PROPOSAL OF ESTIMATION METHOD USING THE ABSOLUTE ANGLE OF A GEOMAGNETIC SENSOR FOR INSTABILITY OF DISTANCE INFORMATION OF LIDAR CAUSED BY MOVING AND VIBRATING OBJECTS

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Abstract - In this paper, we propose a method to improve the strength by using a geomagnetic sensor to perform self-angle estimation using moving objects such as wall and a vibrating object such as human or trees trembling by wind more stably. LIDAR sensor used time of flight information of laser to measure the distance from the target, the micro or Nano second-order time difference would be disturbed by a few physical factors - sensor movement/vibration, target shape complexity, and target movement/vibration. Therefore, the angle estimation is easily disturbed for the features of moving objects and vibrating objects. This is a problem that inevitably occurs in the measurement principle of LIDAR. For this reason, it is necessary to strengthen the angle estimation using not only LIDAR but also a sensor that gives auxiliary information at the time of angle estimation. We focused on geomagnetic sensors that can obtain absolute angles among sensors that can get angle information. We propose a robust angle estimation method using the angle information of the geomagnetic sensor as auxiliary information for localization by LIDAR. The experimental result of experiment 1 shows that even if the object was straight shape board, there was a directional dependence of object movement for angle estimation based on the ICP algorithm. There was a significant effect to (B) back direction movement, and it was related to reducing the measurement points of the LIDAR. However, the proposed method can reduce the self-angle estimation error in all directions by more than 95.62%. In the case of vibration object made with green ribbons, the proposed method was able to follow the angle change and the estimated angle also changed, enabling stable angle estimation. And, the proposed method can reduce the self-angle estimation error in all directions by more than 99.75%. Our experimental result shows that there is a weak direction to move the LIDAR sensor itself, and it is a complicated process to estimate the rotation angle by ICP when the object is vibrating or moving. However, stable estimation was made possible by using a geomagnetic sensor to assist in angle estimation.

Keywords - Geomagnetic Sensor, ICP algorithm, LIDAR, Moving and Vibrating Object.

1. INTRODUCTION

The government and companies cooperate, and the technology development of automatic driving is progressing actively for the aim of practical application by 2020 [1]. To realize autonomous car control without human, the correct, current position estimation (localization) is an essential factor, and it would be measured by LIDAR device generally. LIDAR (Light Detection and Ranging) is used as an essential device for recognizing the surrounding environment like human eyes and ears. LIDAR uses time of flight (TOF) information of laser to measure the distance from the target, the micro or Nano second-order time difference. It would be disturbed by some physical factors - sensor movement/vibration, target shape complexity, and target movement/vibration(Fig. 1).

In the previous study, we confirmed the instability in angle estimation using ICP (Iterative Closest Point) algorithm [1]-[5] with the object that disturbs the LIDAR data as the measurement object. Even the slight movement of the object itself, as shown in Fig. 1, has similarly collapsed. Besides, the estimation collapsed even with a change of only a few centimeters in the shape of the object, such as a tree branch or leaf shaking. There are two significant reasons for this because of the characteristics of the estimation algorithm. First, as shown in Fig. 2, for example, a broad-angle change is assumed. At that time, due to the characteristics of the ICP algorithm that determines the nearest neighbor as a corresponding point, there is a high possibility of selecting an incorrect corresponding point. Therefore, once the estimated value deviates from the actual value, it is difficult to return to the correct estimated value. It is because the error is included in the next estimation. The second is when measuring unknown environmental point clouds, as shown in Fig. 2(b). Localization by LIDAR is a matching between the measurement point cloud and the corresponding past measurement point cloud. However, since there is no past point cloud corresponding to the unknown point cloud, it causes a false estimation. When moving objects and vibrating objects are measured using LIDAR, there is a very high probability that they have never been measured before. Therefore, the angle estimation is easily disturbed for the features of moving objects and vibrating objects. This is a problem that inevitably occurs in the measurement principle of LIDAR. For this reason, it is necessary to strengthen the angle estimation using not only LIDAR but also a sensor that gives auxiliary information at the time of angle estimation. In this paper, we focused on...
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II. METHOD

In this paper, we propose a method to improve the strength by using auxiliary information using a geomagnetic sensor effectively in order to perform self-angle estimation using moving objects and vibrating objects more stably. Many sensors can assist in angle estimation. Among them, the reason we focused on geomagnetic sensors is that we can obtain absolute angles. For example, the gyro sensor can calculate the current aircraft angle by integrating the acquired angular velocity data, but a calculation error always occurs. The angle detection by the camera does not change from the point cloud matching by LIDAR to the estimation by image matching. Therefore, the estimation error occurs in the same way, and it does not solve the fundamental problem. Thus, in the self-angle estimation using the relative angle, the origin gradually drifts due to the estimation error. However, the geomagnetic sensor can obtain the absolute angle from the origin to the magnetic north by detecting the geomagnetism. Since the geomagnetic sensor detects a weak magnetic field in nanometers, the sensor reacts sensitively even if a slightly magnetized object exists in the surroundings. If the angle information of a sensitive sensor is used as a trap, there is a problem in applying it to angle estimation that can lead to system collapse even with an angle error of 1 degree. Therefore, we focused on the information about which direction the sensor is facing rather than the information of angle, and used it as auxiliary information for angle estimation by LIDAR.

Fig. 3. Evaluation function used for angle estimation in the proposed method using geomagnetic sensors. (a) E(θ) is an evaluation function by LIDAR, and M(θ) is an evaluation function by a geomagnetic sensor. (b) E(θ)' is an evaluation function using LIDAR and a geomagnetic sensor.

\[ E(\theta) = \sum_{i=1}^{n} \exp(-\alpha \| \bar{b}_i - R(\theta) \bar{a}_i \|^2) \quad (1) \]

\[ R(\theta) = \begin{pmatrix} \cos \theta & -\sin \theta \\ \sin \theta & \cos \theta \end{pmatrix} \quad (2) \]

\[ M(\theta) = \begin{cases} \beta & (|\theta_m - \theta| \leq \Delta \theta_m) \\ 0 & (|\theta_m - \theta| > \Delta \theta_m) \end{cases} \quad (3) \]
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III. EXPERIMENT

Angle estimation using a geomagnetic sensor is performed in the presence of moving objects and irregular objects. The effectiveness of the proposed method in the environment shown in Fig.1 is proved. Figure 4 (a),(b) show the LIDAR and geomagnetic sensor used in the experiment. The natural environment cannot quantitatively evaluate the characteristics of the environment, and the reproducibility of the experiment is low. Therefore it is necessary to conduct experiments in an environment that simulates the natural environment to confirm the cause of the conventional problem and the reproducibility of the proposed method. Therefore, we created a simulated tree.
In Experiment 1, self-angle estimation is performed in an environment with moving objects. The effectiveness of the proposed method is shown by comparing the proposed estimation method with the conventional method. Fig. 5 (a), (c) shows the straight board movement experimental setup (experiment 1). The 0.4 m×0.2 m straight board was positioned on the 1.5 m front of the LIDAR sensor, and the board was moved 1 m distance from the original position with 0.25 m/s to (L) left, (R) right, (B) back and (F) front direction. After that, it was returned to the original position. The area of the measurement was limited at a black line square 3 m×3 m area to reject another objects except for the board. A web camera (640 pixels×480 pixels, 30 fps) is installed on the ceiling, and a red marker (0.18 m×0.18 m) is attached to the moving object. Clustering was performed for red in the image data, and the movement trajectory of the moving object was determined. Next experiment 2, the experimental setup was shown in Fig. 4 (b), (d). In Experiment 2, self-angle estimation is performed in an environment with vibrating objects. After rotating 90 degrees, it turned to the initial angle and returned to the initial state. Thus, it is shown that stable angle estimation can be performed even if the angle changes by using the proposed method. An environment surrounding LIDAR was created using three simulated trees that quantitatively mimic the characteristics of a vibrating object. LIDAR measurement is limited to the range of 1 m×1 m, and it reproduces the estimated environment in forests where there are many irregular objects. From the electric fan, wind at a wind speed of 2 m/s is applied to the simulated tree to reproduce the wind fluctuation of the branches and leaves of the plant. The standard deviation (S.D.) of the ribbon vibration was measured as 4.6 cm in the case of 2 m/s wind flow. In order to know the actual value of the estimated angle, a web camera is installed on the ceiling directly above LIDAR. Two red markers (6.5 cm×6.5 cm) were attached to the LIDAR unit, and the actual angle was determined from the coordinate data on the web camera. Besides, the accurate rotation was performed using an angle meter.

Fig. 6 shows the rotation angle θ estimation result of the straight board object movement. Fig. 6 (a) shows the estimated self-angle after moving the straight board object in the forward direction and returning it to the original position. Similarly, (b) is the right direction, (c) is the backward direction, and (d) is the left direction self-angle estimate. This is the final self-angle estimate (average ± standard deviation, 5 trials) in 5 seconds after returning to the original position. In the case of (b) right direction movement, the estimated θ was shifted about 5.31±0.74 degrees by moving 1m of the straight board object. The proposed method was -0.42±0.74 degree, and the self-angle estimation error could be reduced by 92.09%. In the case of (d) left direction movement, the estimated θ was shifted about 10.22±1.72 degrees by moving 1m of the straight board object. The proposed method was -0.65±0.57 degree, and the self-angle estimation error could be reduced by 93.67%. Regarding (b) and (d), the average number of distance measurement points of the straight board was about 7 points during the experiment. Next, in the case of (c) backward direction movement, the estimated θ was
shifted about -17.89 ± 5.16 degrees by moving 1m of the straight board object. The proposed method was -0.36 ± 0.31 degree, and the self-angle estimation error could be reduced by 98.0%. Last, in the case of (a) forward direction movement, there is large unstable \( \theta \) estimation error about -167.95 ± 12.66 degrees, and the estimation could not recover by moving 1m of the straight board object.

![Graph showing estimated angles](image)

But, the proposed method was -0.62 ± 0.42 degrees, and the self-angle estimation error could be reduced by 99.62%. In the (a) forward movement case, the average number of measurement points was about 3.5 after the 1 m movement. Experiment 1 result clearly shows that there was movement direction dependency even if the target was straight board shape. Even when the number of LIDAR measurement points was reduced, and the estimation error increased (a), the estimation method could eliminate the estimation error. Fig.7 and Fig.8 shows the result of self-angle estimation using a simulated tree. Fig.7(a) shows the result of the conventional method using the only LIDAR. Red is the estimated angle, and blue is the trajectory of the angle change obtained from the camera. Although it was rotated 90 degrees from the initial angle, the estimated angle was -6.75 ± 0.38 degrees. After that, the angle was returned from 90 degrees to 0 degrees, but the estimated angle was -73.12 ± 0.34 degrees. Fig.7(b) shows the result of the proposed method combining the geomagnetic sensor and LIDAR. Similarly, when rotated 90 degrees, the estimated angle was 90.06 ± 0.14 degrees. After that, when the angle was returned from 90 degrees to 0 degrees, the estimated angle was -0.08 ± 0.23 degrees. Fig.8 shows the results of five experiments using each method. This is the final self-angle estimate (average ± standard deviation, 5 trials) in 10 seconds after rotating to the 90 degrees and initial angle. The conventional method had a significant influence on the estimated angle \( \theta \), despite the minute vibration of the ribbon about 4.6 cm. In contrast, the proposed method used the auxiliary angle information from the geomagnetic sensor to prevent erroneous estimation in the estimation calculation. As a result, the self-angle estimation was stable without any disruption.

V. CONCLUSION

In this paper, we propose a method to improve the strength by using auxiliary information using a geomagnetic sensor effectively in order to perform self-angle estimation using moving objects and vibrating objects more stably. The experimental result of experiment 1 shows that even if the object was straight shape board, there was directional dependency of object movement for angle estimation based on ICP algorithm. There was large effect to (B) back direction movement, and it was related to reducing the measurement points of the LIDAR. However, the proposed method can reduce the self-angle estimation error in all directions by more than 95.62%. In the case of vibration object made with green ribbons, the proposed method was able to follow the angle change and the estimated angle also changed, enabling stable angle estimation. And, the proposed method can reduce the self-angle estimation error in all directions by more than 99.75%.

REFERENCE