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Development of autonomous driving-based radiation dosimeter transfer robot for real-time monitoring of highly radioactive areas

Jaewook Kim*, Younggil Kim, Jungsik Kim, Misuk Jang, Seoungrae Kim
Nuclear Engineering Services & Solutions, B-811, 6, Jiphyeonjungang 7-ro, Sejong-si, 30141, Republic of Korea
Corresponding author: nessrnd@ness.re.kr

1. Introduction

This study intends to develop a robot equipped with an autonomous driving-based radiation dosimeter in order to secure radiation safety in a high-radiation area or a narrow area before dismantling workers are put in, and to minimize the worker's radiation exposure as low as reasonably achievable(ALARA).

In addition, the data collected from the radiation detector mounted on the robot is designed to be wirelessly transmitted to the radiation integrated management system in real time.

2. Methods and Results

ROS (metaOS), which is easy to communicate between nodes, was used to operate the autonomous driving robot, and major technological elements include SLAM, Navigation Stack, and location tracking-based radiation measurement.

2.1. Odometry

Odometry is a method for a robot to record its mileage and measure its position, and is implemented based on odom_frame, which is useful for accurately grasping the robot position in ROS.

Odometry can be calculated by dead reckoning of linear speed and rotation amount using the encoder of the motor driver. However, there is a problem that the rotation amount estimation using only the encoder is not accurate. To make up for this, the amount of rotation was compensated with the inertia value of the IMU sensor to measure the exact driving distance.

2.2. SLAM (Simultaneous Localization And Mapping)

SLAM is a technology that estimates location and creates a map at the same time. It creates a map by scanning the surrounding space while a robot moves in an arbitrary space, and estimates the current location through it.

The Gmapping algorithm was used to generate a map while estimating the location with Odometry data. Since there may be an error between the actual position and the Odometry measurement position, the temporarily stored map data was continuously corrected with the laser scan data of LiDAR to increase the accuracy of the map data.

Figure 1 is an example of a map file created in an autonomous driving test environment using Gmapping. On the map, movable areas are displayed in white, impossible areas are displayed in black, and unidentified areas are displayed in gray.

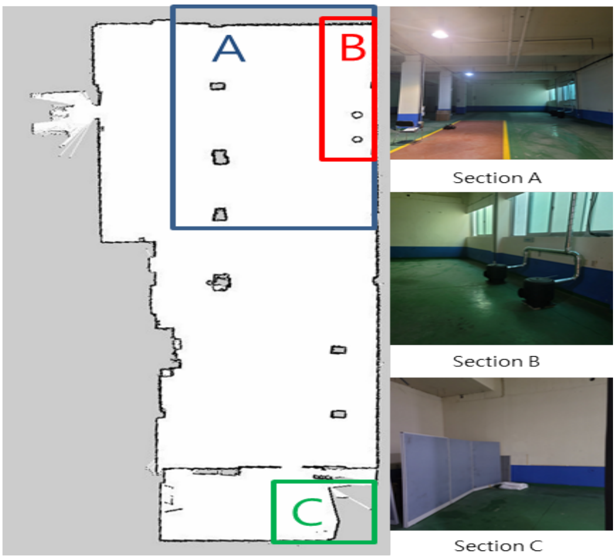

Fig. 1. SLAM map file and test environments

2.3. Navigation Stack

Navigation stack is a package for autonomous driving of robots based on maps created using SLAM. For autonomous driving, it is necessary to create a cost map. In addition to the mobility of the existing map, the cost map is created by additionally considering the footprint, inflation area from the obstacle, and cost map resolution, obstacle layer, and voxel layer. [1]

When generating an autonomous driving path based on a cost map, the modified A* algorithm [2] is commonly used as a global path planner and DWA (Dynamic Window Approach) is used as a local path planner.

During autonomous driving, this package subscribes laser scan data topic published from LiDAR. Using that data, obstacles not shown on the map are added to the cost map while driving and avoided. In addition, to avoid obstacles lower than the LiDAR height, a sub LiDAR was mounted at the bottom of the robot to improve obstacle avoidance ability.

Figure 2 shows an example of creating a cost map (left) and a path planner (right) during autonomous driving.

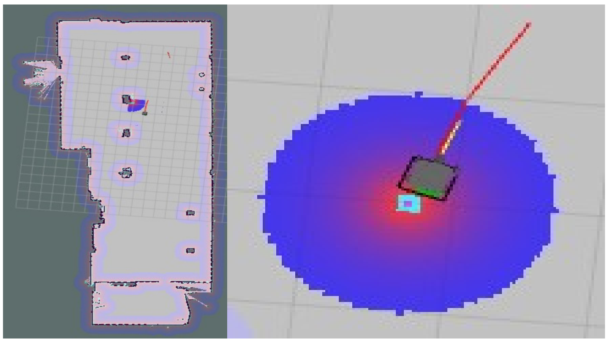

Fig. 2. Navigation Stack and cost-map

2.4. Radiation dosimeter for autonomous robot

Figure 3 shows the composition of the radiation dosimeter board to be mounted on the autonomous driving robot. SiPM and CsI(Tl) scintillator is used in the radiation dosimeter sensor unit. The data measured by the sensor unit is processed by the MCU, and a location module using UWB communication is also mounted to track the current location of the autonomous driving robot. The measured radiation dose and location information data is transmitted to the server of the radiation management system through wireless communication and monitored in real time.

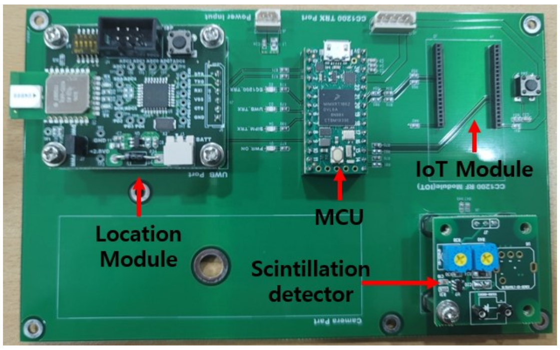

Fig. 3. Radiation dosimeter board

In order to confirm the accuracy of measuring the dose of a dosimeter mounted on an autonomous driving robot, a simultaneous measurement experiment was conducted with a commercial detector at a close distance of 1 cm with a radiation source (Cs-137 5μCi). As shown in Fig. 4, it was confirmed that the measurement results of the dosimeter for autonomous driving robot and the commercial detector were similar. In the future, it plans to improve the accuracy of dose measurement by conducting calibration tests by a certification institute.

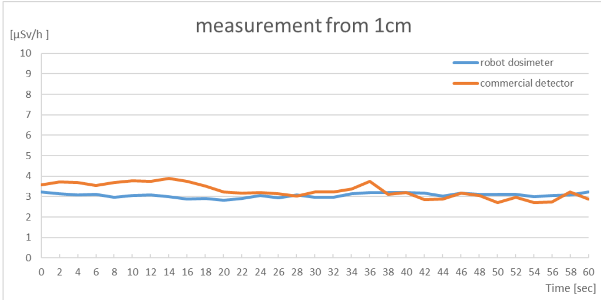

Fig. 4. Experimental result for radiation dosimeter

3. Conclusions

Through this study, an unmanned transport robot equipped with a radiation dosimeter useful for dismantling nuclear facilities was developed. It was checked whether the robot could smoothly find the destination on the map generated while changing the destination and the intermediate obstacles.

Currently, a two-wheel drive robot has been developed, and a four-wheel drive robot is being developed to improve obstacle avoidance and stable driving ability.

Although this robot was developed to be put into dismantling work sites, it can also be applied to operating nuclear power plants in high-radiation areas.

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[2] F. Duchoň, A. Babinec, M. Kajan, P. Beňo, M. Florek, T. Fico, L. Jurišica, Path Planning with Modified a Star Algorithm for a Mobile Robot, Procedia Engineering, Vol. 96, pp.59–69, 2014.

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