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Development of indoor navigation system for monocular-vision-based autonomous mobile robot

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Abstract: In our research, we developed a technology for our robot that uses an indoor navigation system based on visual methods to provide the required autonomy. For robots to run autonomously, it is extremely important that they be able to recognize the surrounding environment and their current location. Because it was not necessary to use plural external world sensors, we built a navigation system in our test environment that reduced the burden of information processing mainly by using sight information from a monocular camera. In addition, we only used natural landmarks like walls because we assumed the environmental to be a human one. In this paper we discuss and explain two modules: a self-position recognition system and an obstacle recognition system. In both systems, recognition is based on image processing of the sight information provided by the robot's camera. In addition, to provide autonomy for the robot, we use an encoder and information from a two-dimensional space map given beforehand. We explain here the navigation system that integrates these two modules. We applied this system to the robot in an indoor environment and evaluated its performance, and in a discussion of our experimental results we consider the resulting problems.

Keywords: Personal robot, Autonomous driving, Visual Processing

I. Introduction

While an increasing number of robots is being used in manufacturing fields, there is at the same time an increasing need for robots to work in non-manufacturing jobs in home environments, in medical care, and in providing welfare for the aging. To deal with various conditions in these places, robots that function autonomously are required. Therefore, in our laboratory we are attempting to develop autonomous drive-type personal robots that are safe, reliable, and useful to humans.

In our research, we have developed an indoor navigation system based on visual methods that provide the required autonomy. For robots to run autonomously, it is extremely important that they be able to recognize both the surrounding environment and their current location. To date there have been very many studies of indoor navigation systems for robots in which the robots are generally equipped with plural cameras or with scanning type light range sensors that allow them to sufficiently understand their surrounding environment[1][2]. However, building a sensor system based on information processing remains a difficult problem.

We assume that the robot should be autonomous over a long distance in an indoor environment where there are relatively few obstacles. We consider the robot's navigation in such an environment to be a success if it arrives at its destination without crashing into obstacles or walls. Because it was not necessary to use plural external world sensors, we built a navigation system in our test environment that reduced the burden of information processing mainly by using sight information from a monocular camera. In addition, unlike many studies that recognize a robot's position by using artificial landmarks[3], we only used natural landmarks like walls because we assumed the environment to be a human one.

II. Specification of the robot

Our robot has a drive mechanism of two front and two back wheels (Fig.1). The two front wheels are attached to a motor, which operates them independently, while the back wheels are castors. DC servo motors are used for the robot's drive mechanism, and the robot's position and speed control are achieved by the control system of the drive mechanism. One CCD camera is installed on the head of the robot and can be rotated to all sides by two DC motors. This camera is able to make an image of about 300,000 pixels. All devices are controlled by a personal computer, and lead batteries supply electric power. A system overview is shown in Fig. 2.

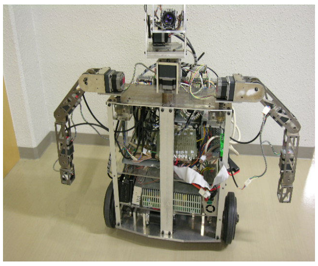

Fig.1 Robot appearance

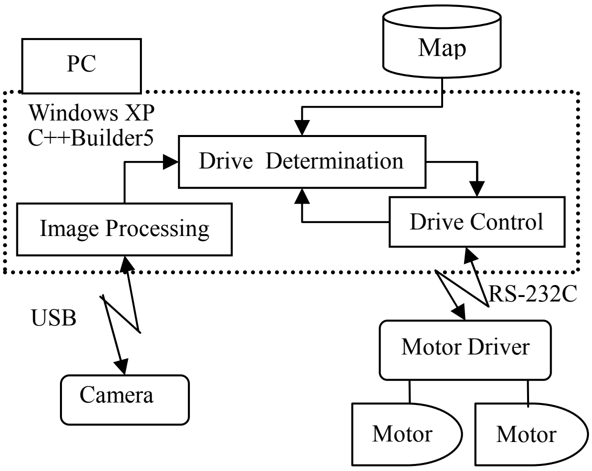

Fig. 2 System overview

Ⅲ. Navigation system

1. Outline

The navigation system consists of two modules: an obstacle recognition system and a self-position recognition system. We explain the systems of each of these modules as well as their integration into the entire system.

2. Obstacle recognition system

The obstacle recognition system is the system which, by processing images that it receives, recognizes still obstacles that exist in the movement environment.

Systems have often failed in recognizing obstacles because they only used color or edge information. Therefore, in this study, the system recognizes obstacles with judgments made by combining plural kinds of information.

At first, the system obtains binarization, floor color, and edge extraction information by processing an image received from a monocular camera. A grayscale image is converted into a binary image according to the threshold that the distinction between aspects of the floor and aspects of obstacles be clear. The binary image is scanned from its bottom to its top end, and the coordinates where black pixels appear are recorded.

Concerning the floor color information, first, a group of image pixels is sampled in a rectangular region at the bottom center of an image. Then, a group of image data inside this region is used as sample image data, which is then used to calculate the deflection. The floor region is extracted in terms of the difference between all the pixels in the image.

Edge extraction information is obtained from edge-enhancement processing with a Sobel operator. Boundary lines between obstacles and the floor can then be recognized by comparing the three above-mentioned kinds of information with each other. Fig. 3 shows the obstacle recognition processing.

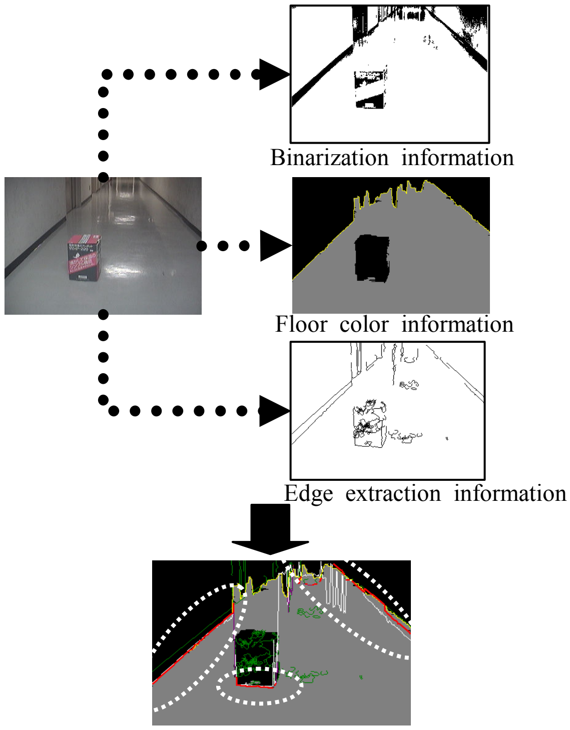

Fig.3 Obstacle recognition system

3. Self-position recognition system

The self-position recognition system is a system for recognizing the self-position of the robot by using landmarks that naturally exist in a movement environment[4]. In this study, because we assume that the robot drives in a corridor environment, we establish relationships between the walls and the robot's position by recognizing the boundary lines between aspects of the floor and walls.

In general, there are characteristic straight lines on right and left sides of a corridor. We make a database of the leaning pattern of these lines on the image that is calculated from the corridor's width and the robot's posture. Next, the two characteristic straight lines are detected by performing a Hough transformation of the straight line[5] from the image acquired during the driving. After the degree that these straight lines lean is calculated, we identify the robot's relative position to the characteristic lines by comparing them with the degree of the leaning pattern derived from the database. By allowing a revision of the robot's self-position on the map when it is running, this recognition helps to solve the problem of the dead reckoning error. Fig. 4 shows the self-position recognition processing.

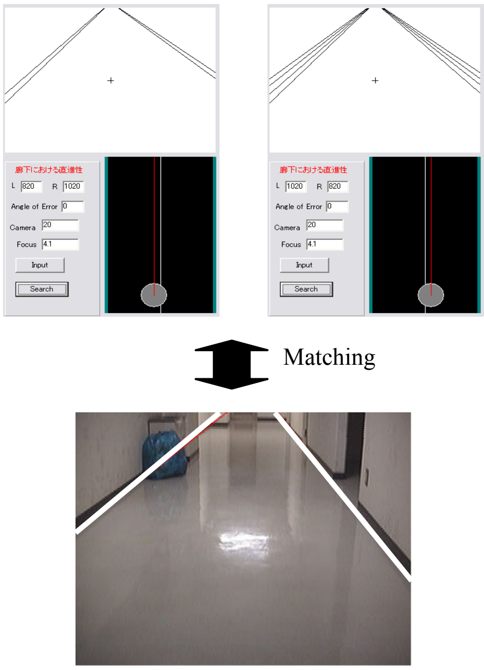

Fig.4 Self-position recognition system

4. Driving plan

4.1 Driving algorithm

The system uses a limited space map, which is a two-dimensional space map given before the driving begins. Fig. 5 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 obstacle and self-position recognitions. When obstacles are detected and it appears likely to crash into them, it takes avoidance action. At these times, it does not process the self-position recognition. We illustrate the obstacle avoidance processing in the following chapters in detail. After its finishes avoiding an obstacle, the robot returns to its original course.

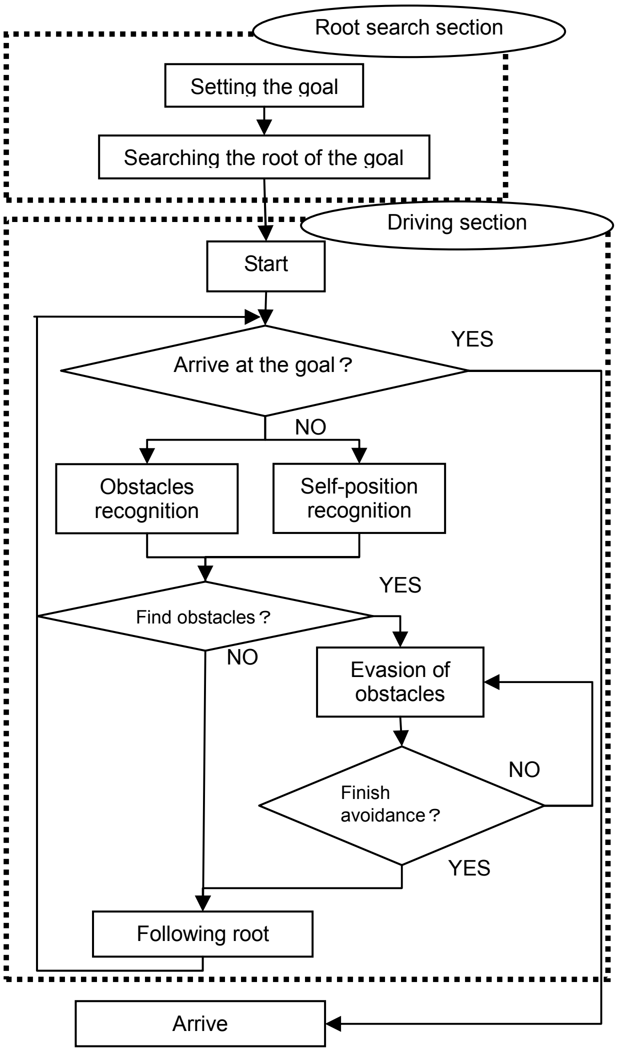

Fig. 5 Driving algorithm

4.2 Obstacles avoidance processing

At first, the system converts the coordinates of obstacles on an image which is recognized by the obstacle recognition processing into coordinates on a map by making calculations from the camera's posture. These are written onto the map. When there is an obstacle in the robot's direction of progress on the map, the systems searches for an avoidance course. It confirms whether or not an obstacle will interfere with the robot's movement in a right, left or straight direction. The attractive potential, U, which represents the energy attracted to the goal from each course's points is calculated by Eq. (1). The robot proceeds in the direction where value of U is the smallest and where is an obstacle won't interfere (shown in Fig. 6). This method enabled the robot to reach its goal after avoiding obstacles.

$$U = A\sqrt{(x_r - x_g)^2 + (y_r - y_g)^2} \qquad (1)$$

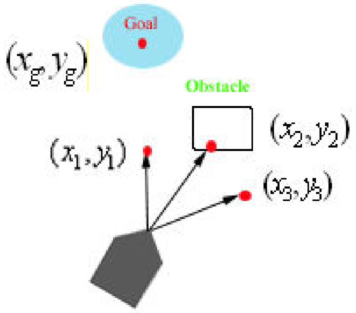

Fig. 6 Obstacles avoidance processing

Ⅳ. Experiment

1. Method of experiment

We conducted drive experiments with the robot in an indoor environment with the same floor pattern and installed obstacles (shown in Fig. 7). If it arrived accurately at the goal while safely avoiding obstacles, the navigation was regarded as a success. Its speed was 0.3 m/s.

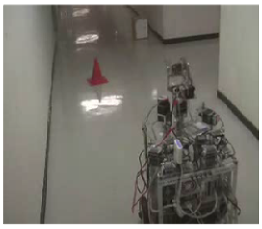

Fig. 7 Environment of experiment

2. Result of experiment

The map after the drive is shown in Fig. 8, and the robot's trajectory data is shown in Fig. 9. Although the robot shifted about 0.05m from the goal, it was able to reach the goal without colliding into two obstacles that were recognized. The error of self-position recognition was about ±0.074m on the average, small enough compared with the passageway width. The average time for each processing is shown in Table.1. It can be said that these speed are sufficiently practical.

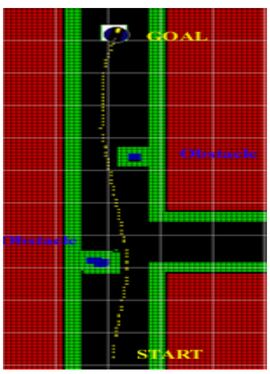

Fig. 8 The map after robot's driving

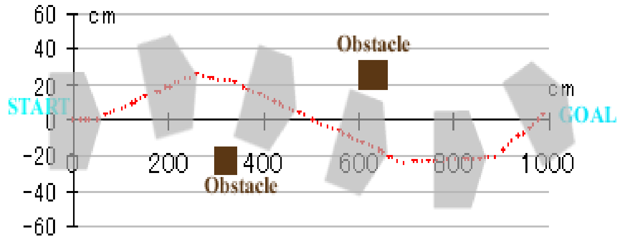

Fig. 9 Robot's trajectory data

Table 1. Average time of processes

	Obstacle recognition	Obstacle recognition and self-position recognition
Time[ms]	181	364

Ⅴ. Conclusions

Based on visual methods, we developed an indoor navigation system for the robot which provides the required autonomy. This system consists of an obstacle recognition system and a self-position recognition system. It is possible for each system to perform simultaneously. The entire system enabled the robot to run safely in an indoor environment where there were relatively few obstacles.

Although the robot can at the present only recognize stationary obstacles, in the future it should also be able to recognize moving obstacles. Moreover, in the future, the navigation system should be able to function in a complicated indoor environment.

References

[1] D.J. Kriegman, E. Triendl, and T.O. Binford(1989), Stereo Vision and Navigation in Buildings for Mobile Robots. IEEE Trans. on Robotics and Automation, vol.5, no.6: pp.792-803

[2] Thorsten Belker and Dirk Schulz (2002), Local Action Planning for Mobile Robot Collision Avoidance. IEEE/RSJ International Conference on Intelligent Robots and Systems '02 IROS: pp. 601–606, 2002.

[3] K. Komoriya, E. Oyama and K.Tani (1992), Planning of Landmark Measurement for the Navigation of a Mobile Robot. IEEE/RSJ International Conference on Intelligent Robot and Systems: pp.1476-1481

[4]Takuma Umeno, Eiji Hayashi (2006), Navigation system for an autonomous robot using an ocellus camera in indoor environment. proceedings of the 11th international symposium on artificial life and robotics, Vol1.11th, Beppu, Oita, Japan, 2006: pp229

[5]D.H.Ballard (1981), Generalizing the Hough transform to detect arbitrary shapes. Pattern Recognition, vol.13, No.2: pp.111-122