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Development of an autonomous-drive personal robot (Self-position correcting by door recognition)

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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. In this study, we focused on developing the necessary self-position recognition that that would allow the robot to move precisely. We limited the environment in which it drove to a corridor. In this system, the robot presumes the position of a door from the image offered by an ocellus CCD camera. Next, it moves to the presumed position and a door is checked. If a door is discovered, the robot calculates the distance between the door and a robot. The calculation result is compared with a map, and the self-position is recognized. This system allows the robot to operate safely and correctly.

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. Thus far, however, the robots used in industry simply carry out the motions indicated 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 independently operates the wheels on either side, 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, when 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 the electric power.

The navigation system uses only an ocellus CCD camera and processes the image information displayed by that camera. In this study, we focused on developing the necessary self-position recognition that would allow the robot to 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, to allow our robot to drive correctly, we have registered a map of the life space with the robot beforehand and developed a system in which the robot's self-position is determined by its recognition of a door as the standard marker of its position by means of a CCD camera. In the system, when a thing like a door is reflected at the end of the picture of a passage, the domain is checked with a camera. The system then determined whether the domain is a door. If it is a door, the distance to the door will be calculated and the self-position will be recognized as compared with a map.

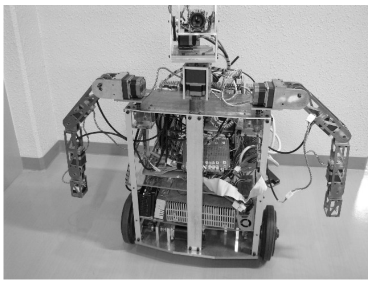


Fig.1. Robot appearance

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

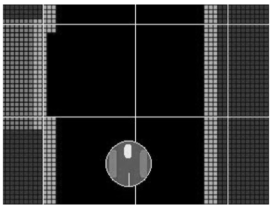


Fig. 2. Map of life space

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.

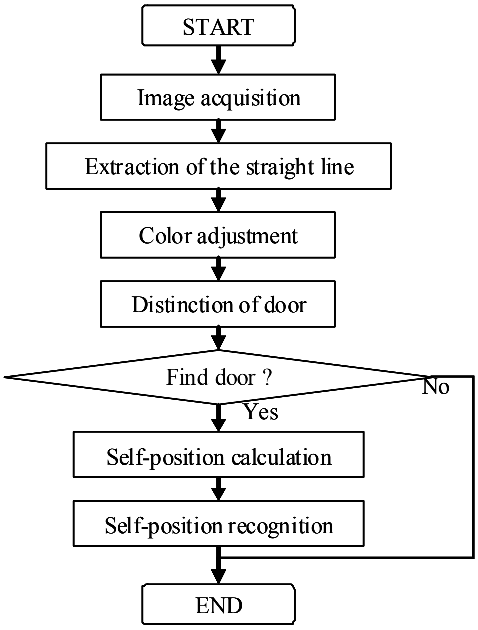


Fig. 3. System flowchart

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.

This system first 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

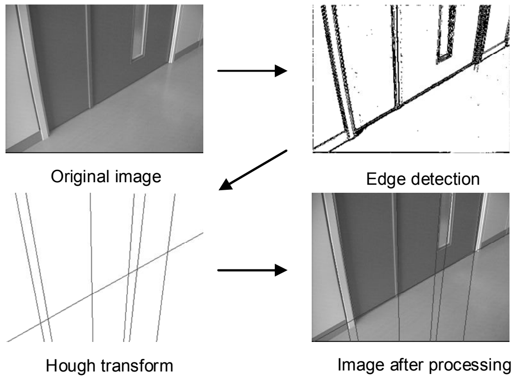


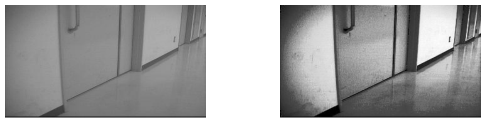
Fig. 4. Extraction of a straight line

transform, the system converts these ingredients into a straight line that divides the domains. A chart of the extraction of a straight line is shown in Fig. 4.

3. Color adjustment

When there is no big difference between the color of a door and the wall in a 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.

It is easy to increase the distinction when there are slight color differences between a door and the wall by performing this processing. The results of this process are shown in Fig. 4 and Table 1.



(a) Before adjustment (b) After adjustment

Fig. 4 Results of color adjustment

Table 1. Results of color adjustment

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

4. 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 of the boundary line of a wall and the floor. In addition, the door is considered to be a domain on this straight line, and the average of the pixel values is calculated 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 at the intersection between the door and the domain that is distinguished from a door. It then considers two points in the outside the both ends of the door most, and records them.

5. Self-position calculation

・Calculation of the camera's pan angle

This process calculates the pan angle of the camera so that it can distinguish a door. As with distinguishing the door, I consider a straight line that declines the most to be the boundary line between the wall and the floor. From this line, the system acquires two points as suitable coordinates, and the degree of leaning is calculated.

・Calculation of the distance to the door

From the above, with the points at both ends of the door that the system recorded for door identification and from the angle of pan of the camera calculated as described above, the system calculates the distance between the robot and the edge of the 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. It is supposed that the door on the map is the door that it detected according to its movement distance and has been provided from the encoder and the initial position of the robot.

It does not perform a revision for the movement distance when it is unable to detect a door.

The results of the self-position revision on the map are shown in Fig. 5.

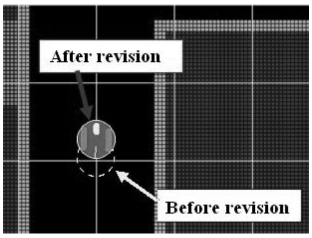


Fig. 5 Self-position revision

Ⅲ. Door-position presumption system

This system detects a domain like a door from camera pictures obtained on-going in a passage. In addition, it calculates the distance to the domain. The timing which checks a door is determined from the calculated distance.

This system is shown in Fig. 6.

1. Shading

This processing rectifies the drop in luminosity of the corner of a camera picture. The characteristics of this drop in luminosity of a camera are investigated beforehand, and the results are reflected in the camera picture.

2. Extraction of the straight line

In this processing, the Hough transform is performed like Ⅱ-2. The edge of the passage is then extracted, and the picture is divided into a wall and a floor. In this system, in order to observe the wall, the floor portion is deleted.

3. Color adjustment

In this processing, the color adjustment is performed like Ⅱ-3.

4. Labeling

Label processing is carried out to acquire a number that is peculiar to each existing connection ingredient in an image and that can be used to classify pixels. In this system, domains other than a wall are extracted from a color.

5. Door presumption

In this processing, a domain with an area more than defined value is presumed to be a door. In addition, it is assumed that a domain that is under a picture most is the nearest. The coordinates of the nearest domain are recorded.

6. Distance calculation

The distance to a thing like a door is calculated based on the coordinates recorded by □-5. The timing which checks a door is determined from this calculated distance.

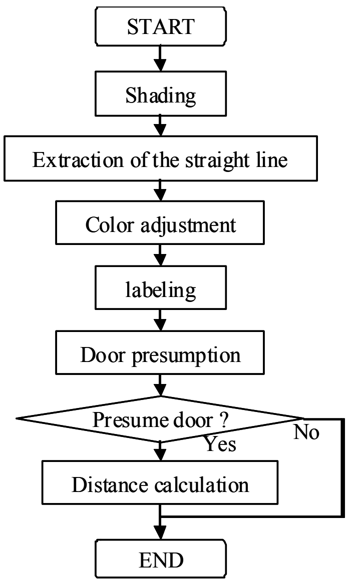


Fig.6 Door position presumption system

Ⅳ. Driving plan

The system uses a map of the life space. Figure 7 shows the driving algorithm. At first, a goal is set up on the map, and a path-finding system searches for a course to arrive at it. Next, the robot starts its movement after having made a driving plan from the course. As the robot runs along the course plan, it constantly repeats the door-position presumption. When the domain that can be presumed to be a door is discovered, a self-position recognition is performed based on the presumed position. The door position presumption is then continuously repeated, and the robot continues toward the goal.

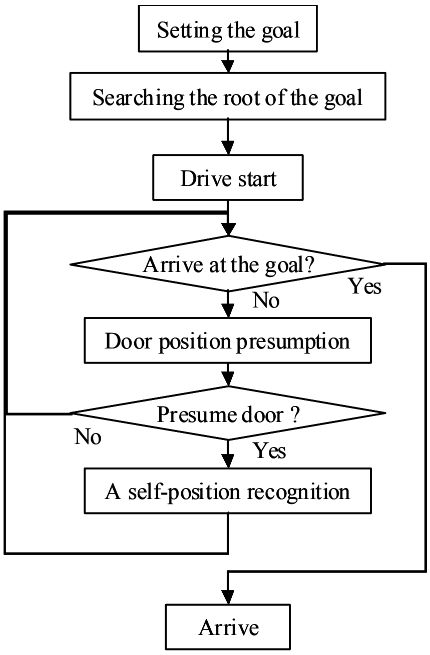


Fig.7 Driving algorithm

Ⅴ. System evaluation experiment

1. Experiment procedure

In order to check the recognition accuracy of this system and to determine the time needed to perform the door-position presumption process, the system evaluation experiment was conducted.

In this experiment, the height of the ocellus CCD camera was set at 87.5 cm from the floor. The robot's migration length was set to 850 cm. The start point was set to 650 cm from the door. The robot's movement speed was 0.5 m/s.

In order to determine the recognition error, the experiment was carried out in an environment that would not easily produce errors. The robot performed the movements and revisions ten times under the conditions described above.

2. Experiment results

The experiment results are shown in Table 2. The average error was 9.6 cm, and the greatest error was 11.7 cm. The average time required for the door-position presumption process was 314 ms.

The error for the system was below the dangerous domain set for the map. This error was an approximately 2-pixel error on the map, suggesting that sufficient revision is possible.

The robot moves 15 cm in 314 ms. The width of the door is between 120 and 150 cm. It is therefore considered that there is little chance of overlooking a door in the door-position presumption system.

Table 2. Experiment results

Average error(cm)	Greatest error(cm)
9.6	11.7

Ⅵ. Conclusions

The average error for this system was found to be 9.6 cm. This is a minute error on a map with regard to the standards of movement. It may therefore be said that the system provides sufficient recognition of the living environment.

It is difficult with this system to recognize doors that are in close proximity to one another. And when an attempt is being made to recognize such doors, other processes cannot be carried out in the meantime. It is therefore considered that the addition of an interval which checks a door is required.

In addition, in the door-position presumption system, other items such as a fire extinguisher may be incorrectly identified as a door domain. It is therefore considered that the conditions for distinguishing the domain of a door from other objects must be added to the system.

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