

Research Article

# High-Frequency Ground Segmentation for Autonomous Mobile Robots: A RANSAC-Based Approach

Emirhan Cibir<sup>1</sup>, Ulas Birgul<sup>2</sup>, Gokhan Atali<sup>3</sup>

<sup>1</sup> Karmetal, Orcid ID: <https://orcid.org/0009-0001-6100-8482>, E-mail: [emirancibir@gmail.com](mailto:emirancibir@gmail.com)

<sup>2</sup> Karmetal, Orcid ID: <https://orcid.org/0000-0003-0378-312X>, E-mail: [ulasbirgul@karmetal.com.tr](mailto:ulasbirgul@karmetal.com.tr)

<sup>3</sup> Sakarya University of Applied Sciences, Orcid ID: <https://orcid.org/0000-0003-1215-9249>, E-mail: [gatali@subu.edu.tr](mailto:gatali@subu.edu.tr)

Received 18 November 2024

Received in revised form 22 December 2024

In final form 23 December 2024

**Reference:** Cibir, E., Birgul, U., & Atali, G. (2024). High-frequency ground segmentation for autonomous mobile robots: A RANSAC-based approach. *The European Journal of Research and Development*, 4(4), 309-315.

## Abstract

*In this study, a RANSAC-based algorithm was developed for ground segmentation on point clouds obtained from 3D LIDAR sensors. The algorithm employs both distance and normal angle criteria to construct a robust ground plane model, even in the presence of noise and outliers. In the initial stage, a height filter is applied to analyze only the points associated with the ground. Subsequently, the RANSAC method identifies the plane model with the highest number of inliers, dividing the point cloud into two groups: ground and obstacles.*

*The proposed method demonstrated real-time performance with a 20 Hz LIDAR sensor, delivering higher speed and accuracy compared to alternative approaches. This study provides an effective and reliable solution for ground segmentation in autonomous systems.*

**Keywords:** 3D LIDAR, Segmentation, RANSAC, Autonomous Mobile Robot, AMR.

## 1. Introduction

Ground segmentation is a critical component in systems such as Autonomous Mobile Robots (AMR) and intelligent vehicles, enabling navigation, obstacle detection, and environmental mapping. The ground plane defines traversable areas, allowing robots and vehicles to operate safely and efficiently. To achieve this, ground segmentation aims to distinguish ground regions from non-ground areas, typically using data obtained from 3D LIDAR sensors. Since LIDAR sensors collect data from both the ground and

surrounding objects, accurately isolating the ground plane becomes a complex challenge. Misinterpreting the ground as an obstacle may lead to erroneous navigation decisions.

Previous studies in this field have proposed both local and global approaches to address the ground segmentation problem. Local methods focus on analyzing point cloud features to detect ground regions. For instance, the Progressive Morphological Filter (PMF) algorithm uses local height information to identify ground points and has proven particularly effective in sloped terrains (Keki Zhang et al., 2003). However, local approaches often come with high computational costs.

Global methods, on the other hand, aim to construct a plane model across the entire dataset, typically offering lower computational complexity. Among these, the RANdom SAMple Consensus (RANSAC) algorithm has emerged as a robust method for constructing plane models in the presence of noisy and outlier data (Mohd Isa et al., 2019). RANSAC estimates plane parameters from a randomly selected subset of points and selects the model that fits the largest number of data points. Nonetheless, traditional RANSAC methods may experience performance degradation in dynamic environments due to the presence of outliers, as they tend to select the largest plane in the scene, which may sometimes correspond to walls instead of the ground.

In this study, a RANSAC-based ground segmentation algorithm was developed to process point clouds obtained from a 20 Hz LIDAR sensor. The algorithm combines global plane modeling with data preprocessing steps to meet the requirements for high speed and accuracy. The proposed method demonstrates advantages over traditional approaches in separating ground and non-ground points. This paper outlines the key steps of the method, presents experimental results, and discusses its potential applications in industrial autonomous systems.

## 2. Materials and Methods

A RANSAC-based algorithm has been developed for ground segmentation on point clouds obtained from a 3D LIDAR sensor. RANSAC is an algorithm designed to robustly estimate the fundamental parameters of a model, even in the presence of noisy and outlier data within the dataset. First introduced by Fischler and Bolles (1981), RANSAC generates model estimates from a randomly selected subset of data points and identifies

the data points that best fit the model. These features make it a particularly effective solution for dense and noisy data sources such as LIDAR.

The core workflow of the algorithm involves three main stages: data filtering, plane detection, and segmentation.

### 2.1. Application of Height Filtering

Initially, a height filter was applied to the raw data obtained from the LIDAR sensor. This filter was designed to analyze only points falling below a predefined height threshold. Points exceeding this height threshold were classified as obstacles or environmental objects and excluded from further analysis. By implementing the height filter, the algorithm's performance was enhanced, and unnecessary data processing overhead was significantly reduced.

### 2.2. Plane Equation Estimation with RANSAC

From the filtered data, three random points are selected to construct the plane equation. These points are represented as PPP, QQQ, and RRR in Figure 1.

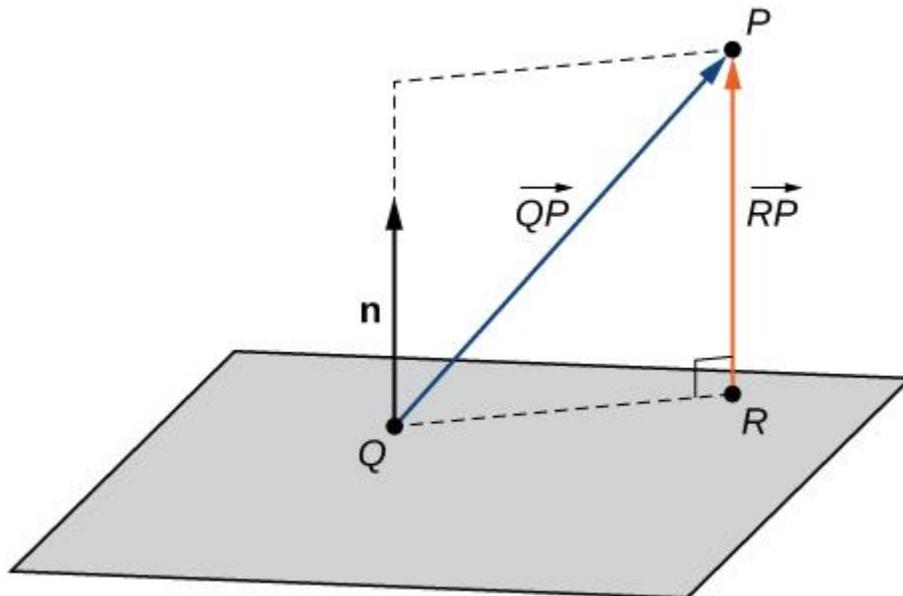


Figure 1 Plane Normal Vector Representation

$$\overrightarrow{QP} \times \overrightarrow{RP} = \vec{n} \quad (1)$$

$$\vec{v}_1 = \vec{Q} - \vec{P} \quad (2)$$

$$\vec{v}_2 = \vec{R} - \vec{P} \quad (3)$$

$$a = v_{1y} \cdot v_{2z} - v_{1z} \cdot v_{2y} \quad (4)$$

$$b = v_{1z} \cdot v_{2x} - v_{1x} \cdot v_{2z} \quad (5)$$

$$c = v_{1x} \cdot v_{2y} - v_{1y} \cdot v_{2x} \quad (6)$$

$$d = -(a \cdot p_x + b \cdot p_y + c \cdot p_z) \quad (7)$$

$$\vec{n} = \vec{v}_1 \times \vec{v}_2 \quad (8)$$

$$ax + by + cz + d = 0 \quad (9)$$

The equation constructed using the coefficients  $a$ ,  $b$ ,  $c$ , and  $d$ , calculated through the formulas provided in Equations 2, 3, 4, 5, 6, 7, 8, and 9, determines whether a point lies on the plane. If a point satisfies this equation, it is considered to be on the plane.

$$distance = \frac{a \cdot x + b \cdot y + c \cdot z + d}{\sqrt{a^2 + b^2 + c^2}} \quad (10)$$

According to the scoring logic of the RANSAC method, the largest plane in the scene is assumed to be the ground plane (this assumption is currently valid). The distance of a point with coordinates  $(x, y, z)$  to the plane is calculated using the formula provided in Equation 10. The plane equations generated by RANSAC are obtained close to the ground plane, as illustrated in Figure 2.

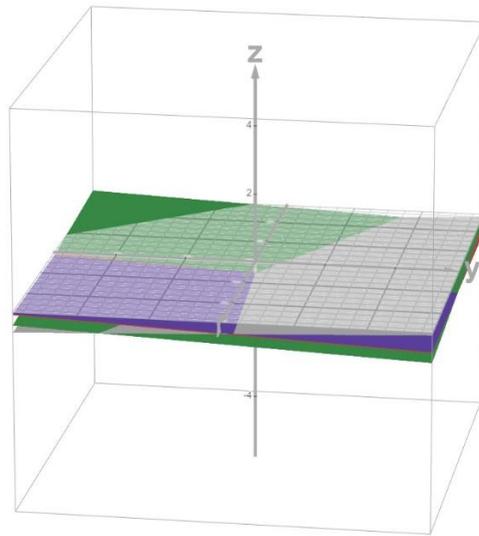


Figure 2 Plane Equations Generated by RANSAC

To determine whether the plane is compatible with the ground, the normal vector of the candidate plane and the distance of each point to the plane were evaluated using a predefined threshold. This distance was geometrically calculated using Equation 11, and points falling below the specified threshold were considered inliers consistent with the model. Additionally, the angle between the candidate plane normals and the Z-axis, as shown in Figure 3, was assessed. Horizontal planes were preferred by the algorithm due to their normals being close to the Z-axis. This dual-validation approach, based on both distance and angular relationships, ensured the selection of a more accurate ground model.

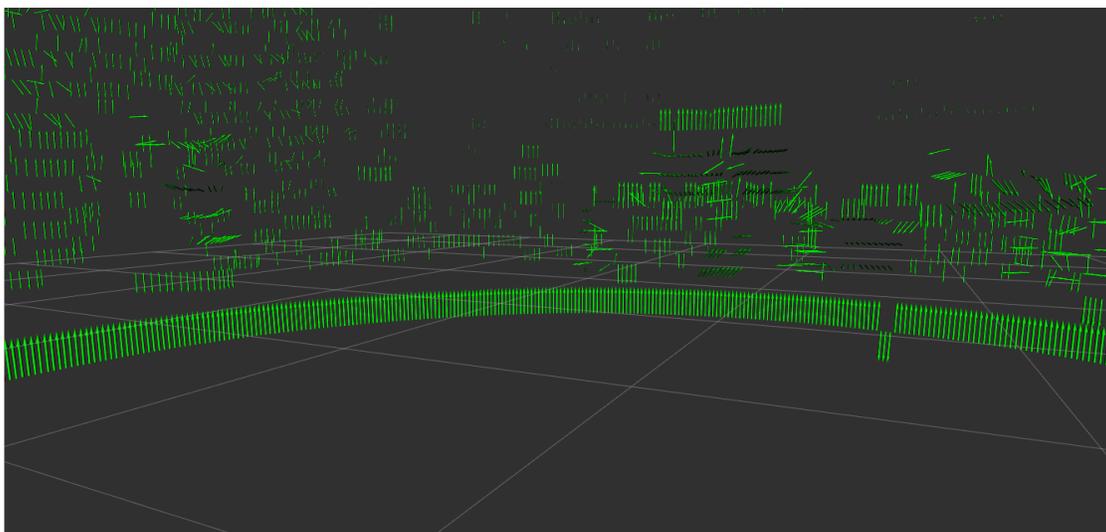


Figure 3 Normal Vectors

### 2.3. Ground Segmentation

The RANSAC-based algorithm identified the optimal ground model by selecting the plane model with the highest number of inliers in each iteration. This approach demonstrated high robustness, particularly in the presence of dense noise and outlier data from 3D LIDAR sensors, significantly improving the accuracy of ground segmentation. The combined use of distance and normal angle criteria prevented potential errors that could arise from evaluations based solely on distance, making ground detection more reliable. The accuracy performance of the algorithm is detailed in Figure 4.

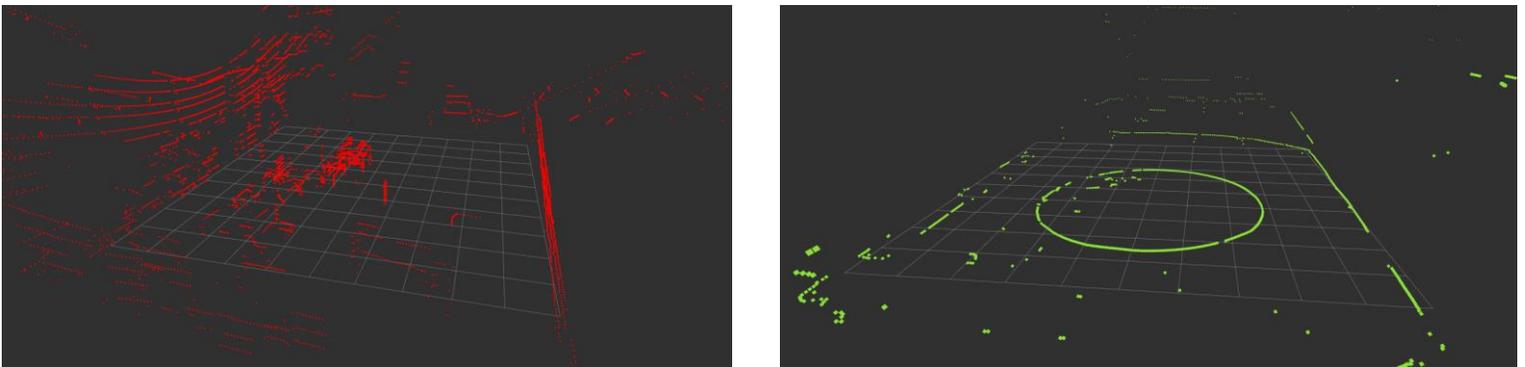


Figure 4. Segmented PointCloud

### 3. Results

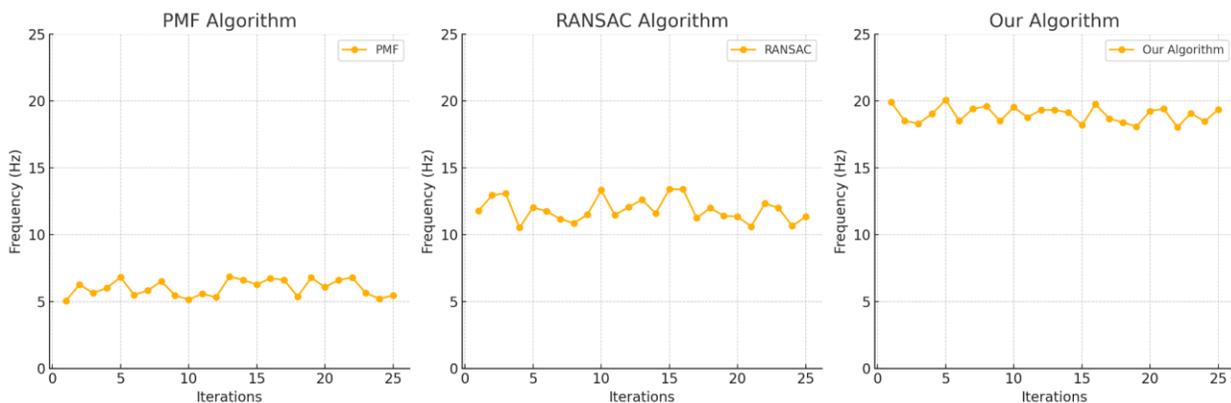


Figure 5. Comparison of Frequency with Other Segmentation Methods

This study presented a RANSAC-based algorithm for ground segmentation on point clouds obtained from 3D LIDAR sensors. Figure 5 provides a comparison of the proposed method with the PMF and RANSAC algorithms. By leveraging both distance and normal angle criteria, the proposed method accurately modeled the ground plane and provided noise-resilient segmentation. The algorithm was tested with a LIDAR sensor providing 20 Hz data output, demonstrating real-time performance. The results showed that the proposed method outperformed other segmentation techniques in terms of speed and accuracy.

This study offers an effective solution for ground segmentation in autonomous mobile robots and intelligent vehicles, providing a reliable foundation for critical applications such as real-time navigation and obstacle detection. In the future, further evaluation of the algorithm's performance in dynamic environments and its integration with data from different sensors could broaden its applicability.

#### 4. Acknowledge

We sincerely thank Karmetal for their invaluable support in the execution of this study.

#### References

- [1] Keqi Zhang, Bryan C. Bourgeois, and David W. Collins, "Progressive Morphological Filter (PMF) Algorithm for Terrain Extraction from Airborne LIDAR Data," *Journal of Photogrammetric Engineering & Remote Sensing*, vol. 69, no. 4, pp. 399-406, 2003.
- [2] Mohd Isa, N. A., Mohamad, N., Yusoff, N. M., and Zabidi, H., "Application of RANSAC Algorithm in Plane Segmentation for Autonomous Driving," *IOP Conference Series: Materials Science and Engineering*, vol. 530, 2019.