Development of a system for self-driving by an autonomous robot

Eiji Hayashi and Keisuke Ikeda
Faculty of Computer Science and Systems Engineering,
Kyusyu Institute of Technology
680-4, Kawazu, Iizuka-City, Fukuoka Prefecture, Japan

Abstract

Expanded and advanced functions for a self-driven robot equipped with environment recognition and the ability to learn using a sensor and a camera are being developed. The robot is active in the manufacturing field, the medical field, the welfare field, the public field, and elsewhere, in each case contributing to a higher quality of life. However, it is difficult for the robot to understand the human environment because the environment is always changing.

In this research, we are developing an autonomous robot that can execute simple directions from a human in a particular environment (the home, the office, the sickroom, and so on). The autonomous robot will execute an action while referring to "finite mapping" when moving around in the room. Finite mapping is data about the space in the field of activities of the robot. The robot recognizes known objects that are shown by this mapping and drives, being autonomous.

1. Introduction

In recent years, the rapid development of semiconductor technology has allowed the development of robots that can perform advanced processing in response to complex information input using a sensor, machine vision, etc. Various functions are demanded of the personal robot using such technology in people's various environments (home, office, a sickroom etc.). However, developing a robot that can fill these requests is difficult.

In our laboratory, we are developing an autonomous personal robot that can apprehend the environment and meet the demands of its users. This robot has the known information called "finite mapping". The map has a movable range and the information about an objective position, and the robot drives with reference to the map. However, the position of the map and the robot's actual position do not always correspond. Therefore, the robot has to aim at synchronization between the position of the robot on the map and the actual robot's position.

This paper describes "a system for self-driving by an autonomous robot" which corrects the position error that occurs when the robot moves. This system corrects a self-position using the image information acquired from a CCD camera.

2. Outline of the personal robot

A general view of the robot being developed at our laboratory is shown in Fig 1. The composition of the self-driving system is shown in Fig 2. This paper explains the robot's drive mechanism.

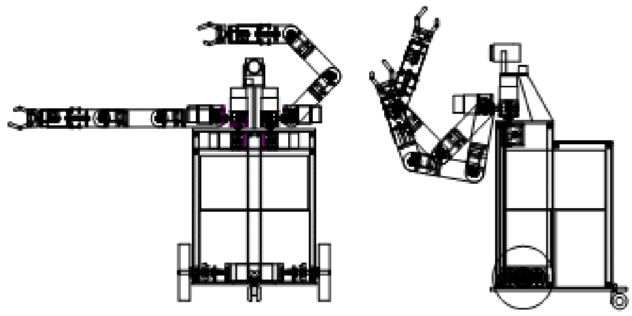


Fig 1. General view of the robot

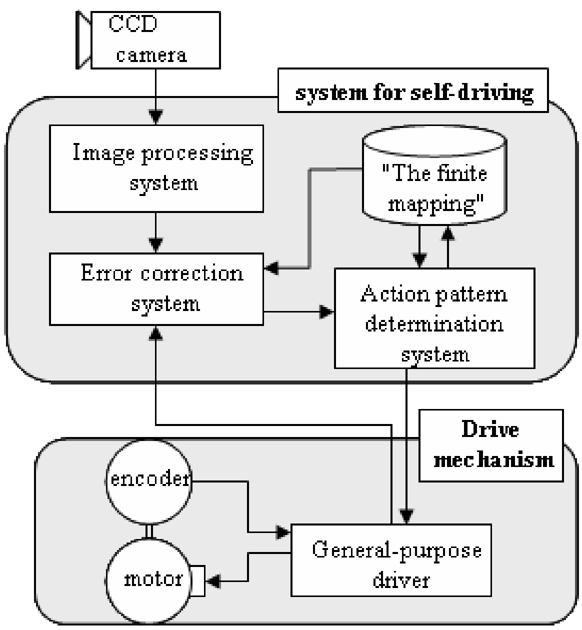


Fig 2.Composition of the self-driving system

2.1 Composition of the drive mechanism

The robot we are developing consists of a drive mechanism of two front wheels and a back wheel, for a total of three wheels. The front wheels are attached to the motor and are independent on either side, and the back wheel is a castor. This method has the advantage of allowing a small turn, compared with the 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 used for the control system of the drive mechanism. It is possible to determine the amount of movement when the robot drives from one known position to another by using position control. Using speed control, the robot can apply load for a fixed time and can drive it continuously. That is, it is possible to move a load from place to place at the speed specified.

The robot moves based on the specified position and speed.

2.2 System for self-driving

By this self-driving system, in order to perform an operation determined, action patterns are generated. And the system transmits the data for the drive to the drive mechanism. Based on past research, the robot was able to aim at the synchronization of the self-driving system and the drive mechanism.

Now, we have developed an image-processing system and an error correction system. Using the image –processing system, a robot acquires an image using a CCD camera and performs image processing. The error correction system has the job of detecting the position error generated at the time of the robot drive, with reference to the data obtained from the image-processing system.

The finite mapping

The environment assumed by this research is a limited space, such as a home, office, or sickroom, and the given space is the range within which the robot can move.

When objects (furniture, a desk, shelves, etc.) exist in the space where a robot drives, they are described on the map of the limited space as known objects. The robot refers to the map. Evasion course calculation is attained by feed forward. Therefore, the robot's efficiency of autonomous drive processing is raised. The finite mapping has parameters indicating the size of the map and the objects, a robot's initial position condition, target position coordinates, and object arrangement coordinates.

Sample the finite mapping is shown in Fig 3.

Action pattern determination system

When it has a target position specified, the robot has to calculate a course and has to generate an action pattern. By this system, the robot refers to the information on the finite mapping, searches for the course to the target point, and creates a set of data for driving. The robot drives based on this data.

Moreover, in consideration of the position error searched for by the error correction system that we have developed, the robot includes performing feedback control into the calculations. Using this control, the robot should be able to drive in spite of position errors.

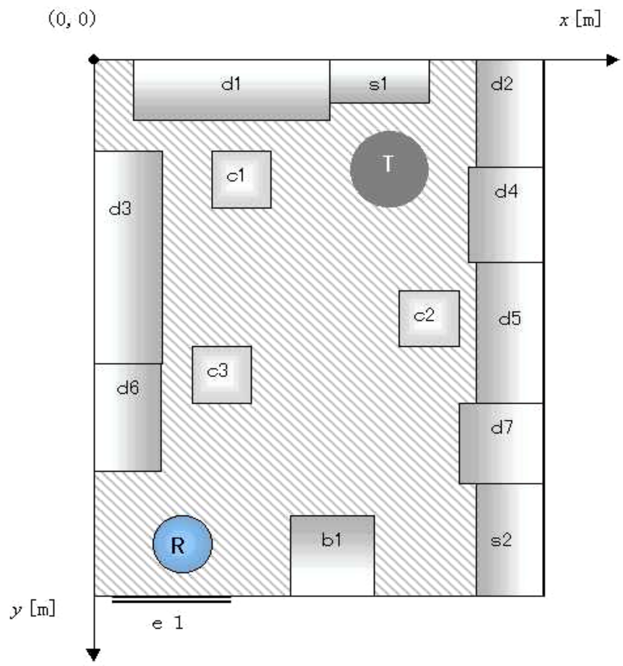


Fig 3. Sample the finite mapping

3. Consideration of position errors

When a robot moves, an error occurs in the mismatch between the position of the robot in the finite mapping and the robot's actual position. When the robot goes from a stopped state to a moving state, the fact that an unstable state is in control of a motor is cited as a cause of this error generation.

The robot at a stopped state needs excessive torque compared with the state where it is moving. Since power is not well transmitted at this time, an error arises in position and speed control of each motor. Then, each motor is converged on the position and speed of the inputted target by feedback control. However, it takes time until each motor converges on the target. Therefore, the robot moves in an unstable state.

Because of this error, the robot performs unstable movement at the time of initial action, and the robot has produced an error in the target value and the actual position.

The moving distance (pulse) of each drive motor and its relationship to timing are shown in Fig 4.

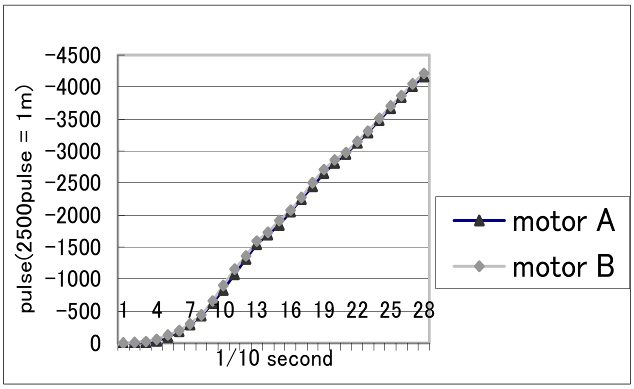


Fig 4 Relation between move distance and time

4. Image-processing system

In order to cope with the problem of error generation described in the preceding paragraph, the robot has to detect its actual position. Therefore, when a robot acquires image data using a CCD camera, the system in which the surrounding environment is recognized can be developed. This system extracts the characteristic point of the target object. And the extraction is repeated and the data flow of the point is created. The characteristic point is defined as the information on the corner of the object obtained from image processing.

The flow of an image-processing system is shown in Fig 5, and the results of processing using the image-processing system are shown in Fig 6. From the image data of the Hough transformation, as shown in figure 6 (d), a linear intersection is calculated. This point is extracted as a characteristic point. At the time of movement, a robot repeats processing of Fig 5 and plots the flow of the characteristic point. The robot recognizes the environment based on the flow.

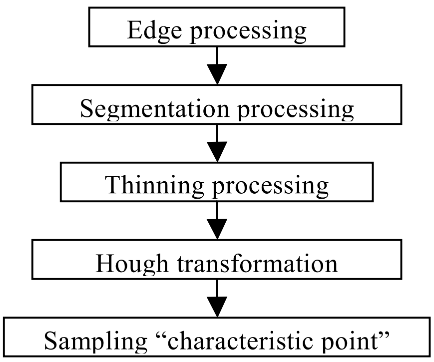
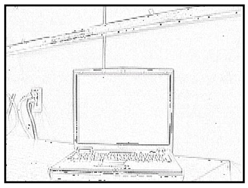
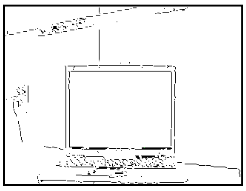


Fig 5. Image-processing system

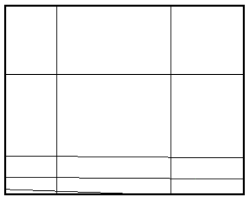
(a) Sample



(b)Edge processing



(c)Segmentation processing



(d) Hough transformation

Fig 6. Image processing

5. Error correction system

5.1 Geometric calculation for the acquisition of Position information

The error correction system calculates a robot's position from the feature point and a robot's move distance. As shown in Fig 7, let picture coordinates be o-xy coordinates, and let camera coordinates be O-XYZ coordinates. As for camera coordinates and picture coordinates, the following relation is realized:

$$x = f\frac{X}{Z}, y = f\frac{Y}{Z}$$

The x-coordinate of the picture obtained from image processing of an initial state is set to x1. If the x-coordinate of the picture obtained when a robot z advanced is made into x2, the following expression of relations will be realized:

$$x1 = \frac{X}{Z}f, x2 = \frac{X}{Z - \Delta Z}f$$

$$X = \frac{x1 * x2 * \Delta Z}{f(x2 - x1)}, Z = \frac{X}{x1}f$$

Therefore, it turns out that the present robot's position (X, Z) can be predicted.

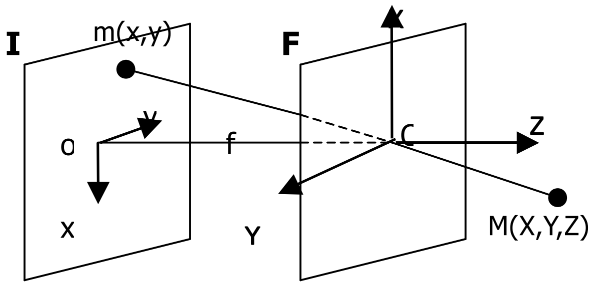


Image plane: I **Focus plane: F**

Fig 7. The relationship between picture coordinates and camera coordinates

A characteristic point flow computed from the relation between a robot and an object is shown in Fig 8. This figure is the flow by which the robot moved as the ideal. By comparing with the flow of an ideal state the flow obtained by image processing, the robot computes the position error.

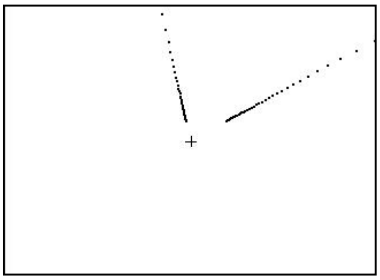


Fig 8. characteristic point flow

5.2 Consideration of error correction

By introducing this system, a robot's position information can be acquired and error compensation can be attained. However, this is during motion, when a robot is stabilized. As shown in Fig 4, gaining stability takes about 1 second. At this time, a robot's driving speed is 0.5 m/second. By the time it goes into a stable state, it has moved at least half a meter.

In areas such as a corridor, this system will have little difficulty. However, error detection is difficult if the robot is moving in a confined space where distances are comparatively short. Therefore, detected errors must be discovered very quickly.

6. Conclusions

When the autonomous drive personal robot moves, a problem arises because coordinates change with respect to objects in the environment. We have proposed an error correction system to solve this problem. This system uses a information on the motion distance acquired from a image data and the drive mechanism, and the system computes an error. However, when a robot's move distance is short, it cannot fully respond. A system to detect position errors immediately is needed.

We have studied the unstable action generated as a cause of the error at the time of initial movement of the robot. In the future, we will analyze the drive parameter at the time of the robot's initial movement and then build a system that can perform action stabilized by the robot.

References

[1]Funakubo, Process and recognition of the vision paturn, Keigakusyuppan, 1990.
[2]Shinoda, Self-driven robot on the grand, Journal of the Robotics Society of Japan, Vol. 18, No.7, pp.928-932. 2000