Autonomous control of a robot arm based on contact with an object

Motoki Shimono

Graduate School of Computer Science
and System Engineering
Kyushu Institute of Technology
680-4, Iizuka City, Fukuoka, Japan, 820-8502
shimono@imcs.mse.kyutech.ac.jp

Eiji Hayashi

Department of Mechanical Information
Science and Technology
Kyushu Institute of Technology
680-4, Iizuka City, Fukuoka, Japan, 820-8502
haya@mse.kyutech.ac.jp

Abstract

In this paper, I focused on developing a robot arm with three degrees of freedom and an autonomous function. I modeled my research on the actions of animals, which adjust well to environmental change, and aimed for control of an autonomous robot that would imitate the action of an animal. Our laboratory developed a software architecture to control the action of the robot by introducing an evaluation function for action choice into the hierarchically structured model. This is the element that specifically connects the consciousness of the robot with its action, and I named it Consciousness-based Architecture (CBA). In this research, I ran an experiment on a search action for a robot arm executing a detour around obstacles and arriving at a target position. An experiment was performed to evaluate the effectiveness of CBA, and its results are discussed. I let the robot arm imitate the groping movement of a human being and allowed a search action to proceed. In the case of an outward trip, the robot arm recognized the positions of obstacles by touching them, and it avoided these obstacles by executing detours. As a result, the robot arm arrived at the target position while memorizing the course of detours around the obstacles that it recognized.

Key words: *robot arm, evaluation function, Consciousness-based Architecture, autonomous function*

1. Introduction

The Japanese robots industry developed for the field of manufacturing has played a key role in producing robots that can assemble cars and operate precision instruments. [1] Hence, in this research, I focused on developing a robot arm with three degrees of freedom and an autonomous function. Fig.1-1 shows the system constitution of this research; Fig.1-2 presents a diagram showing the placement of the degrees of freedom of the robot arm.

This arm is not equipped with sensors to the outside world and cannot take in nearby environmental information before touching it. Therefore, I let the robot arm imitate the groping movement of a human being and allowed a search action to proceed. This paper describes control of a joint angle by a computed torque method, the consciousness architecture incorporated in the robot arm that allows it to act on a search, and an experiment of a course search.

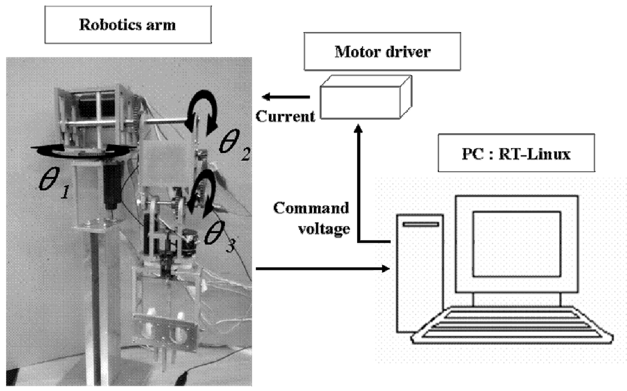


Fig. 1-1 Schematic diagram of the system structure for the robot arm

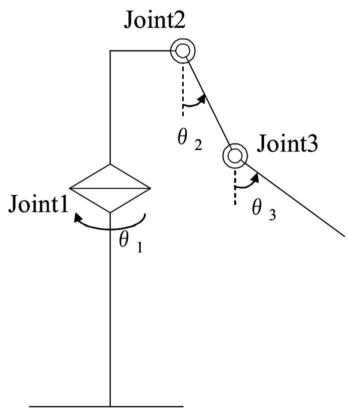


Fig. 1-2 Overview of the 3 DOF of the robot arm

2. Positioning of a robot arm by a computed torque method

A computed torque method is a control technique to make compensations by a reverse dynamics calculation that does not consider centrifugal force and Coriolis force to be agitation. [2] Expression (2-1) below is an exercise equation for motors; expression (2-2) is an exercise equation for a robot arm by the Lagrange method; and expression (2-3) is a law of control.

$$J\ddot{\theta} + C\dot{\theta} = \tau \qquad (2\text{-}1)$$

J: Rotor inertia $[kgm^2]$
C: Braking constant $[kgm^2/\mathrm{sec}]$
τ : Torque $[N\,m]$

$$\tau = M(\theta)v(t) + h(\theta,\dot{\theta}) + g(\theta) \qquad (2\text{-}2)$$

$M(\theta)$: inertia matrix
$h(\theta,\dot{\theta})$: considering centrifugal force and coriolis force
$g(\theta)$: gravity

$$v(t) = \ddot{\theta}_r + K_P(\theta_r - \theta) + K_d(\dot{\theta}_r - \dot{\theta}) \qquad (2\text{-}3)$$

θ_r : aim angle[deg ree]

Each feedback gain is derived with a pole assignment technique. [3] Two poles constitute conjugate imaginary poles, and I assume $s = -\alpha \pm j\beta$ And when I assume $\alpha = \zeta\omega_n$, $\beta = \omega_n\sqrt{1-\zeta^2}$, each feedback gain is found according to expressions (2-4) and (2-5):

$$K_d = \frac{2J\omega_n - C}{M(\theta)} \qquad (2\text{-}4)$$

$$K_p = \frac{J\omega_n^{\ 2}}{M(\theta)} \qquad (2\text{-}5)$$

In addition, each parameter is demanded through consideration of the response and the greatest electric current which a motor permits experimentally. I show a result for a shoulder joint in Fig.2-1. I assumed parameters which determined feedback gain $\alpha = 30,\ \zeta = 0.90$.

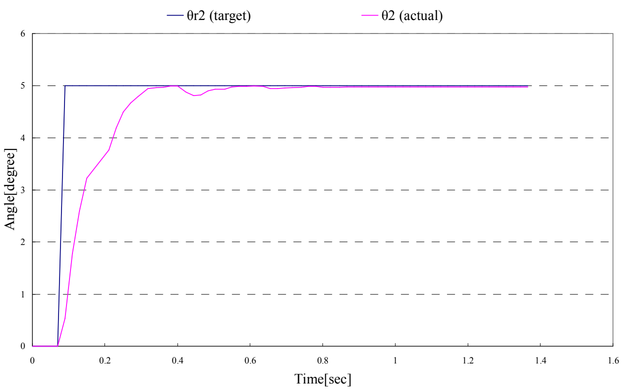


Fig. 2-1 Response of Joint2

3. An autonomous action

3-1 Consciousness-based Architecture (CBA)

Fig. 3 shows a summary of a search action in this research. I applied CBA to a robot arm at level 5 this time. The robot arm moves the shoulder (B) and elbow (C) from (S), which is in an appropriate initial state, and it leads to the aim state (G), while detouring around an obstacle.

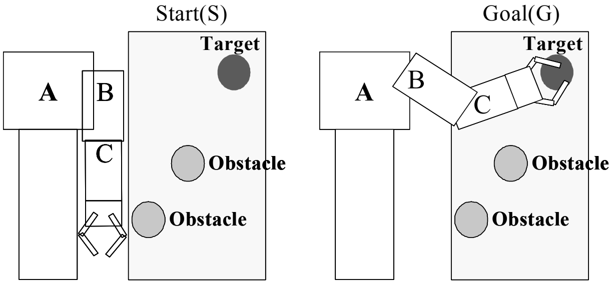


Fig. 3 Schematic diagram of the experimental environment

In addition to the robot arm shown here, our laboratory constructed a hierarchically structured model based on an expression mechanism model of consciousness and the action of an animal. Table 3-1 shows a consciousness module and a restraint object, aspects of an action module applied in this research .

Table 3-1 Details of consciousness, behavior, and deterrent at each level

Level	Consciousness	Behavior	Deterrent
5	Memory for an obstacle	think	A startup to an initial position
4	Memory for an obstacle	detour	A stop of link AB,bc by contact
	Confirmation of an assistant goal position	search	
3	Confirmation of fingers position	avoid	A stop of link AB,bc by contact
	Confirmation of an aim position		
	Confirmation of the obstacle position where a robot arm		
2	Confirmation of fingers position	move	A stop of link AB,bc by contact
	Confirmation of an aim position		
1	************	reflex	A stop of link AB,bc by contact
0	************	sleep	************

In explanation of this hierarchical structure model, a consciousness level first emerges at 1 when a performed action is restrained. A robot arm then makes the best choice from actions on a lower level.

3-2 An evaluation function for behavior choice

Various elements participate in the ground rule of an animal. The thing which a function makes inside the state of an animal is "an evaluation function." In this experiment; an evaluation function assumes an outside environmental state to be a component. Expression (3-1) defines the strength of consciousness Ci of level i in a time t ;expression (3-2) defines an evaluation function that chooses an action:

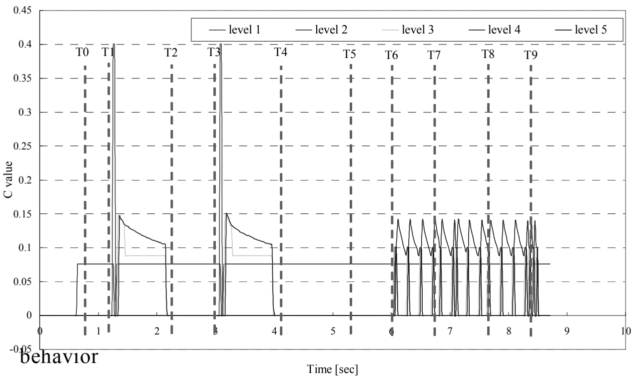
$$C_i(t) = \sum_{j=1}^{N_E} \left|\beta_{ij}(t)\right| \qquad (i = 0 \ldots p) \qquad (3\text{-}1)$$

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

where N_E =the number of things outside perception, and β_{ij} = the degree of the physical outside perception.

4. An autonomy action experiment

I applied an action module and an autonomy action algorithm that I built into a robot arm. I then experimented with a diplomatic shuttle action using these. I tested the action in the environment shown in Fig. 3. In the test, I gave the robot arm only coordinate information about the aim position, none about obstacles. When the fingers arrived at the aim position, the robot arm changed its initial position to the new aim position and moved.



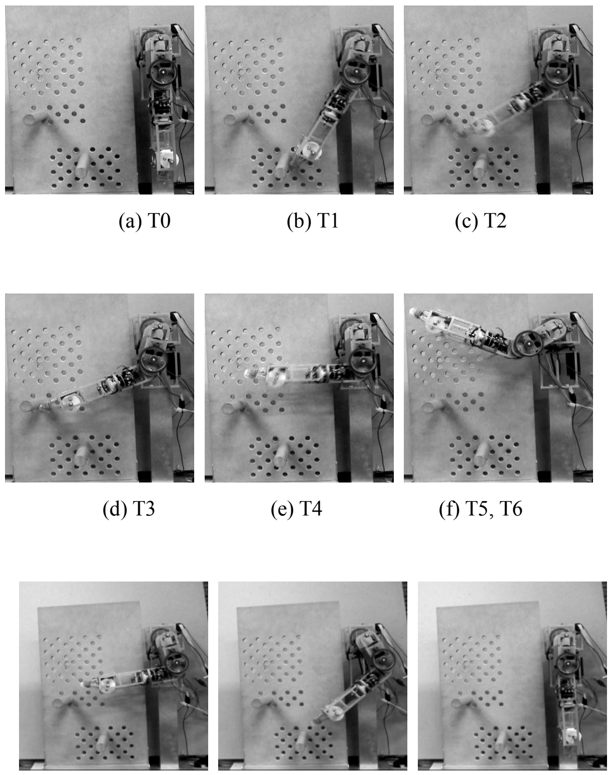
behavior

Fig.4-1 and 4-2I show the experimental result. Fig. 4-1 shows the consciousness evaluation function in CBA when the arm moved to a destination. The vertical axis shows the size of the evaluation function at each level, and the horizontal axle shows time. The figure indicates a series in consciousness from the beginning of movement to arrival at the aim position and an action. Ti (i=0…9) in an explanation helps to support Fig. 4-1

The consciousness level rises to 2 when the program of the robot arm is at T0. When the robot arm comes in contact with an obstacle at T1 and causes a reflection, the consciousness level falls to 1. When the consciousness of level 1 fades away afterwards, a restraint produces an action at level 2 with the memory of the obstacle remaining, and then the consciousness level stops at 2, 3, and 4 sequentially.

Because the consciousness level rises to 4, the robot arm chooses an action to detour around an obstacle. The robot arm judges the obstacle to be a detour in T2, and the consciousness level goes down to 2. Because the consciousness level fell to 2, a robot arm reopens an action to go to an aim position. Just like in the sequence above, the robot arm chooses a reflection/detour action at T3 - T4 and moves towards an aim position. The robot arm judges that the finger reached the target position and stops at T5.

At T4, the robot arm begins a movement to return to its startup posture. In the return journey, the robot arm will trace the most suitable course. Therefore, the consciousness level rises to 5, and it refers to the assistant goal information memorized in the outward trip given it at level 4. Assistant goals given then are the fingers position when the robot arm judged that a detour action was completed at T2 and T4. The robot arm acts on a search in level 4 and starts movement towards a given assistant goal. At T6 and T7, the fingers of a robot arm arrive at an assistant goal. Therefore, the consciousness level rises to 5 and is given at level 4 the next assistant goal information. The robot arm judges that the finger reached the initial position and stops at T9.



(a) T0 (b) T1 (c) T2

(d) T3 (e) T4 (f) T5, T6

(g) T7 (h) T8 (i) T9

Fig. 4-2 Robot arm postures for each time

5. Conclusion

I report performing the positioning of a robot arm by a computed torque method and also an experiment regarding a search action. I will aim at the realization of more practical feel movements in three dimensions in the future. However, a search action recognizes an obstacle only after it is restrained in an action bringing it into contact with the obstacle. Therefore, when an obstacle is soft, there is the danger that it might be damaged. This is a problem for the future.

6. Acknowledgment

The authors would like to acknowledge the advice and assistance of Professor Tadashi Kitamura of Kyushu Institute of Technology who died in 2006.

References

[1] The Japan Machinery Federation, "Technical strategic working papers for robot society creation in the 21st century," 2001, pp.10.

[2] Kobayashi, N., Masuda, R., "Real robot control," Corona Publishing Co., 1997, pp.127.

[3] The Japan Society of Mechanical Engineers, "JSME text series, Control Engineering," 2002, pp.160.