Development of an autonomous personal robot
"The visual processing system for autonomous driving"

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Abstract

Currently, an autonomous self-driving robot is expected to provide various services within the human living environment. Such robotic technology is already seeing practical use in industry and being used in industrial applications. But the robots for industry only faithfully follow the given motion which human make. We are therefore working to develop 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.

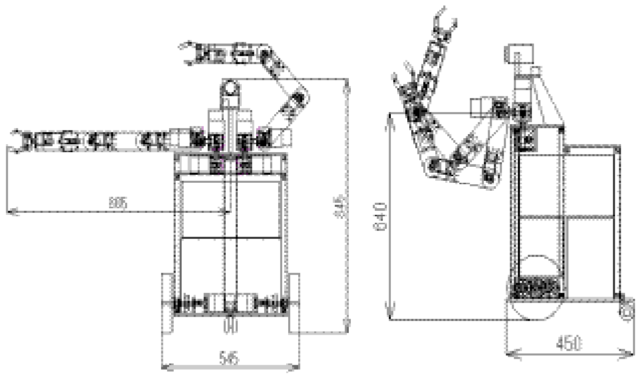

Fig. 1　Robot design

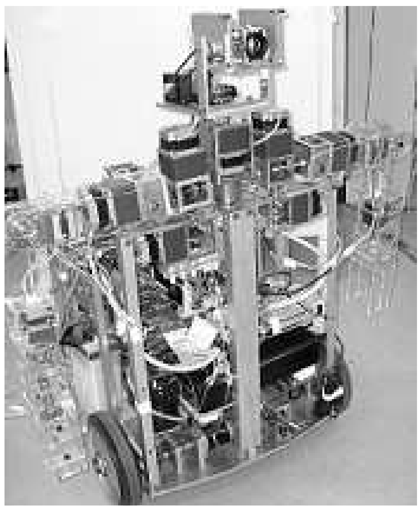

Fig. 2　Robot appearance

1. Introduction

There are many problems to develop autonomous self-driving personal robots which can work like humans instead of us. These problems can be roughly divided into three categories: (1) how to process contextual information regarding the robot's environment; (2) how to form a robot's action plan based on this information; and (3) how to correctly control the robot using the robot's action plan. The purpose of the present study was to develop a way to allow the robot to determine its own position and posture as related to the above-mentioned problems. We have thus developed a visual processing system that enables a self-driven robot to advance in a straight line.

The robot's visual processing system uses only a CCD camera and processes the image information displayed by that camera. We have used the Hough transformation, which is knot to be able to extract straight lines from an image, to extract the features of an image. We define the intersection of vertical lines and horizontal lines as a "characteristic point," and we calculate the errors of position that occur while the robot is moving along a linear path by using the flow of the plotted characteristic points over time. However, the system that we previously developed could not obtain useful data because the rate at which that system acquired the characteristic point was very low. Therefore, in the present research, we have included and have developed an algorithm for extracting straight lines and characteristic points.

We explain herein how the additional image processing and the improvement of the algorithm enhance the stability of the system. In addition, we have experimentally evaluated the visual processing system for autonomous driving.

2. Recognition system and Decision system

The environment for robot activity assumed in this study is a finite space such as a family room, an office, or a hospital room. Our robot has a map showing robot's sphere of activity, and we call this map 'the finite space map'. The finite space map has information including the size of each parameter of the map, the initial position coordinates of the robot, the coordinates of the movement needed to get to the destination, the number of placed objects, and the positions and sizes of those objects. The robot can do autonomous driving based on the finite space map. The finite space map is shown in Fig.3.

In addition, we are developing a recognition system that will allow the robot to recognize the external environment. The recognition system consists of a CCD camera, an optical sensor, and a supersonic wave sensor. The supersonic wave sensor primarily recognizes unknown objects that don't exist on the finite space map. The optical sensor recognizes measurement of an actual distance with an unknown object. The recognition system supports the robot's autonomous action by using information for each device and the finite space map. The composition of the system is shown in Fig.4.

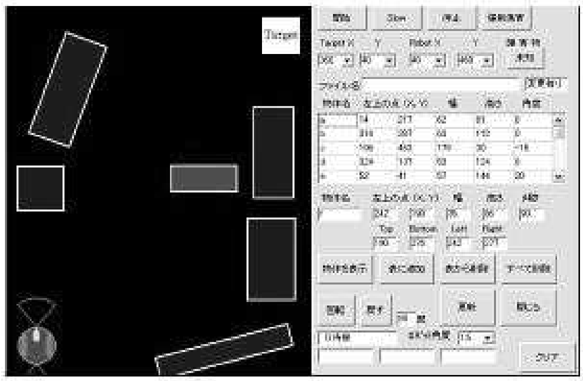

Fig. 3 Map of a finite space

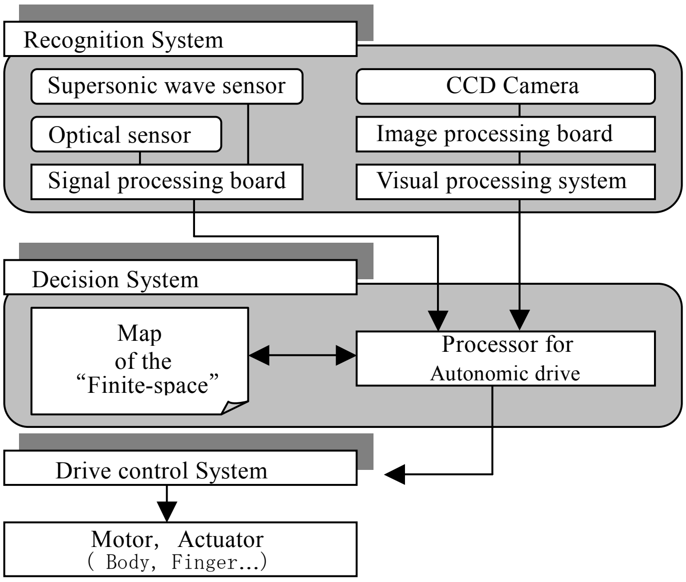

Fig. 4 Processing system for the personal robot.

3. The visual processing system

3.1 Outline of the system

When the robot moves, the positions in the map need to be synchronized with its real position in order to correctly reach the desired destination. Therefore, it is useful to consider a case in which the robot can't correctly drive because of a subtle unevenness in the ground's surface and the resulting slight difference in the rotation of the right and left driving wheels. In addition, we must reduce the error of position produced by this case as much as possible. The purpose of the visual processing system is to enable a self-driven robot to advance in a straight line. The visual processing system captures objects on an image in order to detect errors in the robot's position. Incidentally, this system doesn't consider large amount of error that is produced by disturbances.

3.2 System flow of the system

The system receives an image whenever the robot moves a certain distance. At the same time, the system generates the flow of characteristic points by processing the data obtained from such images. In addition, the system analyzes whether the robot could advance in a straight line. The flow of this system is shown in the following sentences (Ⅰ－Ⅴ).

Ⅰ. Image Acquisition

The image obtained by the CCD camera is read into PC in the robot. The visual processing system uses only form extraction processing, and color information is not needed. Therefore, we only use an 8-bit gray-scale image.

Ⅱ. Edge processing

The system uses Laplacian edge enhancement.

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Ⅲ. Segmentation processing

To limit the extracted data that are required for form extraction, the system performs Segmentation processing.

Ⅳ. Thinning processing

The edge extracted by the edge processing has line width. In order to decrease the amount of calculation and to stabilize the hough transformation, the system performs thinning processing.

Ⅴ. Hough transformation and Characteristic point

The Hough transformation can extract the straight lines contained in an image. And we define the intersection of vertical lines and horizontal lines as the characteristic point.

3.3 Processing for extraction of straight lines and characteristic points

In this system, the portions of straight lines on an image are extracted using the hough transformation. However, an actual image consists of many straight line portions. By virtue of that, the system produces getting unnecessary data. And in the case of extracting characteristic points, if the system captures a characteristic point that are different from characteristic points of the object currently being pursued, the system causes errors. These problems would directly affect the accuracy and speed of the system. So, in order to avoid these problems, we have improved processing for extraction of straight lines and characteristic point in the visual processing system.

■Processing for extraction of straight lines

When the system extracts straight lines, each of two processings is working in order to raise accuracy and processing speed.

In case of using the hough transformation, it is possible to select the threshold value about the reliability of straight lines on an image. The processing chooses automatically the threshold value until it only extracts the effective data of straight lines. The histogram about selecting the threshold value is shown in Fig.5.

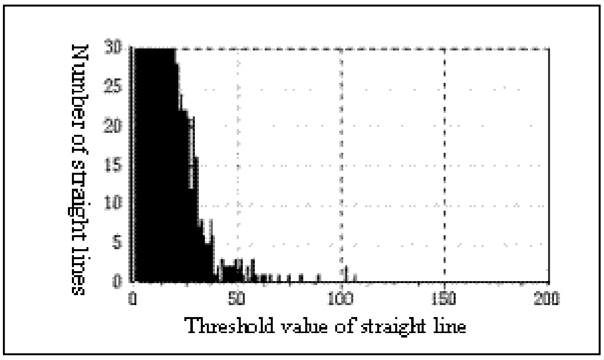

Fig. 5 Histogram for selecting the threshold value

The system is restricted to processing rectangular objects, as the robot environment generally has many rectangular objects.

Figure 6 shows the image taken with the CCD camera, and the image after edge processing. In addition, the bottom part of fig.6 shows the images that have been processed to extract straight lines. In comparing differences between these two images, it can be seen that the one image is normally processed to extract straight lines, while the other is restricted to extract only a rectangular object.

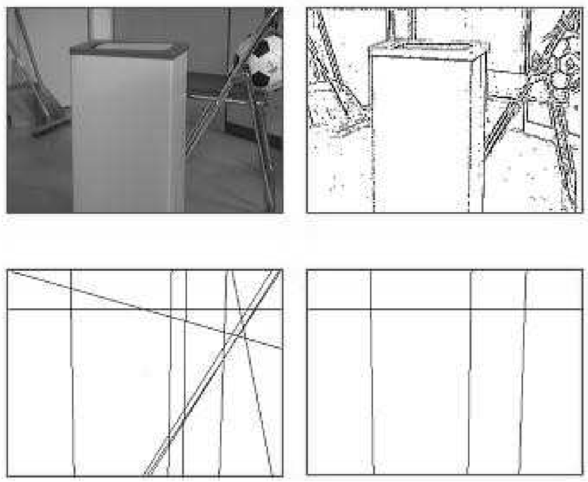

Fig. 6 Processed images to extract straight lines

■Processing for extraction of characteristic points

The data for characteristic points are actually used for detecting errors in the robot's position. It is important in this processing that the characteristic points of the objects being moved by robot's drive be continuously captured. We have therefore developed a processing method that gets the nearest point from the former characteristic point on an image as a new characteristic point.

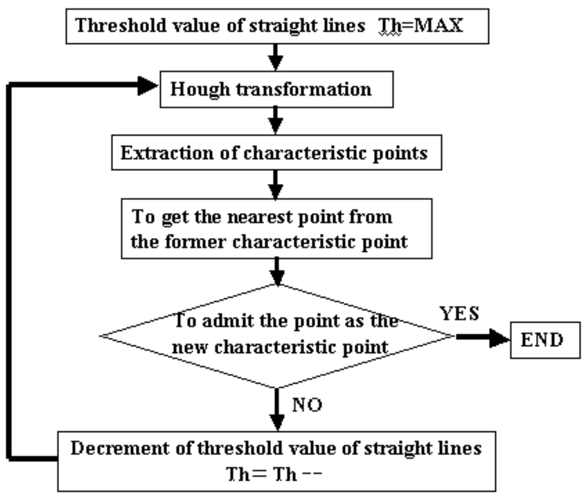

Fig. 7 System flow

3.4 Evaluation of whether the robot is advancing in a straight line

The flow of characteristic points is changed by the state of the robot's driving. Moreover, it is possible to calculate geometrically the flow of characteristic points in the case in which the robot advances normally in a straight line. Therefore, we can evaluate whether the robot advances in a straight by comparing the actual flow with the theoretically calculated flow.

4. Experiment for evaluating the visual processing system

In this experiment, a case in which the robot normally advances in a straight line is compared with a case in which a gap is intentionally produced. The robot has been driven in a flat room using DC motors.

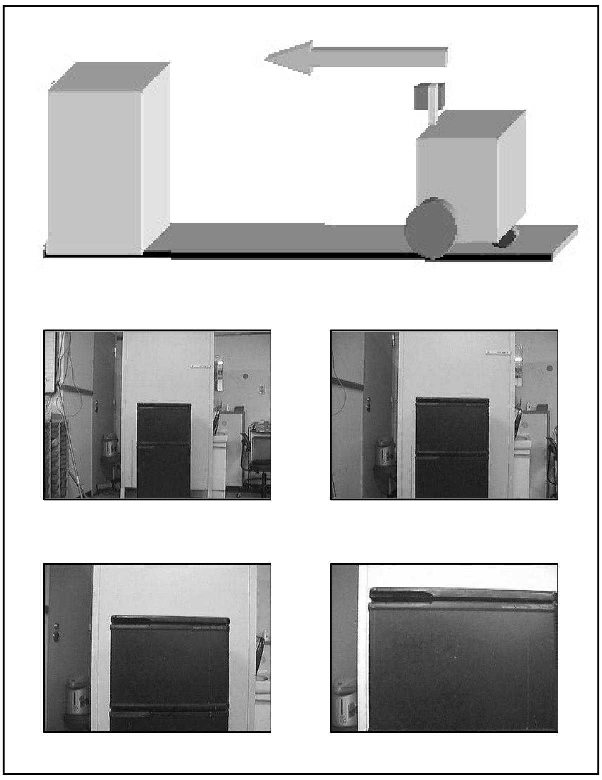

Fig. 8 Situation of experiment

We made the robot go straight toward a rectangular object and used the system to generate the flow of characteristic. The flow of characteristic points in the case where the robot normally goes straight is quite different from that in the case where the robot doesn't go straight (Fig. 9). We have confirmed that the flow of characteristic points drawn by geometrical calculation and such flow drawn by the visual processing system are similar (Fig. 10). As such, we can conclude that the developed system can evaluate whether a robot is advancing in a straight line.

・The case of straight driving ・The case of not straight driving

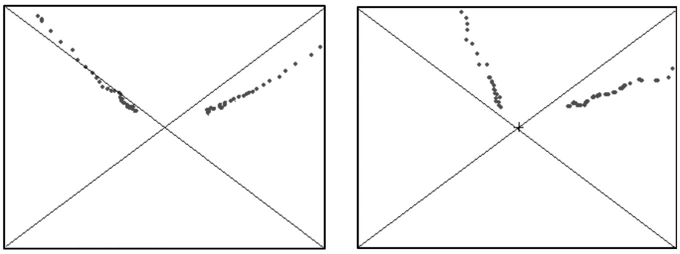

Fig. 9 Flow of characteristic points

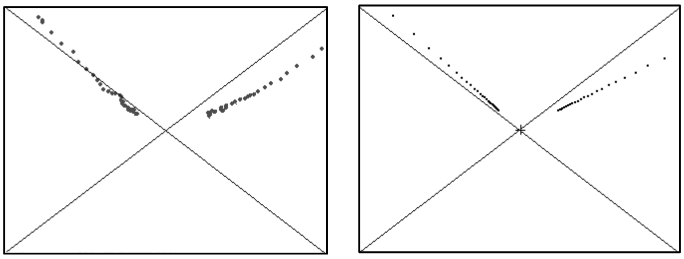

Fig.10 The actual flow and the theoretically calculated flow

5. Conclusions

In this research, we added additional image processing capability to a robot's processing system and developed an algorithm for extracting straight lines and characteristic points. As a result, the system's ability to capture the characteristic points has improved remarkably.

Our results indicate that the system was able to output the flow of the feature point well against the single object. In addition, the system allowed us to evaluate whether the robot is advancing in a straight line.

Our next subject of study for the robot processing system involves calculating actual data regarding errors in the robot's position. In addition, we must develop a system that allows for feedback control of the robot.

References

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