Int. J. Indust. Entomol. Vol. 1, No. 2, 2000, pp. 91~93
[Review]

International Journal of
Industrial Entomology

Insect-Model Based Robots

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(Received 10 October 2000; Accepted 19 October 2000)

Insects have many excellent features and functions in their small bodies, such as hexapod walking, flapping flight, vision systems, sensory hairs, etc, and those characteristics can be thought as good models for many types of robots. Insects also will be good models for micro-machines because of its size. Insect behavior consists of simple reflex acts and programmed behavior. Some robots were made in order to clarify the emergent mechanism of insect behavior. Through some experiments it would be found that even if insect behavior consists of some simple action patterns, it looks intelligent through interactions its sensors and actuators with its complex environment. In the near future, small robots inspired by insects will be used in many fields of our life. I hope that insect-model based robots will play an active part in many fields and that they will make us happy.

Key words : Insect, Robot

Introduction

Why are insects thought as a model of robots? When the author was in the university, I doubted if traditional AI based robots were really intelligent. These robots could not adjust the unknown environment and the behavior rules must be given by a human. Because they could only follow the programs that were given by a human, they were no more than automatic machines that were controlled by a computer.

On the other hand, an insect looks more intelligent and much livelier than those traditional AI based robots. It also looks to have a will. If I could develop an insect-like robot by using many outstanding features of insects, it might be possible to make it look really intelligent or much livelier. It would be a new type of robot intelligence and it may give a small but steady step for investigation of behavior emergent mechanism of a living creature. The motion of insects is produced by simple mechanisms such as reflex acts and programmed behavior. It is interesting to the author that the behavior of an insect that is based on simple mechanism looks intelligent.

By the way, since the late 1980s, micro-fabrication technology has been focused as a promising technology for development of very small sized, for example micrometer or millimeter sized, structures and mechanisms. Millimeter sized insects are all around us, so insects can be good models for micromachines or small robots for design, control, and actuation, just as a human beings and mammals are good models for normal-sized robots.

Robots inspired by insects

Insects have many marvelous features in their small bodies. A lot of robot researchers turn their attention to insect abilities, such as locomotion, sensory organs, and so on.

Locomotion

Many roboticians make a study of hexapod robots. Hexapod is one of the most popular research subjects in the field of walking robots. Legged walking robots can travel on the terrain that is too rough for conventional wheeled vehicles. Hexapods are also more stable than biped and quadruped robots when they move. This is why hexapods are one of popular subjects in walking robot.

Professor Ritzmannís group at Case Western Reserve University, USA, researched hexapod robots (Beer and Chiel, 1993; Quinn and Espenschied, 1993; Bear *et al.*, 1997). They made an artificial neural network that was inspired by a cockroachís neural network (Pearson, 1976). Their neural network could control the leg motion. They

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installed their neural network into a hexapod. It could walk very smoothly and change its walking gate by walking speed just like a real cockroach.

Professor Brooks at MIT also made some hexapod robots. He proposed ìsubsumption architectureî in order to control the behavior of his robots (Brooks, 1993). The subsumption architecture was a control system for mobile robots built from completely distributed networks of augmented finite state machines. These techniques could be used to incrementally build complex systems, which integrated relatively large numbers of sensory inputs and large numbers of actuator outputs. He demonstrated how complex behavior, such as walking, could emerge from a network of rather simple reflexes with little central control. This process may be similar to that of insects.

Professor Shimoyamaís group at the University of Tokyo has made several types of insect-inspired machines and robots by using micro-fabrication technology. Dr. Yasuda had made a micro-sized ant that was mainly made of silicon (Yasuda *et al.*, 1994). It had four supporting legs and two kicking legs. The vibration of the floor actuated kicking legs. Mechanical resonance was efficiently used in his robot.

Flight is very challenging theme for roboticians. It is very difficult to make a robot fly freely in the air. Professor Shimoyama made a micro flapping mechanism (Kubo *et al.*, 1994). In his mechanism, polyimide films sandwiched a thin nickel plate in a wing. Since nickel has magnetism, wings were actuated by an alternating magnetic field.

Vision

Insect compound eyes can be thought as a good model of a mobile robot navigation system. Professor Franceschini at CNRS, France, had developed a simple navigation system that was inspired by a flyís compound eye (Franceschini *et al.*, 1992; Franceschini, 1996). The advantages of his system were simple structures and fast signal process. He called his system ìmotion detector.î His motion detector had photo diodes, lens arrays and operational amplifiers, and it could detect the edges of obstacles by black and white contrast. A mobile robot, which was installed this system, could avoid the obstacles around itself.

Professor Srinivasan at Australian National University had also developed a navigation system that is inspired by insect vision (Srinivasan *et al.*, 1999). He focused on the peering behavior of a grasshopper and the centering response of bees. These experimental investigations of insect functions had led him to make a visually driven odometer for robot navigation.

Dr. Mura and Dr. Hoshino, belonging to Professor Shimoyamaís laboratory, tried to make the motion detector very small by micro fabrication techniques (Hoshino *et al.*, 2000). The advantage of their system was to have a scanning retina. Retinal scanning was also inspired by a flyís compound eye. By vibrating a lens array or a photo diode array, it will be possible to make the range of view extremely wide.

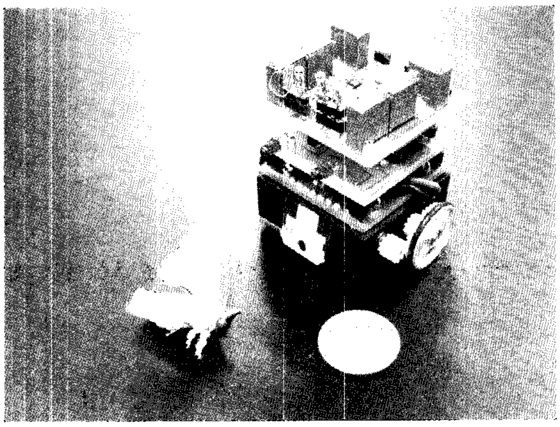

Fig. 1. P5 robot and a silkworm moth.

Sensor

Insects have many chemical and mechanical receptors all around their body. For example, an antenna can detect the pheromone molecules by its pheromone receptors with extremely high sensitivity and selectivity. Cockroaches and crickets have sensory hairs at their legs. Those hairs can be thought as airflow sensors.

Ohyama and Ozaki, at the Professor Shimoyamaís laboratory, had developed an airflow sensor by using microfabrication technology (Ozaki *et al.*, 2000). It seemed like a comb with different lengths of beams. Airflow could be detected by distortion of those beams. In order to adjust the wide range of airflows, those beams had several different lengths.

Professor Schütz, at University of Ulm, Germany, proposed BioFET (Schütz *et al.*, 2000), which is a system that uses an insect antenna as an olfactory biosensor. His BioFET can be used for measurements of plant damage in a glasshouse.

Behavior modeling

Since the number of neurons in insect nervous systems is much smaller than that of human beings or mammals, an insect can be a good model for investigation of behavior emerging mechanisms.

Professor Webb at University of Nottingham had developed a cricket-like robot in order to mimic the behavior of a female cricket (Webb, 1996). Her robot had two microphones as ears. The sound that was produced by a male cricket was emitted from a speaker and then the robot could locate the speaker just as a female cricket locates a male.

Kuwana at National Institute of Sericultural and Entomological Science, Japan, had developed a pheromone-guided mobile robot (PheGMot) in order to simulate the pheromone-oriented behavior of a silkworm moth (Kuwana and Shimoyama, 1998; Kuwana *et al.*, 1999). 0shows PheGMot-V (P5) and a male silkworm moth with a one-cent coin. P5 has three layers: sensory layer, control layer and actuator layer. The distinctive feature of P5 is to have an insect antenna as a living biosensor. On the sensory layer, antennae isolated from a male mothís head were attached as a pheromone sensor. Since these antennae can detect the female sex pheromone, P5 can trace the pheromone plume and locate a female moth as a male moth does. A simple artificial neural network is used to emerge the pheromone source location.

These two results suggested that a rather complex performance could come from a simple control mechanism with interactions between a simple robot and its complex environment.

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