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Design of robotic behavior that imitates animal consciousness: Construction of the user-recognition system

Motoki Yoshida Kei Ueyama 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

***Abstract*:** Our research has been focused on developing a robot with "consciousness" like people 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 software architecture based on this model that can be used to control the action of a robot, called the Consciousness-Based Architecture (CBA). Here, we built on this model both theoretically and practically. First, 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 the robot's determination of action. Our motivation model is based on the dopamine-generating mechanism of sentient beings. Then, as a practical step toward developing an emotionally interactive robot, we developed a user-recognition system using a CCD camera.

***Keywords*:** CBA, Consciousness of the robot, Motivation of the robot, the user recognition

I. INTRODUCTION

At the present time, not only industrial robots but also so-called "service" robots are being quickly developed. There are various types of service robots: business robots, research robots, welfare robots, and domestic robots, to mention a few. 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 emotional 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 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. 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. Previously, as an autonomy action experiment, CBA was applied to the robot arm and the behavior was then inspected.

This paper describes a user-recognition system that can judge a specific person using a CCD camera, and integrates the user-recognition system and CBA. We tested the system to identify target users from among five persons.

Fig. 1 Overview of Robotics arm

Fig. 2 CCD camera

II. SYSTEM STRUCTURE

Fig. 3 shows the appearance of the robot arm, and Fig. 4 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, installed 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. 3 robot arm

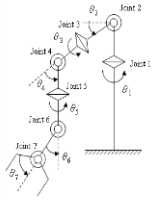


Fig. 4 degree of robot arm

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 objective in orientation. 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 sentient action. When an animal, including a human being, takes some action, it can be represented by a flow chart such as "Recognition → Comprehension → Motivation → Action", shown in Fig. 5. On the other hand, the action of the robot tends to eliminates motivation in the simple flow "Recognition (Comprehension) → Action"

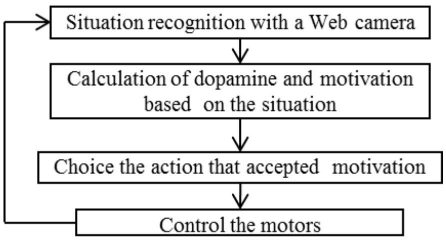


Fig. 5 Flowchart of this system

2. Situation recognition with 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. 6), taken by the Web camera installed on the robot hand. We programmed the system to divide the image into green, blue, and flesh-colored blobs and extract 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 its distance from the target-color object. Furthermore, the system memorized the central point for three frames.

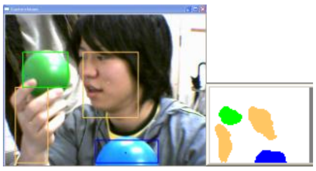


Fig. 6 Web camera image and a labeling image

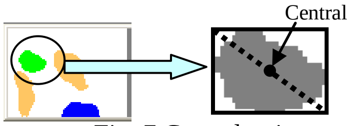


Fig. 7 Central point

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 was regarded as model for determining the robot's motivation, and was copied for the control model. The control model is shown below. In the graph, sample changes in , ω_n and ζ are shown. 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 rising
ζ : braking rate : height of the peak of a rising
T : time constant : attenuation performance

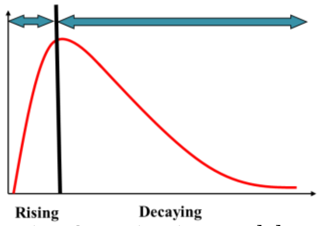


Fig. 8 Motivation model

In the control model dopamine is generated with reference to pleasant or disagreeable stimuli with variables ω_n, and T are determined by the outside environment and the internal state, respectively. Moreover, it is defined by asking for total of the 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 actions that could be chosen for each action level were limited.

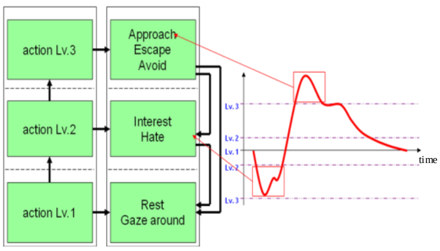


Fig. 9 Choice of the action based on motivation

5. Consciousness architecture (CBA)

Fig. 10 shows a diagram of the 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 appropriate to the environment, 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 that the robot can select an 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 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.

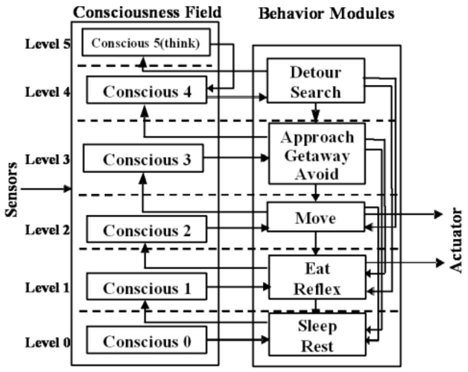


Fig. 10 Consciousness-based Architecture (CBA)

IV. USER-RECOGNITION SYSTEM

4.1. Outline of the system

From an image provided by the CCD camera, the system detects a moving object and carries out a search in its data domain. It pays attention to the shape and color of the object and determines whether it is either a non-human object or a human being. In addition, it detects the parts of person's face and compares each person it encounters with user information on a database. The flow for user recognition is shown in Fig. 11.

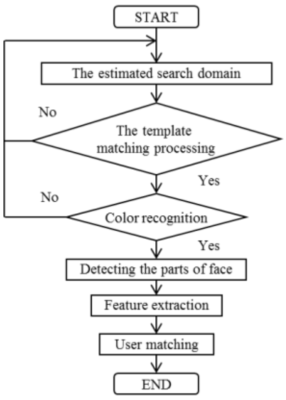


Fig. 11 System flow

Fig. 12 Difference Image

Fig. 13 the maximum height

4.2. The estimated search domain

This process estimates the domain of a human being is from the information provided by the differences between the frames.

4.2.1. The detection of height

This system detects the maximum height Y of each X point in the image from the differential image which it acquired from the differences between the frames. The image from these detections is shown in Fig. 12.

4.2.2. Average

This system makes a smooth graph by creating an average by 40 pixels of values of the height Y which it detected at the maximum, because the position sensing of the domain is difficult only at the maximum height Y. An image of average values is shown in Fig. 14.

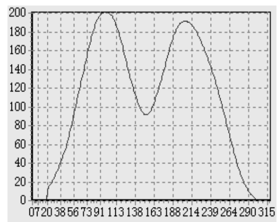


Fig. 14 Graph of the average

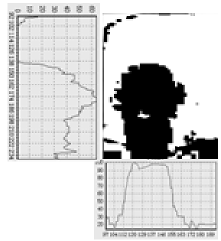


Fig. 15 Histogram

4.2.3. The detection of the search domain

From the graph, the system detects the part at the top and estimates the position of the human being. Next, it scans from a person's position detects the point below the top or the point that is lower than 1/3 from the height of the person's position. One can assume that a part surrounded by points is a search domain.

4.3. The template-matching processing

When this system begins its operation, it reads the template that imitates the head of a person. The outline acquired in the previous process is compared with the template. The size of the template changes according to the size of the search range. Generally, this process requires a great deal of calculation time. Real-time operation is achieved by reducing the number of comparisons. When the matching rate is higher than the threshold and reaches its maximum, the position is output as the position of a human face.

4.4. Color recognition

An image is difficult to identify using only conventional processing. The system has to finally confirm that the image is that of a human being. Skin color is used to ultimately determine this, using the template-matching process to decide the identity and position of the human image. In this case, color information processing uses the HSV color model.

4.3. Detecting the parts of face

The robot automatically makes a histogram of external color pixels for the X and Y coordinates and judges the position of the face from the histogram. The image of the histogram is shown in Fig. 15.

Then, it detects the eyes and nose of a face through a Gabor filter in a 90 degrees direction.

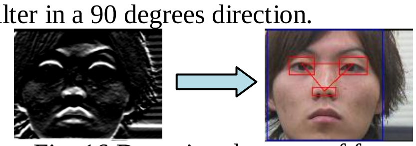


Fig. 16 Detecting the parts of face

Gabor Filter

$$g(x,y,\lambda,\theta,\psi,\sigma,\gamma)=\exp\left(-\frac{x'^2+\gamma^2y'^2}{2\sigma^2}\right)\cos\left(2\pi\frac{x'}{\lambda}+\psi\right)$$

$$x'=x\cos\theta+y\sin\theta \qquad y'=-x\sin\theta+y\cos\theta$$

λ: The cosine component of wavelength

θ: The direction of the striped pattern on the Gabor function

ψ: A phase offset $\quad\gamma$: A aspect ratio

4.4 Feature extraction

As shown in Fig. 17, the distance from a nose to eye is A and the distance between the eyes is B. The robot computes B/A.

It combines and equalizes each image through a Gabor filter pass every 30 degrees. The new image is shown in Fig. 18.

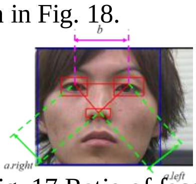


Fig. 17 Ratio of face

Fig. 18 Gabor filter picture

4.5. User matching

It compares the extracted features with the information of the people stored in the database, and checks whether the user is a known person.

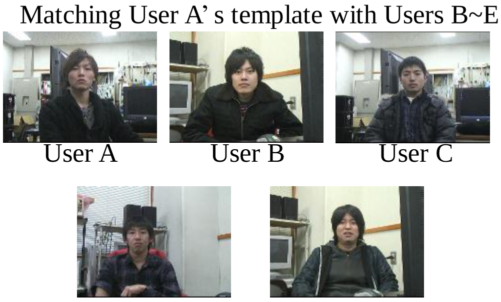
V. Experiment

5.1. Experimental method

The system's performance was evaluated with two experiments.

Template matching rate:

1. In whether a user is a particular target person using five different target persons.
2. Matching User A' s template with Users B~E.



User A User B User C

User D User E

Fig. 19 Objects

5.1. Experiment 1

The result of experiment 1 are shown in Table 1. This system had about a 70 percent recognition rate of the target person. However, since the user's expression always is not the same, the template matching rate can fall.

Tab.1 Result of experiment 1

	User1	User2	User3	User4	User5
1times(%)	77	69	73	70	73
2times(%)	71	73	73	70	76
3times(%)	63	72	68	72	70
4times(%)	72	72	71	71	70
5times(%)	70	71	69	71	50
Average(%)	70.6	71.4	70.8	70.8	67.8

5.2. Experiment 2

The results of experiment 2 are shown in Table 2. When the user differed from the target person, the matching rate dropped below 50 percent.

Tab.2 Result of experiment 2

	User2	User3	User4	User5
1 times(%)	48	47	53	48
2 times(%)	45	41	44	44
3 times(%)	52	41	49	46
4 times(%)	45	43	50	44
5 times(%)	57	46	48	55
Average(%)	47.4	43.6	48.8	46.8

VI. CONCLUSION

In this paper, we created a user-recognition system using a CCD camera. It became possible to identify the target person among 5 different people.

In the future, we will further develop the theoretical and practical tasks needed to design a robot with user affinity, and one that recognizes the user's expression.

VIII. Acknowledgement

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Sports and Culture, Grant-in-Aid for Scientific Research, 2011.

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