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Situational Judgment System for A Robot in Complex Environments Using Hierarchical Neural Network

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Abstract: Human-beings can prevent crashes by avoiding obstructions when detected it in front of them. At the same time, they can take the best action suitable to the surrounding environment. It is considered that an action control algorithm for a mobile robot is feasible by imitating the above-mentioned action control of human-beings. In this paper, we propose a situational judgment system using a hierarchical neural network. This system outputs the action suitable for a robot to the environment (go straight, go back, turn right, turn left, diagonally forward right, or diagonally forward left). After learning of the system, we mounted the system into the robot and let the robot judge the action in various environments. The experimental results demonstrated that the proposed system was effective for determination of the action of the robot in complex environments.

Keywords: Hierarchical neural network, Robot, Situational judgment

1 INTRODUCTION

Human-beings can prevent crashes by avoiding obstructions when detected it in front of them. At the same time, they can take the best action suitable to the surrounding environment. This is because human-beings can recognize the position and posture of obstructions in relation to those of the person through the use of senses. Therefore it is considered that an action control algorithm for a mobile robot is feasible by imitating the above-mentioned action control of human-beings. In recent year, scientists have been working in research and development of mobile robots with the ability to judge like human-beings'[1].

Until now, we have been developing a situational judgment system that uses a hierarchical neural network(called here, NN)[2, 3]. At first, we developed a situational judgment system that obtains information from a single image(in front of the robot) taken from a CMOS camera mounted in a robot. This process allows the robot to attain 4 correct outputs (go straight, go back, turn right, or turn left) in relation to the environment[4]. However, the situational judgment system could not let the robot judge accurately like a human-beings', because this system only uses one image for input information. We confirmed that the robot mounted this system could not obtain sufficient environmental information from the right side and left side of the robot.

In order to let the robot obtain more environmental information, we have been improving the situational judgment system that obtains information from three images(left side, in front, and right side of the robot) taken from a CMOS camera mounted in a robot[5]. Although the robot was able to obtain more environmental information, outputs of this system were still limited to only 4 outputs. Due to the limitation, the robot was unable to judge similarly to human-beings in complex environments. Accordingly, we confirmed that the improved system was also insufficient as a situational judgment system for a mobile robot.

For this reason, we propose a new situational judgment system with an increase of two extra actions for outputs (diagonally forward right, and diagonally forward left). This proposed system uses a hierarchical NN, and outputs the suitable action to the environment (go straight, go back, turn right, turn left, diagonally forward right, or diagonally forward left). In this paper, we show that the proposed system is effective for determination of the action of the robot in complex environments.

2 SITUATIONAL JUDGMENT SYSTEM

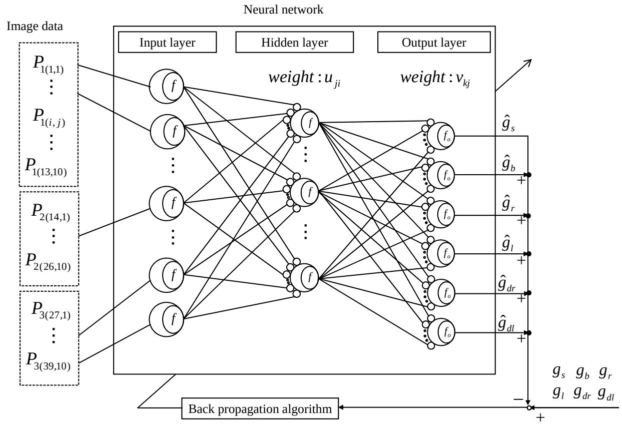


Fig. 1. Situational judgement system

Figure 1 shows the configuration of the proposed situational judgment system using a hierarchical NN. This system inputs images $P_x(i, j)$ that are taken from a CMOS camera mounted in a robot, and outputs the action suitable to the environment (go straight $\hat{g_s}$, go back $\hat{g_b}$, turn right $\hat{g_r}$, turn left $\hat{g_l}$, diagonally forward right $\hat{g_{dr}}$, or diagonally forward left $\hat{g_{dl}}$). Where x is the number of images, i is the number of pixel widths, j is the number of pixel heights.

The NN of the proposed system consists of three layers: input layer, 390 neurons; hidden layer, 195 neurons; and output layer, 6 neurons. In addition, the sigmoid function is used for the nonlinear function of each neuron. Connection weights of the NN are adjusted using a back-propagation algorithm, which is the typical learning technique, so that the sum of square error given by

$$E = \frac{1}{2}\sum\left\{(g_s - \hat{g_s})^2 + (g_b - \hat{g_b})^2 + (g_r - \hat{g_r})^2 + (g_l - \hat{g_l})^2 + (g_{dr} - \hat{g_{dr}})^2 + (g_{dl} - \hat{g_{dl}})^2\right\} \quad (1)$$

decreases, where g_s, g_b, g_r, g_l, g_{dr}, g_{dl} are the teaching data.

3 IMAGE PROCESSING

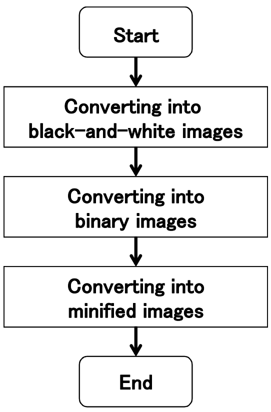


Fig. 2. Flow chart of the image processing

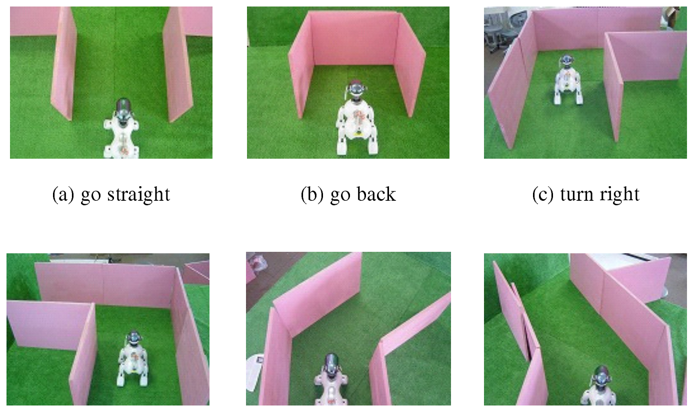
If the amount of input information for the proposed situational judgment system is too much, then the running process of the system will take a lot of time and the proposed situational judgment system will not be able to let a robot judge quickly. Therefore, we use an image processing method to reduce the amount of input information. The proposed situational judgment system inputs processed images by three-step image processing. Figure 2 shows a flow chart of the three-step image processing. At first, the system converts the shot images (colored, 104 pixel widths, and 80 pixel heights) into black-and-white images. Then, the system converts the black-and-white images into binary images. Finally, the system converts the binary images into minified images(13 pixel widths, and 10 pixel heights). These processed images are used to input information for the proposed situational judgment system.

4 LEARNING RESULT

4.1 NN learning

First, we put a robot in environments like Figure 3 and took 108 images of three different directions (6 images each of 6 action patterns) with a camera mounted in the robot. The field of vision of the robot was set to 120 angular degrees for this experiment. These images were used as teaching data, and the proposed situational judgment system was learned. Figure 4 shows some of the images that are used as teaching data.

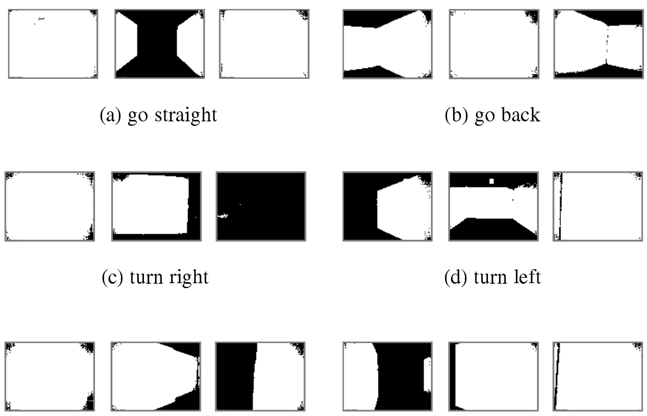
Figure 5 shows the transition of the sum of square error. After two million iterations, the sum of square error decreased and converged to a constant value of about 0.007.



(a) go straight (b) go back (c) turn right

(d) turn left (e) diagonally forward right (f) diagonally forward left

Fig. 3. Example of environments for the NN learning



(a) go straight (b) go back

(c) turn right (d) turn left

(e) diagonally forward right (f) diagonally forward left

Fig. 4. Example of images used for the NN learning

4.2 Simulation result

To confirm the reliability of the NN learning results, we carried out simulation experiment by images used as the

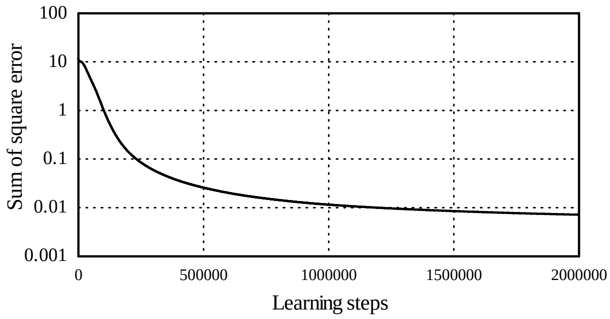


Fig. 5. Transition of the sum of square error

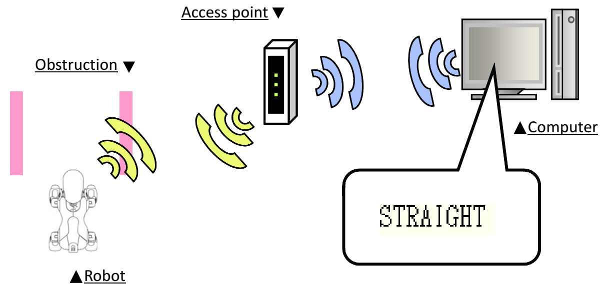


Fig. 6. Experiment system

teaching data for the NN learning. Table 1 shows the results of the situational judgment for the simulation experiment. Here, the proposed situational judgment system outputs 6 values from 0 to 1, and the largest value is the best action suitable in each environment. The data values shown in table 1 demonstrate suitable output values for each environment. From these simulation results, we confirmed that the proposed situational judgment system was sufficiently learned.

5 EXPERIMENTAL RESULT IN COMPLEX ENVIRONMENTS

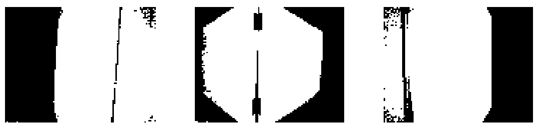
To confirm the usefulness of the proposed situational judgment system, we carried out to let the robot judge the action in complex environments using the learned situational judgment system. The robot mounted the learned system is set in complex environments. Situational judgment results from the robot are displayed on a computer screen using a wireless local area network mounted into the robot as shown in Figure 6. It is important to note that the complex environments are not used as the teaching data for the NN learning.

5.1 Y-junction environment

First, we put the robot in a Y-junction environment shown in Figure 7(a), and let the robot judge the action. Figure 7(b) shows the images shot by the robot in this environment, and Figure 7(c) shows the images after the previously-mentioned image processing. Table 2 shows the result of the situational judgment obtained from the robot in this environment.

(a) experimental environment

(b) shot images



(c) binary images

Fig. 7. Y-junction environment

Table 1. Results of the situational judgment for the simulation experiment

		Result					
		Straight	Back	Right	Left	D-right	D-left
Input image	Straight	**1.000**	0.016	0.004	0.006	0.008	0.010
	Back	0.011	**0.967**	0.000	0.000	0.000	0.012
	Right	0.003	0.006	**0.982**	0.002	0.000	0.002
	Left	0.001	0.000	0.000	**0.973**	0.003	0.013
	D-right	0.000	0.015	0.006	0.001	**0.998**	0.011
	D-left	0.000	0.010	0.000	0.007	0.016	**1.000**

As can be noted from Table 2, the proposed situational judgment system outputted 2 actions(diagonally forward right, and diagonally forward left) suitable to the Y-junction environment. These results clearly demonstrate that this system can output the accurate action in the complex environment.

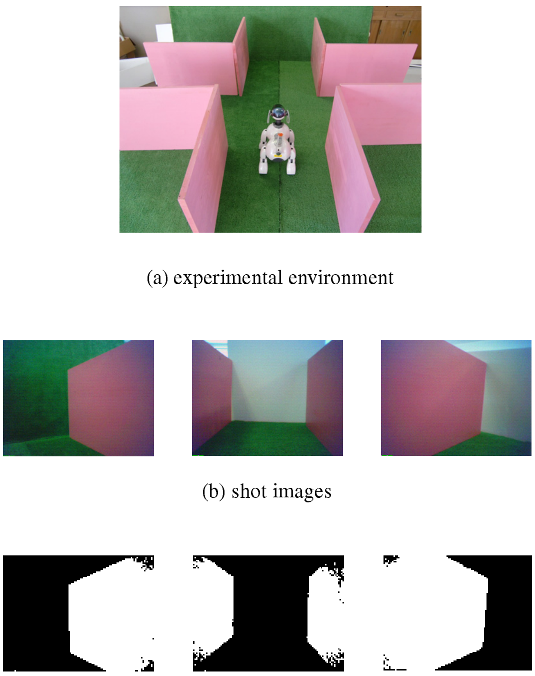
Table 2. Results of the situational judgment for the Y-juntion environment

	Straight	Back	Right	Left	D-right	D-left
Output	0.000	0.002	0.003	0.001	**0.997**	**0.986**

5.2 Cross road environment

Next, we put the robot in a cross road environment shown in Figure 8(a), and let the robot judge the action. Figure 8(b) shows the images shot by the robot in this environment, and Figure 8(c) shows the images after the image processing. Table 3 shows the result of the situational judgment obtained from the robot in this environment.

From Table 3, the proposed situational judgment system outputted 3 actions(go straight, turn right and turn left) suitable to the cross road environment. Moreover, we confirmed that the robot can obtain complex environment information by the proposed situational judgment system.



(a) experimental environment

(b) shot images

(c) binary images

Fig. 8. Cross road environment

Table 3. Results of the situational judgment for the cross road environment

	Straight	Back	Right	Left	D-right	D-left
Output	**0.999**	0.183	**0.858**	**0.999**	0.013	0.000

6 CONCLUSION

In this paper, we proposed a situational judgment system using a hierarchical neural network (NN) for a robot. This system outputs the suitable action for the robot to complex environments. The connection weights of the NN are adjusted by the back-propagation algorithm so that the sum of square error decreases to a small value.

To confirm the usefulness of the proposed situational judgment system, we carried out some experiments in complex environments which were not used as the teaching data for the NN learning. From the experiment results, we confirmed that the robot mounted the proposed situational judgment system could output the action similar to a human-beings.

In future works, we plan to construct a running control system for the robot using the proposed situational judgment system. We will target to let the robot run in more complex situations like labyrinth.

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