Moving Control Method with RFID and Infrared Laser Radar for Indoor Mobile Robot Navigation

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Abstract—
In late years, there are aging of many people in Japan. An aging rate in 2015 of Japan is 26.7% and reaches the standard called the super aging society. By the increase of people requiring nursing care by this, there is the lack of the care staffs. A study of the automation in the field of care and welfare is pushed forward to solve this problem, and one of those includes the indoor navigation system using the autonomy mobile robot. The system is comprised of three elements of position estimation, routing and movement control.

In this paper, we propose a movement control method that considered the collision avoidance with an obstacle in the indoor navigation system that combined infrared radar with RFID (Radio Frequency IDentification). To show the effectiveness of the proposed method, we perform the performance evaluation by experiments using a mobile robot.

I. INTRODUCTION
In late years, aging goes rapidly in Japan. Aging rate in 2015 of Japan is 26.7% and reaches the standard called the super aging society. In addition, aging rate reaches 39.9% in 2060, and it is said that approximately one of 2.5 people in Japan becomes an elderly person 65 years or older. There will be lack of care staffs by the increase of people requiring nursing care.

There are many studies [1]-[3] about the automation in the field of care and welfare to solve this problem, and one of those includes the indoor navigation system using an autonomous mobile robot. The indoor navigation system using the robot refers to a system traveling autonomous mobile robot safely from the present location to the destination. This system can reduce the burden on care staffs drastically.

This system consists of three elements of position estimation, routing and movement control. Particularly, position estimation and movement control is important element concerned with safety avoiding the collision with wall, an obstacle and person. Camera sensor and supersonic wave sensor used for the mobile robot are limited for recognizing surrounding environment. Therefore, the position estimation and movement control technique using the RFID (Radio Frequency Identification) system which is possible to extend with simple configuration is studied.

The RFID system is comprised of RFID tag, RFID reader, RFID antenna and peripheral devices such as PC or server. In RFID tag, ID information is stored. And transmission and reception of ID information stored in RFID tag is performed by RFID antenna. An RFID reader performs reading and writing to an RFID tag. Peripheral devices perform control of the reader, and the movement of the mobile robot. Applied example includes electronic ticket or library collection of books system. By using RFID system in the indoor navigation system, the autonomous mobile robot is able to recognize the surrounding environment stored in RFID tags.

When the robot runs on a passage, a collision with walls and obstacles is considered. To avoid this, detection of walls and an obstacle by using infrared laser radar is performed. Infrared laser radar measures the distance to neighboring objects.

In this paper, we propose a movement control method that considers the collision avoidance with an obstacle and person in the indoor navigation that combined an infrared laser radar with RFID system. This proposed method is comprised of three elements of navigation control, moving control and obstacle collision avoidance control. Navigation movement control derives the robot to the position of the RFID tag which is set as the destination by using RFID system. Moving control calculates the angle between the moving direction and wall and avoids collision with walls. Obstacle collision avoidance control detects obstacles on progress course by using infrared laser radar. To show effectiveness of this proposed method, we perform experiments by using the actual mobile robot.

II. PREVIOUS WORK
In this section, we describe movement control using RSSI [4] and collision avoidance control against an obstacle that RFID tag is attached as an existing movement control method.

A. Movement control method using RSSI
RSSI (Received Signal Strength Indication) refers to the strength of the signal which radio communication equipment receives. In this method, movement control is performed depending on strength of this RSSI. Autonomous
mobile robot runs on a passage and RFID tag is attached on the wall. We explain the movement procedure below.

**Step 1**: Acquisition RSSI of the RFID tag
The mobile robot equipped with RFID reader measures RSSI from the RFID tag while running.

**Step 2**: Turning when exceeding the threshold of RSSI
In the case beyond the threshold, the robot turns inside of a passage depending on RSSI.

This method can avoid collision with wall and the robot. However, an obstacle is on the progress course, the robot can't avoid it. Furthermore, the robot meanders by using only RSSI.

**B. Collision avoidance control with obstacles**
This method avoids collision with obstacles using information stored in obstacle tags attached on obstacles. We describe movement procedure below.

**Step 1**: Position estimation of an obstacle and data acquisition
RFID antenna detects an obstacle tag and acquires width, and length of the obstacle stored in the obstacle tag. Width is the length of the sides that is perpendicular to the estimated wall, and the length is the length along the wall. In addition, when the obstacle is next to the nearest estimated wall from current position of autonomous mobile robot, this robot estimates the setting direction of the obstacle.

**Step 2**: Generation of control point
For collision avoidance of the obstacle, the robot generates two kinds of control points. The first control point is generated to avoid the collision with the obstacle. Second control point is generated from the first control point and set according to the length of the obstacle.

**Step 3**: The passage of each control point and return to ideal course
Collision avoidance and passage of the obstacle perform by going along the control points generated in Step 2. When the RFID antenna reads the obstacle tag during the collision avoidance of obstacle, the robot continues the avoidance with current obstacle. When the information from the tag is about different obstacle, the mobile robot carries out new obstacle collision avoidance.

This method can avoid collision of an obstacle and the autonomous mobile robot. However, this method can't avoid obstacles without obstacle tags. Furthermore, the generation of control point depends on position estimation accuracy by reading RFID tags.

**III. PROPOSED METHOD**
We propose a movement control method that combines infrared laser radar with RFID system on the mobile robot for indoor navigation to solve the above problems. We explain the proposed method in detail as follows.

3.1 Purpose and summary
The purpose of this proposed method is realization of the navigation that the collision avoidance of an autonomous mobile robot and obstacles is possible. In this proposed method, we perform the following eight environmental settings.

1. We set an RFID reader on the upper of the autonomous mobile robot and set RFID antennas in right and left of the robot.
2. We set RFID antenna surface parallel to the moving direction.
3. We equip with infrared laser radar in front of the robot.
4. The robot runs a course via the left of the indoor passage.
5. RFID tag is attached on both sidewalls of the passage with constant interval.
6. Absolute position of the RFID tag is stored in the tag.
7. We set the width of the obstacle to less than half of the passage so that the robot can pass the side of the obstacle.
8. The navigation finishes if the robot reads information stored in the destination tag.

Characteristics of this proposed method include the following things:

1. The navigation to the destination performs by using RFID system.
2. Infrared laser radar is used for the grasp of the traveling angle of the robot and the detection of obstacles.
3. The robot can avoid the obstacle without obstacle tag.

3.2 Infrared laser radar
The infrared laser radar scans surrounding objects. We show the scanning range of the infrared laser radar in Fig. 1. The scanning range of the infrared laser radar is 270 degrees and divides into 1,080 steps. The angle between each step becomes 0.25 degrees, step 720 i.e. the 720th step is 135 degrees and step 900 is 180 degrees.

![Fig. 1 Scanning range of the infrared laser radar](image)

3.3 Calculation of the moving direction of the robot
We show the moving direction in Fig. 2. The information that is necessary in this proposed method is the distance of step 720 and step 900, \( L_1 \) \( L_2 \). Using these distance, \( L_3 \) is calculated by

\[
L_3^2 = L_1^2 + L_2^2 - 2 L_1 L_2 \cos 45^\circ
\]
Here \( \cos 45^\circ \) is derived from the angle of step 720 and step 900. By using \( I_3 \), we obtain the angle \( \theta \) by

\[
\cos \alpha = \frac{l_1 + l_2 - l_3}{2l_1l_2}
\]  

\[
\theta = \alpha - 45
\]

3.4 Components
In this section, we explain navigation movement control, moving control and obstacle collision avoidance control, which are components of the proposed method.

3.4.1 Navigation movement control
Navigation movement control guides the autonomous mobile robot to destination tag using RFID system. RFID tag is attached on wall beforehand and the information of destination place is inputted into the destination tag. The robot reads information that is stored in RFID tag while moving and when it acquires information stored in the destination tag, the navigation finishes.

3.4.2 Moving control
Moving control makes the robot to become parallel to wall. The robot calculates the moving direction angle using the infrared laser radar. Two scanning standard step in the scanning range and standard angles is set beforehand. When comparing the standard angle with the moving angle causes big difference, revision of moving angle is performed. We describe procedures below.

**Step 1:** Setting of two scanning steps and standard angle
This movement is performed beforehand. We assume step 720 and step 900 as standard step and standard angle as 45 degrees in the proposed method.

**Step 2:** Distance measurement of the standard step
The robot measures the distance of the standard step by using infrared laser radar.

**Step 3:** Calculation of the moving angle and comparison with the standard angle
The robot compares the standard angle and angle \( \alpha \) shown in Fig. 2.

**Step 4:** Correction of the moving angle of the robot
According to the moving angle of the robot which calculated in Step 3, it turns to become parallel to wall. This procedure carries out only when the moving angle of the autonomous mobile robot is more than the threshold.

3.4.3 Obstacle collision avoidance control
Obstacle collision avoidance control detects obstacle on the progress course of the autonomous mobile robot by an infrared laser radar. We express the procedures below.

**Step 1:** Detection of an obstacle using the infrared laser radar
Infrared laser radar receives signal from walls or an obstacle. Steps that measurement distance is within 1m become a target of the processing, and steps more than 100 succeeding reflection are wall. When steps are less than 100 and more than 5, the robot recognizes it to be an obstacle. When steps less than 5, the robot assumes it to be recognition error.

**Step 2:** Collision avoidance of an obstacle
When the robot detects an obstacle, the robot stops for three seconds. After that, the robot rescans and moves forward when there is not an obstacle. When an obstacle exists, the robot turns 45 degrees, and runs until the distance of step 900 becomes beyond 1m. The robot turns 45 degrees with the last time adversely and run for three seconds afterwards. The robot records the distance of step 900 at every 0.5 seconds.

**Step 3:** Return to the course
When the robot compares the distance that recorded in Step 2 for three seconds and it greatly fluctuates, the robot judges that an obstacle does not exit in the side of the robot and it turns 45 degrees. The robot carries out the moving control with moving.

**IV. PERFORMANCE EVALUATION**
We carry out experiments using the actual mobile robot to show the effectiveness of the proposed method.

4.1 Purpose and summary
By experiments, we show the effectiveness of the proposed method by the following evaluation criteria.
1. Autonomous mobile robot can arrive at destination definitely or not.
2. The robot can move parallel to wall or not.
3. Obstacle collision avoidance is possible or not.

4.2 Experimental environment
In this experiment, we use UHF band RFID system. RFID tags are made by RFcamp Co. and RFID reader is made by Impinj Co. Ltd. We use three-wheel mobile robot made by Vstone Co. Ltd. The size of the robot is 38cm in total length, overall width is 33cm, and height is 17cm. Two RFID antennas and PC and infrared laser radar are put on the robot. Two RFID antennas are set parallel to the forward moving line of the robot. In addition, the robot is equipped...
with 12V battery and DC-AC converter for RFID system. The PC is laptop CF-SX2 made by Panasonic Co. Ltd. The infrared laser radar is UTM-30LX made by Hokuyo electricity Co., Ltd. This radar can scan 40 times of neighborhood environment per second. We show the RFID tag and the mobile robot in Fig. 3 and 4, respectively.

4.3 Experimental results
In this section, we show experimental results of navigation movement control, moving control and obstacle collision avoidance control.

4.3.1 Navigation movement control
We set 0 degrees as the initial angle of the autonomous mobile robot and 2 patterns of 18dBm and 24dBm of the RFID antenna output. We attached the destination tag on the wall in the height of 30cm and 5m away from the start position. In the cases of 18dBm and 24dBm of the RFID antenna output, autonomous mobile robot stops 45cm, 60cm from the destination tag, respectively. So 18dBm of RFID antenna output makes the robot near the destination tag.

4.3.2 Moving control
We set 3 patterns of 0, 15 and 30 degrees as initial angle of the mobile robot and set 5 degrees as the threshold that the robot turns. Compared with the case of movement control using RSSI, mean course error is shortened to 4.0cm, 6.6cm and 6.4cm in each pattern.

4.3.3 Obstacle collision avoidance control
We set the scanning range of the infrared laser radar from 60cm to 90cm. We show trajectories of the mobile robot in 60cm scanning range in Fig. 5. We find that the mobile robot in the proposed method turns earlier than that in the conventional method. Then it is able to return to original moving course in the proposed method.

![Fig. 3 RFID tag used in experiments](image)

![Fig. 4 Autonomous mobile robot used in experiments](image)

![Fig. 5 Trajectories of the mobile robot in 60cm scanning range](image)

V. CONCLUSION
In this paper, we have focused on the movement control of an autonomous mobile robot and have proposed a movement control method that considered the collision avoidance with walls and obstacles. As a result of experiments using the actual mobile robot, the autonomous mobile robot can move parallel to walls and avoid the collision with walls by combining RFID system and infrared laser radar. In addition, the autonomous mobile robot can avoid the collision with the obstacle on the progress course by using an infrared laser radar.

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