Chapter 45
Silicon Micro-Robot With Neural Networks

Ken Saito
Nihon University, Japan

Minami Takato
Nihon University, Japan

Yoshifumi Sekine
Nihon University, Japan

Fumio Uchikoba
Nihon University, Japan

ABSTRACT

Insect type 4.0, 2.7, 2.5 mm. width, length, height size silicon micro-robot system with active hardware neural networks locomotion controlling system is presented in this chapter. The micro-robot system was made from a silicon wafer fabricated by Micro-Electro Mechanical Systems (MEMS) technology. The mechanical system of the robot equipped with millimeter-size rotary type actuators, link mechanisms, and six legs to realize the insect-like switching behavior. In addition, the authors constructed the active hardware neural networks by analog CMOS circuits as a locomotion controlling system. Hardware neural networks consisted of pulse-type hardware neuron models as basic components. Pulse-type hardware neuron model has same basic features of biological neurons such as threshold, refractory period, spatio-temporal summation characteristics, and enables the generation of continuous action potentials. The hardware neural networks output the driving pulses using synchronization phenomena such as biological neural networks. Four output signal ports are extracted from hardware neural networks, and they are connected to the actuators. The driving pulses can operate the actuators of silicon micro-robot directly. Therefore, the hardware neural networks realize the robot control without using any software programs or A/D converters. The micro-robot emulates the locomotion method and the neural networks of an insect with rotary type actuators, link mechanisms, and hardware neural networks. The micro-robot performs forward and backward locomotion, and also changes direction by inputting an external trigger pulse. The locomotion speed was 26.4 mm/min when the step width was 0.88 mm.

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INTRODUCTION

Many studies have been done on micro-robot for several applications such as precise manipulation, medical field, and so on (e.g., Shibata, Aoki, Otsuka, Idogaki, & Hattori, 1997; Takeda, 2001; Habib, Watanabe, & Izumi, 2007; Habib, 2011; Baisch, Sreetharan, & Wood, 2010). However, further miniaturizations and higher functionalization on the micro-robot system are required to play an important role in these fields. Although the miniaturization of the robot has conventionally been progressed by mechanical machining 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 Electro Mechanical Systems (MEMS) technology based on the IC production lines has been studied for making the simple components of the micro-robot (e.g., Donald, Levey, McGray, Paprotny, & Rus, 2006; Edqvist, et al., 2009; Suematsu, Kobayashi, Ishii, Matsuda, Sekine, & Uchikoba, 2009). In addition, the development of the actuator is important subjects. The type of the micro actuator by MEMS technology is 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 actuator shows a large displacement such as 50% of the total length in millimeter size. However, micro-actuators using field forces or piezoelectric elements to the micro-robot had a weakness for moving on the uneven surface. Therefore, micro-robot 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. 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 mathematical neuron models in large scale neural network 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 neuron 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 is desired. For this reason, we are studying about millimeter size micro-robot system which can control the locomotion by active hardware neural networks.

In this chapter, we will propose the active hardware neural networks controlled 4.0, 2.7, 2.5 mm. width, length, height size silicon micro-robot system from silicon wafer fabricated by MEMS technology.

SILICON MICRO-ROBOT

We constructed the miniaturized robot by MEMS technology. In this section, the basic components of the fabricated silicon micro-robot were shown. The number of the legs of the silicon micro-robot was six. The structure and the step pattern of the robot was emulated those of an ant. The micro-robot consisted of frame parts, rotary type actuators and link mechanisms.