Development of an obstacle recognition system for autonomous robots in indoor environments

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Abstract

We are currently developing an autonomous robot that can work in human living environments and that can carry out users' basic instructions. When such a robot moves and works in a human living space, the robot should be able to recognize elements of its environment.

Thus, we are engaged in research aimed at the acquisition of a sense of distance from based on image information, utilizing sight information and not necessitating remodeling of the human living space.

We give our robot a "finite space map." This map contains information describing a floor plan including obstacles (desk and sofa, etc.), and the robot's position. The robot searches for a route based on the finite space map, and moves along that route. However, numerous obstacles that would disturb the movement of the robot can exist in a human living environment; in addition, these objects are often unknown to the robot. The robot thus needs a system to recognize unknown obstacles not provided by the finite space map beforehand.

Thus, we developed an obstacle recognition system that discovers detects obstacles, and detects determines the distance to the obstacle and obtains three-dimensional data describing the obstacle.

1. Introduction

Recently, the chances of seeing a working robot in our surroundings have increased. Robots with various functions have been developed based on recent technological advances. However, a robot capable of helping us autonomously has not yet appeared. Thus, our laboratory is developing an autonomous personal robot that can work in the home and the hospital while being easy to command.

In order to allow the robot to work autonomously, it is necessary to create a program for the robot that allows it a variety of actions.

We are advancing the development of a robot that acts autonomous by giving the robot functions that allow it to work and move easily in a room, and that allow easy communication with the person it is intended to serve.

Our robot's only sensor is a CCD camera installed in the robot's head, which can rotate and tilt forward and backward. Our robot moves on two motorized wheels (front wheels) and two castor wheels (rear wheels). Moreover, the robot has two arms with which to perform simple work (e.g., grasping an object). The PC installed in the main body executes control of the device and runs an autonomous program. An installed wireless LAN provides the option of remote control for humans. Lead batteries supply the robot's electric power. [1] [2]

In order to detect obstacles, the system extracts the pixel groups whose shapes 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.

In addition, the position and the size of the detected object are reflected in a finite space map, and the robot evades the obstacle by calculating an evasion route.

In this paper, we explain our robot's processing mechanism. In addition, we describe the details of the obstacle recognition system, and show the results of an experiment using this system.

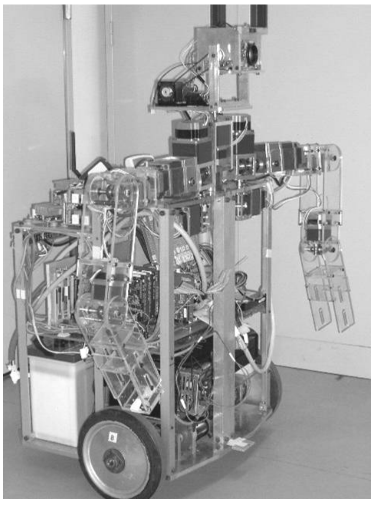


Fig. 1 Robot appearance

2. Self-drive control for robot

Our robot has an action determination program that enables it to act autonomously. The obstacle recognition system explained in this paper is part of this program. The robot has a system that enables it to communicate with humans and recognize moving objects. These action determination programs use the feedback values returned from the CCD camera and the motor encoders. In addition, these programs control the arm and the wheels and command the driving motors. [3]

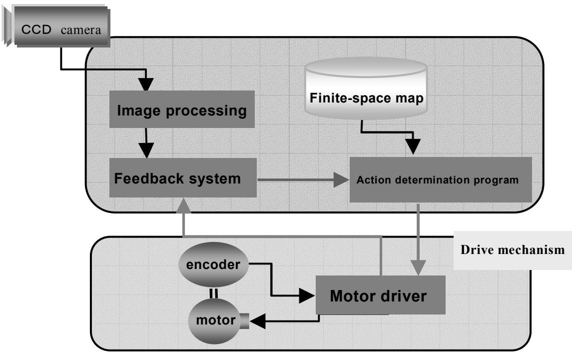


Fig.2 Self drive control for robot

3. Obstacle recognition 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 that can allow it to avoid obstacles is needed. We have developed a system of recognizing obstacles that uses only image data captured by a CCD camera. The purpose of this system is to enable the robot to detect obstacles and roughly recognize an obstacle's size and position. In addition, the position and the size of the detected object are reflected in the finite space map, and the robot evades the obstacle by calculating an evasion route.

3.2 Method of extracting obstacles

First of all, the system converts 24bit RGB image data into HSV data. HSV data shows the image elements of hue, saturation, and value. The processing of the image data could be simplified by using HSV. 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 an then 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 3 shows an extracted obstacle.

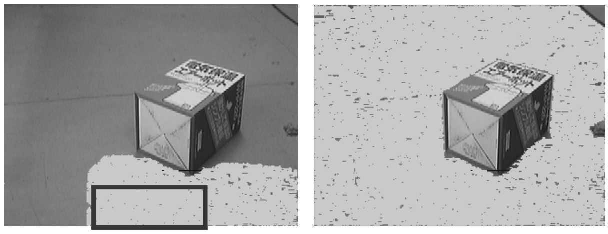


Fig.3 Extract the obstacle

Labeling is used to make one set of each group of image pixels extracted from an image. This is processed from the extraction result of the floor region. The group of image pixels that leads to the detection of an obstacle is distinguished by this process. Figure 4 shows an example of labeling.

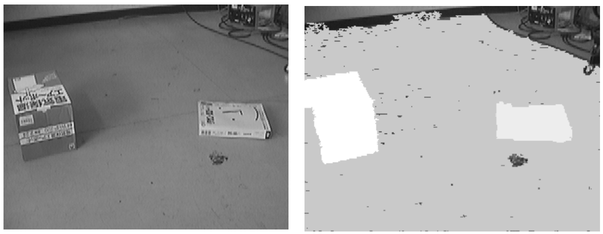
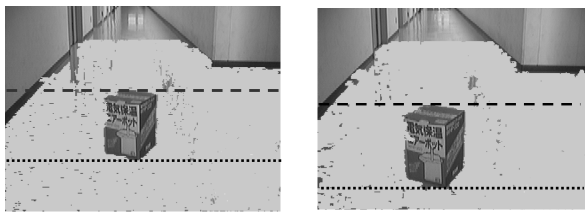


Fig.4 Example of labeling

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 determines 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.



position 1 **position 2**

Fig.5 Estimation of an obstacle's data

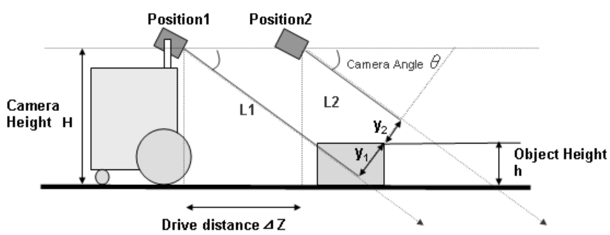


Fig.6 Object recognition from motion stereo

We process the calculation of We process the data of these obstacles in consideration of the focus and geometric calculation of the camera. Lastly, we show the flow of the obstacle estimation processing in Figure.7. [4]

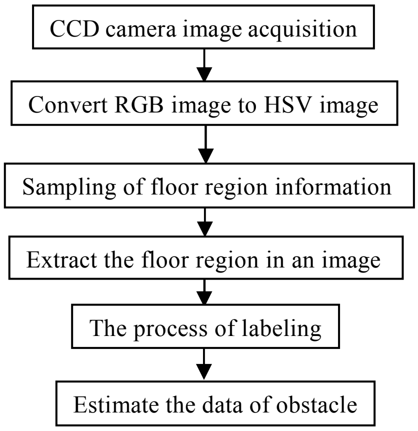


Fig.7 Flow of processing

3.3 Evaluation of the obstacle extraction process

We show the results of a test regarding the accuracy of the estimation of an object. When the system is actually used, processing will be repeated while the robot is moving. However, two images acquired to accurately measure the distance when the robot was in a fixed position were used to verify the accuracy of the data describing the obstacle (width, height, and depth). Table.1～3 shows an example of the verified obstacle data. Figure 8 shows the results in 3-D space.

Table.1 Calculation result of object data (box)

	Actual measurement	Calculation result
Distance to obstacle	100cm	98cm
Obstacle position(horizontal direction)	Right 1cm	Right 3cm
Height	31cm	34cm
width	21cm	30cm
depth	21cm	17cm

Table.2 Calculation result of object data (plate)

	Actual measurement	Calculation result
Distance to obstacle	130cm	128cm
Obstacle position(horizontal direction)	Left 69cm	Left 78cm
Height	0.5cm	0cm
width	50cm	63cm
depth	50cm	57cm

Table.3 Calculation result of object data (ball)

	Actual measurement	Calculation result
Distance to obstacle	96cm	93cm
Obstacle position(horizontal direction)	Right 29cm	Right 33cm
Height	22cm	18cm
width	22cm	27cm
depth	22cm	8cm

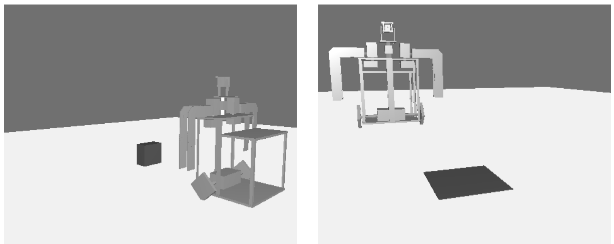


Fig.8 Estimation of obstacle displayed in 3-D

Based on these results, it was judged that the system collects obstacle data at a sufficient level of accuracy to evade an obstacle.

3.4 Method of evading obstacle

The robot evades an obstacle by using the results of obstacle estimation. When the obstacle is initially estimated, the system saves the camera image (the first image). As the robot advances in a regular fashion, the system obtains a second image that is used by the motion stereo process. The distance from the first image to the second image can be obtained according to the value of the encoder installed in the robot's drive wheel. Obstacle data is obtained by using these two images and the method of obstacle extraction.

When the height of an obstacle is detected (if the height of the obstacle is 0, the system determines that the robot need not evade the obstacle), the obstacle's data (width and depth) is written into the finite space map.

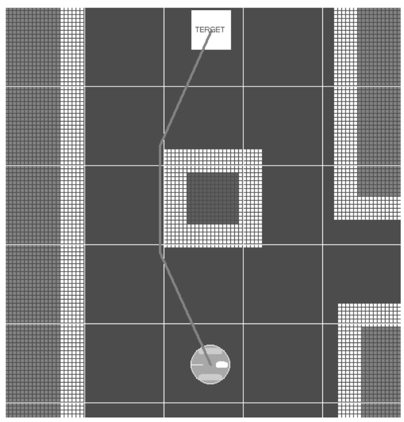


Fig.9 Finite space map

The finite space map is one of the knowledge databases that the robot has beforehand. This map contains information regarding the floor plan including obstacles (desk and sofa, etc.), and the robot's own position. The robot searches for a route based on the finite space map, and moves along that route.

In addition, the route for evading the obstacle is calculated by using the route searching system installed in the robot, and the robot then performs an evasive action. The route searching system calculates and controls the route of the robot by using the finite space map. Figure 10 shows the flow of the evasive action.

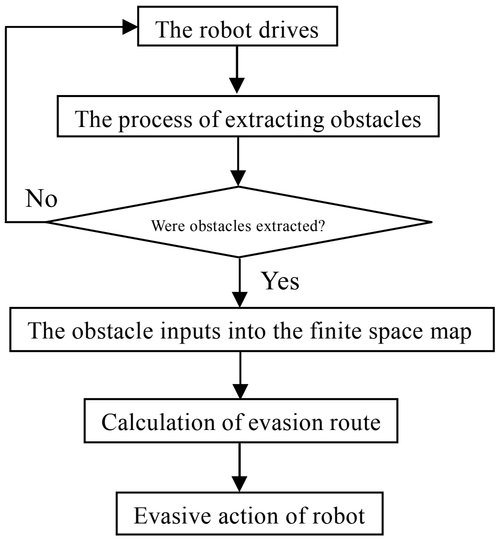


Fig.10 Flow of evasive action processing

4. Conclusion

We developed an obstacle recognition system that allows a robot to drive safely in an indoor environment. This system is able to roughly recognize a three-dimensional object. In addition, the obstacle could be successfully avoided by using data describing the recognized obstacle.

However, the current method for calculating the obstacle's height and depth cannot accurately calculate an obstacle having an intricate shape. Our next focus of study is to find a solution to this problem and to make the system more stable by improving its processing speed and efficiency.

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