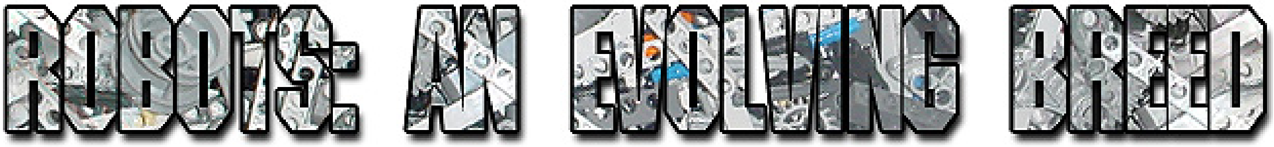
# Dr. Darwin teaches robot!

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## In robot education, does evolution beat all?

Robots are great at what they do — if the job is dull and predictable. Throw in the unexpected, and robots can do the unpredictable.

Courtesy Josh Bongard, University of Vermont

Josh Bongard built this gawky Lego robot, and taught it to (rollover) stand, trot and canter. Those complex linkages allow the legs to extend during the robot's "life."

The task of programming a robot's brain for the real world can be gnarly, says Josh Bongard, an assistant professor in the University of Vermont College of Engineering and Mathematical Sciences. "It turns out that building a robot, and programming it to do something interesting is a very non-intuitive process, and it's a difficult one for humans to do well."

The real world, he says, "is quite messy."

Robots, in the jargon, need "adaptive behavior" to accommodate changing circumstances, says Bongard. When programming a free-roaming robot, "We are not likely to factor in a lighting change or people moving in and out of the field of view."

It's not clear how animals or people make adaptations, Bongard says, "and so it's difficult to program a robot to do them."

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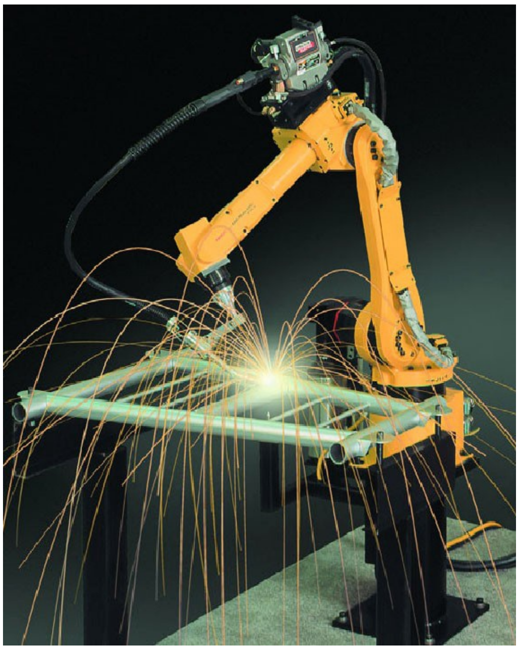

It's not too hard to teach industrial robots — like this welder — so long as every project is identical to the thousands before it.

## Robots: Are they alive?

Bongard, like a number of roboticists, is turning to biology for answers. But he does not want to emulate living structures. Instead, he wants to use evolution to craft robot control.

The process is akin to the "artificial selection" that helped lay the foundation for the science of evolution. Darwin, after all, wrote about how animal breeders had changed their livestock by repeatedly breeding the best animals and eating the rest.

In January, 2011, Bongard reported that he had taught four-legged, digital robots to stand and run toward a light source, by grading their control software on its ability to meet those goals.

Adaptive behavior was necessary, he says, because the light source could appear anywhere, or even take evasive action, "so the robot can't just move its legs blindly every time."

The robots had five seconds to do or die, and their first movements were grotesque because the control software initially moved their body parts at random. After every attempt, the control programs were graded by their ability to walk, stay upright and approach the light.

It's brutal. More than 100 million failed programs went to the virtual graveyard in the name of science, Bongard says. The programs that showed some promise were retained, randomly varied and re-tested.

The same process is found in nature, where successful genes that face random mutation are re-tested by tomorrow's environment.

Like the average biological mutation, the mutated robot software usually failed. But over a year of supercomputer time — equivalent to 1,000 years on a desktop computer — the winning programs evolved the ability to walk toward the light.

Courtesy Josh Bongard, University of Vermont.

Watch a floundering, random robot learn to walk!

## Weird winners

Considering the amount of trial and error, that was a satisfying but not necessarily surprising result. But here's something to chew on. Bongard found that robots "born" with four legs had a handicap. During repeated simulations, the robots that started as snakes and developed legs during the five-second experiment were much quicker to learn the task.

You might guess — we would have — that the quick learning would have occurred in robots with full-time four-leg drive, given their longer experience with legged locomotion, but Bongard says the leg-free starters benefited by chunking the challenge: a) learn to approach the light, and b) learn to walk.

These robots "could evolve the ability to go from point A to point B while they still look like a snake, they don't have to worry about balance, because they are already on the ground," Bongard says. "Once evolution has figured out how to move toward the light, the ability to move on four legs could evolve."

Meanwhile, the four-legged counterparts may still be flipping, flopping and floundering (Note to self: sell soul as political hit-man if science-writing gig crash-burns?) "The robots that had to stand upright would fall over, and it took evolution a long time to master balance," Bongard says.

The approach — take the winners and vary them for a retest — resembles directed chemical evolution, which aims to create a better antibiotic by modifying and retesting molecules that show some ability to kill bacteria. "It's basically the same idea," says Bongard, "but instead of a candidate drug, we have virtual robots, and instead of selecting for … resistance to disease, they are selected for the ability to get to the light."

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We're guessing this ancient attempt at a robot, who is tea timing with its inventor Captain W.H. Richards in Berlin in 1930, was not taught according to the principles of evolution through artificial selection.

## Robots resemble rodents?

As a final exam for the digital robots, Bongard tested their balance with a blast of air. Although the leg-less robots "had evolved into legged robots that looked exactly like the other species, they were better able to run around under simulated windy conditions," Bongard reports.

Bongard is first to acknowledge that he is "stealing from biology to help us build better robots," but says, "the more interesting question is what this tells us about biological evolution. This recent work suggests that robots that change their bodies gain an adaptive advantage … and you see the same radical changes in body plan in nature: in insects, reptiles and in humans as they develop from infant to adult."

– David J. Tenenbaum

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