Design of robotic behavior that imitates animal consciousness

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Abstract

A six degrees of freedom serial hand is designed to move toward an object in an unseen environment. A consciousness-based architecture (CBA) we developed, i.e., a hierarchical human development model showing the relationship between consciousness and behavior, is used to imitate a human groping action. As it moves toward the target, the robot collects information which allows the robot to avoid obstacles. CBA organizes such information in order to determine a path for retracing its motion to the origin without contacting the obstacles it previously avoided. Experimental results show that CBA successfully enables the hand to reach its goal while avoiding obstacles.

Key words: CBA, Learning, Reflection, Hierarchal Structure.

1 Introduction

Recently, robots other than industrial robots (such as home robots, personal robots, medical robots, and amusement robots) have seen active development. Further development of these robots requires improvement of both their intellectual capabilities and manual skills as well as further increases in user compatibility. Up to now, these areas 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, no fatiguing control, robot "friendliness" (i.e., sympathetic use), and human-like capricious behavior Endowing the robot with "consciousness" of the kind identified in humans and animals is a part of these requirements.

In our laboratory we have 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 have 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 the ability to autonomously adjust to a target position. The robotic arm that we use 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. An experiment was conducted in a work space in which were arranged two cylindrical obstacles. The robotic arm attempted to eventually reach the landmark object while evading these obstacles.

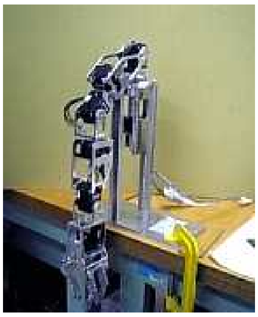
When a person attempts to grasp an object in a box whose internal structure is unknown, he gropes with his hand in the box. In the present study, this groping action is performed by the robotic arm by means of CBA. Holding and carrying tasks, such as approaching a target position, avoiding obstacles, and detouring around obstacles, are performed autonomously.

In this paper, a robot's autonomous behavior in relation to a target position is achieved by using CBA. It is shown experimentally that the robotic arm can trace an optimal return route by studying the route to the target position. These results verify the utility of CBA.

2 System structure

Figure 2-1 shows an overview of robotic arm used by this experimental test. Figure 2-2 shows a schematic view of the robotic arm's degree of freedom. Figure 2-3 shows a diagram of the experimental system's configuration. The robotic arm manufactured by Kihara Iron Works is 450 millimeters long and has 6 degree of freedom. The robotic hand part of robotic arm has 3 fingers and 1 degree of freedom. Additionally, there is a small CCD camera (MTV-54K0N[)] in the robotic hand.

We applied a Dynamixel DX-117 manufactured by ROBOTIS CO., LTD. as an actuator in each joint of robotic arm. The DX-117 contains a motor, decelerator, and an angular sensor in a single unit. This actuator can perform position control by providing the robotic arm with a target angle while limiting its torque and speed, and so on. The actuator uses an RS485 transmission method. Hand wiring can be simplified by connecting each actuator used as a joint of the robotic arm in the form of a daisy chain.



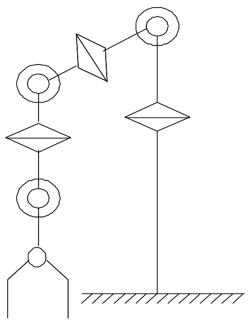


Fig. 2-1 Overview of robotic arm Fig. 2-2 Arrangement chart of degree of freedom

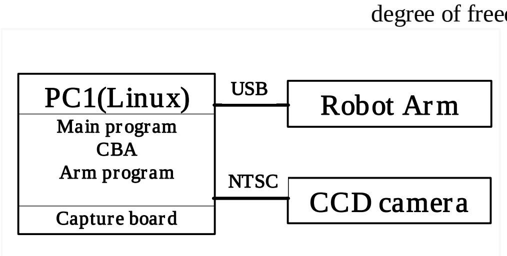


Fig. 2-3 System structure of the robotic arm

3 Autonomous behavior

3.1 The learning control system of the robotic arm

Figure 3-1 shows the experimental environment consisting of a robotic arm, the target object, and two circular cylinders as obstacles. In this figure, consciousness architecture was applied in regard to the space between the robotic arm in the default position (state S) and the target position (state G).

In the first trial, the robotic arm approaches its destination from state S (Approach). If the robotic arm comes in contact with an obstacle, it approaches again (Avoid・Detour) to state G by rotating each joint accordingly. After that, the consciousness architecture considers the return route based on conventional information, allowing the robotic arm to return to the default position (state S) without contacting another object.

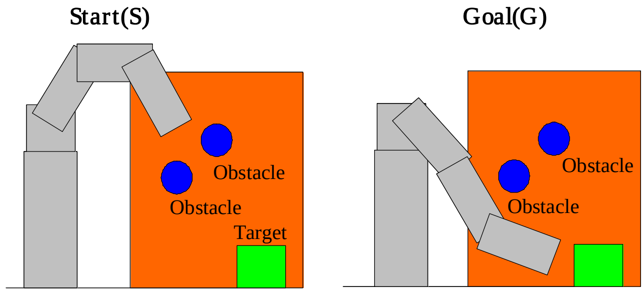


Fig. 3-1 Schematic diagram of experimental environment

3.2 Consciousness architecture (CBA)

Figure 3-1 shows a diagram of the hierarchical structure model called CBA (Consciousness-based Architecture) that relates consciousness to behavior hierarchically. In this model, the consciousness field and the behavior field are built separately. In a dynamic environment, the robotic arm determines the most appropriate consciousness level in relation to this environment and selects an action corresponding to its awareness of its environment and then performs the action. This model is able to advance to an upper level of consciousness and act accordingly when an earlier action was discouraged by some factor in the external environment.

Additionally, upper-level consciousness can choose to perform lower-level actions. The mechanism of this model is that it selects most comfortable behavior in the low-level behaviors at pleasure, so the robot aims for goals.

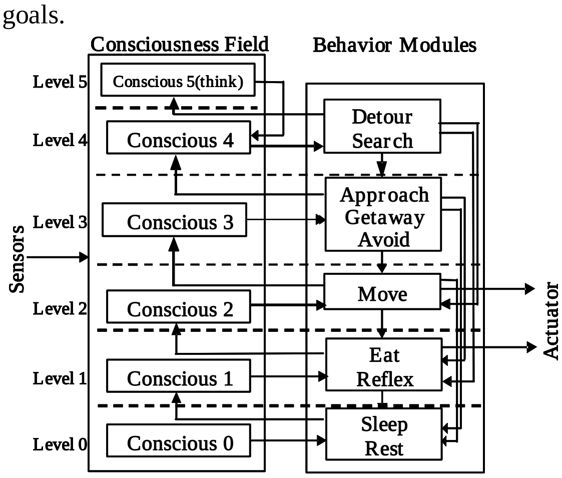


Fig. 3-2 Consciousness-based Architecture (CBA)

3.3 Evaluation function

The following are evaluation functions to select the behavior in CBA in order to imitate human groping action.

$$C_i(t) = \sum_{j=1}^{2} \left|\beta_{ij}(t)\right| + \sum_{j=1}^{2} \left|\zeta_{ij}(t)\right| \qquad (i = 0 \ldots p) \qquad (3\text{-}3\text{-}1)$$

$$I_i(t) = \sum_{j=1}^{2} \beta_{ij}(t) + \sum_{j=1}^{2} \zeta_{ij}(t) \qquad (3\text{-}3\text{-}2)$$

In eq.(3-3-1), $C_i(t)$ is an evaluation function for determining the robot's consciousness level, $\beta_{ij}(t)$ is degree of perception of an external object, and $\zeta_{ij}(t)$ is the expected value necessary for the robot to perceive an external object. The variables are normalized within ±1. If the robot is in a positive state and "feels good," they are positive values, and if robot is in a negative state or "feels uncomfortable," they are negative values.

First, $C_i(t)$ of each level was calculated and the level that the robot is most aware of is determined as the robot's actual level of consciousness. Next, each $I_i(t)$ of each behavior in the level for determining the robot's behavior is calculated, and the largest $I_i(t)$ value or a behavior that makes robot most comfortable is selected as the robot's behavior, as expressed in eq.(3-3-2). Thus the robot's autonomous behavior is realized.

3.4 Autonomous behavior

A geometric model of the robotic arm was constructed and experiments were performed regarding autonomous detour and shuttle movements. Figure 3-4-1 shows the experimental environment. Two cylindrically shaped obstacles are placed between the default position and the target position. In the experiment, the robotic arm is not given information regarding the target position and the obstacle's positions.

When robotic arm arrives at the target position, the default position becomes a renewed target position. It is intended that the robotic arm follow the optimal return route without contacting the obstacles during its return movement.

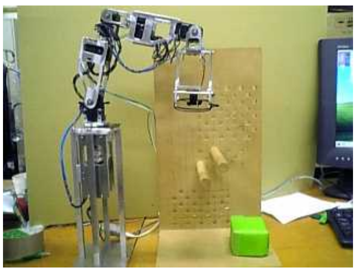


Fig. 3-4-1 Experimental environment

Figure 3-4-2 shows an experimental result. Figure 3-4-2 shows the movement of the robot's consciousness level during the arm's approach and return. First, the consciousness level becomes level-2 and the robotic arm selects the behavior of "move" and goes straight to the target object if the CCD camera in the robot hand locates the target object. At T1, the robotic arm senses obstacles when it comes into contact with them. The consciousness level moves to level-4 and the robotic arm selects the behavior of "detour" and discourages its previous movement. The robotic arm then performs a "detour" action, and when the robotic arm considers that it has finished detouring the obstacle, it memorizes its position as a sub-goal and again selects the "move" action of level-2 (T2). When the robotic arm reaches the target position by repeating "move", "approach", and "detour" (T3, T4), the robotic arm stops (T5). In the approach route, the robotic arm contacted the obstacles twice. However, it could return to its default position without contacting obstacles by running through the sub-goals (T7).

As the robotic arm reaches its default position, its sense of safety increases little by little. It selects the behavior of "rest" of level-0, and ceases its action.

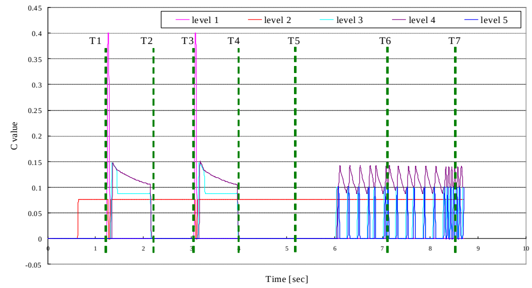


Fig. 3-4-2 Temporal data of C value at autonomous behavior

4 Model correlating between mind and body

4.1 Development of correlative model between mind and body

We developed a correlative model between the mind and body. This model integrates "cognition," "consciousness," "behavior," and "circulatory physiology." CBA is used as a function of "cognition," "consciousness," and "behavior." A model of circulatory physiology that integrates a model in which the human circulatory system is integrated called "HUMAN", and a model of the heart beat, "Beat by Beat", is used as function of "circulatory physiology." This model can calculate stressors and the degree of stress and can simulate stress response, tiredness, and changes in hormone level during exercise[2] (Fig.4-1).

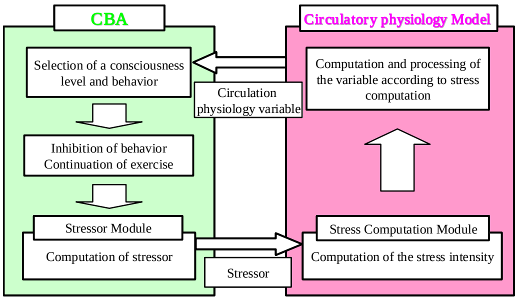


Fig. 4-1 Bilaterally linking the two models of CBA and circulatory physiology

4.2 Method of simulation

An artificial animal was given an exercise stress test by exercising it at an intensity of 88% for 15 minutes. Changes in neurotransmitters and blood lactate and hormone levels were compared to real data.

4.3 Experimental results

Figure 4-3-1 shows the simulation results and those from a human experiment regarding noradrenaline in the blood[3]. Figure 4-3-2 shows the results regarding blood lactate. The graph shows that noradrenaline in the blood and blood lactate influence the artificial animal's condition regarding tiredness and flush.

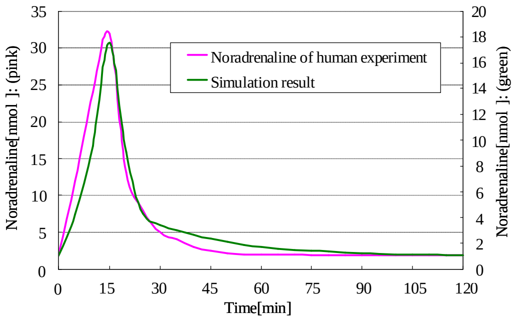


Fig. 4-3-1 Simulation result of noradrenaline by exercise stress

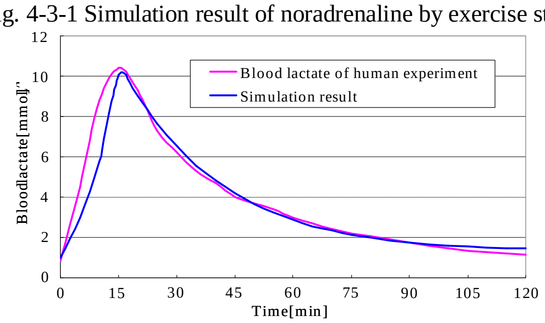


Fig. 4-3-2 Simulation result of blood lactate by exercise stress

5 Conclusion

In this paper, consciousness architecture (CBA) was applied as a control algorithm for the autonomous behavior of a robotic arm. Experiments were conducted in which a robotic arm reached for a target position in an unknown environment by imitating human groping action. The robotic arm established sub-goals in determining an approach route and used these sub-goals in returning to its default position without contacting obstacles.

We integrated models of CBA and circulatory physiology and imposed exercise stress on the model". We estimated an artificial animal's stress and found that the simulation result were similar to those obtained in a human experiment. In a future study, we will load the integrated models of CBA and circulatory physiology into the robotic arm and evaluate the robotic arm's behavior.

6 Acknowledgements

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