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Salamander Robot

Introduction

The ability to move flexibly and efficiently in their environments is a fundamental characteristic of animals. Animal locomotion consists of complex interactions between the animal's neurological signals, its body and its environment [1]. Understanding these interactions gives engineers the ability to design more agile and versatile robots for applications ranging from search and rescue to medical research. Salamander motion is an excellent model for robots, because their musculoskeletal structure gives them the ability to move effectively both on land and in water [2]. Salamanders are adept swimmers and were among the first creatures to walk on land. They are considered central to the transition from aquatic to terrestrial environments. In addition, salamanders have fewer neurons by orders of magnitude than mammals, making them relatively simple to study and model [2]. Finally, a salamander's central nervous system is similar to that of the lamprey fish whose swimming circuitry has been extensively studied [2]. The amount of information available on a lamprey's swimming circuitry facilitates research into a salamander's swimming capabilities. This paper is a review of salamander robots; robots which are designed to emulate the locomotion of salamanders.

Commercial Applications for Salamander Robots

Salamander robots are a nascent technology. Two of the few existing products that are available are both made by the Biorobotics Lab at Ecole Polytechnique Federale de Lausanne (EPFL): Salamandra robotica II and Pleurobot. They are not available for sale and so their costs have to be estimated from the costs of their components. The total estimate of the cost is between $150 - $200, depending on the materials used.

Search and Rescue

Salamander robots can be used in search and rescue operations. They are low lying robots, have a wide range of motion capabilities and can access areas that are difficult to reach for humans. They can be used to scope out a collapsed building or dive into depths of the ocean.

Medical Research

Salamander robots can be used by medical researchers to better understand the function of the spinal cord. A salamander's locomotion is controlled by a series of neural circuits along its spinal cord [3]. Any movement that the salamander makes such as walking, running, swimming depends on the intensity of the electrical signal sent from the brain to the spinal cord [3]. Salamander robots are based on this model. Salamandra robotica II uses a digital model of the salamander's brain which triggers electrical signals similar to a real salamander's brain and controls the speed and direction of the robot's movement [4]. Pleurobot provides torque control for all of the active joints on the salamander robot's body and the joints and muscles on its body are designed to respond to electrical stimuli similarly to those of a real salamander. Therefore, applying various neural network models to the salamander robots and observing the responses of its joints can advance the understanding of vertebrate motion [5]. This could help medical researchers better understand how the spinal cord receives information from the brain and better the care for para and quadriplegics [6].

Underlying Technology

Salamander robots fundamentally consist of a head, a body of several components which gives it the ability to slither, and limbs which give it additional degrees of freedom. The Salamandra robotica II is essentially a series of connected hinge joints for lateral motion in the horizontal plane with legs attached to it for rotational thrust [2]. The elements of the spine are independent of one another, each having its own power source, motor, motor control, and gearbox [2]. While walking, the legs extend out from the body whereas while swimming, the legs fold in just like in a real salamander [2]. The Pleurobot is based on a similar design, however this robot was made after thorough research into salamander motion. After recording the 3D X-ray videos of salamander motion and tracking 64 points on the animal's body to record the 3D movement of bones, the optimal number (11) and positions of joints were determined. The Salamandra Robotica II has 12 degrees of freedom, and a stride length (a measure of scaled forward motion speed) of 0.42 m/s [1]. The Pleurobot has 27 degrees of freedom, and a stride length of 0.40 m/s [3].

Building Blocks for Implementation

Both the Salamandra Robotica and the Pleurobot have certain specific design considerations. For the Salamandra Robotica, the body and limb elements' DC motors are driven by a PD motor controller implemented on a low power PIC18 microcontroller to drive the H-bridges [7]. The head element uses LPC2129 ARM7TDMI microcontroller running at 60 Hz and sends neural signals over a serial line to an 8-bit microcontroller that controls an nRF905 radio transceiver; this allows the ARM microcontroller to be reprogrammed without opening the head [2]. The robot is powered by 600-mAh Li ion rechargeable 5V battery [2]. The Pleurobot uses Dynamixel MX-64R servomotors as these motors offer a high torque to mass ratio (7.3 Nm / 126 g stalled torque), and a maximum no load speed of 78 rpm [3]. The salamander robots require the implementation of complex software algorithms. The Pleurobot uses the Intel Atom 1.6 GHz computer and is able to send position commands to the servomotors at a rate 1 kHz [3].

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