Development of Behavioral Robot
Using Imitated Multiplex Neurotransmitter System

Saji Keita and Eiji Hayashi
Mechanical Information Science and Technology, Kyushu Institute of Technology.
680-4, Kawai, Iizuka, Fukuoka, 820-8502, Japan.
saji@mmcs.mse.kyutech.ac.jp and haya@mse.kyutech.ac.jp

Wisnu Jitviriya
Faculty of Engineering, King Mongkut’s University of Technology North Bangkok.
1518 Pracharat 1, Wongsawang Rd., Bangsue, Bangkok, Thailand 10800
wisnu_jitviriya@hotmail.com

Abstract
This paper presents the design of the robot’s behavior using the imitated multiplex neurotransmitter system. The major neurotransmitters of the nervous system are Dopamine, Noradrenaline and Serotonin, which are called monoamine neurotransmitter and they are related to the motivation, behavior and feeling. The proposed system is analyzed based on Lövheim’s cube of emotion and Wundt’s three-dimensional theory of feeling. So, Dopamine is applied as a comfort dimension, Noradrenaline is defined as a tense dimension, Serotonin is considered as an energetic dimension. In our system, three neurotransmitters are generated in each of the different factors, and then the motivation is calculated. The robot’s motivation and some external information are classified into behavior and emotion maps using Self-Organizing Map learning. Finally, the robot’s behavior and emotion are decided by Markov’s stochastic model. The experimental results confirm the effective outcomes by comparing the conventional model with the proposed model.

Keywords: Neurotransmitter, Self-Organizing Map, Dimensions of Emotion

1. Introduction

Nowadays, the robot technology is applied to service field and developing and advancing rapidly. Domestic robot, medical robot, business robot and rescue robot are classified as service robot. These robots are necessary to work with people. Therefore, the robots need to have enough ability for user affinity. We suggest some function, comforting, attraction, and friendship in order to obtain the affinity. Therefore, the functions of animals (dog and cat) in real life, which is focused on improving our robot. We propose the development of service robot’s behavior design by imitating the animal’s consciousness

The new model of our robot is the dynamic behavior selection model based on emotional states which develops from the Consciousness-Based Architecture (CBA) model [1] combined with Self-Organizing Map (SOM) learning and Markovian model. CBA is based on animal’s motivation system by dopamine in the brain. In this paper, we present the multiplex neurotransmitter system which simulates the generation of neurotransmitters such as serotonin, noradrenaline, and dopamine patterns. The multiplex neurotransmitter system is created to diversify the behavior factors of robot and to imitate animal’s consciousness.

This paper is organized as follows: Section 2 provides the system structure of our robot and CBA model. Section 3 suggests a new method to improve the robot’s behavior factors by the multiplex neurotransmitter system. Section 4 and 5 explain the approximation in applying the generation of neurotransmitters consisting of serotonin, noradrenaline, and dopamine. Section 6 shows the experimental results of the proposed model, and finally, Section 7 concludes the paper.

© The 2017 International Conference on Artificial Life and Robotics (ICAROB 2017), Jan. 19-22, Seagaia Convention Center, Miyazaki, Japan
2. System Structure

In this research work, the robot in our laboratory is being used as shown in Fig.1. This robot has two arms which have the base frame, shoulder, elbow, and wrist (6 DOF), and the robot head is made for acting the facial recognition and expression. The web camera is attached at the end-effector of arm that is used for recognition of an external situation and forward tracking algorithm, in order to recognize the target object. The CCD camera attached at the head that is used for recognition of user’s facial emotional expressions. Fig. 2 shows the overview system of the robot. The procedure of the system can explain by the following steps:

Step1: Recognizing an external situation (the objects) by cameras and calculating the release of Dopamine and a motivation according to the circumstances.

Step2: Creating the maps that classified with default emotions (natural, hope, happiness, sadness, fear, disgust) and behaviors (look around, approach, avoid, etc.) using Self-Organizing Map method.

Step3: Selecting the candidate of emotion and behavior of next time step by a verification of the external situation (including the Dopamine and the motivation) and the map.

Step4: Deciding the emotion and the behavior for next time step by the results of the calculation. The state transition probability of Markov model is determined by the candidate of emotion and behavior.

Step5: The robotics arm drives the actuators according to the selected behavior, and the two displays which attached at the robot head present the eye images according to the selected emotion.

3. Imitated Multiplex Neurotransmitter system

In this paper, we suggest the imitated multiplex neurotransmitter system based on Lövheim’s cube of emotion [2]. That theory is proposed theoretical model aiming at explaining the relationship between the monoamine neurotransmitters and the emotions (Fig.3). In addition, Wundt’s three-dimensional theory of feeling [3] (Fig. 4), three psychological axes of feeling, pleasure-displeasure, relaxation-strain, and excitement-calm, can be applied to these neurotransmitters. In brain, Noradrenaline is known to be related to the attention and impulse, and Serotonin is known to be suppressed by fatigue substance in neuropsychology. Therefore, in this
Fig.4 Wundt’s three-dimensional theory of feeling

paper, Noradrenaline is fitted to relaxation-strain axes and Serotonin is fitted to excitement-calm axes.

Due to generate a motivation from different factors, the behavior factors of robot can be diversified and the system can imitate animal’s consciousness based on biologically inspired artificial emotions.

4. Approximation of neurotransmitters

In this research, not only Dopamine (DA) neurotransmitter but also Noradrenaline (NE) and Serotonin (HT-5) neurotransmitters are applied because they are the element constituting the monoamine neurotransmitters. In this robot, the generating waveforms of these neurotransmitters are simulated based on the experimental results when researchers test them with the rat [3], [4] as shown in Fig.5. The generating waveform of Noradrenaline is approximated by a Gaussian Equation (1), and the generating waveform of Serotonin is approximated by Equations (2) and (3).

\[ y(t) = \lambda \exp \left\{ -\frac{(t - \mu)^2}{2\sigma^2} \right\} \quad (1) \]

\[ y'' + 2\alpha y' + \alpha^2 y = -\alpha^2 u = 0 \quad (2) \]

\[ y = y_{\text{peak}} e^{-t/\tau} \quad (3) \]

5. Applying neurotransmitters

In this robot, the positive Noradrenaline is generated while the robot cannot complete some behaviors after deciding the behavior using Markov model. That means a strain, but the negative Noradrenaline is generated when the robot complete the behavior and that means a relaxation. The positive Serotonin is generated when the robot get some favorite things. That means an excitement. On the contrary, the negative Serotonin is generated when the robot moves and that means a calm. These generating waveforms are calculated using Equation (1), (2) and (3). Dopamine is generated same as the usual model.

Finally, a motivation is calculated by a second order response of the sum of all monoamine neurotransmitters.
6. Experimental results

In this study, the multiplex neurotransmitter system is applied to CBA model. In Fig. 2 shows the process of the CBA system. In each time step, the amount of each neurotransmitter was calculated by the Equations (1), (2) and (3). Fig.7 shows the experimental results of comparison of the transition of emotion between conventional model and the model was applied with the multiplex neurotransmitter system when the robot detected a favorite object and it could complete in approaching and catching the target object.

On the other hand, Fig.8 also shows the experimental results of comparison of the transition of emotion when the robot detected a target object, but it couldn’t be successful in the task.

7. Conclusions

In CBA, the generation process of motivation for emotional and behavior of the robot was improved by the multiplex neurotransmitter system. For this system, in addition to Dopamine, two neurotransmitters in brain Noradrenaline and Serotonin was applied to the generation of the motivation.

As a result of that, the improvement of diversity of emotion was confirmed and that means the behavior factor of the robot is also diversified.

References


Fig.8 the favorite object and the robot cannot catch target object