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Design of robotic behavior that imitates animal consciousness —Emotion expression of robotic arm based on eyeball movement—

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***Abstract*:** In this research, with the aim of "user affinity", a trial which gives a robot "consciousness" like people or an animal is performed. Here, the goal of user affinity suggests the capability for a robot to inspire a sense of closeness in the user, such that the user is not bored with its use. Our laboratory previously conceived a model of the mechanism of consciousness and action and a software architecture by which this model can be used to control the action of an artificial animal based, called the Consciousness-based Architecture (CBA). Here, we newly built a "motivation model" which assumes that certain motives inhere in the actions of an animal, and therefore ascribes to the robot the motive of action. In this motivation model, the dopamine-generating mechanism of an animal is modeled. Moreover, an eye display for the robot to simulate the expression of feelings was developed. As a first step to coherent, "conscious" expression, the speed of the blink was changed according to the motivation model.

***Keywords*:** CBA, consciousness of the robot, Motivation of the robot

I. INTRODUCTION

In recent years, the development of non-industrial robots in such fields as medical care and welfare and for life in general has flourished. The operation of these robots requires not only the basic functions of robots, such as a high level of intellectual activity, but also the function of user compatibility or affinity so that a user can feel close to the robot as a result of its appearance and behavior. User compatibility implies that the user is easily able to operate the given robot, without getting bored with its use, and can easily develop a sense of closeness with it; ultimately, the user can receive the healing benefits experienced in relationships with other conscious beings.

Although a robot may gain in user compatibility by being genuinely modeled after a face, it is far more difficult to achieve user compatibility through its behavior and actions, including human-like "capricious behavior". The attempt to give robots "consciousness" such as that identified in humans and animals is a part of these requirements.

Our laboratory has studied animals' adjustments to their environments in an attempt to emulate animal behavior. We constructed a hierarchic structural model in which consciousness and behavior were hierarchically related. In regard to this, we developed a software architecture we call Consciousness-based Architecture (CBA). CBA introduces an evaluation function for behavior selection, and controls the robot's behavior.

In the present study, we developed a robotic arm that has six degrees of freedom, with the aim of providing the robot with the ability to autonomously adjust to a target position. Fig. 1 shows an overview of the robotic arm. The robotic arm that we used has a hand consisting of three fingers in which a small monocular WEB camera is installed. The landmark object is detected in the image acquired by the WEB camera, enabling it to perform grasping and carrying tasks. As an autonomy action experiment, CBA was applied to the robot arm and the behavior then inspected.

This research was intended to develop the "emotional" display of a robot. Thus, it paid attention to eyes, where feelings appear most easily in the expressions.

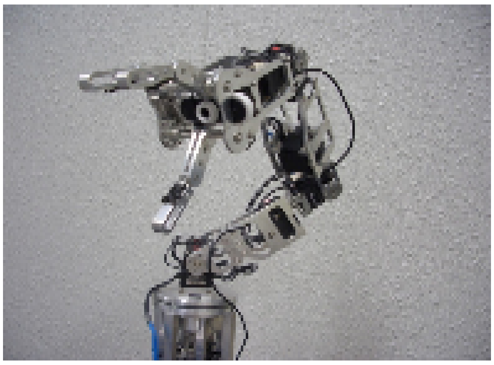


Fig.1. Overview of Robotics arm

II. SYSTEM STRUCTURE

Fig. 2 shows the appearance of the robot arm, and Fig. 3 shows its degrees of freedom. The robot arm has 7 levels of flexibility {shoulder (Joint1, Joint2), elbow (Joint3, Joint4), wrist (Joint5, Joint6), and finger (Joint7)} at its full length of 450 [mm]. The hand part has 3 fingers with one flexibility; the weight of the main part is about 0.8 kg. A small Web camera, equipped at the tip of a robot arm, can recognize the external situation. The web camera and the robot arm's actuator are controlled by USB communication.

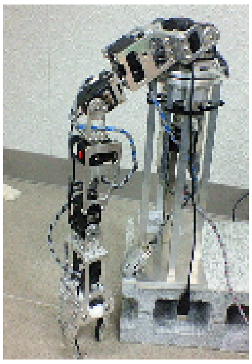


Fig. 2 robot arm

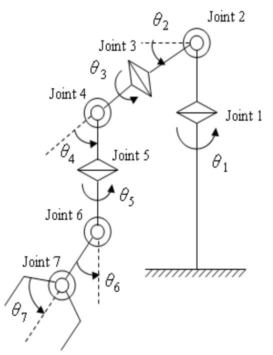


Fig. 3 degree of robot arm

III. AUTONOMOUS BEHAVIOR

1. The motivation of the robot

Most robots are pleasing to people because of their unique movements. However, the action choices of robots are too mechanical. Action choices that resemble those of human beings and animals are needed to actualize user compatibility. Therefore, we at first thought about a human action.

When an animal, including a human being, takes some a ction, it can be represented by a flow chart such as "Rec ognition → Comprehension → Motivation → Action".

On the other hand, the action of the robot repeats a sim ple flow such as "Recognition (Comprehension) → Acti on".

The flowchart of this system is shown in Fig. 4, and th e details of each item are given below.

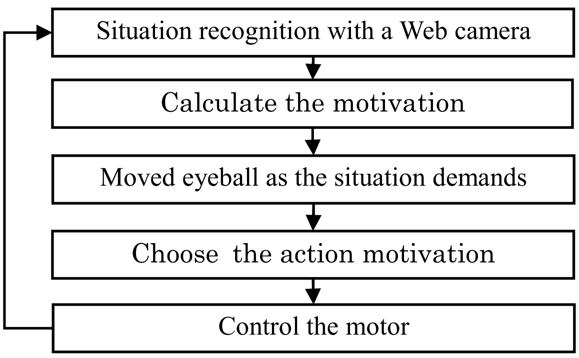


Fig. 4 Flowchart of this system

2. Situation recognition with a Web camera

The first step of the "humanized" robot's system is to recognize a situation. For this purpose we devised a labeling image which we divided into green, blue, and flesh color parts from an image of web camera installed on the robot hand. Then we divided the green, blue, and flesh color into separate blobs and extracted the shape, size, and center of gravity position. From this information and the posture of the robot arm, the robot could recognize the position and the distance of the target colored object. Furthermore, the system memorized the central point for three frames.

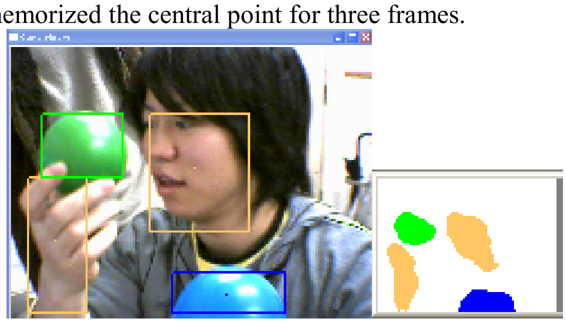


Fig.5 A Web camera image and a labeling image

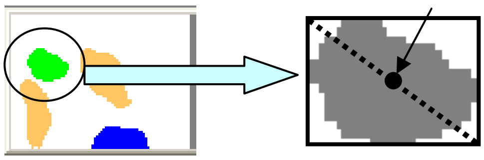


Fig.6 Central point

2-1. The objective move direction prediction

A picture is divided into eight domains in order to predict the movement direction. The movement direction is predicted only when an object is missed at the time of situation recognition. The prediction direction corresponding to the eight domains and the area as a whole is shown in Fig. 9.

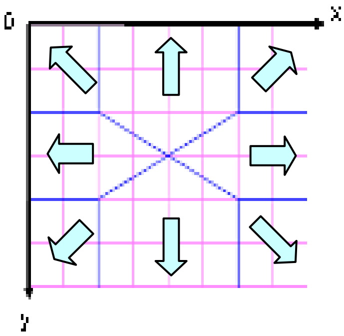


Fig.7. A division domain and the prediction direction

2-2. Virtual object creation

The virtual object corresponding to the predicted movement direction of the object is created in the visual angle. Since it is possible to pursue the obje ct within the visual angle, a virtual object is create d, and the robot runs after a real object by running after the virtual object.

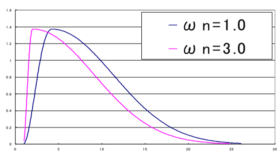
3. Calculation of dopamine and motivation based on the situation

When a man and an animal interact, changes occur in the dopamine level in the brain. The dopamine-generating locus is regarded as the robot's motivation model, and the generating locus was copied using the control model. A control model is shown below. In the graph, sample changes in ω_n, ζ and T are shown.

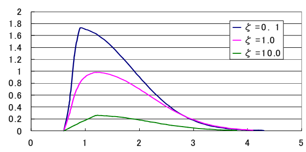
$$\text{Rising} \quad y'' + 2\omega_n \zeta y' + \omega_n^2 y - \omega_n^2 u_{(t)} = 0 \cdots (1)$$

$$\text{Decaying} \quad y = e^{-t/T} \cdots (2)$$

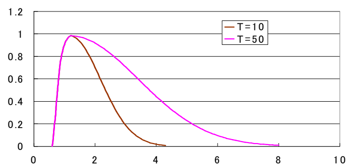
ω_n : natural angular frequency : earliness of a rising
ζ : braking rate : height of the peak of a rising
T : time constant : attenuation performance



(a) change ω_n



(b) change ζ



(c) change T

Fig.8 Motivation model

In this study, we captured the trace of this dopamine as the motivation of the robots and termed this function the "Motivation model". Fig.9 shows this Motivation model.

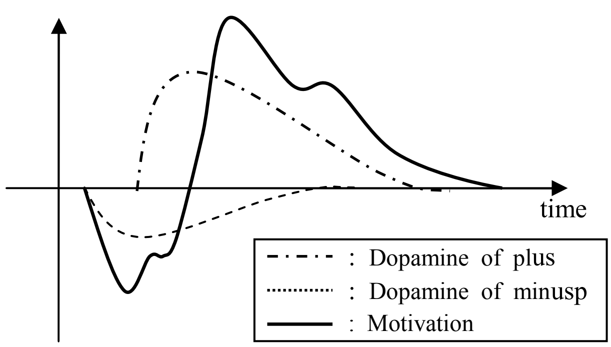


Fig.9 Motivation model

4. Choice of the action that accepted motivation

The action level was set up by dividing a robot's motivation by a fixed value. In this way, the action which can be chosen according to an action level was limited.

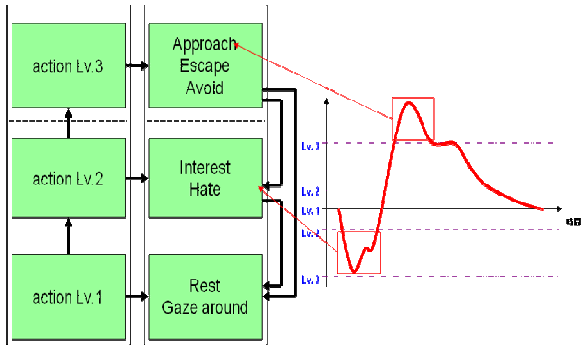


Fig. 10 Choice of the action based on motivation

5. Consciousness architecture (CBA)

Fig. 11 shows a diagram of a hierarchical structure model called CBA (Consciousness-based Architecture) which relates consciousness to behavior hierarchically. The characteristic of this model is that the consciousness field and behavior field are built separately. In a dynamic environment, this model determines the consciousness level to the environment that a robot most strongly consider, and the robot then selects the behavior corresponding to that consciousness level and performs the behavior. This model is characterized in that the consciousness level approaches an upper level so robot can select advanced behavior when certain behavior corresponding to the consciousness level is discouraged by some external environmental factor.

Additionally, an upper-level consciousness can make a choice of low-level behavior. The mechanism of this model is that it selects the optimum behavior within the low-level behaviors , so the robot aims for goals.

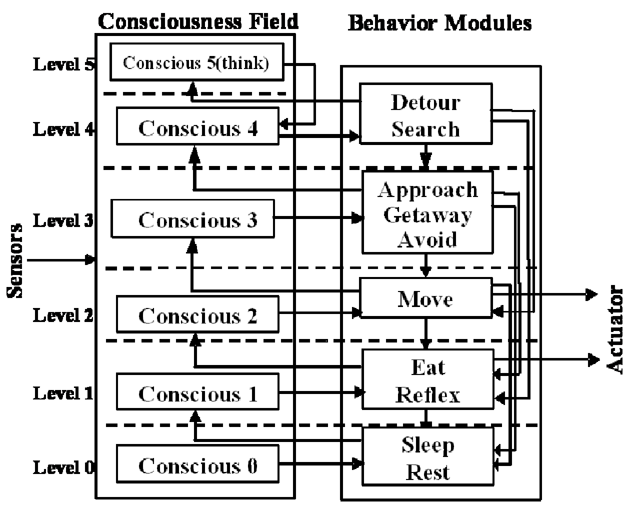


Fig.11 Consciousness-based Architecture (CBA)

IV. The eyeball system which operate in response to external conditions

Facial expression is an important factor in the role of conveying feelings. This study focuses on the eyes, which greatly influence emotional expression. A pair of eyes was made in 3-D graphics using the Open GL (Open Graphics Library). Fig. 12 shows the eye display we created.

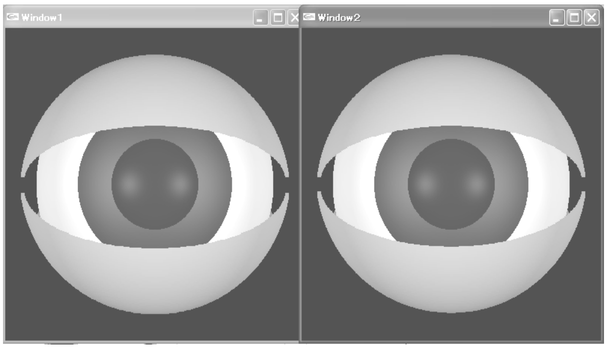


Fig.12 The eyeball created

1. The eyewink system

The study implemented the eye-blinking system found in the human eye. Blinking is among the most important expressive human eye movements. In order to imitate the actual state of mind, we measured the timing of blinks of humans in different psychological states. Fig. 13 shows the measurement result of blinking in a human.

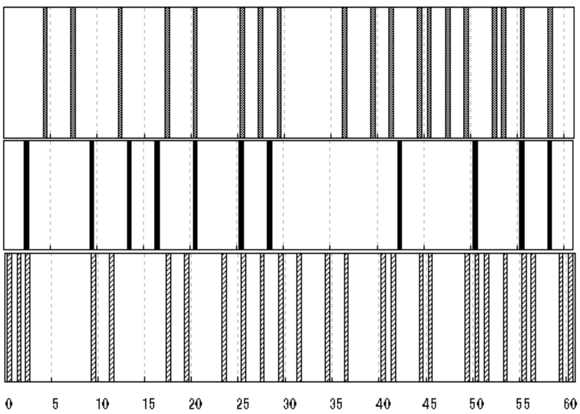


Fig.13 Measured result of the wink of human

In this figure, the horizontal axis represents one minute of time and the three timelines show the timing of blinks in different psychological states. The upper graph of Fig.13 shows the usual state. The second graph shows a state of concentration and the third graph shows a state of agitation. This result can be confirmed that eye-blinking rate is suppressed with concentration and is increased with excitation. This provides clues to a person's psychological state. Based on this result, an eye-blinking system was developed to synchronize with the robot's assigned "motivation"..

V. INSPECTION OF AUTONOMOUS BEHAVIOR

1. Validation experiment

We conducted a validation experiment to synchronize the robot arms with the eye system. The experiment confirmed whether the eye would follow a green ball when someone moved the green ball before the camera on the robot arm. Another experiment confirmed whether the number of blinks changed in response to the robot arm's motivation.

Fig. 14 shows validation results. It demonstrates that the eye operates in response to external conditions.

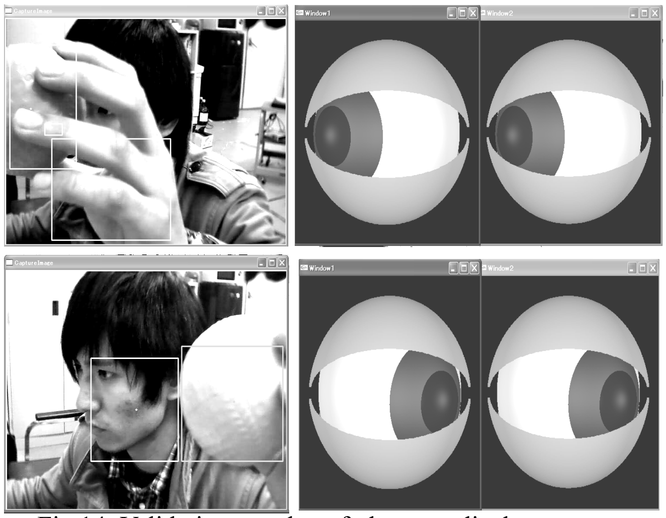


Fig.14 Validation results of the eye display system

VI. CONCLUSION

In this paper, we created the eye diaplay of a robot arm using Open GL. It became possible to synchronize the expression depending on the situation outside.

In the future, we will try to improve the eye display system because the eyeball's movement was delayed. Although we focused on only one color of ball at present, we will expand the robot's repertoire to respond to another color in a different way; i.e., a system which performs eye movement that refuses to follow a blue ball's motion.

VIII. Acknowledgement

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Sports and Culture, Grant-in-Aid for Scientific Research, 2010.

IX. References

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