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A Study on Detecting Elevator Entrance door using Stereo Vision in Multi Floor Environment

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Abstract: This paper describes algorithm to recognize an elevator entrance door in the multi floor environment in the house and office. The algorithm is useful in developing a service mobile robot which can be the moving on the environment. First, the process to detect the entrance is started with a reliable camera calibration and then through image process to acquire a clear image. Second, a candidate of elevator door is extracted by method to detect the corner of an elevator door using stereo vision instead of conventional method such as clustering process using a laser scanner. Third, the size of an elevator door is compared the uncertain door image acquired from stereo vision with the information of the standard size to find an elevator door. This paper confirmed that the proposed algorithm is easily to detect the elevator door on the multi floor.

1. INTRODUCTION

Service robots need to move in their working areas autonomously from one place to another, without collision. In addition, robots must be able to perform various operations such as carrying a user-specified object. Robots for working in house and office have to deal with a vast variety of environments and operations. Most services that the robot offers are based on the autonomous navigation. Therefore, the autonomous navigation is one of the most important fields in the intelligent mobile robot. Many service robots were introduced and they performed the autonomous navigation successfully in house or office environment. However, their autonomous navigation capabilities consider only the single-floor environment. So they are not able to navigate to the goal on another floor. To navigate in multi-floor environment, mobile robot should use an elevator. As a first step for moving to the other floor, the robot should recognize the elevator door[1].

Kang et al[2] proposed the method of detecting an elevator by using laser scanner. It can detect 2D plane corner of the elevator door by the laser scan but may occur the detection errors in the same shape with the elevator[3].

To increase a rate of detection of an elevator door, we propose the method of recognizing the door based on 3D image using the stereo vision. The vision system is more effective than ultrasonic sensors or laser sensors for recognizing an object and estimating the position of an object. And the robot recognizes the elevator without the position information of the environment.

In this study, the detection algorithm for recognizing elevator door is proposed by using the only visual information. The position of the elevator in unknown environment is computed by using a stereo vision system and the accuracy of the measured position is evaluated.

The elevator detection algorithm consists of preprocessing, elevator candidate extraction, and elevator detection. First, preprocessing is a camera calibration and to acquire a clear image. Second, an elevator candidate extraction is finding the intersection point of the straight lines. Finally, the distance between an elevator door and a robot is estimated after recognizing the door as matching the elevator size. Fig.1 shows an overview of the proposed algorithm of the elevator detection.

In section 2, we present preprocessing, the elevator candidate extraction, and the elevator detection. Section 3 shows the experiment results of the elevator detection. The conclusion is given in section 4.

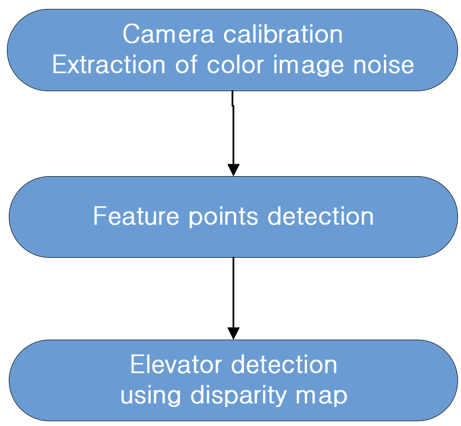

Fig. 1 An overview of the proposed algorithm

2. ELEVATOR DETECTION

In this paper, stereo vision is used to determine the 3D coordinate corresponding to an image plane point. The use of the stereo system requires less strict camera calibration while monocular vision is concerned with a number of assumptions such as geometric properties. The robot can measure the position of an object by using stereo images. Stereo matching methods divided into two methods: area-based and feature-based. Area-based method has the advantage of reducing computation quantity but is sensitive to noises because

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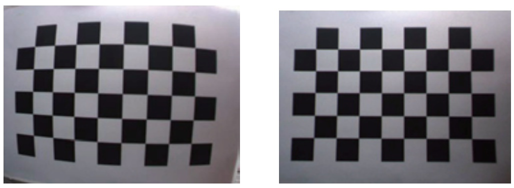
it depends on the intensity. Feature-based method includes complex processes such as interpolation but it is effective to reduce noises. In indoor environment with several sources of light, feature-based method is suitable to applications. The position of the elevator is computed by camera's geometry and visual information. The 3D position of the elevator can be measured by the disparity map. Also, the template matching algorithm is used the elevator detection.

2.1 Preprocessing

First, a camera calibration for exclusion of the camera distortions is performed by Zhang's method[4]. Zhang's method using a simple planar pattern has been able to calibrate the camera distortion because of easy-to-use and accurate algorithm for obtaining both intrinsic and extrinsic camera parameters. Fig 2 shows the result of camera calibration by applying Zhang's method.



(a) before (b)after

Fig. 2 image of camera calibration

Second, extraction of acquired image noise is performed by the Gaussian smoothing, because the use of the RGB color space is non-intuitive and non-uniform in color separation.

2.2 Elevator candidate extraction

Because the elevator is represented as lines, we used edge image and a position of corner in order to extract elevator candidate.

The robot extracts the feature points from the edge image[5]. To find the feature points, 'cornerness' is computed in gray-level. Cornerness is defined as the product of gradient magnitude and the rate of change of gradient direction with gradient magnitude. In order to measure cornerness, Forstner operator is used. If weight, W and cornerness, C in (2) are larger than threshold, we regard these points as candidates of feature points. The threshold value is determined experimentally. Local maxima among candidates are determined as feature points.

$$A = \begin{bmatrix} < g_r^2 > & < g_r g_c > \\ < g_r g_c > & < g_c^2 > \end{bmatrix} \quad (1)$$

$$W = \frac{Det(A)}{Trace(A)}, \qquad C = \frac{4Det(A)}{Trace^2(A)} \quad (2)$$

$< g_r^2 >$, $< g_r g_c >$, $< g_c^2 >$ indicate normalized values of g_r^2, $g_r g_c$, g_c^2 using Gaussian smoothing filter. g_r and g_c are gradient value calculated by Sobel operator. The normalized matrix, A is determined by (1). To get feature points, the left image is used as a reference. The right matching point corresponding to the left feature point is found by using gradient-based matching method. This method depends on gradient values to estimate resemblance between gradient values of the left and right points in gray-level. For searching the most similar point, gradient values of each pixel on the right image are compared with the gradient value of the left feature point within searching window. For efficiency of this operation, a size of a searching window is determined in proportion to the size of the mark in the image. If an object is far from cameras, the disparity which is the difference between the left and right image is small enough to search the matching point by a smaller window's size. Contrary, if an object is close to cameras a searching window being a large size is needed.

The size of a window is determined by (3). (r_s, c_s) and (r_e, c_e) indicate the upper left corner and the lower right corner of the mark in the image like Fig 3 a is a constant determined experimentally. Similarity S is expressed as (4) and the right matching point is (row, column) where S is the smallest.

$$window = a(|r_s - r_e| \times |c_s - c_e|) \quad (3)$$

$$S = -\alpha |g_L(\text{left matching point}) - g_R(row, column)| \quad (4)$$

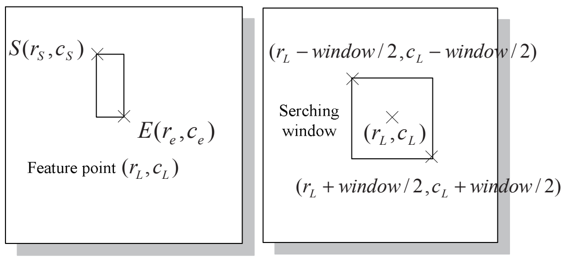


Fig. 3 Searching window in the right image related to a feature point in the left image

2.3 Elevator Detection using the disparity map

The disparity map is calculated by the stereo matching[6]. The goal of stereo matching process is to find a match between the pixels in the first (reference) R and second (wrap) W image such that the pixel located at (i, j) in the R image and a pixel located at (i+I(i, j), j+J(i, j)) in the W image view the same point in object space, i.e., W(i+I(i, j), j+J(i, j)) -> R(i, j), where I(i, j) is horizontal disparity map, and J(i, j) is vertical disparity map. The index i (column index) is measured along scan lines and the index j (row index) is measured across scan lines. In this paper, we used epipolar resample images, and $J(i, j) = 0$ for all i and j. This relation can be reduced to $W(i+I(i, j), j) \rightarrow R(i, j)$.

3. EXPERIMENT

Fig. 4 shows configurations of the robot. The system of robot is separated the mobile robot system, stereo vision system and main controller. The driving part of the mobile robot has two servo motors. The sensor part consists of sixteen ultrasonic sensors and two encoders. Encoders generate pulses up to 9,850 per 1 second and ultrasonic sensors can detect the range of 10cm~5m.
CCD cameras which stand in a row on 20cm from the upper plate support resolutions of 640×480. The distance between two camera's center is 12cm and camera's lenses are set to 3.8mm focal length. Cameras' specification is as following Table. 1.

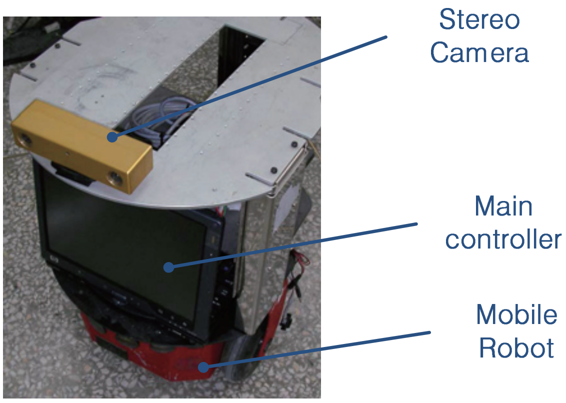


Fig. 4 image of camera calibration

Table 1 Camera specification

Camera Specification	
Image Sensor	Two 1/3" Color CCD SONY
Effective Pixel	7.4μm square pixel
Lens	3.6mm focal

The experiment in the building was performed by using the mobile robot with a function of rotating stereo camera angle. The robot searches the elevator of right side wall under various angle conditions such as 30, 40, 50, 70 degree as shown in Figure 5. And the distance between the robot and the elevator is 8m.

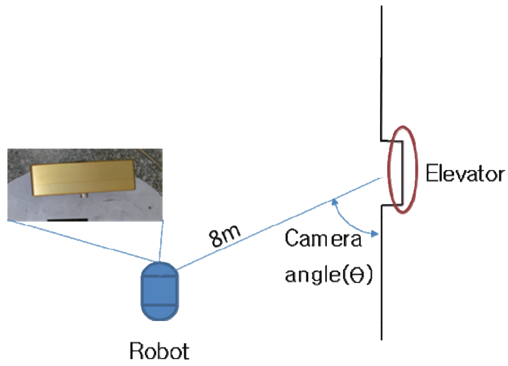
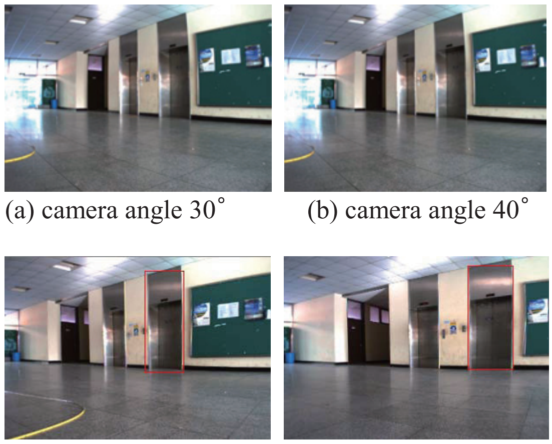


Fig. 5 experiment method

The experiment results of elevator detection on a floor show that elevator have been detected in Figure 5.
The elevator detection results of the camera angle 30 and 40 degree was a failure because of the error the disparity map.



(a) camera angle 30˚ (b) camera angle 40˚

(c) camera angle 50˚ (d) camera angle 70˚

Fig. 6 experiment result of the proposed algorithm

4. CONCLUSION

In this paper, we have described the elevator detection using stereo camera in multi floor environment.
First, the robot found the elevator candidate. Second, the elevator was detected by the disparity map in the elevator candidates.
However, applying disparity map was not efficiency because of calculation time for 3D matching. And the applied service robot does not have any robot arm, yet. Therefore the robot cannot push the button for calling the elevator and use the elevator by itself. Thus, we will use 4-axis robot manipulator to operate the elevator button. When the mobile robot get on the elevator by herself, the algorithm for exactly pushing the elevator button and detecting elevator will be more studied.

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