Animals as Models for Robot Mobility and Autonomy: Crawling, Walking, Running, Climbing and Flying

Roger Quinn

Abstract

The biorobotics program at Case Western Reserve University (CWRU) has been active for more than 20 years. This presentation highlights many of the projects undertaken during that time and describes how neuromechanical principles have benefited a number of robots. As this list of principles grows, so does the functionality and performance of the biorobots.

We use biological inspiration to incorporate neuromechanical principles of locomotion and autonomy into robot designs. The dual goals are to develop useful robots and also to develop neuromechanical models of animals to test hypotheses about their design, movement and control. These goals are complementary. Better models lead to more efficient experiments and new neuromechanical knowledge, which points the way to improved robot designs and animal models.

A robot that captures the leg designs important for cockroach locomotion will be extremely agile and therefore suitable for many missions. For example, the after action report for the robot search and rescue mission at the World Trade Center recommends that legs be used instead of tracks or wheels because they can better adapt to complex terrain. However, before a robot with the intricate leg designs of a burrowing animal such as an insect can be deployed some technical issues must be solved. Therefore, the Quinn-Ritzmann groups are using two complementary approaches to develop mobile robots. Using the direct approach we have developed a series of robots that are each more similar to cockroach. These have multi-segmented legs requiring a controller that captures neurobiological principles. Models of insect legs are being used to understand animal leg control circuits and how descending

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commands from the brain interact with intermediate and local networks to profoundly change leg movements and coordinate legs. This knowledge is simplifying the control circuits for our legged robots and making them more robust.

In the more abstract biorobotics approach the fundamental principles of cockroach locomotion are applied using existing technologies. Robots called Whegs have mechanical designs that passively solve lower level motor control problems and their subsequent agility makes them suitable for many applications in the near term. Small robots called Mini- Whegs can run rapidly over relatively large obstacles and even jump up stairs. A Mini- Whegs with specially designed legs and animal inspired adhesive feet can climb vertical glass walls. It places each of its adhesive feet on the wall, propels itself through the stance phase, and peals its feet from the wall mimicking insect foot motions. Mini- Whegs has also been integrated with a micro air vehicle to form MALV (micro air and land vehicle). A new robot called DIGbot uses a biologically inspired concept called Distributed Inward Gripping (DIG) to walk inverted.

The WTC report also recommended that search and rescue robots should be capable of autonomous locomotion. A long term goal is to develop an artificial insect head with sensors and a guidance and stabilizing system. Preliminary research resulted in a Whegs robot autonomously climbing obstacles using tactile antennae and avoiding obstacles using ultrasonic sensors in a bat-inspired configuration. CWRUs Urban Challenge vehicle, Dexter, and our autonomous lawnmower, CWRU Cutter, benefit from animal inspired control architectures. Animals that have soft bodies can very effectively locomote and manipulate materials in their environment. For example, worms, leeches and slugs are all capable of moving through complex environments. The Chiel-Quinn groups have developed peristaltic robots and a soft gripper device. The peristaltic robots are hollow to allow fluid to pass through them.

Biography

Roger D. Quinn is the Arthur P. Armington Professor of Engineering at Case Western Reserve University. He joined the Mechanical and Aerospace Engineering department in 1986 after receiving a Ph.D. (1985) from Virginia Tech and a M.S. (1983) and B.S. (1980) from the University of Akron. He has directed the Biorobotics Laboratory since its inception in 1990. His research, in collaboration with Roy Ritzmann, Hillel Chiel, Mark Willis at CWRU and other biologists, is devoted to the development of robots and control strategies based upon biological principles. He has more than 200 publications and several patents. His biology-engineering collaborative work on behavior based distributed control, robot autonomy, and human-machine interfacing have each earned IEEE awards. His work on robot autonomy is resulting in the development of an inexpensive autonomous lawnmower that can edge obstacles and mow patterns.