PHYSICS DIVISION TECHNOLOGY REVIEW

Biomorphic Robotics, Nervous Networks, and Living Machines

Survival-oriented "intelligent" robots, constructed of simple hardware at minimal cost, move under solar power and can negotiate hostile environments using only simple mechanics and an electronic core. These biomorphs (**bio**logical **morph**ology) have artificial nervous systems, which produce appropriate adaptive walking gaits that allow these robotic systems to interact with the external world. The biomorphs' legs are equipped with explicit and implicit local sensors that allow them to make highly abstract images of their immediate environments. These autonomous mobile mechanisms have many potential applications from environmental cleanup to space exploration.

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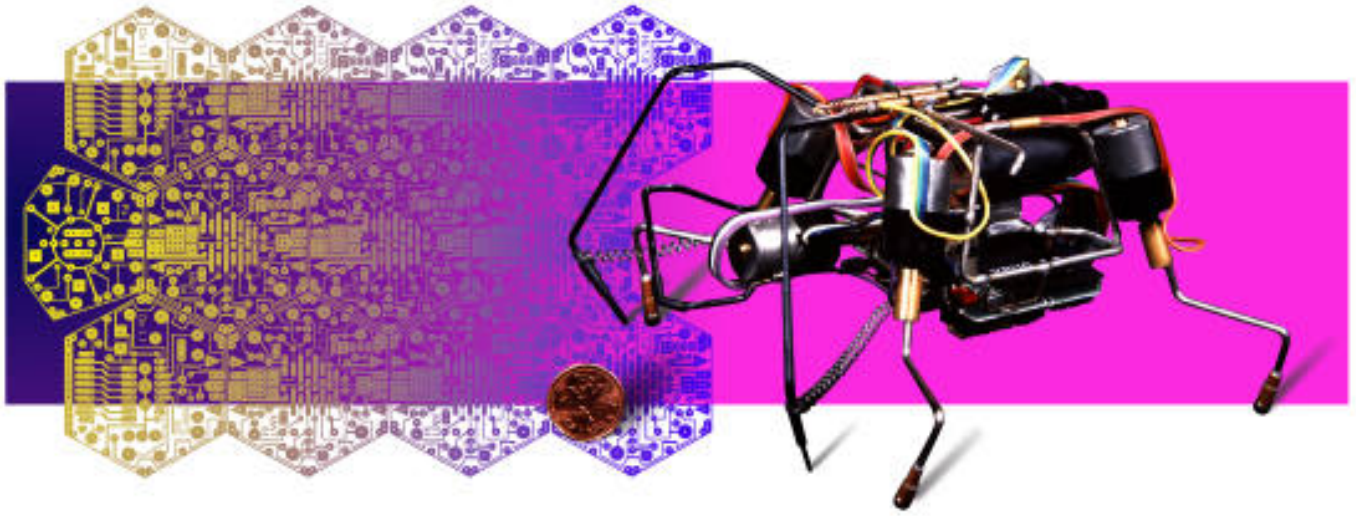

Biomorphs, autonomous mobile mechanisms.

Despite promises and attempts, digital machines are not good at dealing with the real world, and analog machines are not good at dealing with precise computation. The goal of our research is to combine the two to produce capable machines with a high performance-to-cost ratio. Although current technology has made great strides in building artificial reasoning machines, there has yet to be any definitive way of interfacing such "brains" with robot bodies capable of surviving real-world complexity. Almost every attempt to make truly autonomous robots has resulted in failure. Exceptions have usually involved fantastic sums of money and thousands of man hours.

There are simple and elegant solutions to making autonomous robotic devices that are adaptable and dependable even after they incur significant damage in operation in the field. Our idea is not to study just one aspect of autonomous robot construction, but all of them, with attention to costs, efficient designs, and biological precepts without digital computer simulation or dependence. To date, over 70 functional robotic devices have been constructed. Most are solar powered, are smaller than a telephone, and do not have processor-based controllers. Best of all, they are capable, long-lived, and extremely inexpensive.

Current research is focused in four areas: construction research, vertebrate design, invertebrate design, and cooperative-behavior studies. These fields and principles are not studied independently but in parallel, introducing new types of robots into a simple "ecology" where they have to deal with the real world and each other. Some have been built to solve simple needs (e.g., exploration, security, maintenance, and environmental management); others were built just to test some principle, material, or unique electronic device.

From our research, we have concluded that cooperative behavior amongst autonomous, goal-seeking organisms may not only be possible but also inevitable under low-stress circumstances. Moreover, it seems that the pervasive idea that robots must be fashioned upon some biological morphology (i.e., insects) may be inherently flawed. Robots are made from different materials and are based upon very different principles, so it follows that optimal robotic forms might also vastly differ from what we might expect. As for function, these robots have evolved from simple devices with wheels to some recent multilegged forms with astonishing adaptability.

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