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Design of robotics arm's behavior in imitation animal consciousness: Development of altruistic behavior

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Abstract**:** Our research has been focused on developing a robot with a "consciousness" like that of a person or an animal to enhance the user affinity of service robots. Our laboratory previously conceived a model of the mechanism of consciousness and action and a related software architecture, called Consciousness-based Architecture (CBA), by which this model can be used to control the action of an artificial animal. Here, we newly theorized a "motivation model" which assumes that certain motives inhere in the actions of sentient beings, and that the motivational processes involved could become part of how a robot determines what action to take. Our motivation model is based on the dopamine-generating mechanism of sentient beings. In the present study, we focus on the altruistic behavior of animals so that the consciousness and behavior of the robot approximate those of an animal. We added altruistic behavior to the CBA and tried to construct a system in which the robot cooperates with the user and chooses altruistic behavior. Our goal is to enhance the user affinity of service robots with this system.

Keywords**:** CBA, Robot consciousness, Robot consciousness

1. INTRODUCTION

At present, not only industrial robots but also so-called "service" robots are being developed swiftly by many researchers around the world. There are various types of service robot, including business robots, research robots, welfare robots, and domestic robots. 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 readily develop a sense of closeness with it. One design goal is that the user will ultimately receive from service robots the emotional benefits experienced in relationships with other conscious beings.

Although a robot may gain user compatibility by being genuinely modeled after a face, it is far more challenging 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. Based on this model, we developed a software architecture we call Consciousness-based Architecture (CBA). CBA introduces an evaluation function for behavior selection. Here, we elaborate on the evaluation function, using the dopamine-based motivational system as its basis.

For the present study, we developed a robotic arm that has six degrees of freedom, so that the arm could autonomously adjust to a target position. Fig. 1 shows an overview of the robotic arm, which 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. In a previous study, as an autonomy action experiment, we applied CBA to the robot arm and inspected the arm's behavior. We thus determined that the arm could successfully perform the maneuvers used in the present study.

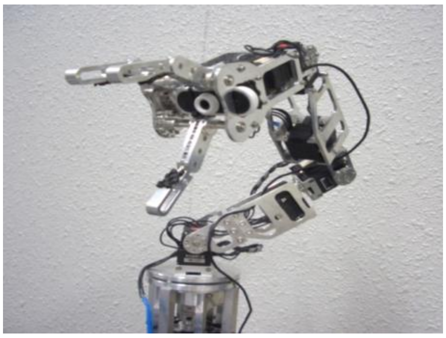

Fig. 1 Overview of robotics arm

2. SYSTEM STRUCTURE

Figure 2 shows the appearance of the robot arm and 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 level of flexibility; the weight of the main part is about 0.8 kg. A small web camera, installed at the tip of the arm, can recognize the external situation. The web camera and the robot arm's actuator are controlled by USB communication.

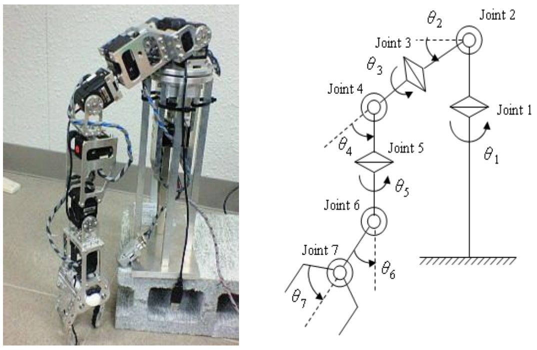

Fig.2 Robot arm and degree of freedom in the robot arm

3. AUTONOMOUS BEHAVIOR

Most robots are pleasing to people because of their unique movements. However, the action choices of robots are very objective in orientation, and we believe action choices that resemble those of subjective human beings and animals are needed to enhance user compatibility. Therefore, we at first considered the structure of a sentient action. When an animal, including a human being, takes an action, it can be represented by a series of steps, such as "Recognition → Comprehension → Motivation → Action." Typically, the action of the robot tends to eliminate motivation and instead engage in the simple flow "Recognition (Comprehension) → Action." Figure 3 shows the ideal series of steps for a robot with both objective and subjective behavior.

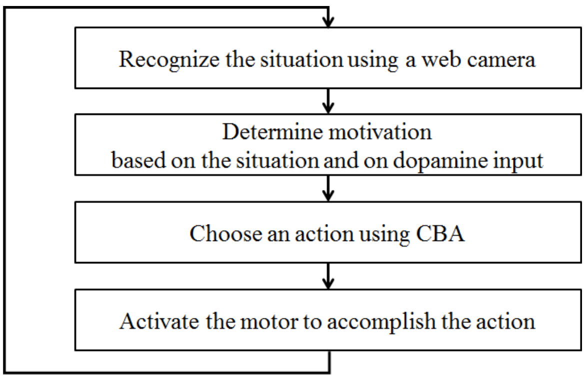

Fig. 3 Flowchart of this system

3.1 Recognize the situation using a web camera

The first step of the "humanized" robot's system would be to recognize a situation. For this purpose we devised a labeling image (Fig. 4), taken by the web camera installed on the robot hand. We programmed the system to divide the image into green, blue, red and flesh-colored blobs and extract the shape, size, and center of gravity position (Fig. 4). From this information and the posture of the robot arm, the robot could recognize the position and its distance from the target-color object. Furthermore, the system memorized the central point for three frames.

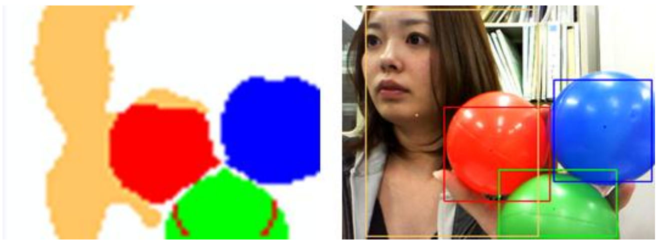

Fig. 4 Simplified image and labeling image

3.2 Determine motivation based on the situation and on dopamine input

When a human and an animal interact, changes occur in the dopamine level in the brains of both the human and the animal. We used the dopamine-generating locus as the model for determining the robot's motivation and copied it for use in the control model. The control model is shown below. In Fig. 5, the graph shows sample changes in ω_n , ζ and T .

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

Decaying $$y=e^{-t/T}$$

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

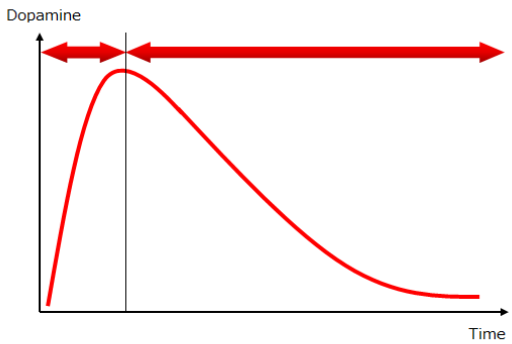

Fig. 5 Dopamine model

In the control model, dopamine is generated with reference to pleasant or disagreeable stimuli represented in variables.

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

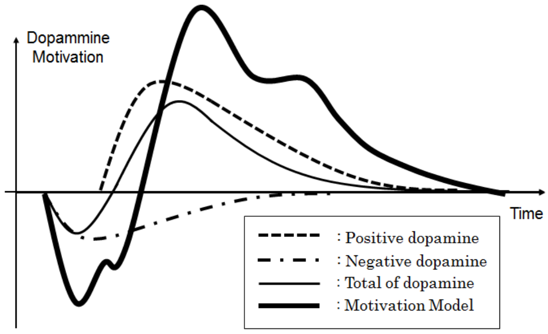

Fig. 6 Motivation model

3.3 Choose an action using CBA

Figure 8 shows a diagram of CBA, which relates consciousness to behavior hierarchically. In this model the consciousness behavior fields are built separately. In a dynamic environment, this model determines the consciousness level appropriate to the environment, and the robot then selects the behavior corresponding to that consciousness level and performs the behavior. When certain behavior corresponding to the consciousness level is discouraged by some external environmental factor, the consciousness level approaches an upper level so that the robot can select an advanced behavior.

Alternately, while operating at upper-level consciousness the robot can choose to perform a low-level behavior. The mechanism of this model is that it selects the optimum behavior within the low-level behaviors, to achieve the robot's goals.

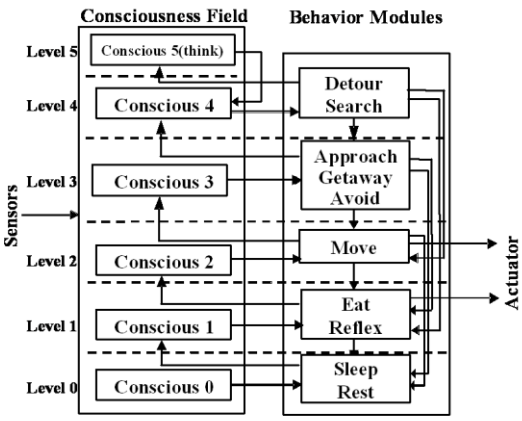

Fig. 7 Consciousness-based Architecture (CBA)

3.4 Activate the motor to accomplish the action

The action level was set up by dividing a robot's motivation by a fixed value. In this way, the actions that could be chosen for each action level were limited. Figure 8 shows the robot's choices in this system.

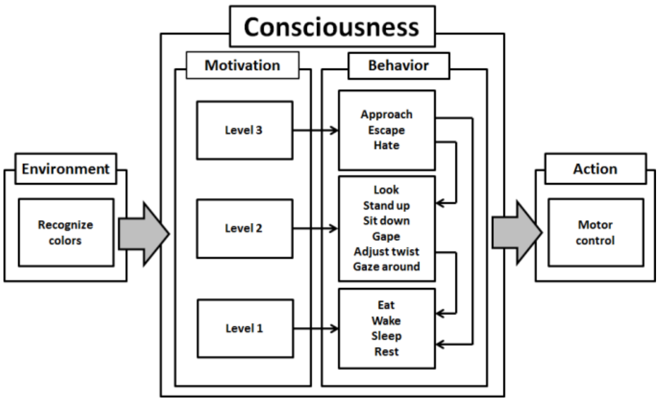

Fig. 8 Choice of action based on motivation

4. ALTRUISTIC BEHAVIOR

Our robot acts in proportion to the value of the motivation. For example, when the robot sees a favorite object, the value of the motivation rises and the robot approaches or catches the object. On the other hand, when the robot sees an object it dislikes, the value of the motivation drops and the robot avoids the object. This behavior of the robot can be considered to be selfish. In the present study, we focus on the altruistic behavior of animals so that the consciousness and behavior of the robot approximate those of an animal. We added altruistic behavior to the CBA so that the robot cooperates with the user, and our goal was to construct a system in which the robot would choose altruistic behavior.

4.1 Flow of imitated action

The altruistic behavior that we added to the CBA is an imitation of the action *sit*, which is a typical command given to a dog. The owner says "Sit." whereupon the dog sits on his hind legs and waits for the owner's direction. The dog acts altruistically during the waiting time, knowing that the appropriate behavior will get him what he wants. In this case, the altruistic behavior includes conquering his desire to simply chase the ball and instead cooperating with his owner. We imitated the *sit* dog command and established an altruistic behavior that the robot could perform, as shown in Fig. 9.

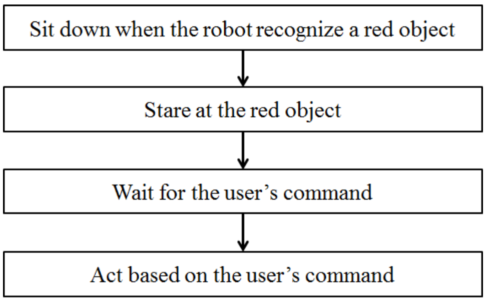

Fig. 9 Flow of altruistic behavior

4.2 Algorithm for altruistic behavior

The robot recognizes the outside situation using the web camera installed on its hand. We programmed the robot to act based on switching from selfish consciousness to altruistic consciousness when the robot sees a red object.

If the robot sees a red object, the robot throws itself into a posture, like the position assumed by a dog when the *sit* command is given. When the user moves the red object, the robot keeps the object in its sight as if it wishes to chase the object. The robot waits until the user gives directions. If the value of the motivation changes while the robot is waiting, the robot doesn't choose its action based on the motivation; instead, it follows the user's direction. If the user brings the object near to the robot, the robot judges that it could catch the object, and it thus tries to catch it. On the other hand, if the user keeps the red object at a distance from the robot, the robot judges that it could not catch the object, and it thus tries waits for the user's direction.

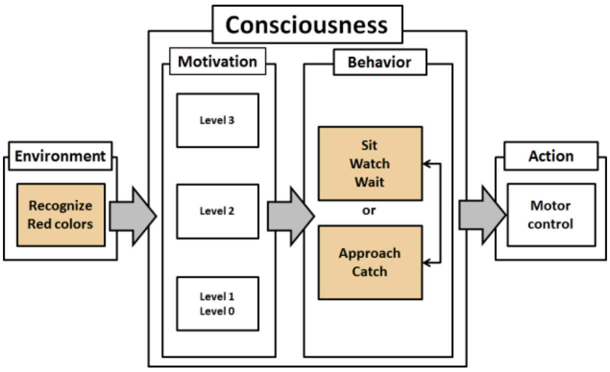

Fig. 10 Choice of altruistic behavior based on altruistic consciousness

5. VERIFICATION EXPERIMENT

We added the system of altruistic behavior to the CBA and verified the subsequent action of the robot experimentally. Figure 11 shows a result of the verification experiment. The robot saw a red object and sat down (A). Then, the robot stared at the red object and waited for the user's direction to catch it (B). If the motivation rose during this time, the robot went on waiting without being selfish (C). The user directed the robot to catch the red object by bringing the subsequent (D). The robot approached the red object (E) and caught it (F).

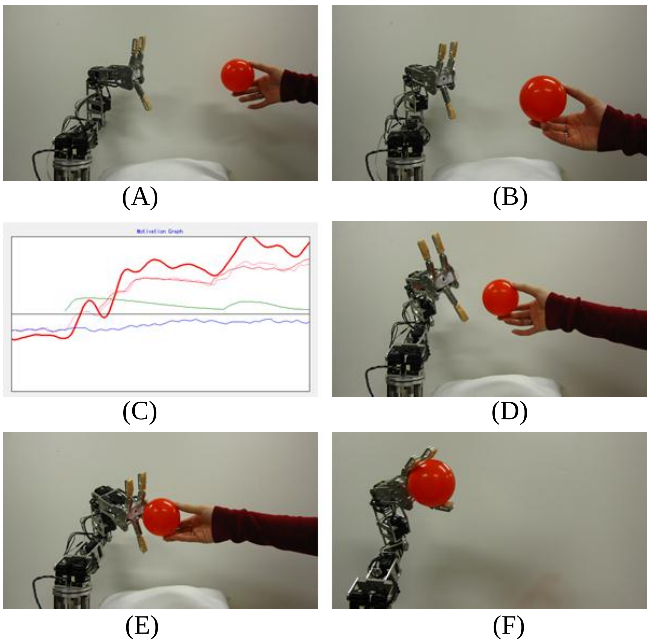

Fig. 11 The action of a robot arm

6. CONCLUSION

We created a system of altruistic behavior for a robot, which acted based on not selfish consciousness but altruistic consciousness. In this case, the robot cooperated with the user when it saw a red object, as shown in the result of the verification experiment. We thus confirmed the effectiveness of this system.

Our system of altruistic behavior will enable the robot to act sophisticated. For example, when the robot sees an object it does not like as well as a red object, the robot will appear to have difficulty following the user's directions. Eventually we would like the robot to express embarrassment at such a predicament. We believe such behavior would enhance the user affinity of the robot.

7. ACKNOWLEDGEMENT

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8. REFERENCES

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