Design of robotic behavior that imitates animal consciousness

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Abstract: In response to the need for enhanced user affinity for robots, we are attempting to give robots a "consciousness" such as that identified in humans and animals. We developed software to control a robot's actions by introducing the evaluation function of action choice into the hierarchical structure model. This connected the robot's consciousness with the robot's action. We named the process Consciousness-based Architecture (CBA).
We developed a robot arm with a small Web camera built into the fingers. We installed CBA on this robot arm, and inspected the autonomous action performed to catch an object. A "motivation model of the robot" was devised to describe interests for the aim thing of the robot and the desire of the robot. To build this motivation model, we studied the action of dopamine, which added activity to the robot, in conjunction with the incentive to do an action. We incorporated this motivation model in a robot arm, and studied the expression of the emotion by a robot..

Keywords: CBA, consciousness of the robot, Reflection, and Hierarchal Structure, Motivation of the robot

I. INTRODUCTION

Recently, there has been active development of robots other than industrial robots, such as home robots, personal robots, medical robots, and amusement robots. The further development of these robots requires improvement of their intellectual capabilities and manual skills, as well as further increases in user compatibility. Up to now, these aspects of the robots constituted problematic issues in regard to the robot's use by robots other than industrial robot. User compatibility in this case entails ease of use, non-fatiguing control, robot "friendliness" (i.e., sympathetic use), and human-like capricious behavior". The attempt to give robots "consciousness" such as that identified in humans and animals is a part of these requirements.

In our laboratory, we studied an animal's adjustment to its environment in an attempt to emulate its behavior. We constructed a hierarchic structure model to which consciousness and behavior were hierarchically related. This model is based on the mechanistic expression model of animal consciousness and behavior advocated by the Vietnamese philosopher Tran Duc Thao[1]. In regard to this, we developed a software architecture we call Consciousness-based Architecture (CBA). And I made a program in imitation of a state of the dopamine as motivation of the robots and took in it in 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. The robotic arm that we used has a hand consisting of three fingers in which a small monocular CCD camera is installed. The landmark object is detected in the image acquired by the CCD camera, enabling it to perform holding and carrying tasks. As a n autonomy action experiment, CBA was applied to a robot arm and the behavior then inspected.

II. SYSTEM STRUCTURE

Fig. 1 shows an overview of the robotic arm used in this experimental test. Fig. 2 shows an arrangement plan of the degree of freedom of the robotic arm. Figs. 2-3 show a configuration diagram of the experimental system. The robotic arm manufactured by Kihara Iron Works is 450 millimeters long and has 6 degrees of freedom. The robotic hand part of the robotic arm has 3 fingers and 1 degree of freedom. Additionally, there is a small Web camera in the robotic hand.

We applied the Dynamixel DX-117 manufactured by ROBOTIS CO., LTD. as the actuator of each joint of the robotic arm. The DX-117 is an actuator that makes motor, decelerator, and angular sensor to unit. This actuator is able to do position control by providing it with a target angle, torque limit, speed limit, and so on. Its transmission method is RS485. Hard wiring can simplify by connecting daisy chain to each actuator used as a joint of the robotic arm.

Fig.1. Overview of Robotics arm

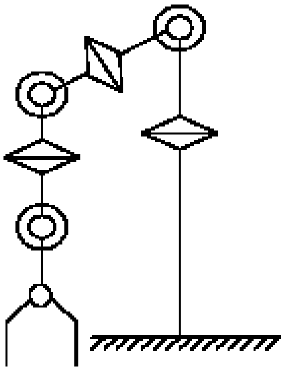


Fig.2. Arrangement chart of degree of freedom

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", a s shown in Fig.3.

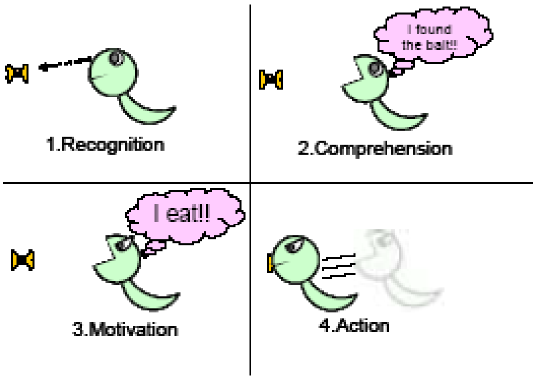


Fig. 3. A flow before an animal taking action

Fig. 4. The flow that occurs leading up to a robot taking action.

On the other hand, the action of the robot repeats a simp le flow such as "Recognition (Comprehension) → Actio n", as shown in Fig.4. We considered this simple flow to be one of the causes of "the mechanical action choice of the robot". Therefore, in this study, we incorporated t he concept of "the motive" in a robot, and aimed at an a ction choice that resembled that of a human being and a n animal.

2. Imitation of the outbreak mechanism of dopamine

Dopamine is a hormone like substance in the brain that is related to motivation. When animals including human beings take some actions, dopamine secretes in the brain. We thought that more biologic action choice would be enabled if the outbreak mechanism of motivation by dopamine could be reproduced in a robot.

For background information, we read the medical article *"A trial to analyze the effect of an atypical antipsychotic medicine, risperidone, on the release of dopamine in the central nervous system"* [2]. We noticed the graph that showed the change of the quantity of dopamine when the author administered a stimulant to a rat. As a result, it was recognized that the dopamine in the brain suddenly increased when medication was taken, and afterwards decreased slowly. The figure shows a model that expresses the change in the quantity of dopamine. The Fig.5 shows a model that expresses the change in the quantity of dopamine outbreak.

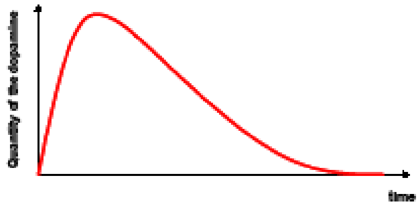


Fig. 5. Traces from outbreak of the dopamine to ext inction

We output a trace to show in the figure with the control model that combined "a second order system" with "a fi rst order system". First, we used a second order step res ponse for the start of the dopamine. After having arrived at the peak value, we used the primary delay reply that assumed the peak value input. We could express a trace of various dopamine by setting natural frequency ωn, da mping ratio ζ, and time constant Tc of the variable inclu ded in this control model appropriately. In this study, I c atch a trace of this dopamine as motivation of the robots and will call this function a motivation model in future.

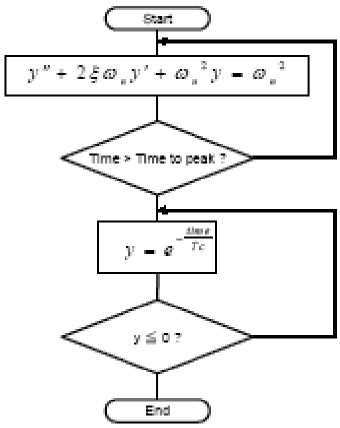


Fig. 6. Flow charts of the dopamine trace

3. PLEASURE and UNPLEASURE of the robot.

With the motivation model that was built, the pleasure and unpleasure of the robot was expressed. First, we prepared two parameters, "PLEASURE" and "UNPLEASURE" in my program. "PLEASURE" and "UNPLEASURE" has a stack structure. If a good thing happens for a robot, small motivation is added to "PLEASURE". In contrast, if a bad thing happens for a robot, small motivation is added to "UNPLEASURE"

If a new motivation is added when a small motivation is calculating, it is reserved and new motivation calculates. If a small motivation that is calculated becomes approximately 0, it erases the motivation which has been calculated, and reopens the calculation of the small motivation which it has reserved.

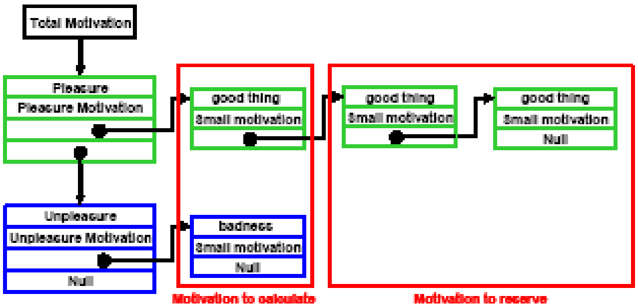


Fig.7. Diagram of the PLEASURE and UNPLEASURE of the robot

I assume a summation of the all small motivations which "PLEASURE" has, and it named "PLEASURE MOTIVATION".I assume a summation of the all small motivations which "UNPLEASURE" has, and it named "UNPLEASURE MOTIVATION". In addition, I named "TOTAL MOTIVATION" included "PLEASURE MOTIVATION" and "UNPLEASURE MOTIVATION".

4. Consciousness architecture (CBA)

Fig. 8. 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 a 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 then performs the behavior. This model is characterized in that the consciousness level gets up to upper level so robot can select advanced behavior when certain behavior corresponded to the consciousness level was discouraged by some external environment.

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

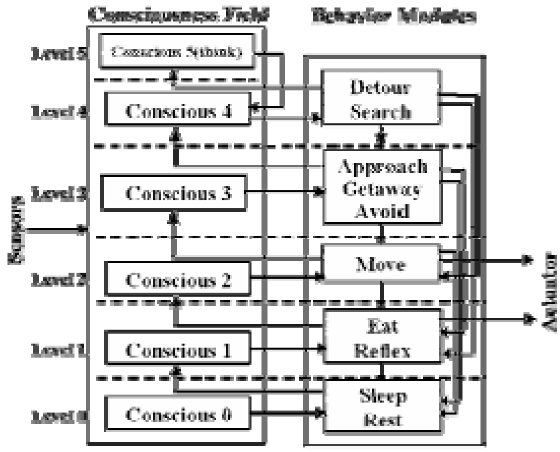


Fig.8. Consciousness-based Architecture (CBA)

5. Evaluation function

The following evaluation function was used to decide the consciousness level of CBA.

$$C_{(t)} = Total\ Motivation - \frac{1}{\omega_n^2} C''_{(t)} - 2\frac{\xi}{\omega_n} C'_{(t)} \quad - (1)$$

$$I_{(t)} = \left| C_{(t)} \right| \quad - (2)$$

$C_{(t)}$ decides the consciousness level in CBA by a second delay reply to assume Total Motivation input. $I_{(t)}$ is a function to choose an action in the consciousness level that we calculated in $C_{(t)}$.Their theory makes a robot's autonomous behavior come true.

6. Situation recognition with a Web camera

I make the labeling image which I divided into green, blue, flesh color from an image of web camera installed to a robot hand. And divided the green, blue, and flesh color into every lump and demanded the shape, size, and center of gravity position. From this information and the posture of the robot arm, the robot could recognize a position and the distance of the color object.

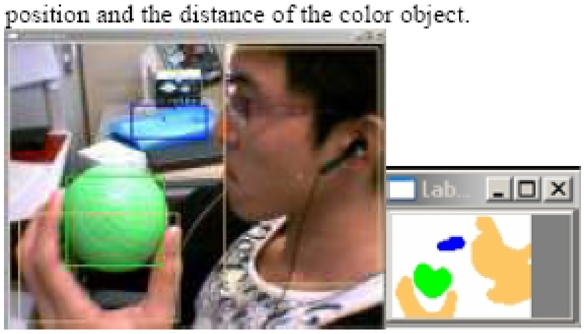


Fig.8. A Web camera image and a labeling image

IV. INSPECTION OF AUTONOMOUS BEHAVIOR

We applied the motivation model and CBA which I showed with Chapter III for a robot arm and inspected the autonomous behavior.

1. Condition setting

First, we set "preference" to a robot. Now, we assumed t hat the favorite thing of the robot arm was "a green ball" and the thing which the robot most hated to be "a blue thing". Next, according to this "preference", we set the o utbreak condition of the motivation as follows.

A condition to add small motivation to "PLEASURE MOTIVATION".

・Robot can expect that if object is a green and spher e, it maybe a ball.

・A green ball stops and seems to be able to catch it if Robot extends a hand.

・The distance between the green ball and hand shrink.

A condition to add small motivation to "UNPLEASURE MOTIVATION".

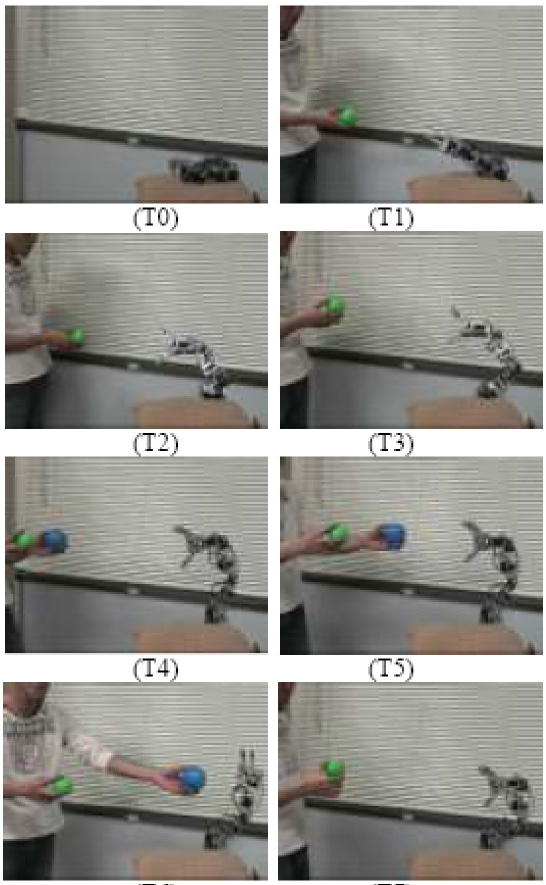
・Robot sees a blue thing.

・The blue thing is bigger than the green ball.

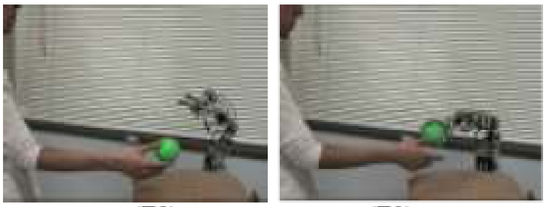
・The load of the joint motor is too large.

2. Movement experiment of the robot arm

We let the robot arm recognize a favorite green ball and a hateful blue ball appropriately. We inspected the actio n of the robot arm. We show the behavior of the robot arm in Fig. 9 (T0-T9).In addition, we show the transition of the motivation of the robot arm in Fig.10.



(T0) (T1) (T2) (T3) (T4) (T5) (T6) (T7)



(T8) (T9)

Fig. 9. Behavior of the robot arm

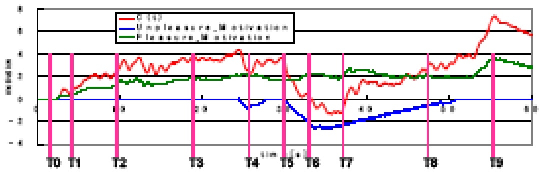


Fig.10. Transition of the motivation

First, the robot arm takes a rest. (T0)
Second, the robot arm recognizes a likeness green ball, motivation increases slightly, and the robot begins to run after the ball. (T1)Third, the motivation of the robot arm increases more when the green ball is not moved. In addition, the robot arm is going to recognize the ball from a higher position. (T2)Forth, the motivation is sufficiently increased, the robot arm begins to approach the green ball. (T3)Fifth, however, we show the robot a hateful blue ball, the motivation of the robot arm suddenly decreases, and take robot's eyes off the blu e ball. (T4)Sixth, because we showed the robot the more hateful blue ball, the robot arm exhibits beha vior which shows that it hates the blue ball. (T5)(T6)I stopped to show a hateful blue ball to a robot arm, and showed only a likeness green ball. (T7)Therefore, its motivation increased again, and it ran after the green ball. (T8)When the motivation increased, it began to approach the green ball. Then the robot arm got close enough to the green ball to be able to catch it. (T9)

V. CONCLUSION

In this paper, we built a motivation model for a robot in reference to an outbreak trace of dopamine used to medi cate rats. Consciousness architecture (CBA) was applied as the control algorithm of autonomous behavior of a r obotic arm. It was hard to anticipate the movement of the robot arm. The robot never did the same movement and was able to catch a green ball. This was not mechanical obvious movement. Therefore, we think this robot arm has action choice that resembles that of a human being or an animal.

VI. REFERENCES

[1]Tran Duc Thao, "Phenomenology and Dialectical Materialism", Godo-shuppan CO., LTD. 1989

[2]Hitoshi Kimura, "A trial to analyze the effect of an atypical antipsychotic medicine, risperidone, on the release of dopamine in th e central nervous system" (J.Aichi Med. Univ. Assoc.) vol.33, No.1, pp.21-27