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Development of an autonomous-drive personal robot (Self-position recognition by characteristic point detection)

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Abstract : We are attempting to develop an autonomous personal robot that has the ability to perform practical tasks in a human living environment by using information derived from sensors and a knowledge database. When a robot is made to function in a human environment, the issue of safety must be considered in regard to its autonomous movements. Thus, robots absolutely require systems that can recognize the external world and maintain correct driving control. We have thus developed a navigation system for an autonomous robot. The system requires only image data captured by an ocellus CCD camera. This study paid attention to the necessary self-position recognition so that the robot can move precisely. We limited the environment in which it drove to a corridor. In this system, the robot recognizes a door from an image provided by an ocellus CCD camera, and it calculates its position relative to the door. In addition, it recognizes its self-position by comparing the calculated result about the door to map information that we registered beforehand. From all of this and based on the understanding of its self-position that it has developed, the robot performs safe and correct movements without hitting walls.

KeyWords : Personal robot, Autonomous driving, Ocellus camera

Ⅰ. Introduction

Currently, autonomous self-driving robots are expected to provide various services within humans' living environments. Such robotic technology is already seeing practical use in industry. But so far the robots for industry simply follow motions given by humans. Therefore, we are developing an autonomous personal robot with the ability to perform practical tasks in a human living environment by using information derived from sensors and a knowledge database.

Our robot has a drive mechanism consisting of two front wheels and one back wheel. The front wheels are attached to a motor that operates the wheels on either side independently, while the back wheel is a passive castor wheel. This method has the advantage that a far smaller turn can be negotiated than, for instance, that using a steering system that turns the wheel of a passenger car. DC servo motors are used for the robot's drive mechanism, and position control and speed control are achieved by the drive mechanism's control system. An installed wireless LAN can provide a remote control for humans. All devices are controlled by a PC, and lead batteries supply electric power.

The navigation system uses only an ocellus CCD camera and processes the image information displayed by that camera. This study paid attention to necessary self-position recognition so that the robot can move precisely. We limited the environment that it drove in to a corridor. A human being in a corridor recognizes his own rough movement distance and current position by placements such as a door, a window, and a fire hydrant. Therefore, in order for our robot to drive correctly, it recognizes a mise en scene with the sight information that a CCD stemma camera like a human being's eyes provides it. We have registered a map of the life space with the robot beforehand and intend to develop a system in which the robot's self-position is determined by its recognition of a door as the standard marker of its position than a CCD camera.

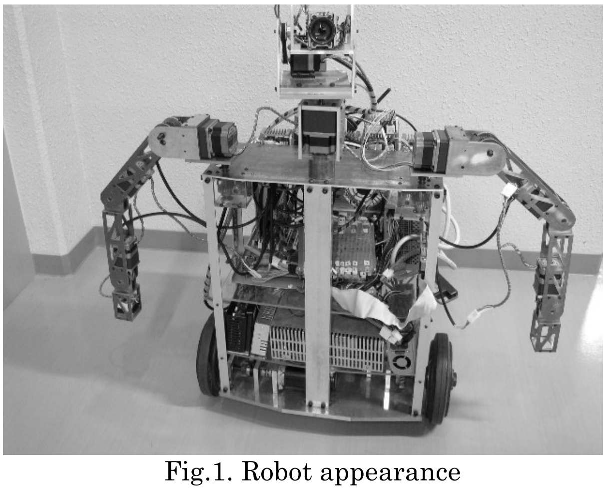

Fig.1. Robot appearance

The map of the life space can indicate a dangerous domain that will prevent the robot from colliding with walls, a door and other obstacles. One pixel in its map represents a true distance of 5cm, and the robot moves with the map as a standard. The map of the life space is shown in Fig. 2.

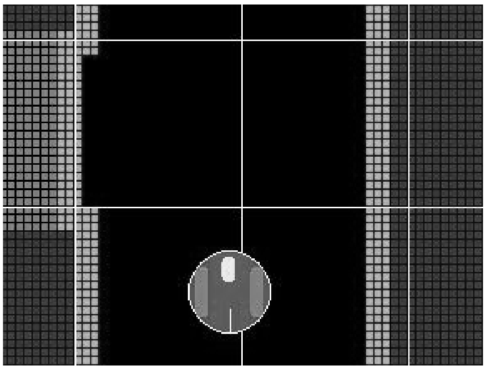

Fig. 2. Map of life space

Ⅱ. A self-position recognition system

This system extracts a straight line ingredient from an image provided from the ocellus CCD camera and distinguishes the door from information about the color of a domain that is surrounded by a straight line.
This system's flowchart is shown in Fig. 3.

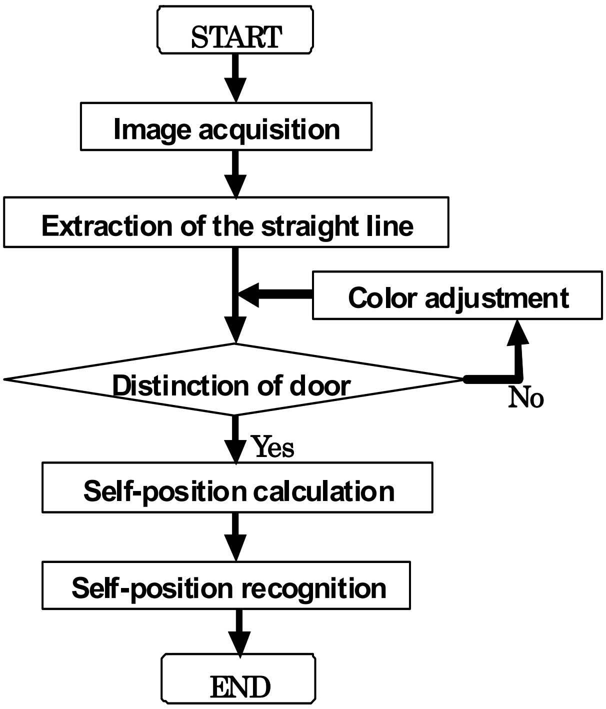

Fig. 3. System flowchart

1. Image acquisition
The image acquired from the ocellus CCD camera has a size of 320×240 pixels and is a 24-bit color image in the RGB form.

2. Extraction of the straight line
The system performs Hough transform processing of the acquired image in order to extract straight lines and circles from points that lie scattered on the image. The extraction of the straight lines is intended to distinguish the boundary lines between the door and wall and between the floor and wall.
First, this system performs an edge extraction to determine the border of each domain. The edge extraction detects a discontinuity in the color density by the use of a differential calculus filter. I consider that detected discontinuous ingredients represent the border of a door and the wall or the floor. With a Hough transform, the system converts these ingredients into a straight line that divides domains. A chart of the extraction of a straight line is shown in Fig. 4.

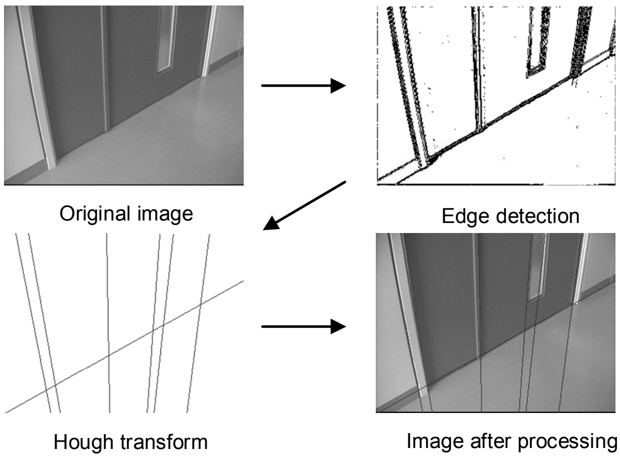

Fig. 4. Extraction of a straight line

3. Distinction of door
By extracting a straight line, the system distinguishes the domain of a door from an image divided into plural domains. I consider a line straight when its lurch is within 0 to 0.9 that of the boundary line of a wall and the floor. In addition, I consider the door to be a domain on this straight line, and I calculate the average of the pixel values in the upper part of each domain . As a result, when the domain satisfies a condition set by every working environment, the system distinguishes the domain from a door. To calculate the distance to a door, the system takes a point on the intersection between the door and the domain that is distinguished from a door. considers two points in the outside the both ends of the door most, and record them.

4. Color adjustment
When there is no big difference between the color of a door and the wall in a working or living environment,

the system performs a color revision. This is a method to increase contrasts by expanding the distribution in a histogram showing the brightness of the image. The histogram when it revises a color is shown in Fig. 4.

It is easy to increase the distinction when there are slight color differences between a door and the wall by performing this processing. The result of this is shown in Fig. 5 and Table 1.

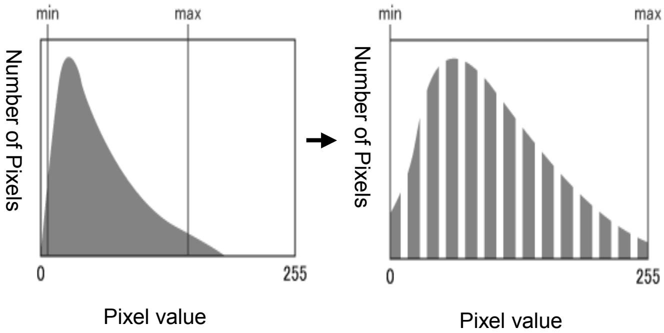

Fig. 4. Color adjustments

(a) Before revision (b) After revision
Fig. 5. Result of color revision

Table 1. Result of color revision

	Before revision			After revision		
	R	G	B	R	G	B
Wall	138	137	136	152	160	158
Door	139	132	129	157	141	132

5. Self-position calculation

・The angle of pan calculation of the camera

This process calculates the angle of the pan of the camera so that it can distinguish a door. Like the distinction of the door, I consider a straight line that declines the most as the boundary line between a wall and the floor. The system acquires two points of suitable coordinates from this and calculates the degree of leaning.

・The distance calculation to a door

From the above, with the points at both ends of the door which it recorded for door identification and from the angle of pan of the camera which it calculated, the system calculates the distance between the robot and the edge of door based on its movement direction and also the shortest distance to the wall.

When the system is not able to detect a door, it calculates only the distance to the wall.

6. Self-position recognition

The system compares the distance between the robot and the edge of the door based on its movement direction and the distance between the robot and the wall based on the angle of the pan of the camera, which it calculated with a map and which allowed it to revise its self-position. I suppose that the door on the map is the door which it detected according to its movement distance and has been provided from the encoder and the initial position of the robot which I set.

It does not perform a revision for the movement distance when it is unable to detect a door. However, it revises only the distance beween the wall and the robot.

The result of the self-position revision on the map is shown in Fig. 6.

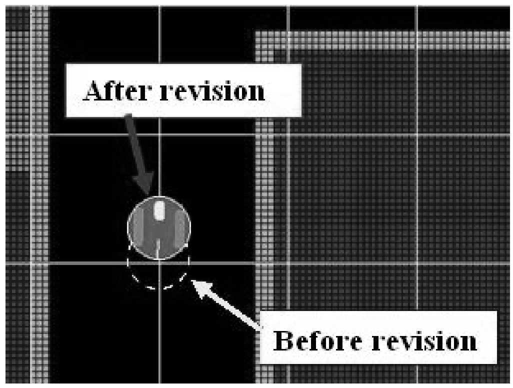

Fig. 6. Self-position revision

Ⅲ. System evaluation experiment

1. Experiment procedure

An obstacle avoidance system was developed in this laboratory from a conventional study. However, I understand that a big movement error occurs when the robot evades an obstacle using this system. Therefore, I performed a system evaluation by revising this movement error.

In this experiment, the height of the ocellus CCD camera was set at 87.5cm from the floor and the angle of declination at 30 degrees, and the mileage of the robot was set at 750cm. In addition, the position of the obstacle was set at a spot 300cm from the robot. The position of the door was set at a spot 650cm. from the robot

A robot performed movements and revisions ten times in the above-mentioned condition. From the results, I confirmed the length between the destination and the position of the robot slip off and consider it.

2. Experiment result

The experiment result is shown in Table 2. Without revisions, the average error became 57.1cm, and the greatest error became 70cm. With the revisions to this system, the average error became 6.49cm, and the greatest error became 11cm.

This system, then, was able to reduce the movement error to nearly 10% of its previous value. This error is around a 1 pixel error on the map. Therefore, I believe that sufficient revision is possible.

It is considered that an error in the straight line extraction by the Hough transform and a calculation error from the resolution caused the error that occurred by this system.

Table 2. Experiment result

	Average error (cm)	Maximum error (cm)
No revision	57.1	70
Revision	6.49	11

Ⅳ. Conclusions

This system was able to reduce an error of around 60cm to around 6cm. This is a minute error in a map with regard to the standards of the movement, and it may be said that it is a sufficient revision.

With this system, the robot stops and makes calculations from the acquired image. Therefore, there is a problem of its taking too much time when it moves in a corridor. There is the need to develop a system for self-position revision along with movement in order to solve this problem. In addition, identification of a door becomes difficult when robot is too far from a wall when a robot is over by a wall. I have to integrate the solution to this problem with the movement angle error revision system developed in this laboratory.

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