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About point cloud data from an orthogonal mounted laser range finder on a mobile robot

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Abstract. Recently, production factories have become increasingly automated. And factories need to produce high-mix low-volume products for customer's order. RoboCup Logistics League (RCLL) is the competition to suppose an automation high-mix low-volume production factory. The Modular Production System (MPS) used in RCLL is a modularizing production line.

The robot needs approaching to the MPS in the competition. So, the robot uses a laser range finder (LRF) for detecting the MPS and the surrounding walls at the border of the competition area. The robot uses the detected information and the preliminary map to make running plan. The preliminary map is given to the robot in advance. In general, the preliminary map for the robot is often created based on a floor map, and thus is often a two-dimensional map. The LRF needs getting two-dimensional information same as the preliminary map. So, the LRF is mounted horizontally to the ground on the robot.

When the LRF which is mounted horizontally to the ground detects the MPS, the robot has a risk which is failing detection the MPS and the wall. We focus the different between the MPS and walls. The MPS is higher than wall. Thus, we propose to mount the LRF orthogonally to walls for measuring the height of an object. In addition, the LRF scans continuously while the robot rotates, we can get three-dimensional data.

Keywords: Mobile robot, Laser range finder, three-dimensional sensing

1 Introduction

Recently, production factories have become increasingly automated. And factories need to produce high-mix low-volume products for customer's order. RoboCup Logistics League (RCLL) [1] is the competition to suppose an automation high-mix low-volume production factory.

The Modular Production System (MPS) is a modularizing production line. The MPS is machine for automation technology education, it is produced by FESTO [2]. MPSs are used in RCLL. The size of MPS is 700[mm]×350[mm]×700[mm] (width × depth × height) and it has 4 wheels under the body. The short side of the MPS has the acrylic door which storages batteries and control equipment. And some devices have such as a conveyor and a vacuum-arm on the MPS body (Fig.1). There are some types of MPS.

The workpiece is the part supposes production process. The MPS assembles to the workpiece when the robot delivers the workpiece to the MPS. In RCLL, robots receive orders. Robots compete delivering speed and delivering accuracy. So, robots need to detect the MPS and to make the running plan.

Fig.1 Modular Production System (MPS)

2 How to detect the MPS

There are some methods for detecting the MPS. Most teams use the laser range finder (LRF) for detecting the MPS. An LRF has a laser sensor that measures the time it takes for the laser to be reflected back from an object. So, the laser sensor calculates the distance value from the flight time. The laser sensor itself or the module that reflects the laser rotates in the LRF. Thus, the LRF gets the distance and angle data to the surrounding object. The robot can use these data as point cloud data. These point cloud data draw the measurement surface along the point cloud. The robot uses point cloud data in order to recognize the object shape and the object position. And the robot uses objects information to make the running plan.

When the robot estimates own position, the robot compares objects information and the preliminary map. In general, the preliminary map for the robot is often created based on a floor map, and thus the floor map is often a two-dimensional map. The LRF needs getting two-dimensional information same as the preliminary map. So, the LRF is mounted horizontally to the ground on the robot.

The laser penetrates the acrylic plate. The short side of the MPS made of the acrylic. So, it is difficult for the LRF to detect the short side of the MPS. Therefore, the LRF cannot to get the point cloud data which characterized as MPS shape. The long side is made of a material that does not allow the laser to penetrate. The robot can find the MPS's long side because the LRF detect the point cloud data that draws 700[mm] longs straight line.

However, in the RCLL competition, walls are lower than the MPS. When the LRF got data from these walls, the robot may misrecognize the straight lines of walls as the MPS's long side.

3 Proposed Method

In this paper, we focus on the height differentiation of the MPS and the wall of the field. Thus, we propose mounting the LRF orthogonally to walls for measuring the height of an object. In addition, the LRF scans continuously while the robot rotates, we can get three-dimensional data. Usually, in order to measure the three-dimensional data servomotors are used in order to rotate the sensor[2].

In our proposed method, the LRF is mounted with a tilting of $\pi/2$ [rad] to the roll axis on direction of the robot movement. And the robot calculates three dimensional coordinate from the orthogonal LRF.

How to calculate three-dimensional coordinates is below. Fig. 2 shows the measurement point $d_{a_n} = (d_{a_{n_x}}\ d_{a_{n_y}}\ d_{a_{n_z}})$ where the center of the LRF is the origin. Fig. 3 shows one of the measurement point $p_{a_n} = (p_{a_{n_x}}\ p_{a_{n_y}}\ p_{a_{n_z}})$ in point cloud data on the point a. And $r_a = (X_a[mm] \quad Y_a[mm] \quad \varphi_a[rad])$ is the odometry at the point a.

Because the LRF tilts orthogonal, the three-dimensional coordinate of the point d_{a_n} is shown in Eq. (1).

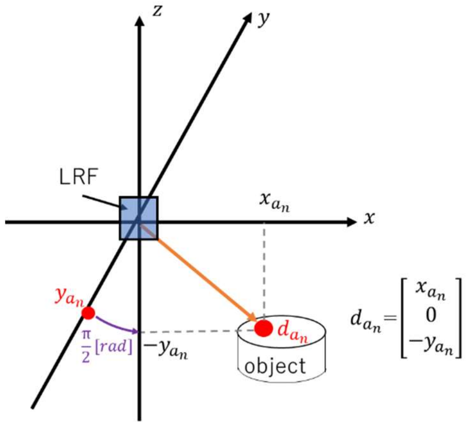

Fig.2 The measurement point d_{a_n}, from tilting LRF

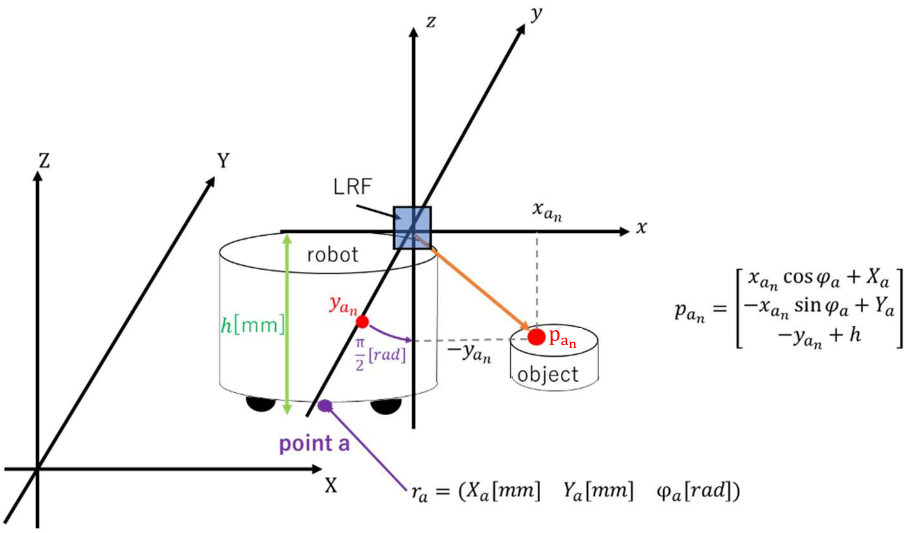

Fig.3 The measurement point p_{a_n}: a one of point data in point cloud on point a

$$d_{a_n} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\frac{\pi}{2} & \sin\frac{\pi}{2} \\ 0 & \sin\frac{\pi}{2} & \cos\frac{\pi}{2} \end{bmatrix} \begin{bmatrix} x_{a_n} \\ y_{a_n} \\ 0 \end{bmatrix} = \begin{bmatrix} x_{a_n} \\ 0 \\ -y_{a_n} \end{bmatrix} \quad (1)$$

The measurement point p_{a_n} calculated from the measurement point d_{a_n} , the odometry r_a and the height h[mm]. Thus the coordinate of the point p_{a_n} show as Eq. (2).

$$P_{a_n} = \begin{bmatrix} \cos\varphi_a & -\sin\varphi_a & 0 \\ \sin\varphi_a & \cos\varphi_a & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x_{a_n} \\ 0 \\ -y_{a_n} \end{bmatrix} + \begin{bmatrix} X_a \\ Y_a \\ h \end{bmatrix} = \begin{bmatrix} x_{a_n}\cos\varphi_a + X_a \\ -x_{a_n}\sin\varphi_a + Y_a \\ -y_{a_n} + h \end{bmatrix} \quad (2)$$

These measurement point cloud draws orthogonal measurement surface. In addition, the orthogonal LRF gets multiple measurement surfaces while the robot rotates. Merging these measurement surfaces show three dimensional data.

4 Experiment

We have experiment where the robot measures the MPS and walls.

Table.1 This is the datasheet of LRF used in experiment

Device	RPLIDAR-A3
Range of distance	White object:25 meters Black object: 8 meters
Range of angle	6.28[rad](=360[deg])
Sampling rate	16 kHz
Scanning Rate	Typical value: 15 Hz(adjustable between5Hz-20 Hz)
Angular Resolution	0.00392[rad](=0.225[deg])

Fig.4 This figure shows the robot in experiment

We use Robotino3 as a mobile robot in experiment. Robotinno3 is produced by FESTO. And we use RPLIDAR-A3 as a LRF in this experiment. RPLIDA-A3 is produced by SLAMTEC. Table.1 shows the datasheet of the RPLIDAR-A3[3]. RPLIDAR-A3 is mounted orthogonal on the robot as Fig.4.

Fig.5 shows the experimental environment. Two mock-up machines which is instead of real MPS and L-shaped walls are placed. The mock-up machine is made of white papers and aluminium frames. The walls consist of cardboards and aluminium frames. Fig.6 shows the robot setting positions in this experiment. The robot gets point cloud data with rotating on three locations in Fig.6.

Fig.7 shows the experimental result which are point cloud data got by the robot. Fig.7 also show the MPS height and wall height. We output the MPS height values are average for 10 data.

The average height of wall is about 379 [mm], and those of MPSs are about 692 [mm] and 693 [mm]. The MPS is taller than the wall over 300[mm]. We think that our propose method which can recognize the MPS and the wall by height difference information.

Fig.5 The experiment environment

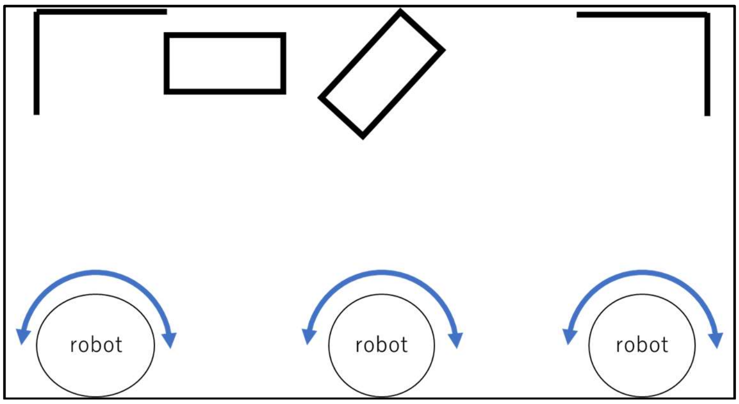

Fig.6 The robot rotates position in experiment

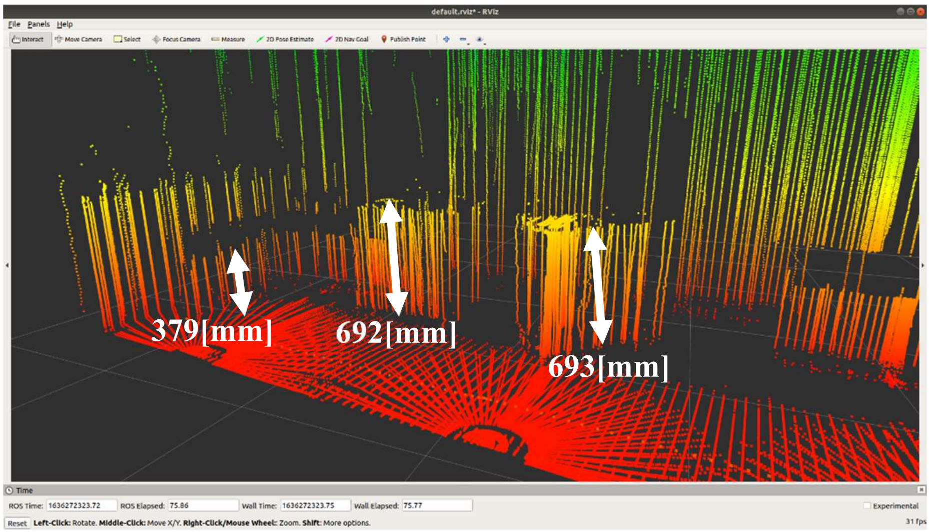

Fig.7 Experimental result point cloud

5 Conclusion

In this paper, we described the method to detect the MPS by used LRF in RCLL. And we presented the conventional method problem to misrecognize the wall's straight lines as the MPS's long side. To avoid this problem, we focused the height difference the MPS and the wall. We proposed mounting the LRF orthogonal to recognize the MPS and the walls by height differences between the MPS and the walls. In this experiment, we showed the three dimensional point cloud data in our proposed method. And our proposed method can show height differences between the MPS and the walls.

In the future, we apply our propose method on the running robot in RCLL competition.

References

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