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Design of robotic arm's action to imitate the mechanism of an animal's consciousness

Takahiro Yamasaki Eiji Hayashi

Department of Mechanical Information Science and Technology
Faculty of Computer Science and Systems Engineering, Kyushu Institute of Technology
680-4, Kawazu, Iizuka-City, Fukuoka Prefecture, Japan
(Tel: 0948-29-7793)
(yamasaki@mmcs.mse.kyutech.ac.jp)

Abstract: We are attempting to develop a system so that a user is able to let robots perform an intellectual action that has a healing and friendly feeling. Based on the development process of the actions and consciousness of animals[1], we constructed a structure model which connects consciousness and action hierarchically, built a valuation function for action selection, and developed software to control the action of a robot. This software is called Consciousness-Based Architecture (CBA). With it, our aim is to connect a user and robot as closely as possible and to allow smooth communications between them by developing an emotional system that takes notice of consciousness.

In our system, the robotic arm's finger is outfitted with a small Web camera, which allows the arm to recognize external information so that the robot can select various actions that comply with certain factors in the outside environment. Furthermore, by using the actuator of the robotic arm, the system we have built provides a correspondence between the robot's internal states, such as the degree of rotation angle, and the outside temperature. In the present study, a motivation model which considers the outside environment and the internal states has been built into the CBA, and the behavior of the robotic arm has been verified.

Keywords: CBA, The consciousness of the robot, Motivation, Tiredness, Outside environment, Internal state

I. Introduction

At the present time, not only industrial robots but also non-industrial robots are being quickly developed. The non-industrial robot is called a service robot and is of various types: a business robot, a research robot, a welfare robot, and a domestic robot, to mention some. The necessary thing in the development of these robots is user affinity, such as the healing possibilities that are facilitated by making a robot's appearance similar to that of a living being and by adding sociability to a robot. In order to provide ways to prevent users from becoming bored and also to create a sense of closeness or affinity that could give a healing quality to a user, we have paid attention to how animals (such as dogs and cats) by their existence in real space fulfill these functions for people.

In order to copy the consciousness of an animal, we modeled our generating locus by paying attention to dopamine, a substance in a brain which manages an animal's actions. By regarding this as a robot's motivation, the robot is given a way to make action choices.

The service robot is defined as "the machine which can acquire external information by itself, can determine self-action, and has the purpose of substituting for people, providing the support and cooperation that people would provide." To fulfill these functions, the robotic arm's finger is outfitted with a small Web camera, allowing the arm to recognize external information so that the robot can select various actions in compliance with the outside environment by changing the amount of dopamine released. Moreover, a behavioral selection process that is more intellectual considers the outside environment. In addition, an internal state for the robot becomes possible through the construction of a system which changes the amount of dopamine released. Through the actuator on the robotic arm that is able to change its angle rate, the system can regulate the robot's internal states (with regard to such things as the degree of the turning angle and the temperature). As a result, the robotic arm can express "Tiredness" and "Stress" just like living creatures.

In the present study, we verified the behavior of a robot arm according to a motivation model that considers both the outside environment and internal states.

II. System structure

Fig. 1 shows the appearance of the robot arm, and Fig. 2 shows its degree 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 a main part is about 0.8 kg. A small CCD camera, equipped at the tip of a robot arm, can recognize an external situation. The web camera and the robot arm's actuator are controlled by USB communication.

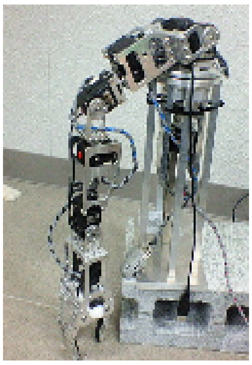


Fig. 1 robot arm

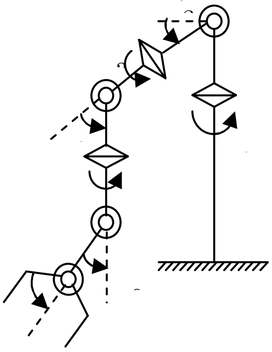


Fig. 2 degree of robot arm

III. Consciousness-Based Architecture

Fig. 3 shows a diagram of the hierarchical structure model called CBA (Consciousness-based Architecture) that relates consciousness to behavior hierarchically. The characteristic of this model is that the consciousness and behavior fields are built separately. In a dynamic environment, the CBA determines the consciousness level for the environment that the robot is most strongly considering, and the robot then selects a behavior corresponding to the consciousness level and performs this behavior. This model is characterized by the consciousness level reaching an upper level so that the robot can select advanced behaviors when a certain behavior corresponding to a particular consciousness level is discouraged by the external environment. In addition, from an upper level behavior, the robot can choose a low-level behavior. The mechanism of this model allows the robot at its pleasure to select the most comfortable behavior among the low-level behaviors in such a way that the robot aims for certain goals.

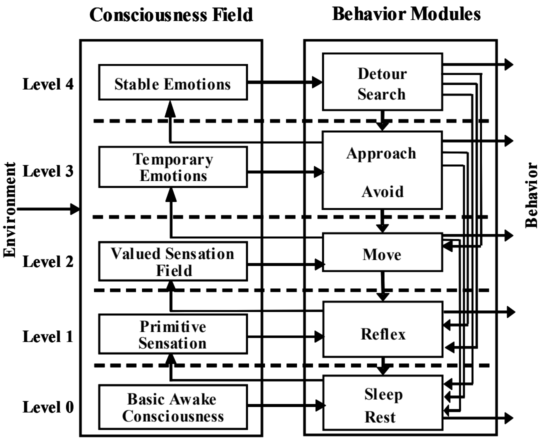


Fig. 3 Consciousness-Based Architecture (CBA)

IV. Flowchart

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

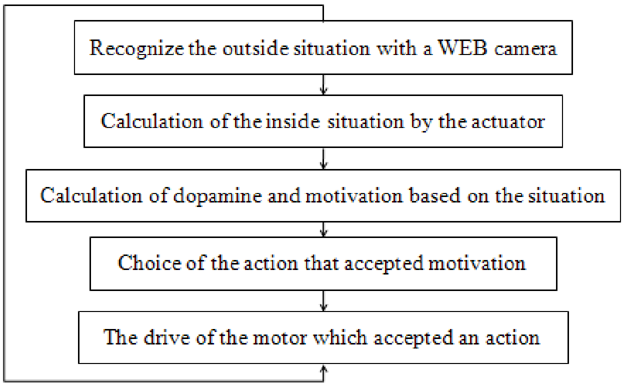


Fig. 4 Flowchart of this system

1. Recognize the outside situation with a Web camera

In this research, we simplify the picture acquired from the Web camera to three kinds, such as green, blue, and other colors We also perform labeling processing so that green and blue are recognized to be qualities of variety-entertainment objects For example, the system may dislike a blue ball and instead like a green ball, which then becomes the favorite. The ability to like something are thus set into the robot arm so that as a result of a labeling process both favorite and disagreeable things can be recognized by the size and form of variety-entertainments objects .

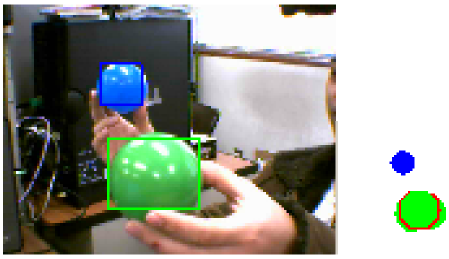


Fig. 5 A former image and a labeling image

2. Calculation of the inside situation by the actuator

The actuator currently used for a robot arm is a DX-117. In operation, this actuator can feed back position, speed, temperature, and other characteristics. Therefore, in real time, you can ask for the temperature and the degree of the rotation angle, and have these reflected by the action of a robot arm, which by its movements indicates a rise in heat or the change in an angle. In relating these values, a robot can be made to express "Tiredness" for example.

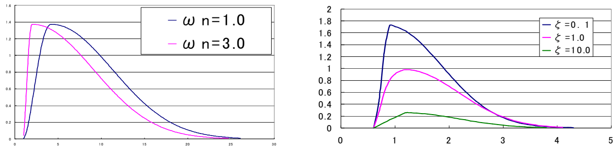
3. Calculation of dopamine and motivation based on the situation

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

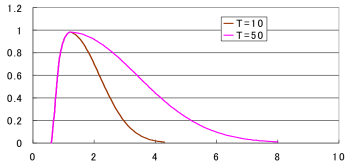
$$\text{Rising} \quad y'' + 2\omega_n \zeta y' + \omega_n^2 y - \omega_n^2 u_{(t)} = 0 \cdots (1)$$

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

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. 6 Motivation model

Based on this, a control model is created, and dopamine is generated with reference to a favorite thing or a disagreeable thing.

ω_n, ζ and T are determined by the outside environment and the internal state. Moreover, they are defined by asking for the total generated dopamine and calculating the secondary delay response in such a way that the total is considered as the input into a robot's motivation.

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.

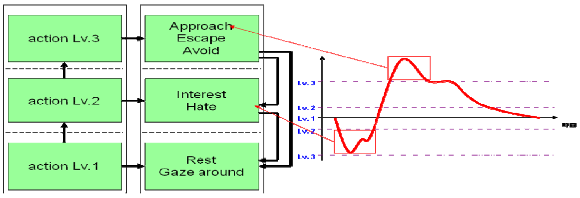


Fig. 7 Choice of the action that accepted motivation

5. The drive of the motor which accepted an action

The robot arm is divided into the shoulder, the elbow, and the wrist, and is driven by giving each control over a finger.

V. Expression of tiredness

A robot arm has the feature that its actions change not only as a result of the outside environment but also internal states. Therefore, it becomes possible to make a robot express tiredness. First, the concept of tiredness is explained. Although various aspects of the factor of tiredness have been considered, the factor of tiredness has not been solved yet. We tried to express tiredness by paying attention to the accumulation of lactic acid. Fig. 8 shows a transition in the lactic acid value at the time of movement, while Fig. 9 shows a transition at the time of the end of the movement.

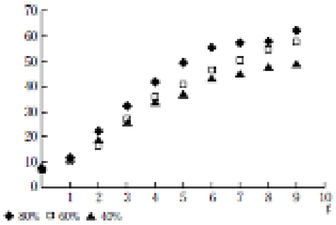


Fig. 8 Transition of the lactic acid value at the time of movement

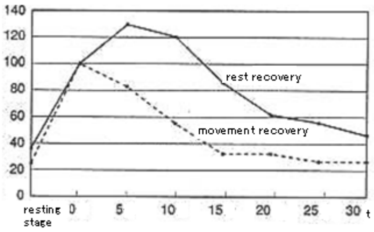


Fig. 9 Transition of the lactic acid value at the time of the end of movement

The speed of a motor and the parameter of motivation were changed by using the graph above. In such a way, the system tried to express tiredness.

Tiredness can be classified into two categories: whole body tiredness and partial tiredness. Whole body tiredness concerns tiredness from moving the whole body greatly and is caused mainly by jogging movements and aerobic workouts. Partial tiredness concerns tiredness of small muscle groups in the hand, shoulder, etc. It is the tiredness which mainly begins in the shoulder and the waist when lifting something. Therefore, whole body tiredness is computed from the internal temperature and the total amount of rotations and is expressed by changing motor speeds and a motivation parameter. By contrast, partial tiredness is computed from the rotation moment of each motor and is expressed by changes to posture positions.

VI. Verification experiment

In order to verify the expression of tiredness, the system verified both whole body and partial tiredness.

1. Whole body tiredness

Since whole body tiredness is defined as tiredness depending on the internal temperature or the total amount of rotations, we investigated each numerical value at the time of operating a robot arm for 5 minutes. Fig. 10 shows the internal temperature; Fig. 11 shows the amount of rotations.

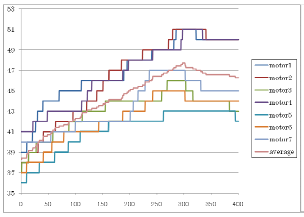


Fig. 10 Internal temperature

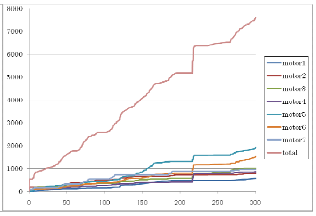


Fig. 11 the amount of rotations

Since the temperature change was lost from the beginning to the end in Fig. 10, it turned out that it is difficult to express tiredness. Moreover, although the value of Fig. 11 was remarkable, since tiredness was related also to the driven time, computations were carried out using the amount of integration and the amount of rotations. Fig.12 shows the integration value of the amount of rotations.

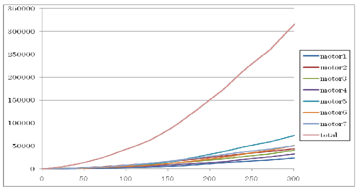
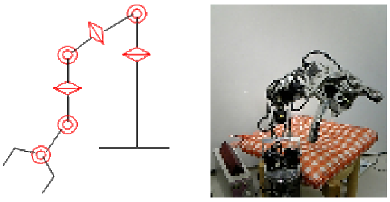


Fig. 12 The integration value of the amount of rotations

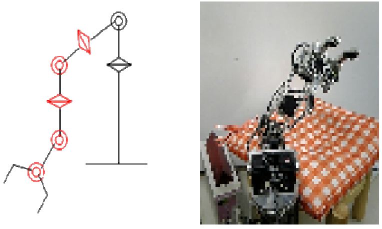
In order to express whole body tiredness using Fig. 12, motor speed and a motivation parameter were changed.

2. Partial tiredness

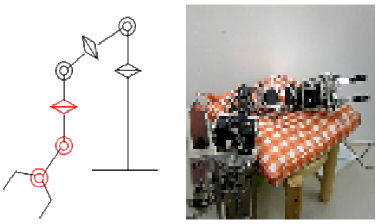
Since partial tiredness is defined as tiredness depending on rotation movements, calculation of the rotation moment was attempted. However, since calculation of the rotation moment did not meet the deadline, only posture change is described. By setting a threshold value as the computed rotation moment, the robot arm can change from usual to light tiredness or from light tiredness to tiredness. Fig. 13 shows the posture change: (a) usual, (b) light tiredness, and (c) tiredness. In Fig. 13(a), an object is followed using all the motors. However, in Fig. 13(b), the object was followed using the motor of an elbow and a wrist, while the motor of the shoulder was stopped. Furthermore, in Fig. 13(c), the object was followed using the motor of only a wrist, while the motor of the shoulder and an elbow were stopped.



(a) Usual



(b) Light tiredness



(c) Tiredness

Fig. 13 Posture change

VII. Conclusion

In this paper, we designed the action of the robot arm so that it reflected both the outside environment and an internal state. It is thought that the development of a new action selection based on tiredness would give a user greater affinity. Since at this time we have advanced to a division of tiredness into two categories, we should express tiredness from now on so as to unify the two measures of tiredness.

VIII. Acknowledgement

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Sports and Culture, Grant-in-Aid for Scientific Research, 2009.

IX. References

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