Lidar-based Glass Reconstruction for Urban Robotics Application

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Abstract

This paper proposes a light detection and ranging (LiDAR) based method for glass plane reconstruction in urban robotics applications. This approach addresses challenges faced by robotics in urban environments that are abundant in glass surfaces, particularly when LiDAR is the only sensor equipped on the robot. The reconstruction process is carried out using trigonometric calculations based on the detected glass points. By utilizing this method, it is expected that the mapping of glass planes in the environment will be improved, enhancing the accuracy of simultaneous localization and mapping (SLAM) in urban robotics applications.

Keywords: glass, robot, LiDAR, SLAM.

I. Introduction

Glass planes are naturally difficult to detect using LiDAR and even cameras. With LiDAR, only a few points on the point cloud may be obtained from glass planes, specifically when the LiDAR laser beam strikes the glass plane at a normal angle (the laser beam is perpendicular to the glass plane). Consequently, as illustrated in Figure 1, not all areas of the glass plane are detectable by LiDAR, and the few points that are obtained from the glass plane are considered as noise and often ignored by SLAM algorithms. This leads issues ranging from mapping errors and localization failures to navigation mistakes that result in collisions with hard-to-detect glass obstacles.

Previous studies [1], [2], [3] observed the intensity values of a small number of glass points detected by LiDAR when the laser beams were emitted near the normal angle of the glass plane. At this normal angle, the LiDAR laser beam typically produces points that have a higher intensity value than those from other types of materials. From this observation, a threshold value for the intensity of the LiDAR points was established. If the intensity value of a point exceeds this threshold, then the point is categorized as a glass point.

Following this, the mapping process involves storing the positions of detected glass points and adding them to the map as the robot moves across the entire surface of the glass plane. Such a mapping process can lead to navigation failures in applications of active SLAM as the glass plane areas are not directly mapped. Therefore, to address this issue, this paper proposes a comprehensive system for reconstructing glass planes as soon as they are detected.

II. Proposed System

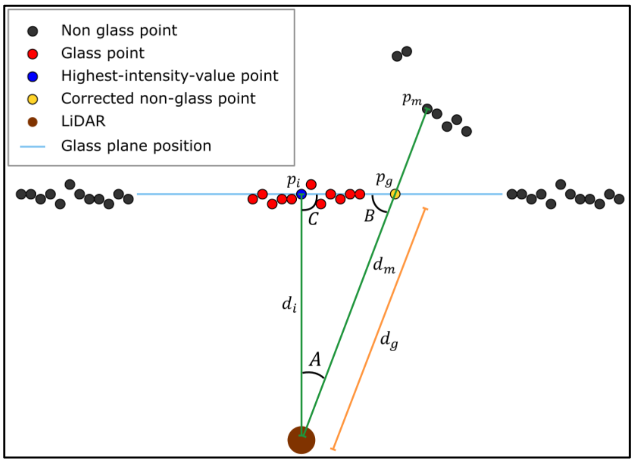

Figure 1. Trigonometric calculation for glass plane reconstruction.

By utilizing the method for detecting glass in the environment as performed in [1], [2], [3], a glass point, $p_i(x_i, y_i)$, is selected, which is the glass point with the highest intensity value. This point is the closest to the normal angle of the glass plane, meaning it is near the intersection point of a laser beam emitted almost perpendicular to the glass plane. Starting from p_i, the system checks points within the point cloud to the left and right for potential measurement errors caused by the glass plane, until it detects a point indicated as a glass boundary. As shown in Figure 1, angle C is the angle of the line perpendicular to the glass plane, which is assumed to be 90°. Angle A is the azimuth angle of the LiDAR laser beam that produces the LiDAR measured point, $p_m(x_m, y_m)$, and d_i is the distance from the LiDAR's position, $p_0(0,0)$, to p_i. Using simple trigonometric calculations, the estimated distance to the undetected glass point in the glass area is performed by finding d_g, the distance from p_0 to a point on the glass plane, $p_g(x_g, y_g)$. Knowing that the total of the three angles of a triangle is 180°, angle B is calculated as $B = 180° - A - C$. Then, using the law of sines, as shown in equation 1, d_g is calculated.

$$d_g = \frac{b \sin C}{\sin B} \tag{1}$$

Subsequently, the measured distance d_m, which is the distance from p_0 to p_m, is compared with d_g. If $d_m > d_g$, then p_m is declared as an incorrect measurement point because the point lies behind the glass plane, and the position p_g in the coordinate space will be identified to replace the position value of p_m. If $d_m \leq d_g$, then p_m is declared as a glass boundary, or as a point from an object in front of the glass plane, and the checking will be stopped.

The process to obtain p_g is performed using the parametric equation of a line, $(x(t) = t \cdot x_m, y(t) = t \cdot y_m)$, that passes through p_0 and p_m. The distance from p_0 to any point $p(t)$ on the line is given by the magnitude of the position vector at $p(t)$, as shown in equation 2.

$$d_g = \sqrt{(t \cdot x_m)^2 + (t \cdot y_m)^2} \tag{2a}$$

$$t = \frac{d_g}{\sqrt{x_m^2 + y_m^2}} \tag{2b}$$

By substituting t into the parametric equation, p_g can be obtained, as shown in equation 3.

$$x_g = \left(\frac{d_g}{\sqrt{x_m^2 + y_m^2}}\right) x_m \tag{3a}$$

$$y_g = \left(\frac{d_g}{\sqrt{x_m^2 + y_m^2}}\right) y_m \tag{3b}$$

$$p_g = \left(\frac{d_g \cdot x_m}{\sqrt{x_m^2 + y_m^2}}, \frac{d_g \cdot y_m}{\sqrt{x_m^2 + y_m^2}}\right) \tag{3c}$$

With this method, it is expected that the glass plane can be mapped immediately upon detection.

III. Conclusion

This paper proposed a glass plane reconstruction method which, in the future, is expected to be implemented and further tested to determine its robustness.

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References

[1] X. Wang and J. Wang, "Detecting glass in Simultaneous Localisation and Mapping," Robotics and Autonomous Systems, vol. 88, pp. 97–103, Feb. 2017, doi: https://doi.org/10.1016/j.robot.2016.11.003.

[2] Lasitha Weerakoon, G. S. Herr, J. Blunt, M. Yu, and N. Chopra, "Cartographer_glass: 2D Graph SLAM Framework using LiDAR for Glass Environments," arXiv (Cornell University), Dec. 2022, doi: https://doi.org/10.48550/arxiv.2212.08633.

[3] A. Mora, A. Prados, P. Gonzalez, L. Moreno, and R. Barber, "Intensity-Based Identification of Reflective Surfaces for Occupancy Grid Map Modification," IEEE access, vol. 11, pp. 23517–23530, Jan. 2023, , doi: https://doi.org/10.1109/access.2023.3252909.