Control of Autonomous Mobile Robot through Environment Recognition with Photoelectric Sensor

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Abstract

With the advancement of computing technology, robot industry has grown substantially in the past few years. However, most of the current robots are still simply following through the pre-defined procedures and moving in a well-defined workspace. The control of an autonomous mobile robot remains challenging. A truly autonomous mobile robot will definitely benefit our life in many areas, including but not limited to nursing care services and office guide.

How to get to know the current location is the most difficult issue that an autonomous mobile robot has to deal with. Without knowing its current location, it is impossible for the mobile robot to move towards its destination. Let us think how we identify our location when we are put in an unfamiliar place. The most common things that we do will be to collect the geographical features and then match what we have collected with the information on a map. The method is considered applicable to an autonomous mobile robot as well. This paper discusses how to collect the geographical features with a photoelectric sensor and how to identify the current location by comparing the sensor information and the map information.

Key Words

Autonomous Mobile Robot, Environment Recognition, Photoelectric Sensor,

1 Introduction

Mobile robots in use are still moving within a well-defined static environment. This indicates that the research and development of autonomous robots still have a long way to go. Some day in the future, if a mobile robot could autonomously move in a dynamically changing environment, it would definitely have a lot of applications in many areas of our daily life.

At the current stage, however, our very first goal is to come up with a practical approach to the control of a mobile robot so that it will move autonomously towards its destination within a static environment. Our second goal is basically along the same line, which is to keep the mobile robot moving smoothly with no stops. Although it sounds unavoidable to stop in order to avoid obstacles, sensor information integration and fast-speed route planning will be used so that stops are not needed anymore.

With the control program experimented in this study, a mobile robot could move autonomously to the destination specified by a person.

2 System Organization

2.1 Communication subsystem

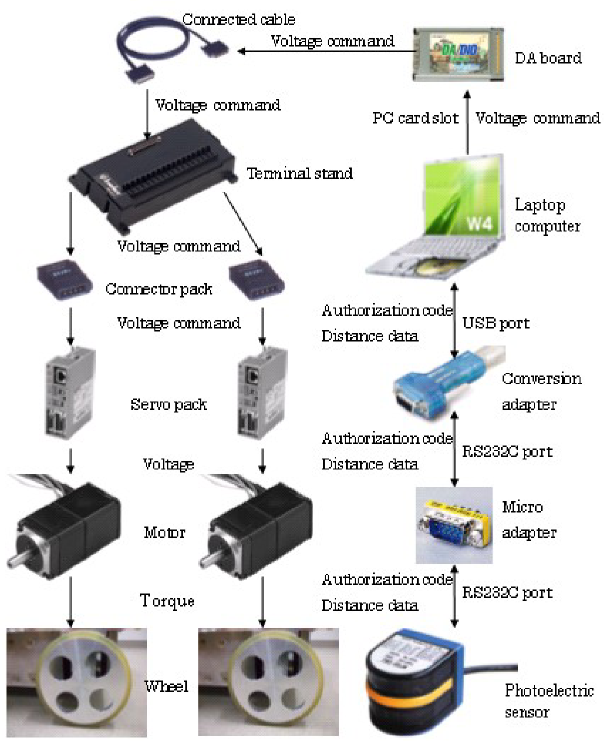

Fig.1. Communication configuration

A laptop computer is put on the mobile robot for the communication with a motor and a photoelectric sensor. At the beginning, the laptop computer sends an authentication code over to the photoelectric sensor. Once the code has been authenticated by the photoelectric sensor, will the laptop computer start receiving the distance data from the photoelectric sensor. The laptop computer recognizes the environment of its current location through the analysis of the distance data.

Based on the result of environment recognition, the laptop issues a voltage command to the servo pack through the DA board. The servo pack will apply a steady voltage to motors, which control the wheels for the movement.

2.2 Driving subsystem

The mobile robot in this study can move forward as well as backward, turn right as well as left, and can even change its facing directions through rotation without turning right or left. Changing the facing directions of a mobile robot could of course be achieved by turning right or left. But instead of turning, using the freedom of rotation could keep the photoelectric sensor staying at the same location and the same direction. This is because the photoelectric sensor is mounted between the front wheels, which are the driving wheels. The benefit is that the environment recognition results obtained before the rotation stay valid even after the rotation.

3 Control program

The environment recognition is accomplished by applying the minimum mean square algorithm to the distance data. As a result, a set of feature points are extracted. The feature points here are the uneven points on the walls. Figure 2 shows the flow chart of the program.

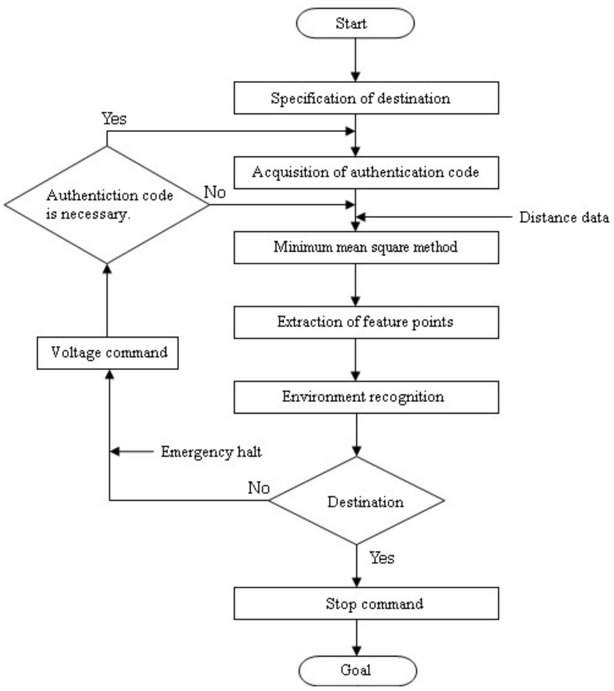

Fig.2. Flow chart of the program

3.1 Minimum mean square method

The photoelectric sensor generates 100 samples of distance data every 1.8 degrees. If all the samples are directly used for the feature point extraction, an overwhelmingly large number of feature points will be extracted. This is because the existing variance among the samples leads to the extraction of uneven points from a flat wall. The minimum mean square algorithm is used for the approximation of straight lines so that no feature point is extracted from a flat wall.

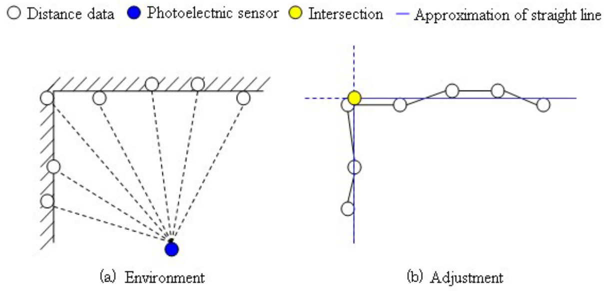

Fig.3. Minimum mean square method

3.2 Extraction of feature points

Environment recognition is solely based on the extraction of feature points, which makes the extraction of feature points extremely important. The feature points here are the uneven points on the walls. Let us see the triangle in Figure 4, where the vertexes, *A*, *B*, and *C* are the points that three approximated straight lines intersect. As soon as the length of all the three sides of the triangle a, b, c is calculated, could the angle θ at B be calculated with the formula (1).

$$\theta = \arccos\left(\frac{a^2 + b^2 - c^2}{2ab}\right) \tag{1}$$

If θ is smaller than a pre-determined threshold, point B will be extracted as a feature point.

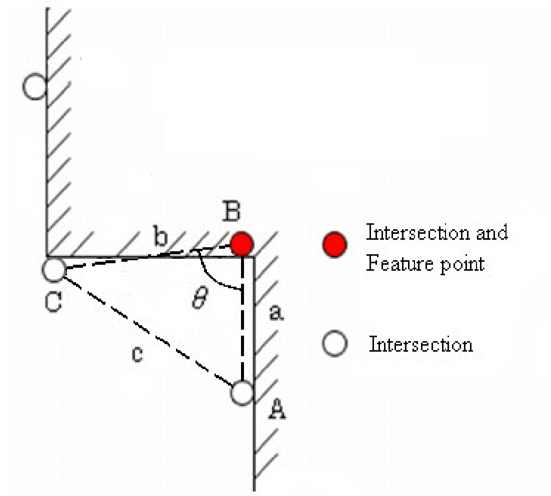

Fig.4. Extraction of feature points

Although the minimum mean square algorithm has already been applied, it is still possible to extract extra feature points. One solution to this problem is to dynamically reduce the threshold from 150 to 140 degrees in the process of selecting the feature points. Another criterion is to choose one when two or more feature points are nearby. Since the two criteria are applied to the feature pointed extracted, the removed extra feature points will not be re-selected.

3.3 Environment recognition

The length of the wall is used as a reference for the environment recognition. Since the feature points correspond to the joint points of different walls, the length of a wall could be measured by finding the distance between the feature points. The current location is identified by comparing the length of walls with the information given in a map.

3.4 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. In order to minimize the potential collision, the robot is kept moving along the centerline of the road. To keep it on the centerline, the wheels with shorter distance data will be controlled to move forward while the wheels on the opposite side move backward. This adjustment keeps going until the robot moves to the point on the centerline. When the distance data sampled at 35 and 145 degrees are equal, wheels on both sides will be controlled to move forward. The data sampling and the control of wheel rotation are constantly happening during the entire movement until the robot arrives at the destination.

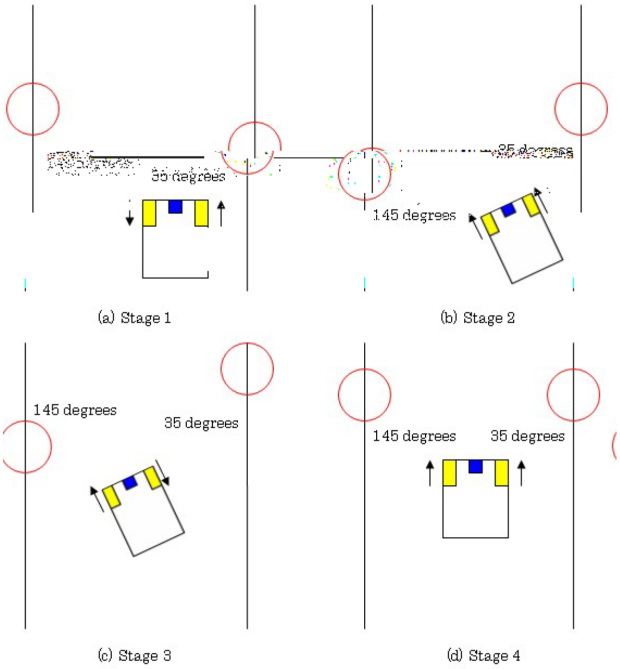

Fig.5. Move to the center

3.5 Obstacle avoidance

When the robot moves, the control program compares the distance data sampled at 35 degrees on the right side with those at 145 degrees on the left side this time. When there is an obstacle that doesn't exist in the given map on the road, the robot may collide with it. How to avoid collision against an obstacle is shown here.

To detect unknown obstacle, it examines distance data captured with the photoelectric sensor from 35 to 145 degrees. When an obstacle is found on the road, the distance between the obstacle and the right wall is compared with that between the obstacle and the left wall. Then the robot changes the moving direction toward the center of the wider space and successfully passes over the obstacle. After the robot recognizes that it has passed over the obstacle, it switches back the moving direction to the previous one.

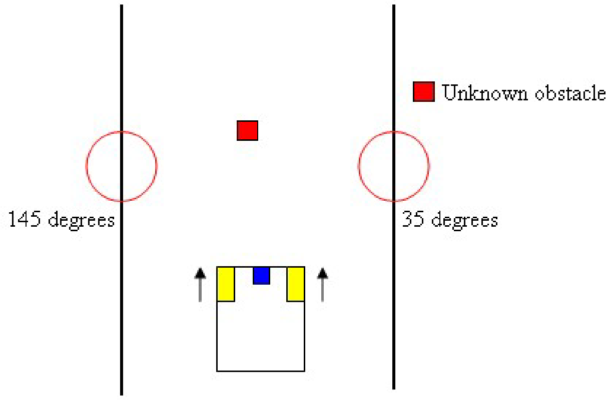

Fig.6. Evading obstacle

4 Experiment

The autonomous mobile robot has been experimented in a narrow indoor environment. Simply with the distance data collected by the photoelectric sensor, the mobile robot is moving autonomously.

4.1 Test cases

The following two experiments are conducted:

- Experiment 1: the centerline of the road is specified as the destination.
- Experiment 2: the destination is specified to be on the side of a road.

In Experiment 2, when the robot arrives at a point with the same y coordinates as the destination, it rotates by 90 degrees and then move forward to the specified destination. The moving speed of the robot is set to be $0.5 km/h$.

4.2 Experimental result

4.2.1 Experiment 1

Figure 7 shows the console of our control program in execution. It indicates that the robot has arrived at the specified destination. Point d is the destination. Point e is the current location and c is the wall that was identified through the environment recognition by point a and b. The error of the x coordinate was -45mm in the destination and the error of the y coordinate was -20mm. The total execution time was 21360msec.

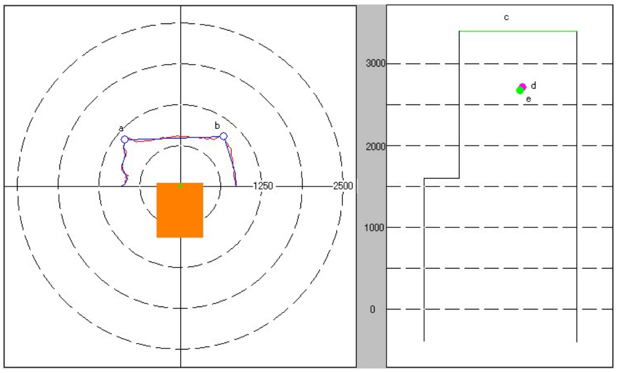

Fig.7. Result of experiment 1

4.2.2 Experiment 2

Figure 8 shows the console of our control program in execution. It indicates that the robot has arrived at the specified destination. Point e is the destination. Point f is the current location and d is the wall that was identified through the environment recognition by point b and c. The error of the x coordinate was +10mm in the destination and the error of the y coordinate was -90mm. The total execution time was 15000msec.

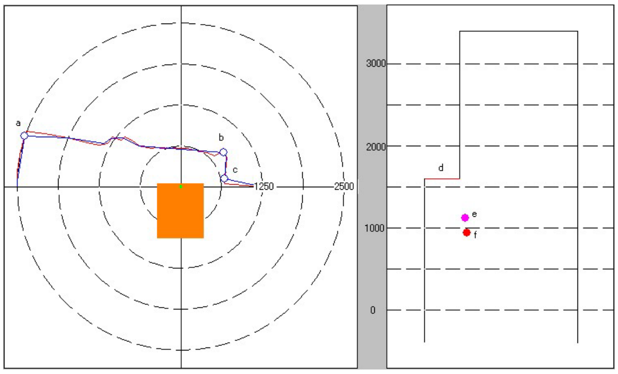

Fig.8. Result of experiment 2

4.3 Result analysis

The experimental results in Experiment 1 showed us that the error of each coordinates could be 50 mm or less, which indicates that the destination set at centerline of a road could be easily reached with very high accuracy. The experimental results in Experiment 2, however, showed big errors. The reason is because the robot is controlled to move along the centerline of the road all the way to the point with the same y coordinate as the destination and then rotates by 90 degrees and move towards the destination. In the case that 90 degrees rotation is not accurate enough, the error occurred along the y axis will be increased substantially. As a future solution, a counter board can be used to measure the cycle of wheels so that the rotation could be well controlled to be close to 90 degrees.

The control program in the experiments is to control the robot move along the centerline while doing the environment recognition. It stops the movement only when both the environment recognition is achieved as well as the destination is reached. In another words, in the case that the robot arrived at the destination with no environment recognition completed, the robot may keep going and pass the destination. One solution could be to keep track of the previous locations and match with the current location. This way, the speed of robot could be reduced as soon as it is identified that it getting close to the destination. With the reduced speed, the robot will have more distance data collected for the environment recognition. As a result, the robot will stops at the destination more frequently.

5 Conclusion

In this research the environment recognition was achieved by processing the distance data obtained through the photoelectric sensor. The control of an autonomous mobile robot through the environment recognition has been experimented. The goal of controlling the mobile robot so that it moves autonomously to the destination in a static environment was achieved. The second goal that the robot moves with no stops was achieved.

The approach in this study is going to be enhanced to deal with the issues that an autonomous mobile robot may encounter in a dynamically changing environment. A dynamically changing environment could be an environment with people walking around or some other moving objects. In a dynamically changing environment, the robot needs to predict the movement of other objects including people and try not to interfere with other moving objects.

Acknowledgment

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