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An Indoor Autonomously Mobile Robot with Laser Sensor and Image Processing Approach

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***Abstract*:** Robots have been studied over a couple of decades. Nowadays, a lot of robots have been developed for improving the productivity at factories or helping with the daily chores in offices. A truly autonomous mobile robot will definitely benefit our life in many areas, including nursing care services and office guide. Most of the robots, however, are still at the stage of being controlled remotely or performing a set of predefined tasks. In addition, an autonomous movement in complex geographical features is very difficult. In order to do things autonomously, a robot must be capable of recognizing and interacting with its environment. This research aims at developing an autonomous mobile robot, which will move without collision with obstacles in an indoor environment. This requires the robot to be able to recognize its own location, select routes, and avoid collision with obstacles.

Keywords: robot, Laser Sensor, Image Processing, route selection, self-position recognition, obstacle avoidance.

I. INTRODUCTION

This research aims at developing a robot that moves autonomously in a dynamically changing environment. In order to do so, it is considered a basic capability for the robot to identify obstacles. It is necessary for an autonomous robot to perform several tasks including the self-position recognition, route selection and obstacle avoidance.

At the current stage, our very first goal is to make a robot move autonomously towards the destination in a static environment.

This paper discusses how to identify the current location of a robot by comparing the geographical features and the environmental map and recognize obstacles with a laser sensor and stereo camera.

II. System Structure

1. Mobile Robot System

Fig.1 shows the robot that is developed in this research. A laser sensor, a laptop PC and two cameras are mounted on the mobile robot. The two cameras are at the same altitude with their optical axes in parallel.

A robot recognizes the environment around its current location through the analysis of the distance data. Based on the result of environment recognition, it issues a voltage command to the servo pack through the DA board. The servo packing applies a constant voltage to the motor, and the motor controls the wheel.

At the current stage, this mobile robot is still moving in a static indoor environment. But the ultimate goal of this research is to put the robot in a dynamic environment with moving obstacles.

Fig.1. Mobile Robot

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Fig.2. Communication configuration

2. Autonomous movement

When the robot moves, the control program compares the distance data sampled at 35 degrees on the right side with the distance data at 145 degrees on the left side as shown in Fig. 3. In order to minimize the potential collision, the robot is kept moving along the centerline of the road. When the distance data is almost equal, both wheels will be controlled to move forward. When there are short distance data and long distance data, the wheel with shorter distance data will be controlled to move forward and the wheel on the opposite side move backward. This adjustment keeps going until the robot moves to the point on the centerline.

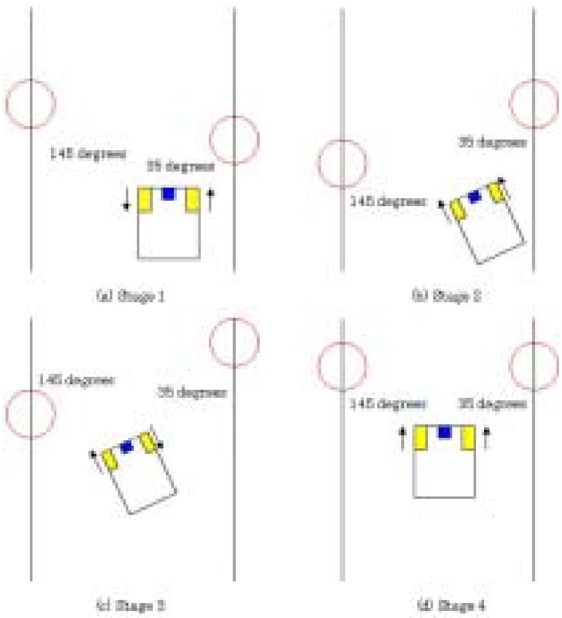

Fig.3. Move to the center

3. Control Program

The environmental map is given to the program in advance. Both an initial position and posture of the robot are also given to the program. Next, the destination is specified. It searches for the route from an initial position to the destination by using the A-star algorithm. Next, a laptop computer obtains the distance data sent from the laser sensor. The robot compares the distance data images made from the distance data with the environmental map image. The present position of the robot is calculated from the result. If the present position of the robot is a destination, the robot is stopped. Oppositely, if the present position of the robot is not a destination, the robot is controlled along the searched route. Figure 4 shows the flow chart of the program.

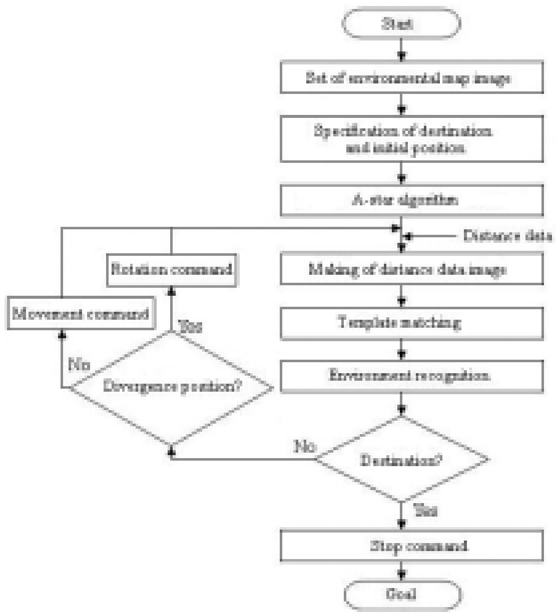

Fig.4. Flow chart

III. Route Selection

A* search algorithm is used for route selection, where the environment map is given; the initial location and posture of the robot are also given. The environmental map is divided into each area at the divergence position as shown in Figure 5. Moreover, the distance between each area is as shown in Figure 5. Once a destination is specified, A* search algorithm will find the shortest route from the initial location to the destination.

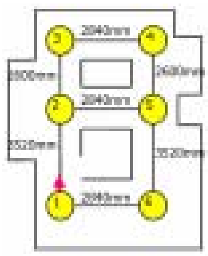

Fig.5. Indoor environmental map

IV. Self-position Recognition

On its way to the destination, the robot needs to be constantly aware of its current location. Otherwise, it will be impossible to reach the destination. Identifying the current location, however, proved to be the most difficult task for developing an autonomous mobile robot. In this study, a new approach is proposed for the identification of the current location. It is basically a template matching method, which compares the geographical features measured with a laser sensor with the pre-given environment map.

At any given location, the robot will first collect the distance data through the laser sensor. The distance data will then be represented as a distance image. At this stage, template matching could be conducted between the distance image and the environment map. However, it is computationally costly to directly match with the entire environment map. Therefore, only the portion of the environment map that is within the neighborhood of the spot where the robot was previously located is selected for the template matching. An image processing software package named Halcon is used for the template matching. As the result of template matching, the current location and the posture of the robot will be determined.

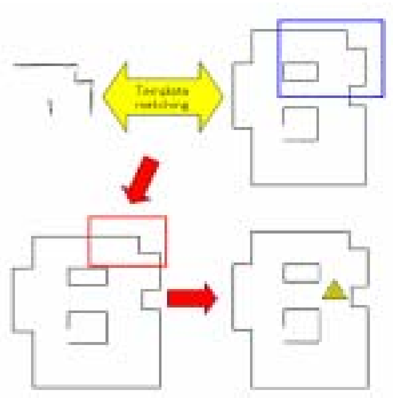

Fig.6. Template Matching

V. Obstacle Avoidance

1. Obstacles avoidance with a laser sensor

Collision with any obstacle that does not exist on the environment map needs to be avoided. Detection of this type of obstacles could simply be done by checking the difference between the distance image and the matched environment map. Since the range covered by the laser sensor is limited, not all the obstacles could be detected solely by the laser sensor. In this experiment, the laser sensor is mounted on the bottom part of the robot. When the robot moves underneath a table, for instance, the legs of the table could be detected by the laser sensor. The table top, however, will not be captured by the laser sensor. Similarly, when an obstacle is hanged from the ceiling or coming out from the side walls, laser sensor will fail to detect them. In order to handle all these cases, optical sensor is needed. Nevertheless, at the current stage, it is assumed that all obstacles are standing on the ground.

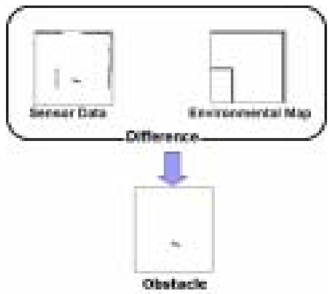

Fig.7. Difference

2. Obstacles avoidance with image processing

Stereo image processing is considered the right methodology for detecting the obstacles out of the coverage of the laser sensor. Two cameras are mounted on the mobile robot with their optical axes in parallel and at the same altitude. Finding corresponding points in the two images captured by the cameras is important for the distance measurement. Features based on color, brightness and shape are used for identifying the corresponding points. As soon as the corresponding points are located, the distance will be calculated. Based on the distance and the speed at which the robot is moving towards the obstacles, a control command will be generated and sent to the robot so that any potential collision will be avoided.

During the stereo matching, the feature points extracted from the right image are used as the references.

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For any point picked on the right image, a corresponding point will be searched in the left image. Here is a constraint that helps with the reduction of the search space. For point (x, y) on the right image, the corresponding point on the left image should have the same coordinate value of y and a larger x because of the way that the two cameras are mounted.

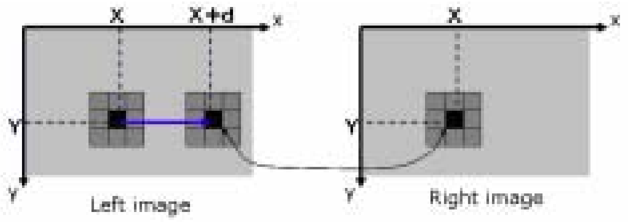

Fig.8. Stereo Matching

Whenever a feature point on the right image is selected, pixels on the left image with similar color, brightness, or shape will be extracted. The probability that a pixel actually corresponds to the feature pixel on the right image is calculated with the Correlation method. Pixels with large correlation coefficients are considered the correspondences. Image processing algorithms for the correspondence detection have been implemented and the performance has been evaluated. For the regions rich in features, the correspondence went well. For the regions with less reliable features, the correspondence is not as good due to the small variance. Therefore, for the regions with small variance, it is more reliable to use edge detection algorithms and search for the correspondence in the vicinity of edge elements.

3. Obstacles avoidance with Database System

When more than one obstacle with uniform color and shape features are captured on the images, however, the current correspondence searching algorithms will not work well. Currently, the alternative is to register all the obstacles in a database. Fig.9 illustrates the case that the robot is moving towards a table. The laser sensor will identify the tables with the information collected through the detection of the table legs. If the table top is lower than the height of the robot, the robot must avoid it referring to the data base.

To identify the table with the laser sensor, however, will be difficult when a long and slender stick exists near the leg of the table. Moreover, any table that is not registered will still cause collision. Further, if a table is put on the floor diagonally against a robot, it may be difficult to walk through under the table. This is one of the future problems to resolve.

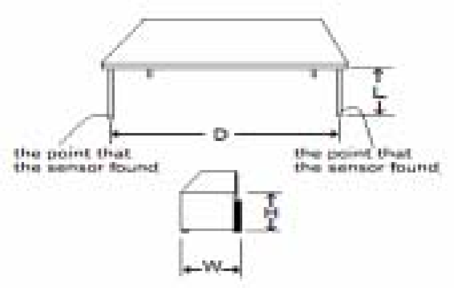

Fig.9. A table is used as an obstacle

VI. CONCLUSION

The present position of the robot was able to be calculated at any time based on the template matching. Moreover, the robot was able to move to the destination along the route calculated by the A-star algorithm. The avoidance of the obstacle will become a problem now. The robot will identify the obstacles referring to the data base.

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