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Recognition of Lane Markings in Factories and Method for Self-Position Estimation Using AR Markers

Kento Hisanaga[1,a], Shiyuan Yang[1,b], Seiichi Serikawa[1,c,*]

[1]Department of Electronic system, Kyushu Institute of Technology, 1-1 Sensui-cho, Tobata-ku, Kitakyushu-shi, Fukuoka, 804-8550, JAPAN

[a]<kento.hisanaga426@mail.kyutech.jp>, [b]<yang@elcs.kyutech.ac.jp >, [c]<serikawa@elcs.kyutech.ac.jp>

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Abstract. Currently, automations of factories are progressing, and the demand for introduction of automatic transfer robots is increasing. However, there are many factories that cannot introduce automation of factories because of cost and time. In this study, we propose an automatic transfer robot system using AR markers in addition to lane markings originally drawn in the factory, to reduce the above problems. This makes it possible to flexibly determine and change the route without reattaching the tape as a method using magnetic tape. Lane markings and AR markers are recognized in real time using a camera. Then, the distance and self-position are gotten by using the angle, position of the lane marking and the AR marker. The self-position could be estimated from the information.

1. Introduction

An introduction of factory automation has a long history, and more than half a century has passed since robots were well used in factories [1]. In recent years, needs of unmanned operation of factories has increased, and a demand for automatic transfer robots is increasing. The advantages of automatic transfer robot include a reduction of cost such as labor cost and improvement of productivity. Moreover, in Japan, labor shortages due to declining birthrate and aging population are serious problem, and the need of factory automation will increase more in the future. Currently, a method using magnetic tape is often used as tape of line trace for automatic transfer robot. In this method, a magnetic tape is attached in advance on floor. A robot can correctly move to a destination, because line trace technology is so simple and tough. However, it has some disadvantages. (1) If there is a layout change in the factory, it is necessary to reattach the tape, then it takes time and cost. This greatly affects the productivity. (2) If there is an obstacle on a path, the robot cannot avoid the obstacle [2],[3],[4].

To improve the problems, we propose an automatic transfer robot system which can estimate self-position using AR markers in addition to lane markings originally drawn in the factory. This makes it possible to change and add routes more flexibly than a method using magnetic tape.

2. Method

2.1 Method for detecting lane markings by image processing

To use robot system in real space, it must work real-time. Therefore, a simple processing is preferable. In detecting lane marking, grayscale conversion is first performed. By the conversion, the amount of data is reduced to 1/3 of the original color image acquired from a camera. Next, histogram flattening is performed on the converted image. By performing this process, the contrast of the image can be increased, and the image can be easily analyzed. At 3rd, an edge detection and Hough transform are performed. Some candidates of lanes are detected by edge extraction. From the candidates, a lane is detected more accurately using Hough transform.

2.2 Calculation of distance to lane markings

For calculating the distance from the lane marking, we explain a shooting range of the camera. Figure 1 shows the range. Equations (1) and (2) are obtained from the image sensor size (H_i in the vertical direction and W_i in the horizontal direction), the focal length f of lens, the maximum shooting range (H_{max} in the vertical direction and W_{max} in the horizontal direction), and length z between lens and an object.

$$H_{max} = \frac{z \times H_i}{f} \tag{1}$$

$$W_{max} = \frac{z \times W_i}{f} \tag{2}$$

Next, Fig. 2 shows the positional relationship between camera and ground, and Fig. 3 shows an example of an image after detecting lane markings. Let the height of the camera be H_c, the horizontal distance from where the angle of view can be seen be z_0. In the three-dimensional coordinate system, the camera is placed on the y-axis form the origin, and it is placed in the z-axis direction. In Fig. 3, PICTURE_WIDTH is the number of pixels in the horizontal direction of image, and PICTURE_HEIGHT is the number of pixels in the horizontal direction. The starting point of the lane marking at the bottom of the lane marking screen is $p_1(x_1, y_1)$, and the point where the lane marking is detected at a position where p_2 is shifted vertically by 20 [pixel] from p_1. It means p_2 $(x_2, y_1\text{-}20)$. The symbols H_c, H_{z1}, H_{z2} ,z_0, z_1, z_2 represent the length in the real world, and H_{p1}, H_{p2}, W_{p1}, W_{p1} show the number of pixels. The values of H_{z1} and H_{z2} are calculated by Eqs. (3) and (4).

$$H_{z_1} = H_{max} \frac{PICTURE\_HEIGHT - y_1}{PICTURE\_HEIGHT} \tag{3}$$

$$H_{z_2} = H_{max} \frac{PICTURE\_HEIGHT - (y_1 - 20)}{PICTURE\_HEIGHT} \tag{4}$$

The distance z_1 between the camera and the point (PICTURE_WIDTH / 2, y_1) and the distance z_2 between the point (PICTURE_WIDTH / 2, y_2) are calculated by Eqs. (5) and (6), respectively.

$$z_1 = -H_c \frac{z_0}{H_{z1} - H_c} \tag{5}$$

$$z_2 = -H_c \frac{z_0}{H_{z2} - H_c} \tag{6}$$

The maximum horizontal shooting ranges W_{max1} and W_{max2}, when the distances to the camera are z_1 and z_2, are calculated by Eqs. (7) and (8), respectively.

$$W_{max1} = \frac{z_1 \times W_i}{f} \tag{7}$$

$$W_{max2} = \frac{z_2 \times W_i}{f} \tag{8}$$

From these values, the distances W_1 and W_2 between the z-axis and the points p_1, and p_2 in the real world are calculated by Eqs. (9) and (10).

$$W_1 = W_{max1} \frac{W_{p1}}{PICTURE\_WIDTH} \tag{9}$$

$$W_2 = W_{max2} \frac{W_{p2}}{PICTURE\_WIDTH} \tag{10}$$

Next, Fig. 4 shows each point viewed from the direction above camera. The distance W of the lane markings in x-direction can be calculated by Eq. (11).

$$W = \frac{(Z_2 W_1 - Z_1 W_2)}{Z_2 - Z_1} \tag{11}$$

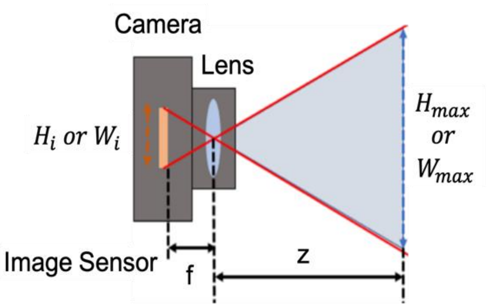

Fig. 1. Shooting range of a camera.

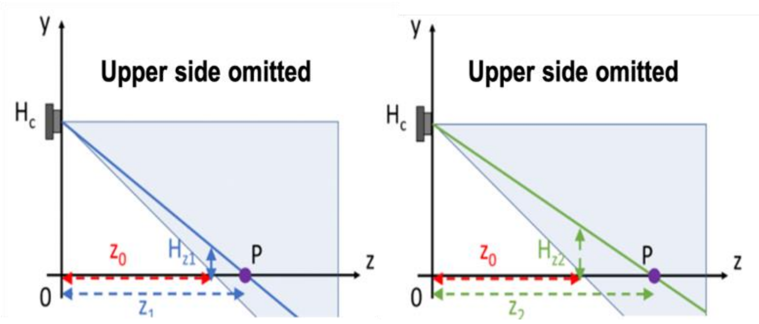

Fig. 2. Relationship between camera and ground.

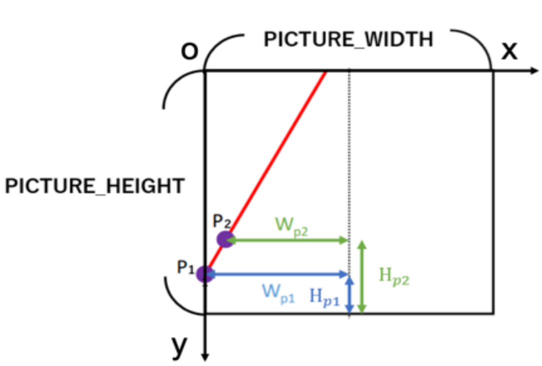

Fig. 3. Image after detecting the lane markings.

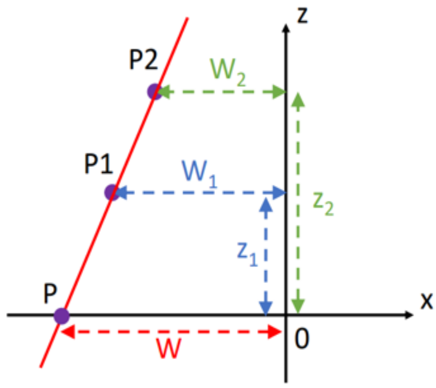

Fig. 4. Each point viewed from the direction above camera.

2.3 Detection of AR marker and estimation of position

We used a marker-type AR composed of black and white. To detect an AR marker, the surrounding black frame recognizes is utilized, and the bit information is extracted by pattern of in the frame. In this study, we used an AR marker with 4x4 bit information. In this experiment, the size of the AR marker and bit information are fixed in advance. Different information is incorporated into the marker for each installation position. Let the height of the camera be a fixed value h_c. From the size and angle of the AR marker on image, the position of camera c (x_c, y_c, z_c) in the real three-dimensional coordinates can be estimated.

The angle θ_c formed by the distance l_c between the AR marker and camera and unit vector n (1,0) in x-axis direction is calculated by Eqs. (12) and (13). If an AR marker does not appear in a camera, it cannot be detected, then the current position is estimated from the most recently estimated value.

$$l_c = \sqrt{({x_c}^2 + {y_c}^2 + {z_c}^2) - {h_c}^2} \tag{12}$$

$$\cos\theta_c = \frac{x_c}{\sqrt{x_c^2 + y_c^2}} \tag{13}$$

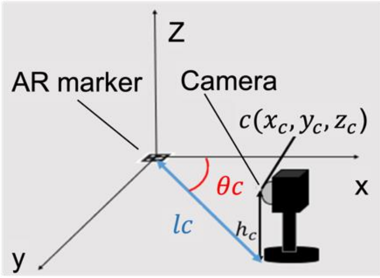

Fig. 5. Schematic diagram of position relationship between camera and AR marker.

3. Experiment

In this experiment, we practice two experiments. One is to calculate the distance by recognizing the lane marking, and another is to estimate the self-position using the AR marker.

3.1 Distance calculation by lane markings

Figure 6 shows a schematic diagram of the experiment using the lane markings. The speed of camera is 4 [cm / s], the moving distance is 200 [cm], and the width of lane marking is 2 [cm]. One is the experiment in case that the camera is placed parallel to the lane marking. Another is the experiment in case that the camera is set to 45 degrees. When the camera is parallel to the lane marking, the distances to the lane marking are 30 [cm], 50 [cm], 70 [cm], and when the angle of camera is 45 degrees, the distances are 50 [cm], 60 [cm], and 70 [cm].

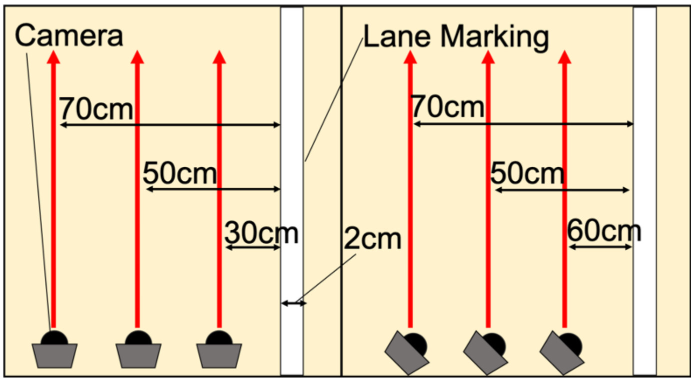

Fig. 6. Schematic diagram of distance measurement using lane markings.

3.2 Estimation of self-position by AR marker

Figure 7 shows a schematic diagram of the experiment using the AR marker. The speed of camera is moved is 5 [cm / s], the moving distance is 100 [cm], the size of the AR marker is 3.4 x 3.4 [cm]. AR markers are placed in parallel to the moving direction of camera. One is the experiment in case that the camera is placed parallel to the lane marking. Another is the experiment in case that the camera is set to 45 degrees. When the camera is parallel to the lane marking, the distance to the lane marking is 20 [cm], and when the angle of camera is 45 degrees, the distance is 30 [cm].

4 Experimental result

The experimental results are shown here. One is the measurement distance to lane marking, and another is self-position estimated by using AR markers.

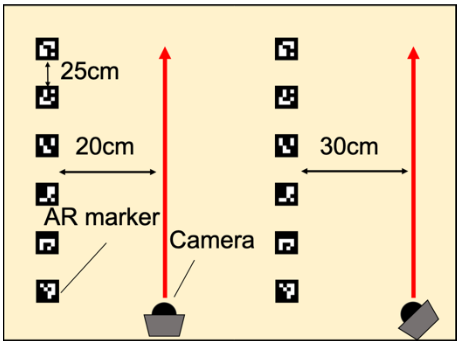

Fig. 7. Schematic diagram of self-position estimated by AR marker.

4.1 Measurement distance to lane marking

Figure 8 shows the results when the camera is parallel to the lane marking, and Fig 9 shows those when the camera is placed at 45 degrees. When the cameras were placed in parallel, the error rate was the largest at 16% when the distance was 30 [cm], and the distance could be calculated accurately. When the camera was placed at 45 degrees, the calculation result between the side surface of the camera and the lane marking had a large error, and the shortest distance had a small error. This is thought to be a human factor caused by manually moving the camera. In the future, we will install a mobile robot and detect more accurately the distance from the number of revolutions of the motor.

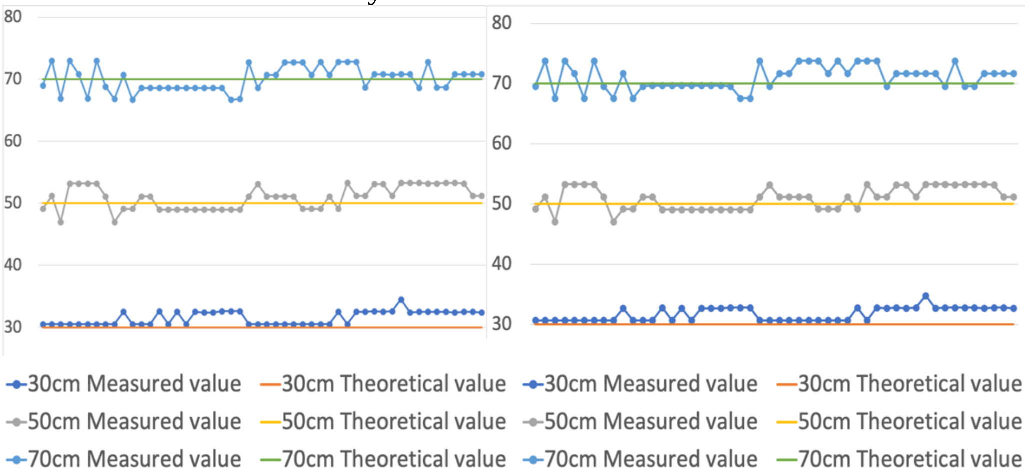

Fig. 8. The shortest distance (left) and the distance (right) to the side when camera is placed in parallel to lane marking.

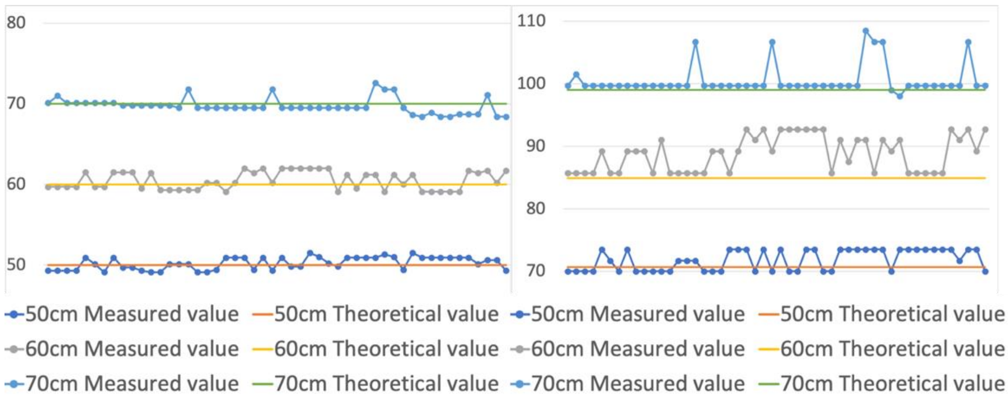

Fig. 9. The shortest distance (left) and the distance (right) to the side at 45 degrees of camera.

4.1 Self-position estimated by using AR markers

Figure 10 shows the results when the camera is placed in parallel to the AR markers, and those when the camera is placed at 45 degrees. In both cases, it can be seen that the positions were estimated because the difference the estimated value and theoretical value is small. However, self-position is not sometimes estimated because AR marker itself is not detected. This should be improved in the future.

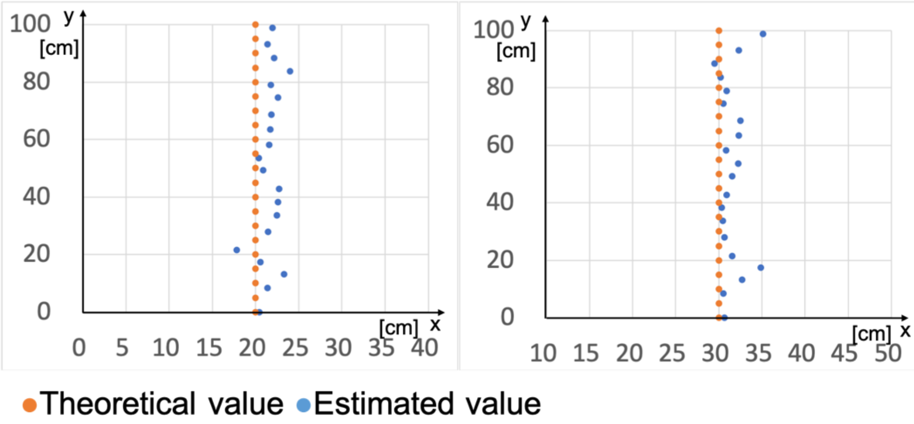

Fig.10 Self-position estimation results when the cameras are parallel (left) and when the cameras are slanted (right)

5. Conclusion

In this study, we propose an automatic transfer robot system using AR markers in addition to lane markings originally drawn in the factory in the factory. The distance to lane markings was measured, and self-position was estimated by using AR markers. As the results, it was possible to detect the distance and estimate the self-position by processing the image taken in real time by the Web camera. In addition, the self-position could be estimated from the value estimated immediately before, when AR marker could not be detected. This can be expected to reduce the route miss during automatic transfer.

When the AR marker could not be detected, the self-position was estimated from value immediately before, AR marker itself should be detected more correctly in the future.

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