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Autonomous Control of Mobile Robots by Image Data Processing and Development of the Simulation System

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Abstract: Recently, the cases where the autonomous mobile robots enter into human society have increased. However, it is rare that a large number of robots share the narrow space, because it is too danger for them to avoid other robots in real time. Therefore, this research aims at developing a system to simulate the behavior of multiple robots when they share the same environment.

This system eventually aims at overcoming a lot of weak points caused when robots are controlled in real space.

As a result, it succeeded in the simultaneous control of two or more robots which use the image processing as a method of measuring environment. .

Keywords: Autonomous mobile robot, Image processing, Virtual realty

I. INTRODUCTION

A lot of robots are widespread together with the development of robot industry. Especially autonomous mobile robots are expected to solve the problems such as "nursing care of the senior citizens" and "decrease in the percentage of working force",

However, their development needs expensive cost. Additionally the behavior of them must be debugged using real machinery in real environment, but it is difficult to test the behavior in various real environments because of the difficulty of building such environment in real space. Further the debugging in the habitat like a slope or stairs is so difficult for fear of destructing robots..

To solve these problems, the simulation system using virtual reality space is brought to attention. "Virtual reality space" is the world actuality made by a computer. The system helps developers to construct robots with high reliability because the algorithm and the specification to control them can be examined before real machinery is made.

Then, this research aims at controlling a large numbers of robots autonomously. As the first step, the concrete target of this research is the following two

1. In a real space, to make a mobile robot with the network camera evade autonomously obstacles.
2. To develop the simulation system of robots control. (in the virtual space, generating multiple numbers of virtual robots with the same configuration as real ones are generated, we would like to solve problems occurring when they move around.)

II. ROBOT CONTROL IN REAL SPACE

In this chapter, it is a purpose to make a single mobile robot equipped with the network camera evades the obstacle autonomously in a real space.

1. System Overview

Our robot's composition is so simple and is equipped with a network camera, a wireless LAN card and a motor driver. This composition makes it possible for a PC outside of the robot to drive the robot by receiving and processing an image from the robot and then transmitting motion commands to the robot. As a result, we succeeded in the miniaturization of the robot because it is needles to mount a PC on a robot.

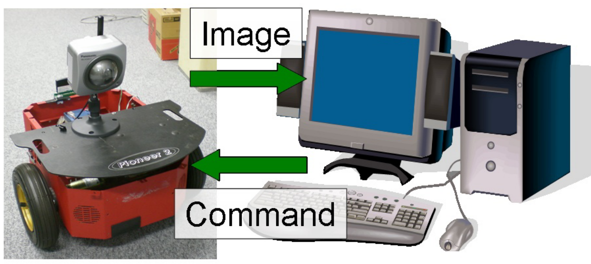


Fig.1. System Overview

As shown in Fig. 2, a network camera is installed forward on the robot. And a motor driver and a wireless LAN card are set up inside and in the rear of the robot, respectively.

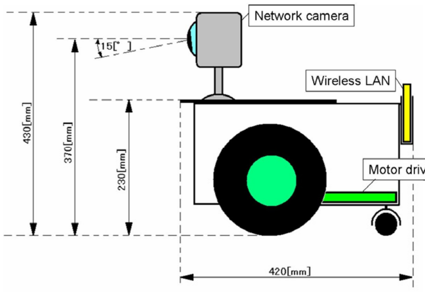


Fig. 2 Robot Overview

2. Algorithm for Dodging Obstacles

The robot recognizes the floor in front of itself to roam indoors. In this algorithm, a robot regards everything except for a floor as obstacles and drives while avoiding them.

A. Floor-Extraction Algorithm

Floor-Extraction is conducted according to the following steps.

Step 1: The image is captured. (Fig. 3 (a))

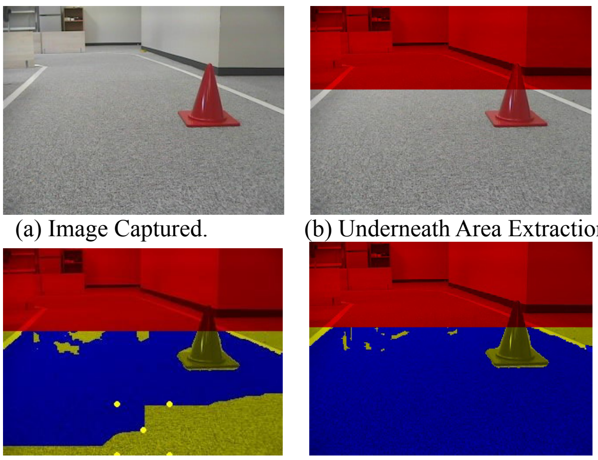
Step 2: The lower area of the image is extracted. (Fig. 3 (b))

Step 3: Floor surface is extracted based on the floor color information acquired from five yellow points as shown in Fig.3 (c). (Fig. 3(d))

Step 4: A robot keeps the color of a floor updating because a light may give effect to the color.

Note here that the algorithm assumes that no obstacle is in front of the robot immediately before it starts driving and there is no pattern on a floor.

Red area in Fig.3 (d) is regarded as a non-target of image processing because it is far from a robot. Blue area is recognized as the floor while green area is recognized as that including obstacles.



(a) Image Captured. (b) Underneath Area Extraction

(c) Floor-Extraction (d) Resultant image

Fig.3. Appearance of Floor-Extraction

B. Choice of Motion Command

The robot is controlled by five kinds of operation. They are "direct advance", "curve to the left", "curve to the right", "counter-clockwise turning" and "clockwise turning". When a robot confirms an image of the extracted floor, it selects and drives the appropriate operation from them.

It judges the possibility of going straight by examining whether the free area recognized as the floor is included in yellow and green rectangles shown in Fig.4. Otherwise, the free areas included in green rectangles are checked out, and if the occupied area including obstacles is small, it is judged that the robot can take a curve. In the case, the direction where obstacles can be evaded effectively is judged on the comparison of the areas included in the right and left yellow rectangles. Finally, it is judged on the areas included in green rectangles whether a right or left curve can efficiently evade the obstacle.

These results are stored in the memory of 4bit as shown in Fig. 5. The operation corresponding to the lowest bit among bits whose value is 1, in the case shown in the figure LEFT, is selected as the most plausible motion.

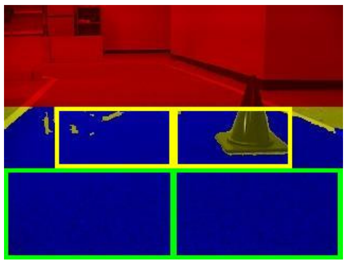


Fig. 4 Rectangle to Choice the Action

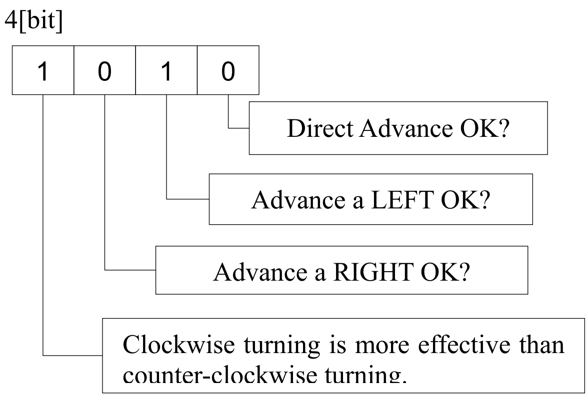


Fig. 5 Storage of Operable Action

C. Algorithm to give a weight to an obstacle

The operation selected by a robot may continuously change when the difference between the amount of a right side floor and that of a left side floor is little. So the algorithm puts a weight on an obstacle so that the operation is stably selected. For example when a clockwise turning is selected, the weight of obstacles in the left rectangle is increased.

4. Experimental Methodology

We had a robot move in the environment shown in Fig. 6. The gray region in Fig. 6 is a course in which a red triangle is an initial position of the robot, and it a blue rectangle is an obstacle.

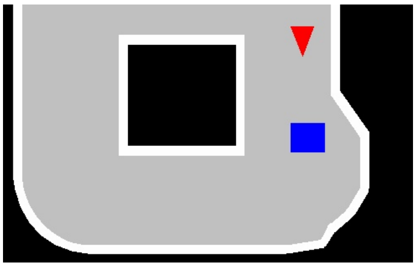
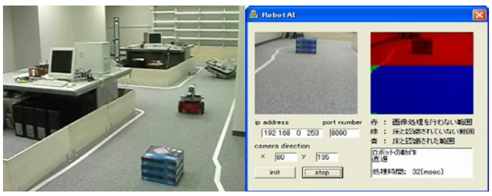


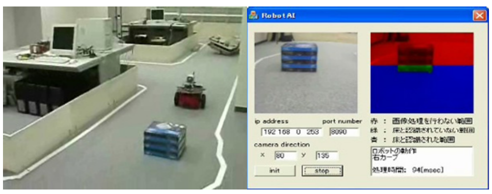
Fig. 6 Experimental environment

5. Result

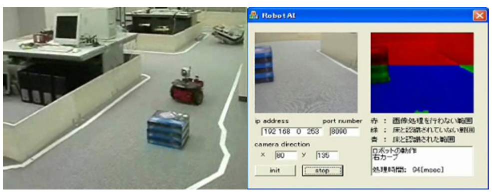
The robot successfully confirms the floor region and wanders dodging an obstacle in front to of it by selecting suitable operation as shown in Fig. 7. Additionally, it successfully goes along the boundary of the course by recognizing it as well as the obstacle.



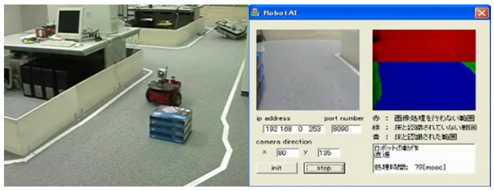
(a) Time = 0.0[sec]



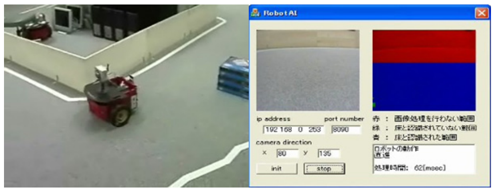
(b) Time = 4.0[sec]



(c) Time = 5.5[sec]



(d) Time = 8.0[sec]



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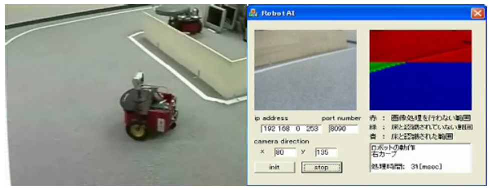
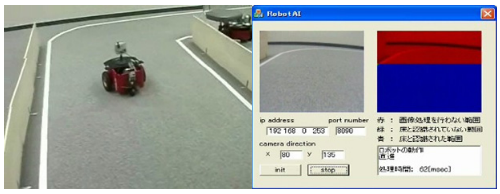


(e) Time = 15.5[sec]



(f) Time = 18.5[sec]

Fig.7. Locus of Robot

III. ROBOT CONTROL IN VIRTUAL SPACE

In this chapter, it is a target to simulate the control of virtual robots in virtual space.

So the specific targets are the following two.

1. To make the system simulate the control of virtual robots.
2. To drive virtual robots of which functions are the same as the real ones.

1. System Overview

One server computer has information of both a virtual space and virtual robots in the simulation system. And each client computer remotely controls one virtual robot allocated to the client.

A virtual robot acquires an image with a virtual camera and sends it to a server. Next it sends the image to a client which performs an image processing, then sends a command to the robot.

This composition reflects the situation in which multiple real robots move in a real space.

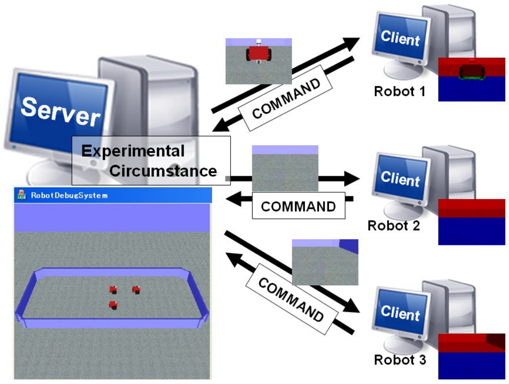


Fig.8. Control of robots in virtual space

2. Virtual Space & Virtual Object

The virtual object consists of three components. They are "Dynamics Element", "Collision Detection Element" and "Graphics Element". Giving these three components the same transformation matrix in the process of simulation allows the system to simulate and render the behavior of a virtual object.

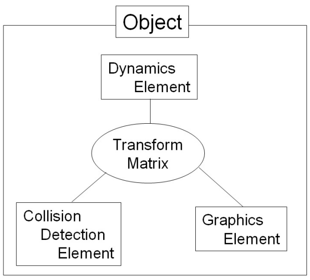


Fig.9. Generation method of virtual object

3. Virtual Network Camera

"A virtual network camera" is used in virtual space as a real one is mounted on a real robot. The virtual camera acquires a three dimensional scene generated by Open GL and then transforms it to two dimensional image. Next the image compressed to make transmission rate high is sent to a client who should analyze it. The client restores it to its original state and processes it.

4. Algorithm Built into Virtual Robots

The algorithm built into virtual robots is the same as that in the real robot. In a word, a virtual robot also evades obstacles by extracting the floor side area. (See II.2. Algorithm for Dodging Obstacles)

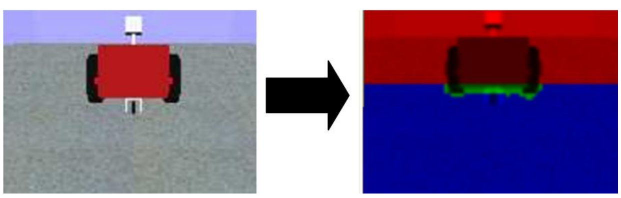


Fig10. Image processing in virtual space

5. Result

It is confirmed that three virtual robots can be controlled while evading obstacles dynamically as shown Fig.11.

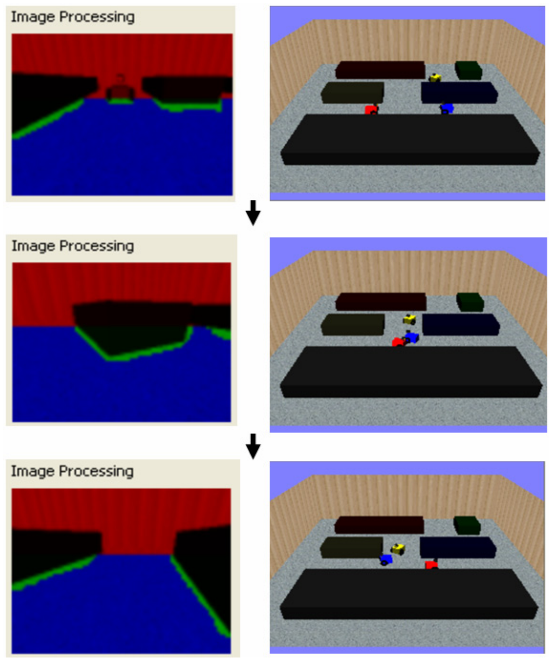


Fig.11. Pictures of simulation
(Left figure is processing result of blue robot)

IV. FEATURE WORK

As two or more robots successfully drive in dynamic virtual space, it seems that the algorithm of obstacle avoidance proposed in this research works well.

The robot, however, can observe only information in front of itself because the network camera is installed ahead of a robot. If robots run side by side while gradually shortening the distance between them, they will collide because the situation makes them invisible each other. Therefore we are planning to give a virtual distance sensor to a virtual robot to make it possible to evade obstacles being at the side of it.

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