}$ and $\overrightarrow{PR}$ are in this plane, they will produce a perpendicular or normal vector for the plane if they are cross produced.

$$\vec{n} = \overrightarrow{PQ} \times \overrightarrow{PR} \quad (1)$$

After determining the normal vector, the plane was calculated using the plane equation formula in 3D space.

$$Ax + By + Cz + D = 0 \quad (2)$$

To see the process more clearly, the three-coordinate calculation process determines the normal vector, followed by calculations using plane equations using the normal vector, which can be seen in Fig. 5.

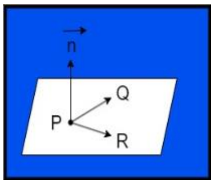

Fig. 5. Normal Vector Calculation Process.

Deleting Ground Point

In this research, authors use the RANSAC algorithm to remove ground points by selecting three coordinate points, which are used to calculate the normal vector, followed by calculating the plane equation coefficients. Then, the plane equation was calculated in cartesian form, which was used to determine the distance at each point to the ground plane and identify inliers based on the specified threshold.

$$Distance = \frac{ax+by+cz+d}{\sqrt{a^2+b^2+c^2}} \quad (3)$$

The threshold value authors use is less than 0.2, which means the value used to determine the extent to which points should be considered as inliers or outliers. The calculation of each point in the ground plane can be seen in Fig. 6.

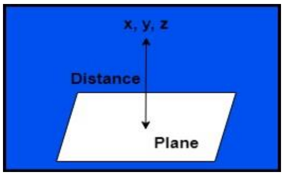

Fig. 6. The calculation of each point in the ground plane.

However, a threshold value of less than 0.2 is only sometimes accurate because it must adjust the human pose of the analyzed LiDAR data. The accurate threshold value for each pose can be seen in Table 2.

Table 2. The accurate threshold value for each pose

No	Poses	Threshold
1	Lying	< 0.2
2	Standing	≤ 0.2
3	Bending	≤ 0.2
4	Sitting	< 0.2
5	Squatting	≤ 0.2
6	Side Arms	≤ 0.2

After adjusting the threshold value to the specified human pose, it will be considered an inlier if the distance is less than 0.2 (threshold) from the estimated plane. The points identified are inliers. After the identification of inliers is complete, authors start looping the inliers to ensure that what is identified and

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removed is the ground point. Once the looping process is complete, inappropriate inliers (ground points) are removed.

Results

The following process is a visualization of the analysis results. The results of ground point removal using the RANSAC method are visualized to see how accurate this method is in removing ground points. The results of ground point removal are shown in Fig. 7.

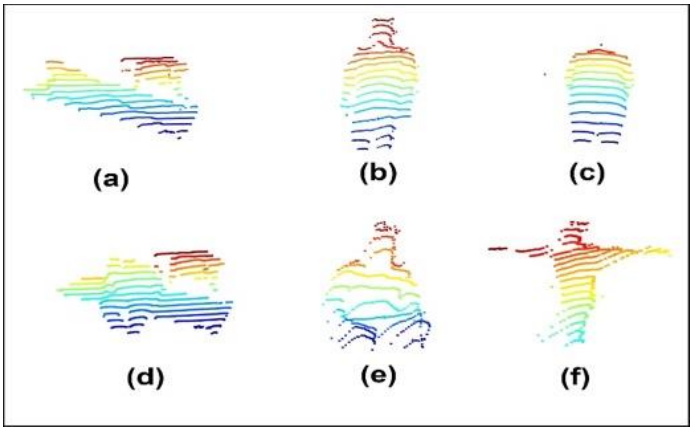

Fig. 7. The calculation of each point in the ground plane.

Based on the research results above, the analysis that has been carried out shows that using the RANSAC algorithm has succeeded in effectively overcoming the problem of ground points in 3D Point Cloud data produced by LiDAR technology. This algorithm can identify and delete ground points accurately, resulting in cleaner and more accurate data. Thus, using the RANSAC algorithm significantly improves data quality, enabling performance in various computer vision tasks sensitive to ground points, such as object recognition, detection, segmentation, and classification.

The implications of the results of this research are very important in the context of 3D data processing related to computer vision. With the success of ground point removal using the RANSAC algorithm, LiDAR data can be used more effectively in various practical applications, including object recognition, detection, segmentation, and classification. Thus, this research makes a significant contribution to overcoming the main challenges in LiDAR data processing, as well as opening new potential in the development of high-quality computer vision applications.

Overall, this research successfully overcame technical problems in LiDAR data processing and has a broad impact on developing more advanced and effective computer vision applications. Thus, this research has important value in developing remote sensing technology and computer image processing, which continues to develop.

CONCLUSION

In the conclusion of this research, the authors can see that this research has several stages in removing ground points, including selecting three coordinate points to determine the normal vector and calculating the plane equation coefficients using the normal vector. Then, the deletion uses the RANSAC approach by calculating the plane equation in Cartesian form, which determines the distance of each point from the ground plane and identifies inliers based on the specified threshold.

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AUTHOR'S CONTRIBUTION

Muhammad Rifqi, who carried out this research, Oddy Virgantara Putra, and Dihin Muriyatmoko as supervisors in this research.

CONFLICT OF INTEREST STATEMENT

The authors declare that no conflicts of interest are associated with this manuscript's publication.

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