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UVM professor explores robot's ability to evolve

By Tim Johnson, Free Press Staff Writer

If you had to choose the word that best describes the robots Josh Bongard has been working with lately, “robotic” would not be it.

“Adaptive” is more like it. He designs robots that can change or evolve — in body and in mind. “Mind,” that is, to the extent that a robot has a one, or a brain, in the form of the program that’s driving it.

Bongard, an assistant professor of computer science at the University of Vermont, got some attention a few years ago for his work on a robot dubbed “Starfish” that taught itself to walk. His recent research, which has also received national notice, looks at a robot with a flexible spine and four legs. Robots with this physique are given a simple task (the scientific term is “phototaxis”): to move from Point A to Point B (a light source) as quickly as possible, without falling.

Rather than providing the robots with a program that prescribes how to walk — as a conventional robotics engineer would do — Bongard feeds them an algororithm that lets them know all the possible ways they might move limbs and spine and then lets them reject the thousands of alternatives that don’t work in favor of the few that do.

Bongard does this with two variants: a “fixed body” robot that stands erect, on four vertical legs; and a “variable body” robot, which begins the exercise flat on the ground, with four legs splayed out.

What happens, over the course of many thousands of trial runs?

The variable-body robot starts out slithering like a snake, then totters on outstretched legs somewhat like a lizard, then rises up to the point of walking, and finally, running.

The fixed-body robot starts out by stumbling — and eventually gets to the running phase, but it’s not as stable as its counterpart. Add a stiff wind to the experimental mix and the fixed-body version gets blown over, while the other one remains upright, with a smoother gait. Bongard describes the variable-body robot as “more robust.”

The more successful robot has not merely changed, but it has also gone through evolutionary stages. Having solved the movement problem in the early going, it builds up speed without sacrificing balance.

The computer algorithm sets up a series of countless trials and errors, much like evolution in the natural world.

"The real goal," Bongard said, "is to demonstrate how biology can help us build better machines, using evolution to design them."

The robot's body and its motion-controlling "brain" change throughout the process, mimicking not just real-world evolution but also the development of an individual organism. Bongard noted that a baby learning to walk, too, is changing physically and mentally in ways that result eventually in bipedal locomotion.

Evolutionary robotics is a small but promising field, Bongard said. Robots capable of adapting are likely to be more practical for some tasks — exploring another planet, say, or clearing a construction site — than robots that have to be programmed how to respond to every possible eventuality.

He said another form of evolutionary research is under way in Switzerland, where groups of robots are being studied for the extent to which they can communicate or cooperate in performing a joint task.

Bongard does most of his research via computer simulation — he's more interested in the mathematics than in nitty-gritty robotic engineering. Nevertheless, to demonstrate that his findings go beyond theoretical abstraction, he used Legos to build a four-legged, flexible-spine robot that behaves pretty much like the video-game-like stick forms on the computer screen.

The calculations underpinning the full evolutionary transformation of his "robust" robot — from undulating mode to galloping — took eight hours on UVM's super computer. An ordinary PC, he said, would require 100 years to complete the same assignment.

Why wouldn't the evolving contraption just keep slithering toward the light? Can't a snake move about as fast as a dog? One advantage quadripeds have is that they require less energy (per unit of weight) to get from Point A to Point B, Bongard noted. A snake uses all its muscles continuously to advance; a dog's legs use relatively little energy when they're moving forward to get ready for their next propulsion. And bipeds — humans — require even less energy to walk.

So, why didn't the variable-body robot evolve into a biped? The algorithm limited it to the use of four legs. A future experiment that puts a premium on energy-efficiency could result in a light-seeking robot walking on two legs, Bongard said.

If a chore as simple as phototaxis takes eight hours of high-priced computer time, the more complex tasks Bongard would like to assign his mutable robots — fetching things, for example, or manipulating objects — might be unaffordable on the big computer.

So, he has another idea: Set up the tasks in the form of a video game, and then turn it loose on the Web, so that anyone with a PC anywhere in the world can have a crack at it.

If this works, the global "crowd" of video gamers will play the same role as the supercomputer in designing his next wave of evolutionary robots.

Perhaps one day, robots will be able to repair themselves — or even reproduce, Bongard mused, if they're given the right parts.

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Additional Facts

Watch the video

To see Bongard's robots in action — both the computer-simulations and the Lego versions — click here.
