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A droid for all seasons

No job is too unusual for a breed of robots that reinvent themselves

IMAGINE an automaton that can design itself, assemble itself and even kill itself. No, it's not the liquid metal robot from Terminator 2--but this droid can certainly build itself to perform a particular task, melt itself down and recycle itself, say researchers in Massachusetts.

The scientists have developed what they call a polymorphic robot--a machine that can change its shape to suit the job in hand. Shape-shifting robots could be used as planetary explorers, or for search-and-rescue missions, changing their shape to meet each new challenge and adapting to strange and unpredictable environments.

The researchers have produced a simple thermoplastic-framed robot, says Hod Lipson, who developed it with Jordan Pollack at Brandeis University, near Boston. "All the robot has to do is find a way to move," he says. The prototype is very basic and has no sensors, so it is unaware of the world, though sensors could be added at a later design stage.

The idea is that a task will be set for the robot, such as: "Figure out how to move using only one leg and one motor." A computer will then attempt to design a body that will help it to meet this challenge most efficiently. At present, the robot's body is built using the "rapid prototyping" technology common in the car industry, which can produce complex three-dimensional structures very quickly. A device called a 3D printer uses a nozzle to build up progressive layers of thermoplastic, slowly creating the required structure (click on thumbnail graphic below).

Although 3D printers are large and cumbersome, says Lipson, much smaller ones could one day be built into a robot, allowing it to change parts of its body, for example, to reshape an arm to produce a new tool for a novel situation. Mark Yim of the Xerox Palo Alto Research Center (PARC) in California says this is one area in which polymorphic robots could be most useful. There's no point in taking an entire toolkit into space, he says, when you don't know which tools you'll need: a single robot arm can be shaped to do the job of all of them.

It is also conceivable, says Lipson, that the 3D printing technology will allow several materials to be printed, including conductive, nonconductive

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and even semiconductive materials. "Wires, motors and logic circuits, as well as structure, could be printed in one pass without the need for assembly," Lipson predicts.

With each new task, the look of a polymorphic robot is impossible to predict, because each design is "evolved" using a genetic algorithm. The physical structure, and the neural network that will be the brains of the proposed robot, are treated like genetic information that can be combined and mutated in simulation to produce entirely new designs. The "fitness" of these offspring is then evaluated and the best are "bred" to produce more offspring. This process is repeated many times until the design has evolved to do the best job.

To keep things simple, Lipson allowed the algorithm only basic components with which to design the prototype robot: straight plastic bars of varying lengths and electric motors that can extend or shrink the length of a bar. Joints are all ball-and-socket designs, as these are easily created by a 3D printer. From these basic parameters a host of complex--sometimes lifelike--structures have been evolved.

Some versions push themselves along on one leg, while others produce a hinge-like motion and crawl about like a fish out of water. Yet another moves sideways like a crab. "The robot is ready to move when it comes out of the printer," says Lipson. Its motor, however, must be inserted by a person. But the aim is to make the robots totally independent, much like the vengeful shape-shifter in Terminator 2.

When the robot has performed its task, it offers itself up to be melted down, so its thermoplastic components can be recycled into another useful droid by the 3D printer.

The idea of building and melting down robots is novel, says Yim, who makes modular robots that reshape themselves by fitting smaller robots together. "I've never seen anything like it." But he warns that to make truly useful robots, stronger plastics and more materials are needed.

Further reading:

- www.demo.cs.brandeis.edu/golem

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