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Book reviews

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NEUROTECHNOLOGY FOR BIOMIMETIC ROBOTS, edited by Joseph Ayers, Joel L. Davis and Alan Rudolph, MIT Press (Bradford Book), Cambridge, Massachusetts, 2002, xiv + 636 pp., ISBN 0-262-01193-X (Hbk, £43.50).

This is a collection of 29 papers stemming from a conference in Nahant, Massachusetts, in May 2000. The main focus is on biomimetic robots, and the emphasis on "neuro" is perhaps slightly misleading, though all the projects involve internal communication and hence something analogous to neurons, and it is emphasised in a preliminary overview that the intention is to embody biological principles in the basic organisation of the devices and not only in their interfaces with their environment.

The aim is to produce robots that mimic animals in being smaller and more agile as well as usually cheaper, than traditional robots. Their great advantage is that they can operate in environments that are closed to traditional robots by mimicking the animals that already survive there. As is observed in the Preface of the book, animals have evolved to occupy almost any environment in which we might want to operate a robot, with the exception of outer space.

Besides producing useful robots, the work throws light on the biological mechanisms it mimics. The robots are necessarily simpler than their biological prototypes, but sometimes the search for relatively simple solutions has indicated ways in which the biological example proves to be itself less complex than was first thought.

One important problem area is that of finding suitable actuators that have some of the features of muscles including direct production of linear force and less stiffness than is associated with rotary motors and arrangements of gears. Special sensors are also needed and the first paper in the book (following the Preface and overview) is on flow sensors and contact sensors needed to simulate the locomotion of a lobster over an irregular ocean floor. This particular project has a potential military application to the sweeping of mines in shallow waters where neither deep-water nor dry-land methods are possible. Lobsters are mentioned also in other papers, including no. 6 where muscle-like actuators utilising a shape memory alloy are described with particular attention to underwater use, and in paper no. 12 by the first-named of the editors, on a biologically inspired central pattern generator for lobster-like locomotion.

The cover picture is of a distinctly menacing snake-like robot, but the application area seen for such devices, in paper no. 13, is in search and rescue, and the attraction of this conformation is the enormous range of environments occupied by snakes, including deserts, swamps and treetops, with some even capable of a controlled aerial glide. Snakes are capable of different forms of locomotion including the familiar undulatory one, and a concertina-like version for confined spaces, as well as sidewinding allowing rapid advance.

A good deal of attention is given to the matter of overall control, where a central problem is that of combining a stored pattern of movement with appropriate responses to environmental perturbations. The method described in paper no. 12 is said to achieve this with remarkable fidelity. In paper no. 10, describing a robotic fish (RoboTuna), genetic algorithms are employed to optimise the controllers, but the method is still under development.

The papers are grouped under the three main headings of Neurotechnology, Vehicles, and Autonomous Behaviour. Under the first of these they are further divided among Biomimetic Sensors, Biomimetic Actuators and Biomimetic Control Architectures. Under sensors there is the paper on sensors appropriate to a lobster-like robot, and three on aspects of vision including insect vision, and one on olfaction. The last-mentioned gives an extensive review of the biological literature and has again a potential military application in clearing minefields. The papers on actuators indicate several possible ways of achieving muscle-like activation.

Under the general heading of Vehicles, the papers are divided among Undulatory and Swimming Robots, Ambulatory Robots and Flying Robots. A great deal has been achieved and in an overview it is suggested that readers should open the websites of the various contributors where they will find video clips of the robots in action. Paper no. 17 concentrates on the positional control offered by the pectoral fins of fish and refers to two artificial systems simulating such a fin, referred to as the Two-Motor-Driven Mechanical Pectoral Fin or 2MDMPF and the extension to 3MDMPF. It is argued that these have advantages over rotary thrusters for the precise positioning of slow-moving underwater vehicles and tests are reported.

Consideration of ambulatory locomotion is restricted to cockroach-like devices, which obviously bypass many problems of bipedal locomotion, but there are still important considerations in ensuring the robustness of progress across unknown terrain. One of the illustrations shows such a robot successfully negotiating a surface of regularly spaced slats, where with less sophisticated control it could easily become trapped by having all of the leg pairs sunk into gaps between slats. Two studies of flying robots (papers 22 and 23) are based on very thorough studies of the responses of living insects. The last paper in the section (no. 24) describes a device currently under intensive development called the Entomopter which should fly, crawl and swim, and depends on a mixture of conventional and biomimetic principles. Here again there is military interest, but since it has been planned with a power source not dependent on oxygen there are also plans to use a version in exploration on Mars in conjunction with a rover vehicle.

The papers under the heading of Autonomous Behaviour are concerned with types of animal behaviour that are illuminated either by the building of robots or by considering the task from a robotic viewpoint. In paper 25 there is modelling of a means by which insects may navigate home using landmarks though without image matching, and in no. 26 it is of the means (phonotaxis) by which female crickets are guided toward males by their sound. The three remaining chapters deal respectively with the way that a lobster can locates the source of a plume of a released substance in water, the free-flight search behaviour of fruit flies, and visual flight control and navigation by honeybees.

The papers are all well presented, with numerous diagrams and photographs and an overall subject index. This is an excellent guide to the state of the art in this intriguing and potentially valuable area.

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