The effect of delay time for response to action on the sense of living organisms

Ayano Yoshida[1] and Shigeru Sakurazawa[2]

[1] Graduate School of Systems Information Science, Future University Hakodate, Hokkaido, Japan
(Tel : +81-138-34-6335; E-mail: g2112038@fun.ac.jp)
[2] School of Systems Information Science, Future University Hakodate, Hokkaido, Japan
(Tel : +81-138-34-6335; E-mail: sakura@fun.ac.jp)

Abstract: The relationship between action and response are very important for what people feel to objects. In locomotion, it is considered that there are differences between the robot which makes people feel living organisms and which do not make them that. In this study, we investigate the effect of delay time for response to action with an autonomous distributed robot. This experimental result shows that the subjects feel the strongest the locomotion of the robot like living organisms under the appropriate delay time condition. It suggests that the delay time is the one of the key factor of impression of life of the robot.

1Introuction

We have some impression with objects through interactions with them. The relationship between action and response are very important for what the people feel to objects. In locomotion, it is considered that there are differences between the robot which makes people feel living organisms and the robot which do not make them that. There is an example about the difference between living organism and non-living material from the feature of locomotion. Matsuno compared the movement of living organism to the movement of non-living material. He explained the difference of motion mechanism between living organism and non-living material from viewpoint of the imbalance. In particular, he compared a flagellar movement of sperm of starfish to flexion movement of swung chain with imbalance locomotion model. As the result, he showed the propagation velocity of force equilibration in living organism was finite and the propagation velocity in non-loving material diverges to infinity [1]. This means the hiding of imbalance of internal force in dynamic system.

In this study, the hidden information existing between layers was modeled as temporal integration of load. We implemented the model into an autonomous distributed robot consisting of several identical modules. When the integration value exceeded a threshold value, each module behaved in order to resolve the load of one-self. Then we investigated the effect of delay time to resolve the load on people's impression of the robot locomotion.

2 Proposed Method

2.1 Delay time

The hidden information existing between layers was modeled as temporal integration of load. When the integration value exceeded a threshold value, each module behaved in order to resolve the load of one-self. Here, the movement of the module was set as constant stepwise. If the present load increasing as the result of the stepwise movement, the modules move toward opposite direction to prior movement. Otherwise, if the present load decreased or was same as before, the modules move toward same direction to prior movement. The time lag from generation of strain to action of servomotor become longer with increasing this threshold value, so in this study, it was represented as "Delay time" for resolving the load.

2.2 Control System and Robot

Fig. 1 shows the top view of the whole structure of the robot. The robot consisted of 6 modules by linking each other. The module has servomotor (Futaba RS406CB) and linking materials. The load sensor was included in each servomotor. The load sensor detects the load of oneself as electrical currents on the motor. The each module controlled by PC with RSC-U485 (Futaba).

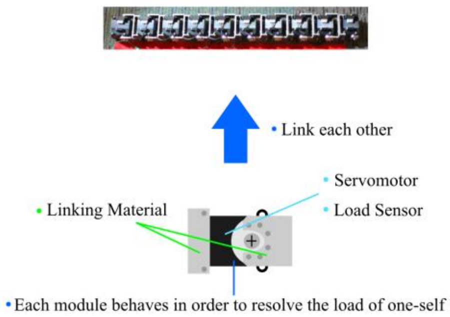

Fig. 1 Structure of robot

3 Experimental Method

3.1 Equipment

Each servomotor and RSC-U485 was connected to BA2081 TB-RV71EH-7.4V/4W (Futaba). Poweer source of the robot and RSC-U485 was supplied through connector cable from outside. 7.4V power was supplied to them by PMM18-2.5DU (KIKUSUI). RSC-U485 connected with PC (TOSHIBA, dynabook CX/47EE) by USB cable.

3.2 Experimental

The number of subjects for this experiment was 3 people between 21 to 24 years of age (two male and one female). They were instructed to move the robot toward goal line without lifting in one minute. The number of touching the robot and the strength of touching were not limited. After the each trial, we got an answer to following 5 questions about locomotion of the robot on an scale of 1 to 6 (Table 1). The amount of angle change of servomotor at one step was set as 25 degree. The threshold was set as 0.0001, 1.0, and 10 for each trial.

Table 1 Questions about locomotion of the robot

Question 1	Did you feel that the locomotion of the robot seems like living organisms?
Question 2	Did you feel an affinity with the locomotion of the robot?
Question 3	Did you feel a distastefulness to the locomotion of the robot?
Question 4	Did you feel a sence of dread?
Question 5	Did you think that your action has relations with the robot reaction?

4 Results

Fig. 3 shows the results of the questionnaire. The vertical axis shows an average of the each point of each question. The horizontal axis shows the question number. When the threshold was 1.0, the points of Q.1, Q.2 and Q.4 were most high value. When the threshold was 0.0001, the point of Q.3 and Q.4 were most high value. When the threshold was 10, the point of Q.5 was most high.

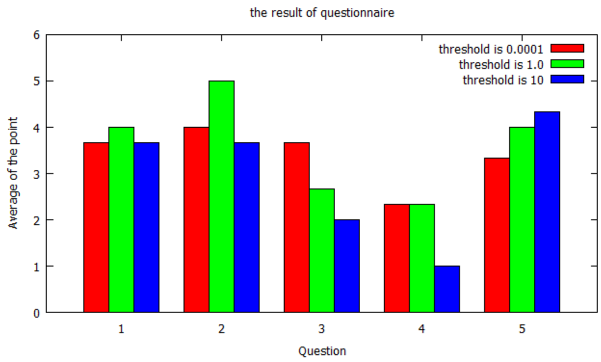

Fig. 2 Results of the questionnaire

Fig.3 – Fig.5 show time development of the amount of angle changes of each module under each threshold conditions. The Y-axis was the module ID. If the amount of angle change was bigger to plus direction, the color was red. If the amount of angle change was bigger to minus direction, the color was white. The arrow in the figures showed the propagation of amount of angle changes. The longer arrow showed long distance propagations. When delay time was 1.0, the points of Q. 1, Q. 2, and Q. 4 were most high condition, the amount of angle changes propagated long distance. When delay time was 0.0001, the points of Q. 3, and Q. 4 were most high condition, the amount of angle changes did not propagate long distance compared to other condition. When delay time was 10, the point of Q. 5 was most high condition, the amount of angle change propagated long distance. In this condition, the long distance propagation was occurred more often.

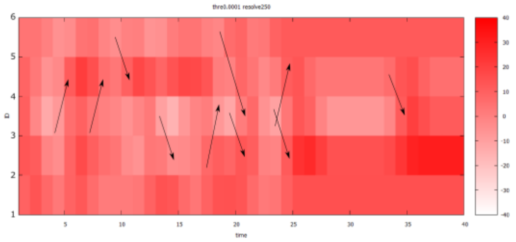

Fig. 3 Amount of angle change
(Threshold value was 0.0001)

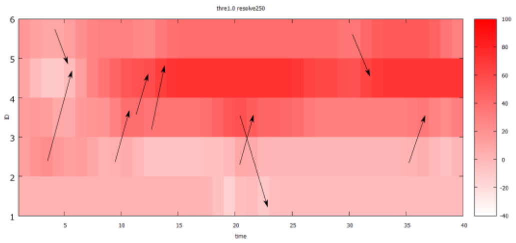

Fig. 4 Amount of angle change
(Threshold value was 1.0)

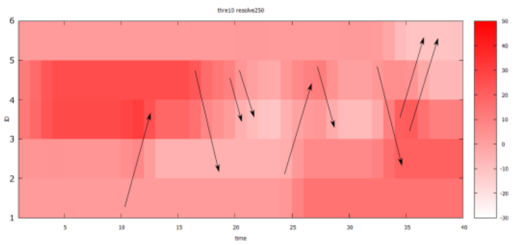

Fig. 5 Amount of angle change
(Threshold value was 10)

Fig. 6 - Fig. 8 showed time development of the load on each module under each threshold conditions. The Y-axis was the module ID. If the load was bigger, the color was red. If load was 0, the color was white. The arrow of the figures showed the propagation of load. The longer arrow showed long distance propagations. When delay time was 1.0, the points of Q. 1, Q. 2, and Q. 4 were most high condition, the load propagated long distance like the amount of angle change. When delay time was 0.0001, the points of Q. 3, and Q. 4 were most high condition, the load did not propagate long distance compared to other conditions like the amount of angle change compared to other conditions. When delay time was 10, the points of Q. 5 was most high condition, the load propagated long distance like the amount of angle change. In this condition, the long distance propagation was occurred more often too.

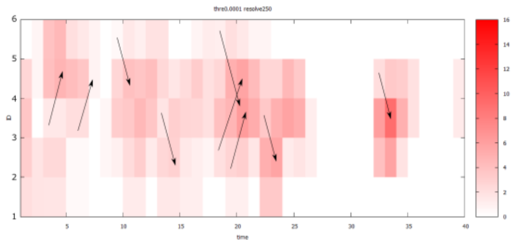

Fig. 6 Load
(Delay time was 0.0001)

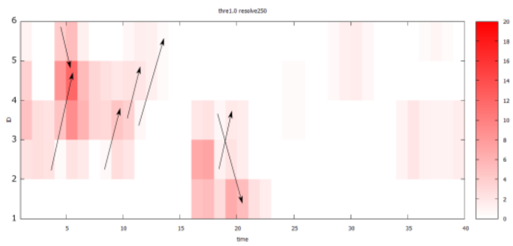

Fig. 7 Load
(Delay time was 1.0)

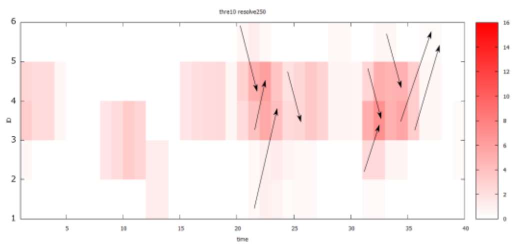

Fig. 8 Load
(Delay time was 10)

5 Discussion

These results indicated that the impression that subjects receive from a robot is affected by the delay time from when subject touch the robot till when it respond.

When the delay time was 1.0, the subjects felt feelings like living organisms from the locomotion of robot. It was suggested that the reason of this results was following. When the delay time was 0.0001, the subjects could not find a relationship between own actions and the locomotion of robot because the delay time was too short. On the other hand, when the delay time was 10, the subjects could find a relationship between own actions and the robot locomotion. However, they strongly felt that the robot was controlled by own actions because the delay time was too long. It was supported by the questionnaire result. Additionally, when the delay time was 1.0, the subjects felt an affinity and dread to the robot locomotion too. It suggested that the delay time had a relationship to the affinity or dread which we felt with the living organisms.

The long distance propagation of amount of angle change and load was observed when the delay time was 1.0. It suggested that the concatenation of local locomotion effects for subject's impression to the robot locomotion. However, when the delay time was 10, the long distance propagation occurred more often. Therefore, It suggested the relationship between the delay time and long distance propagation was important for what subject felt with the locomotion.

References

[1] K.Matsuno.: Protobiology. Crc Pr I Llc, New York, (1989)