Autonomous Mobile Robot Navigation Using Braille Blocks in Outdoor Environment

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Abstract

A mobile robot can use the walls or the pillars to localize itself when it navigates in indoor environment. However, in open space or outdoor environment there are few easy detectable and stable objects that the robot can use. In this paper, we propose a method for the detection of braille blocks, which are originally used for visually handicapped people, for autonomous mobile robot navigation. To recognize the braille block, a CCD camera and a laser fan beam projector are used as sensor[1] to detect bumps on road surface. This paper also presents the experimental results of braille block following and simple navigation task using the sensor system to detect the braille block position and orientation. This experiment shows effectiveness of the sensor system for the braille block recognition and implies the possibility of braille block based mobile robot navigation.

1 Introduction

Localization is an important function of autonomous mobile robot. In indoor environments, there are many objects which are easily observed such as walls, doors and pillars. These objects are also easily recognized by human, so environmental maps for mobile robots can be built easily by human. On the other hand, localization in outdoor environments is not easy. Some projects use the image processing technology for localization [2][3][4], but their systems are too complex and too large to implement into a small sized mobile robot.

There are many places where braille blocks are placed these days in urban areas in Japan and some other countries. The braille block is a safety equipment for visually handicapped people. Hence they can walk along the street using information of the braille blocks. In this study, we use the braille blocks to guide the autonomous mobile robot.

In this paper, we describe mobile robot navigation using the braille blocks. At first, what the braille blocks are and how the mobile robot uses them for navigation are described. Then the mobile robot system including sensors and controllers we have developed are described. And finally, experimental result of the localization process using the braille blocks is discussed.

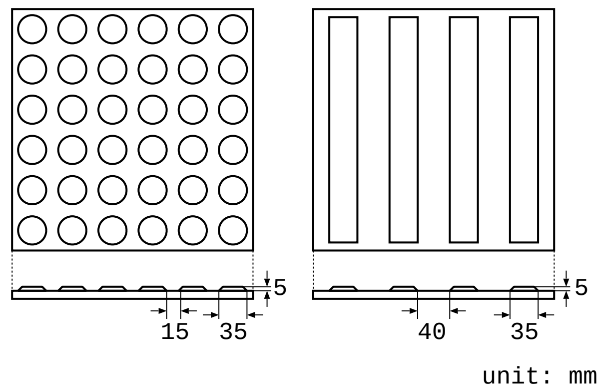

Figure 1: Two styles of braille block
left: dot style block
right: line style block

2 The braille block

The braille block is a very popular facility for guiding visually handicapped people in Japan. The blocks are often found in stations, on sidewalks, in public institutions.

As shown in Fig.1, there are two kinds of braille blocks, dot style block and line style block. Each style of blocks

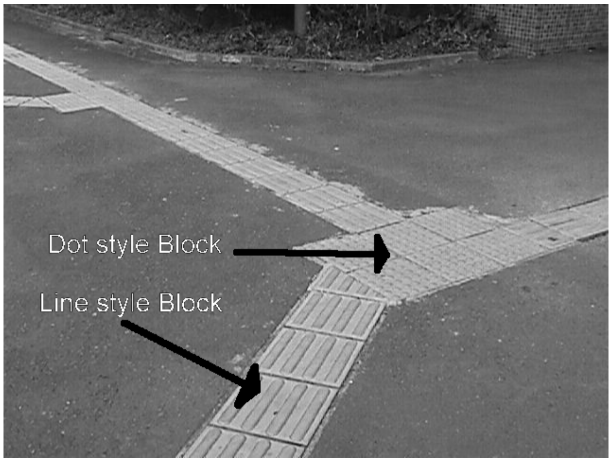

Figure 2: Example of braille blocks on pedestrian

has line style or dot style of convex parts which are 5mm high. The standard color of the block is yellow, but several variations are permitted.

When visually handicapped people step on the blocks, using the sense of touch through their soles, they can know information about the street such as the direction they can follow and the existence of junctions.

Line style blocks are usually arranged in line and figure the position and direction of the path. At the corner of the path, dot style blocks are placed. Dot style blocks are placed also at the junction of the path and some interesting places such as bus stops or the entrances of buildings. Fig. 2 shows the actual arrangement of the blocks on pedestrian.

3 Utilization of braille blocks for mobile robots navigation

In structured environments, wall following and line tracing are easy and effective methods for mobile robot to track the pre-defined long path.

Using the sequence of the line style blocks as a pre-defined path, outdoor environment can be simplified. Basically the mobile robot follows the sequence of line style blocks. When a dot style block is found, using a map built in advance by human, the robot can decide the next action. Building the map is relatively easy because the path is already defined as sequence of line style blocks and the length of the path can be measured by counting the number of the blocks.

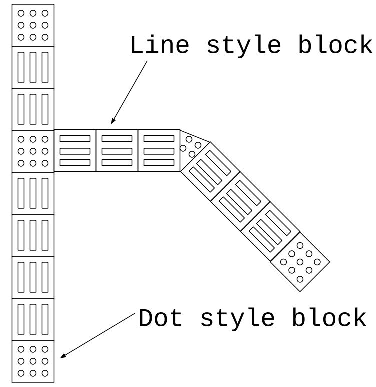

Figure 3: Example pattern of the braille block

3.1 Detection of braille blocks

Braille blocks have two major special features which are used to distinguish them from normal road surface. One is its color, which normally is yellow. This feature is for weak eyesight people and help them to find it by its high contrast color. This feature can be used to detect the blocks with color camera [6]. However this is a recommended feature by the guide line and not mandatory, so it is not always yellow especially in sight aware places. Also with this feature, it is hard to distinguish the type of braille block.

The other feature is its physical shape. The height of its convex part is 5mm regardless of the type of the braille block, and the type of the block can be distinguished only by the shape of convex part. We use this feature for detecting the braille blocks with a laser fan beam projector and a camera. In this way, it should be possible to detect the existence of block and recognize the type, position and direction of the series of blocks.

3.2 Map of braille blocks

The mobile robot should have information about the braille block arrangement as an environmental map so that the robot can plan the path using the map. The map should contain the following information.

- Length of the series of the line style blocks
- The junction or the corner where the dot style blocks are placed and directions of the paths connected to the junction
- Terminal of the series of braille blocks

Fig.3 shows a example pattern of braille blocks, and the corresponding environmental map should contain the information shown in Fig.4.

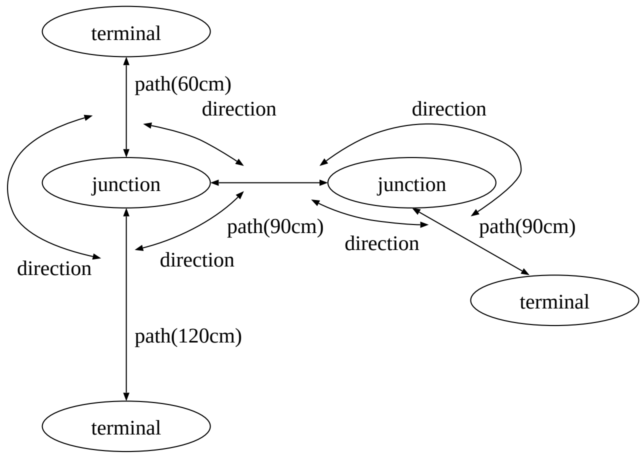

Figure 4: Corresponding environmental map to the block pattern shown in Fig.3

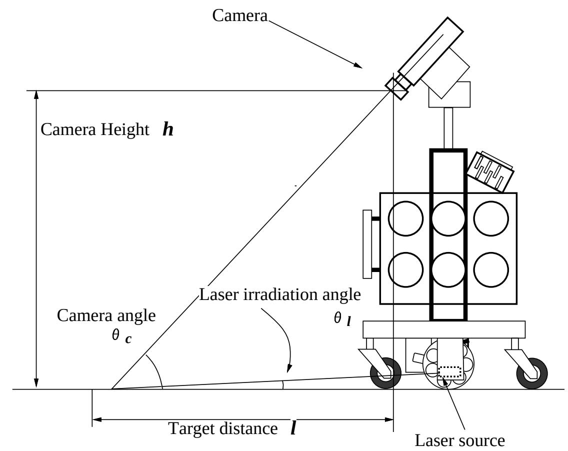

Figure 5: Configuration of the laser source and the camera

The length of the path is used to predict that a dot style block could exist at the end of the path. With this prediction, the robot can slow down and carefully search for the dot style block if necessary.

3.3 Navigation with braille blocks

By giving the current and target position in the environmental map, the mobile robot can plan a path on the map and navigate by itself to the target position. Navigation is done by tracing the series of line style blocks and choosing the proper path at a junction according to the plan.

4 Robot system

4.1 Sensors

Using infrared laser fan beam and camera with interference filter, the difference of height on the road surface can be detected by triangulation with simple image processing. To satisfy the requirement of resolution to detect the braille block, the laser source and the camera must be carefully configured. Fig.5 shows the configuration of this sensor system. With a CCD camera which outputs NTSC video signal with a lens whose focal length is 8.5mm, the camera height should be 50cm high and laser irradiation angle must be less than 10 degrees to gain enough accuracy.

We use a mobile robot equipped with the sensor system whose laser irradiation angle is 5 degrees and the camera height is 55cm. Fig.6 shows the robot and Fig.7 shows an image taken with the camera of the sensor system.

4.2 Mobile robot platform

The mobile robot which is used for this study is named YAMABICO-fra, one of YAMABICO mobile robots family developed in our laboratory [1]. Its dimensions are approximately 40 cm (W) X 40 cm (D) X 50 cm (H) without camera and 70 cm high including it.

4.3 Controllers

A distributed controller architecture is used in YAMABICO-fra (see Fig.8). It has some function modules which are the common system of YAMABICO mobile robots family such as ultrasonic sensor module and locomotion module. Each function module has own processor connected with high speed serial link or dual port memory and works simultaneously.

A note book PC running Linux is used as image processor and as main controller. The PC and the other function modules are connected with standard serial port to control low level function modules from the PC. Two of three TYPE-II PCMCIA slots are used by a Video capture card and an Ethernet card which is connected to a wireless LAN module for monitoring the robots status.

5 Recognition of braille blocks

The purpose of recognition of the line style block is to follow the series of line style blocks. Hence two parameters must be known. One is the distance between the line of the blocks and the robot and the other is angle between robot's heading direction and the one of the line.

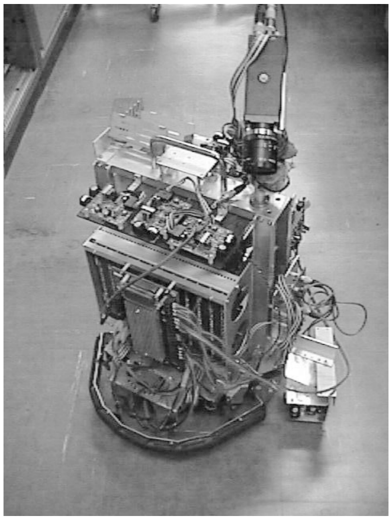

Figure 6: Mobile robot equipped with the laser source and the camera

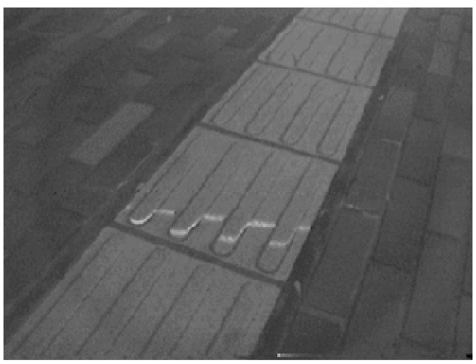

Figure 7: Image from the camera aimed at the line style block

5.1 Position of a line style block

Because of line style block's shape, the block can be found by searching for periodically appearing bumps on the projected laser fan beam in a captured image(see Fig.9). Once the position of the bumps on the captured image determined, the actual position of the block on the ground can be calculated.

5.2 Direction of a line of blocks

Comparing the interval of detected bumps and the actual distance of convex parts on the line style block, the direction of the line of blocks can be calculated.

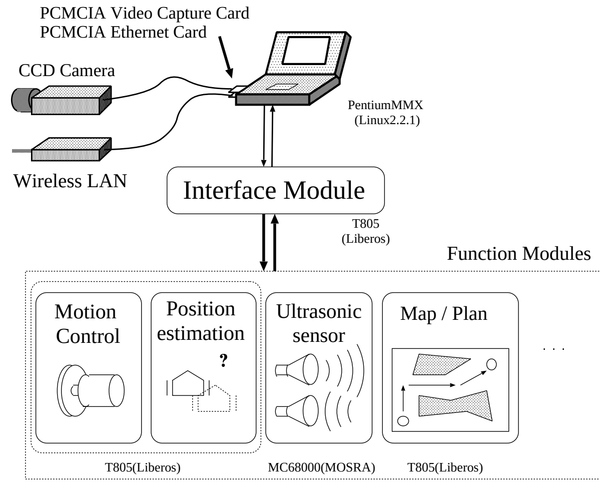

Figure 8: The controller architecture of YAMABICO-fra

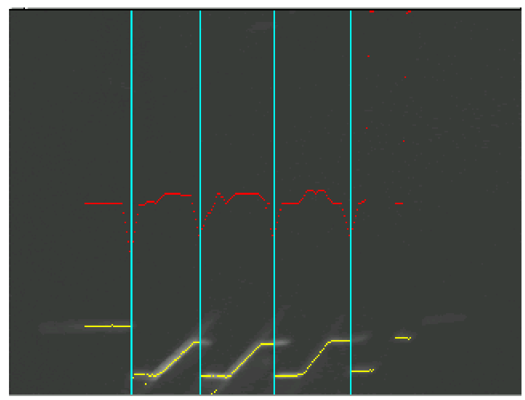

Figure 9: A captured image of a line style block and drawn result of bump searched on it as vertical line

5.3 Dot style block detection

Dot style blocks have many bumps on its surface, and they can be found by the sensor system(Fig.5.3). Using number of bumps and distribution of bump interval, dot style blocks are easily distinguish from line style blocks or any other noises.

6 Experimental results

With the mobile robot YAMABICO-fra, two experiments have been conducted to verify the effectivness of this system.

The first experiment is line style block following for confirming the proposed block recognition method. In this

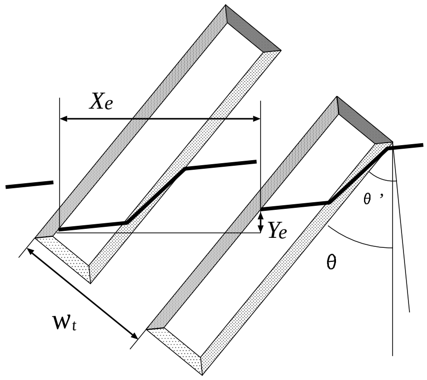

Figure 10: The line style block on which laser fan beam projected

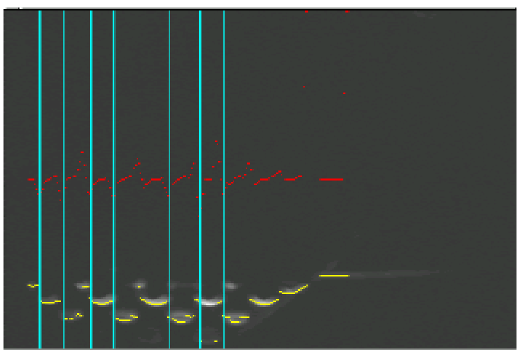

Figure 11: A captured image of a dot style block and drawn result of bump searched on it as vertical line

experiment, the robot does not have the environmental map and just follows line style blocks. The path defined by line style blocks includes a corner without dot style block. The experiment has been done just after sunset and also day time of cloudy day. It runs at 9cm/s and captures camera image every 200ms.

Fig.13 shows one of the experimental results. The robot successfully followed the line style blocks in this experiment. At the corner, it failed tracking line style block in short term because of narrow sensor range. However, it could follow new direction and start tracking new line of blocks again because the robot has ability of detecting direction of linestyle blocks not only the position of them.

The second experiment is a simple navigation task. In this experiment, the robot has a route map, and it contains informations of a route to the destination described using braille blocks(see Fig.15). The experiment has been done in indoor environment(see Fig.14).

Firstable, the robot follows line style blocks. When it

Figure 12: Experimental environment for line style block following

reaches to terminal area (according to route map), it starts searching for a dot style block simultaneously. If a dot style block detected, it turns right to follow a new path and follows it. Finally, it reaches the goal area where is indicated by dot style block.

Fig.13 shows the experimental result. Also in this experiment, the robot successfully reached to the goal area.

7 Conclusion

In this paper, we described a detection method of braille blocks for mobile robot navigation and presented sensor system for recognition of braille blocks. Using this sensor system, mobile robot can follow the line style blocks and detect the dot style blocks. The result of the experiment shows effectiveness of this method in both indoor and outdoor environments.

In the future work, we will construct a route map generation system for more complex navigation task. Also we will conduct some experiments of navigatin system in out door environment using the proposed sensor system.

References

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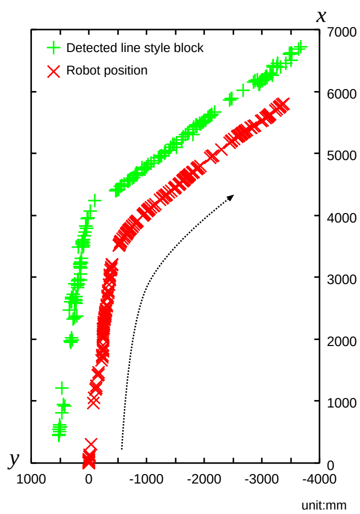

Figure 13: Detected line style block positions and robot position in the following task

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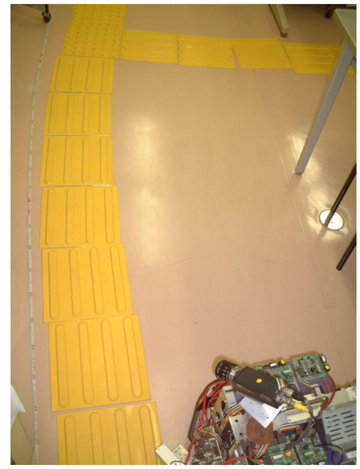

Figure 14: Experimental environment for simple navigation task

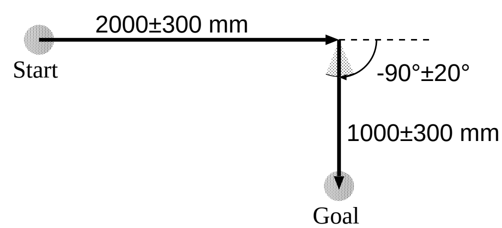

Figure 15: A map for the second experiment

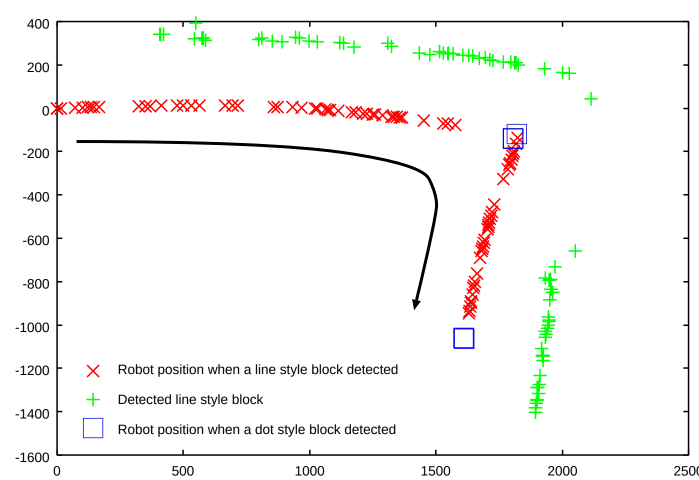

Figure 16: Detected line style block positions and robot position in the simple navigation task