Navigation system for an autonomous robot using an ocellus camera in indoor environment

Takuma Umeno  Eiji Hayashi
Department of Mechanical Information Science and Technology
Faculty of Computer Science and Systems Engineering, Kyushu Institute of Technology
680-4, Kawazu, Iizuka-City, Fukuoka Prefecture, Japan

Key Words: Personal robot, Autonomous driving, Ocellus camera

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 adjust to a human environment, the issue of safety must be considered in regard to its autonomous movement. Thus, robots absolutely require systems that can recognize the external world and perform 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 navigation system has two functions: One is to determine whether or not the robot is driving itself accurately down a corridor. The other is to allow the robot to search for obstacles present on the floor. We applied this system to a robot in an indoor environment and in a discussion of our experimental results considered the system’s advantages and problems.

1. 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 a given motion 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 steers 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. The robot also has two arms and hands and sensors; these devices enable the robot to respond to various demands. 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. In order to detect the robot’s distance errors in a corridor, the system uses the sides of the corridor as feature parameters and extracts them using the Hough transformation algorithm. Thus, this system allows the robot to advance in a straight line without distance errors, because the changing amounts of feature elements extracted from actual images are compared with the ones calculated from the knowledge database. In order to detect obstacles, the system extracts the pixel group whose pixel groups are much different from the main background pixels and interprets them as obstacles. The system can predict the distances to the obstacles and also the obstacle’s height and width by using the extracted information and attached drive encoders.
2. Visual feedback system for autonomous driving

2.1 Outline

We developed a visual feedback system for robots that can detect distance errors using image information captured by an oculus CCD camera. First of all, as an initial step in developing the overall system, we have started to develop a system that enables the robot to advance in a straight line in corridors. This visual feedback system detects the errors in distance calculation from the accurate driving course when the robot is advancing.

2.2 Method for estimating distance error

We have considered that the most significant feature elements in an image are the lines on the sides of a corridor. We applied the Hough transformation algo-rism to the system for image processing in order to extract lines on an image as feature elements. The processing flow is as follows.

I. Image Acquisition
The image obtained by the CCD camera is read into a PC in the robot. This visual processing system uses only an 8-bit gray-scale image.

II. Edge processing
The system uses Sobel edge enhancement.

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 necessary 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.

For detecting the robot’s distance errors, the system should evaluate the extracted straight lines. So, the system uses the pattern database. This database can show the predicted straight lines changed by advancement situation of robot. Figure 2 shows the pattern database. The system compares the extracted straight lines in an image with the lines given by the pattern database. As a result, the system can estimate the distance errors.

2.3 Experiment

We let the system work continuously while the robot was advancing down a corridor. We evaluate the availability of system by considering whether or not the system can estimate the distance error accurately. Figure 3 shows the straight lines extracted by the system in the case of that the robot advances straight. Figure 4 shows that the robot experiences a distance error to left. The results of the experiment show that the system was able to detect distance errors at an accuracy of +-5cm.
3. The visual processing system

3.1 Outline of the system
In order to ensure that the robot can drive safely in an indoor environment, the system must detect obstacles. Thus, data for avoiding obstacles is needed. We have developed a system of recognizing obstacle that uses only image data captured by an ocellus CCD camera. The purpose of this system is to enable the robot to detect obstacles and roughly recognize an obstacle's size and position.

3.2 Method of extracting obstacles
First of all, the system converts 24bit RGB image data into HSV data. The system samples a group of image pixels in a rectangular region at the bottom center of an image. The system uses the group of image data inside this region as its sample image data. The system uses the deflection calculated by the sample data. The system extracts the floor region in terms of the difference of all pixels in the image. Figure 5 shows an extracted obstacle.

![Fig.5 Extracted obstacle.]

The conditions of a real environment shift due to changes in light and shadows. Therefore, it is considered that this system is a source of some errors. We added the edge enhancement processing to the system so that the system can extract objects more accurately.

![Fig.6 Obstacle extracted using edge data.]

The chain code is used to make one set of each group of image pixels extracted from image. The group of image pixels that leads to the detection of an obstacle is distinguished by this process.

![Fig.7 Chain code.]

Next, the system analyzes the object that has been determined to be an obstacle. We define the lower side of a group of image pixels as the distance to the object, and the system presumes the width of the obstacle based on the width of a group of image pixels. In addition, we defined the uppermost part of a group of image pixels as the height or a depth of the object. The robot runs on the floor side, and presumes the height of the obstacle based on the position of the change in the image pixel group, the camera position, and the angle between the two images.

![Fig.8 Estimation about obstacle’s data]

The data identified by the system as an obstacle is reflected in the decision processing part of the robot. As a result, the robot can roughly recognize the obstacle. Figure 9 presents an image showing the obstacle in the system’s virtual space.

![Fig.9 Obstacle in virtual space]
The entire flow of the obstacle extraction process is shown below.

![System flow diagram]

4. Conclusions

We have proposed a system that enables an autonomous robot to navigate an indoor environment using only an ocellus camera.

The developed system could produce visual feedback and successfully recognize objects when the robot drives down a corridor. The system could also obtain available information necessary for the robot’s safety using a visual approach.

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

References


