Chapter 2
MEMS Microrobot with Pulse-Type Hardware Neural Networks Integrated Circuit

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ABSTRACT

Hexapod locomotive Micro-Electro Mechanical Systems (MEMS) microrobot with Pulse-type Hardware Neural Networks (P-HNN) locomotion controlling system is presented in this chapter. MEMS microrobot is less than 5 mm width, length, and height in size. MEMS microrobot is made from a silicon wafer fabricated by micro fabrication technology to realize the small size mechanical components. The mechanical components of MEMS microrobot consists of body frames, legs, link mechanisms, and small size actuators. In addition, MEMS microrobot has a biologically inspired locomotion controlling system, which is the small size electrical components realized by P-HNN. P-HNN generates the driving pulses for actuators of the MEMS microrobot using pulse waveform such as biological neural networks. The MEMS microrobot emulates the locomotion method and the neural networks of an insect with small size actuator, link mechanisms, and P-HNN. As a result, MEMS microrobot performs hexapod locomotion using the driving pulses generated by P-HNN.

INTRODUCTION

Many types of microrobot have been proposed by several researchers. (e.g., Shibata, Aoki, Otsuka, Idogaki, & Hattori, 1997; Takeda, 2001; Habib, Watanabe, & Izumi, 2007; Habib, 2011; Baisch, Sreetharan, & Wood, 2010). Microrobot will be useful for several applications such as precise manipulation on medical, electronic component or mechanical component assembly and so on. However, further miniaturizations and higher functionalization to the microrobot are required to play an important role in these fields. Although the miniaturization of the robot has conventionally been progressed by mechanical machining

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and assembling, some difficulty has appeared in order to achieve further miniaturizations. In particular, frame parts, actuators, motion controllers, power sources and sensors (e.g., Tsuruta, Mikuriya, & Ishikawa, 1999). Instead of the conventional mechanical machining, micro fabrication technology based on the integrated circuit (IC) production lines has been studied for making the small size actuators of the microrobot (e.g., Donald, Levey, McGray, Paprotny, & Rus, 2006; Edqvist, Snis, Mohr, Scholz, Corradi, Gao, ... Johansson, 2009; Suematsu, Kobayashi, Ishii, Matsuda, Sekine & Uchikoba, 2009). The development of the small size actuator is important subjects. The type of the small size actuator by micro fabrication technology was categorized into two groups. For example, uses the field forces. Otherwise uses the property of the material itself (e.g., Tang, Nguyen, & Howe, 1989; Sniegowski, & Garcia, 1996; Asada, Matsuki, Minami, & Esashi, 1994; Suzuki, Tani, & Sakuhara, 1999; Surbled, Clerc, Pioufle, Ataka, & Fujita, 2001). In particular, shape memory alloy and piezoelectric element were often used for small size actuator of the microrobot. However, microrobot using these small size actuators had a weakness for moving on the uneven surface. Therefore, microrobot which could locomote by step pattern was desired.

Programmed control by a digital systems based on microcontroller has been the dominant system among the robot control. However, it is difficult to program the autonomous operation to the microcontroller because of memory capacity. On the other hand, insects realize the autonomous operation using excellent structure and active neural networks control by compact advanced systems. Therefore, some advanced studies of artificial neural networks have been paid attention for applying to the robot. A lot of studies have reported both on software models and hardware models (e.g., Matsuoka, 1987; Ikemoto, Nagashino, kinouchi, & Yoshinaga, 1997; Nakada, Asai, & Amemiya, 2003). However, using the software models in large scale neural networks is difficult to process in continuous time because the computer simulation is limited by the computer performance, such as the processing speed and memory capacity. In contrast, using the hardware model is advantageous because even if a circuit scale becomes large, the nonlinear operation can perform at high speed and process in continuous time. Therefore, the construction of a hardware model that can generate oscillatory patterns such as biological neuron was desired.

In this chapter, active hardware neural networks controlled less than 5 mm width, length and height in size MEMS microrobot was proposed. Firstly, mechanical system of MEMS microrobot was shown. Secondly, pulse-type hardware neural networks (P-HNN) IC which is driving waveform generator of the MEMS microrobot was discussed. Finally, hexapod locomotion of MEMS microrobot which was controlled by the P-HNN IC was shown.

MEMS MICROROBOT

Generally, microrobot consisted by electro systems and mechanical systems. Therefore, micro-electro mechanical systems (MEMS) technology is useful to construct the microrobot system. However, most devices constructed by MEMS technology were planar structure. It was difficult to construct space structure devices. The mechanical components of the MEMS microrobot were fabricated by micro fabrication technology. Mechanical components were assembled by manual assembly to construct the space structure of the MEMS microrobot. Mechanical components of the MEMS microrobot are micro-mechanical systems. Pulse-type hardware neural networks (P-HNN) locomotion controlling system is micro-electro systems. Therefore, proposal microrobot system is micro-mechanical systems plus micro-electro systems equals MEMS technology.

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