Development of an autonomous mobile system for an autonomous robot in an indoor environment

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Abstract

We are developing an autonomous robot that can perform work in a human living environment. To move safely in a human environment, a robot should be able to recognize changes in the environment. Thus, we have developed a mobile system for autonomous robots with an obstacle-detection function and a human-following function. This system uses image information from a CCD camera and image processing. The obstacle-detection function, which is one of the functions of this system, detects obstacles for safe move, while the human-following function allows the robot to follow a person using information from images.

In this paper, we explain in detail the image-processing algorithm used with both the obstacle-detection function and the human-following function. Furthermore, we experimentally evaluate the system and discuss its problems based on the results.

1. Introduction

Autonomous robots are expected to provide various services in human living environments in the future. It is important that such robots can move safely in an environment with human activity and can communicate with humans. Therefore, we are developing an autonomous robot that can perform work in a human living environment and possesses these abilities.

Our robot has a drive mechanism of two front wheels and one back wheel. The front wheels are attached to the motor, which operates the wheels on either side independently, while the back wheel is a castor wheel. This method has the advantage of being able to negotiate a far smaller turn than that of a passenger car's steering system, for instance. DC servo motors are used for the robot's drive mechanism, and position control and speed control are achieved by the control system of the drive mechanism. The robot also has two arms and hands and sensors; these devices enable the robot to respond to various demands. An installed wireless LAN provides remote control for humans. All devices are controlled by a PC, and lead batteries supply electric power. [1], [2], [3]

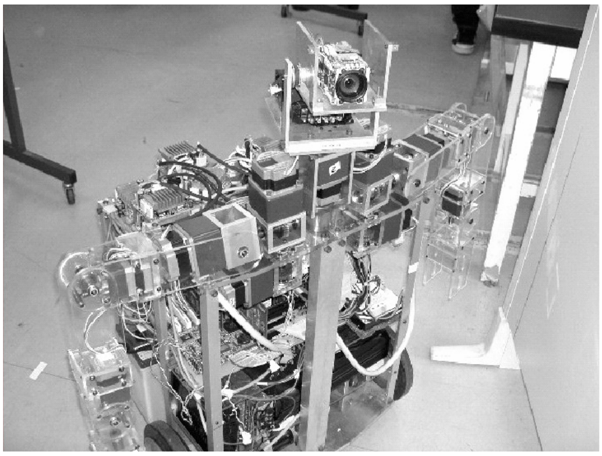

Fig. 1 Robot appearance

In order to acquire a distance perspective for the autonomous driving robot, we developed an autonomous mobile system. This system creatively uses two functions based on the presence of an obstacle or human in the first image. The obstacle-detection system is used when there are no humans in the image; the human-following function is used when there are. The obstacle-detection function uses image differences found during the robot's motion, by which obstacles can be quickly detected. After detection, the position of the obstacle is calculated using the principle of triangulation. From this result, the suitable operation of the robot is decided. In the human-following function, the location of the human user is first determined from the location information acquired before the robot runs. After acquisition, this function uses the color distribution of the area specified as a human image as a model to match. A similar area of the present image is sought using this model color distribution. Thus, if the robot can recognize a human, it can be made to follow the human.

2. Obstacle-detection function

2.1 Outline

The robot being developed in this laboratory moves by using the finite-space map stored in the database. If an unknown obstacle not existing on the map appears during this motion, the robot cannot avoid this obstacle without an obstacle-detecting function, such as the one we developed. In section 2, we explain and experiment on this function.

2.2 Method for obstacle detection

In this section 2.2, we explain the method for the obstacle detection. The flow for obstacle detection is shown in Fig 2.

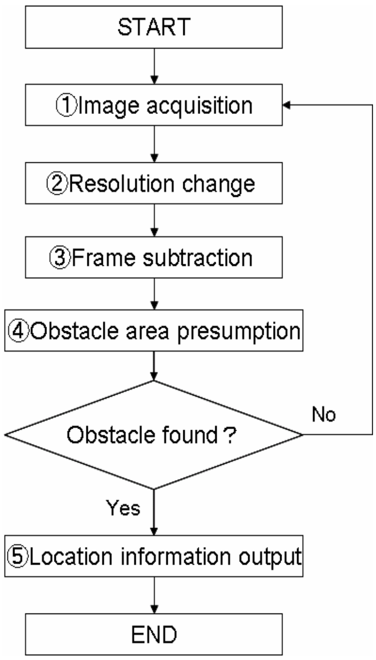

Fig.2 Flow for obstacle detection

Step1. Image capture

The PC in the robot captures two CCD camera images at short intervals of time for the post-processing algorithm.

Step2. Image resolution change

The mean value of an arbitrary block in the image is found, and the pixels in the block are replaced by the mean value.

Step3. Image differences

The wall and an obstacle in the image that doesn't actually move seem to have moved due to the movement of the robot. Thus, a moving obstacle and a static obstacle cannot be distinguished by simple image differences. Thus, we subtract each pixel of the two images of low resolution. As a result, the change in the appearance of the background is removed. The surrounding area of the moving obstacle appears as an output image.

Step4. Obstacle area presumption

A histogram of the image differences value is made for the vertical and horizontal axes of the image. The moving obstacle area is presumed based on this histogram.

Step5. Output of position information

The distance from the moving obstacle area specified in the image to the bottom of the obstacle in real space is calculated by the following equation:

$$L = \frac{hf}{f \sin\theta + y_i \cos\theta},$$

where f is the focal length, θ is the depression angle, and y_i is the y-coordinate in the image.

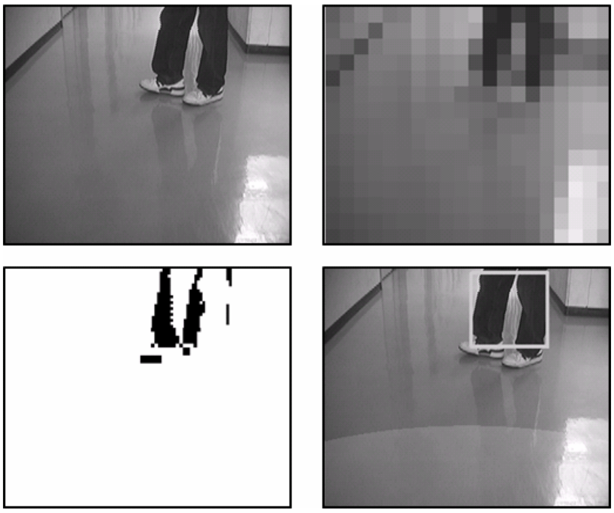

Fig.3 Result of obstacle detection

2.3 Experiment

We performed an experiment to evaluate the performance of the function. The robot was made to run on an indoor flat passage at the speed of 0.5m/s. The function detected when an obstacle approached and when an obstacle appeared suddenly from the side. Moreover, the angle of depression of the camera was set to 30 degrees. Fig. 4 shows the result of the obstacle's approach. Fig. 5 shows the result of the obstacle's sudden appearance from the side.

As a result of the experiment in the two situations, the obstacle was almost exactly detected using the function. Thus, the effectiveness of the system at the speeds used in this experiment was shown.

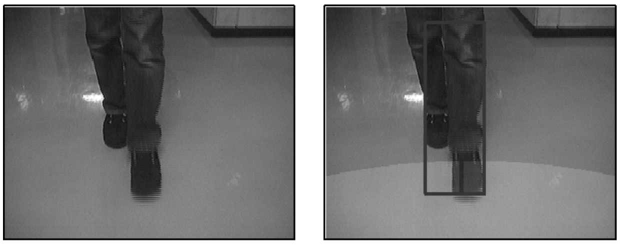

Fig.4 Approach of an obstacle

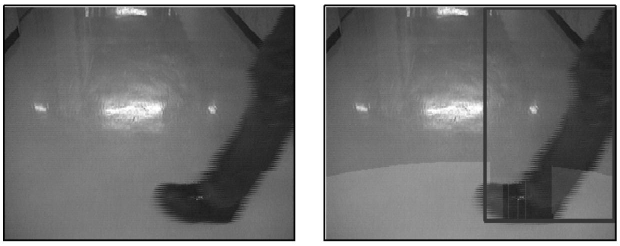

Fig.5 Sudden appearance of an obstacle from the side

3. Human-following function

3.1 Outline

To move safely in a human environment, a robot should be able to recognize the external environment. This environment recognition must combine self-positional presumption, obstacle recognition, route selection, etc. It is difficult for the robot to correctly recognize the environment given the limitations in its memory and calculation capacities. Therefore, when a person is walking forward, the robot can be made to follow the human. The amounts of memory and calculation required decrease because the robot simply has to recognize the human. In addition, it is possible to move safely because the robot can follow the route of the human, who recognizes and understands the environment. In section 3, we explain this human-following function.

3.2 Method for human following

The human who is the target of tracking is not a constant shape, but rather, the change in shape is great. Thus, the tracking of a human using the shape feature is difficult. Consequently, in order to acquire the human feature, this function uses color distribution. First, the area where the human exists in the image is selected. After the area is selected, a histogram in RGB space is created for this area. Fig. 6 shows the appearance of the image by which the histogram is created. The RGB space is divided into 8×8×8. The memory required for a more detailed RGB space, for instance, 256×256×256, is huge.

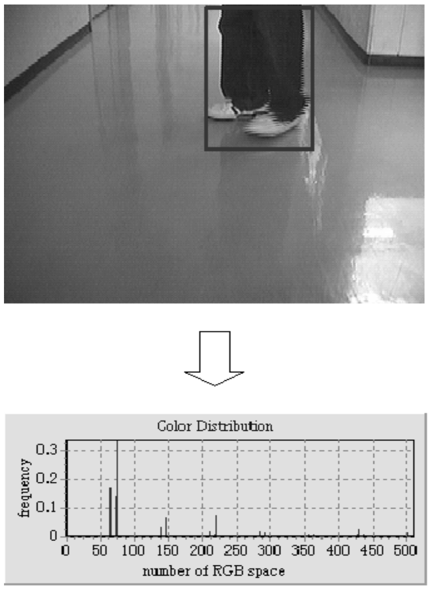

Fig.6 Creating a histogram

Next, in order to seek a similar area in image we analyze correlation between created histogram of human feature and histogram of arbitrary area of present image. Two normalized histograms are overlapped, and the minimum value of the pair of the value is taken. The value in which all these minimum values were added is set as a similarity. If this similarity is high overlapping of two histograms increase as shown upper in upper of fig6. In contrast, if this similarity is low overlapping of two histograms decrease as shown in bottom of fig.7. The area where this similarity is the highest in the image is judged to be an area where the human exists.

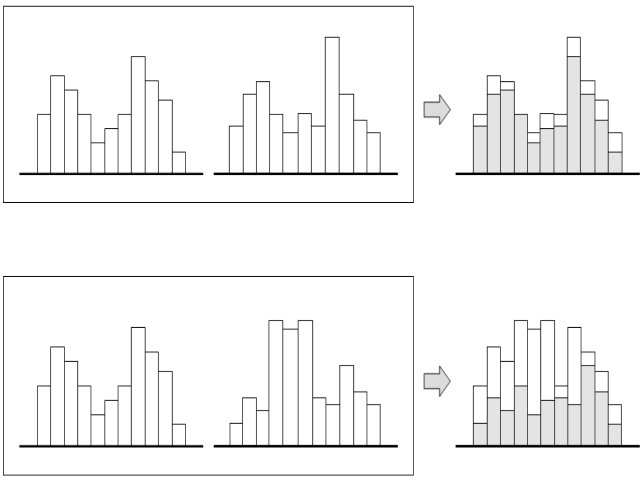

Fig.7 Comparing histograms

After seeking the similar area, the distance is calculated using the y-coordinate at the bottom of the area specified as a human. The speed of the robot is changed in proportion to this distance, and the human is followed.

3.3 Experiment

We experimented of human tracking in the image for the evaluation of the function.

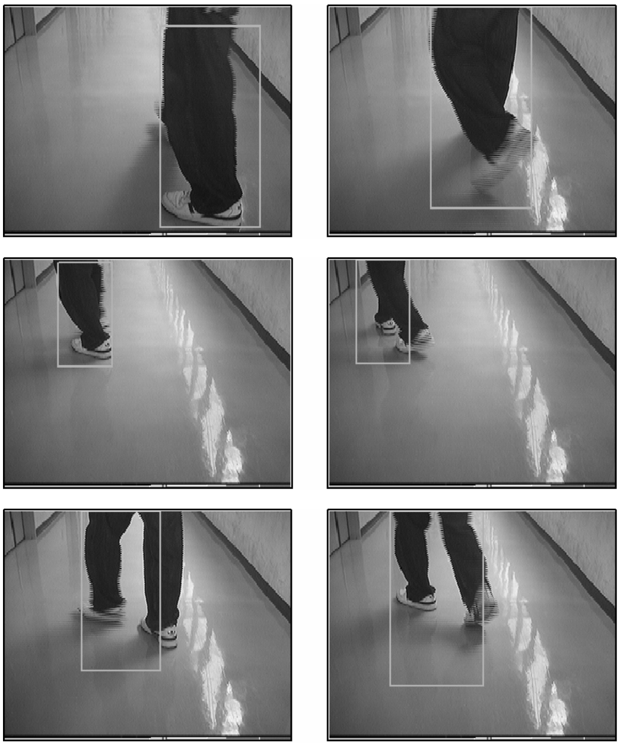

Fig. 8 Tracking images

The tracking image for every fifth frame is shown in Fig. 8. The human was tracked over 30 frames. The similarity of the histogram during the pursuit of the person was maintained at 70% or more. As a result, the area where the human existed was able to be presumed with considerable accuracy. Furthermore, the distance to the bottom of the obstacle was able to be calculated with considerable accuracy.

4. Conclusions

We have proposed a mobile system for autonomous robots with an obstacle-detection function and a human-following function. We were able to show the effectiveness of both the obstacle-detection function and the human-following functions.

The problem of the obstacle-detection system is to reflect the obstacle data detected in a finite space map so that the robot can select a safe route that avoids an unknown moving obstacle. However, changes in the speed of the robot or increases in the background's complexity impairs this detection. Thus, we want to improve the accuracy of the obstacle-detection by combination with other method.

In order to acquire a human-following function, we used color distribution. However, this function has not been mounted on the robot yet. Thus, we mount on the robot this function and we want to test in real space the performance of the human-following function.

Our next subject of study is to develop a system for action planning.

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