This robot takes 120 seconds to recover from a limb amputation

ROBOTS / 28 MAY 15 / by LIAT CLARK

The scene in *Terminator 2* where the T-1000 melts and reforms after Arnold Schwarzenegger's T-800 blasts it to pieces just got one step closer to becoming a reality. Sort of.

In a rather less dramatic, but no less impressive scene (particularly considering it's real), a six-legged robot has been shown to recover in under two minutes after having two of its limbs broken, thanks to a new piece of software. In another video, a robotic arm that has had several motors

https://youtube.com/devicesupport *YouTube Help*

smashed, relearns how to hold and move an object with the same accuracy.

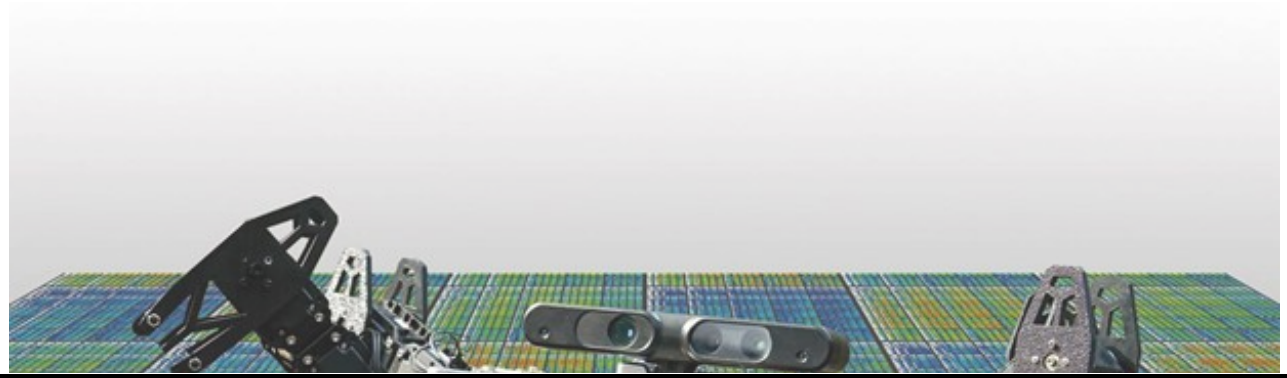
The videos, presented in the journal *Nature*, are the work of a team led by a pair of roboticists from the Pierre and Marie Curie University in France, working on building robots that are able to survive and thrive post-injury.

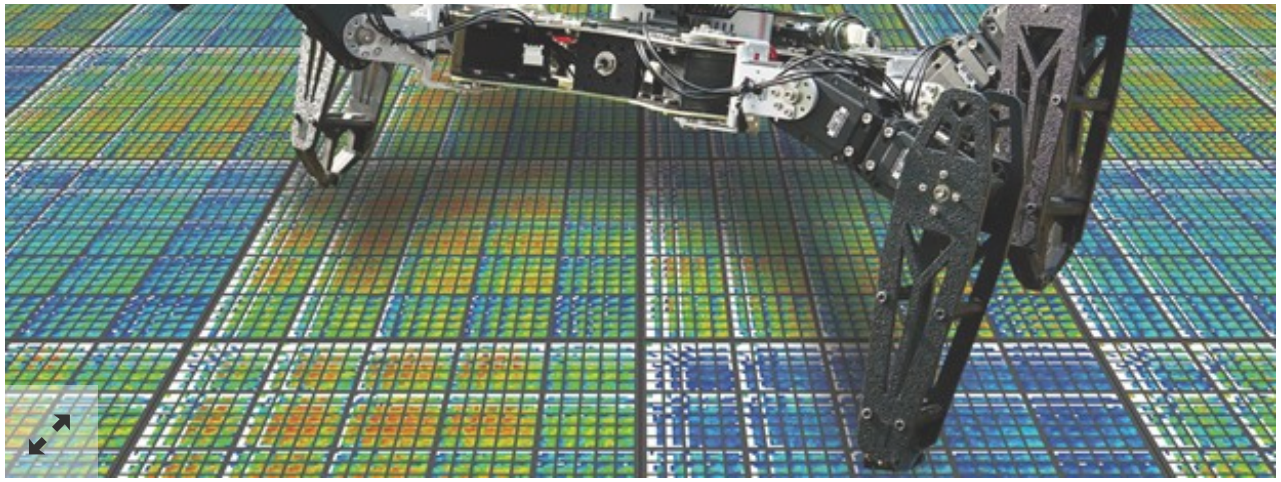
Of course, they do not have a dystopian vision of the T-1000 rising from the ashes in mind. In *Nature*, they note: "Robots... have the power to deliver tremendous benefits to society, such as in search and rescue, disaster response, health care and transportation. They are also invaluable tools for scientific exploration in environments inaccessible to humans, from distant planets to deep oceans."

Robots are already commonplace in factory settings, but what's holding them back from disrupting the aforementioned industries, the researchers say, "is their fragility" outside of a controlled environment. "Current robots cannot 'think outside the box' to find a compensatory

behaviour when they are damaged: they are limited to their pre-specified self-sensing abilities, can diagnose only anticipated failure modes, and require a pre-programmed contingency plan for every type of potential damage, an impracticality for complex robots."

The team looked to the animal kingdom for inspiration, where a process of trial and error allows critters to adapt. "When injured, animals do not start learning from scratch," said senior author Jean-Baptiste Mouret in a statement. "Instead, they have intuitions about different ways to behave. These intuitions allow them to intelligently select a few, different behaviours to try out and, after these tests, they choose one that works in spite of the injury. We made robots that can do the same."





The starting point, was to create a robot that would not need "pre-specified contingency plans" to recover from an injury. Instead, the robots are programmed to store knowledge from previous experiences and create a map based on these behaviour-performance histories. "This map represents the robot's prior knowledge about what behaviours it can perform and their value. When the robot is damaged, it uses this prior knowledge to guide a trial-and-error learning algorithm that conducts intelligent experiments to rapidly discover a behaviour that compensates for the damage."

So the robot might not choose the optimum solution first time around, but in a classic trial-and-error

approach will keep learning from each false start until a solution is found -- something other roboticists have in mind elsewhere.

The team inflicted a whole series of different injuries on their robots, from breaking to completely removing limbs or joints. Every time, the robot relied on the algorithm -- an evolutionary algorithm known as MAP-Elites -- to carry out a series of tests. "For example, if walking mostly on its hind legs, does not work well, it will next try walking mostly on its front legs," explained lead author Antoine Cully. "What's surprising is how quickly it can learn a new way to walk. It's amazing to watch a robot go from crippled and flailing around to efficiently limping away in about two minutes."

Coauthor Danesh Tarapore predicts that a robot equipped with this algorithm could help rescue teams, without ever becoming a burden for them.

There are, of course, plenty of other dystopian uses for an adaptive robot. In this instance, the research was funded by the Agence Nationale pour la

Recherche and the European Research Commission. But over in the US, Darpa has been funding two programmes for creating drones that can completely autonomously track and kill targets. In another paper published in *Nature* this week, author Stuart Russell, professor of computer science at the University of California, Berkley, warned that if such a robot were created and deployed, it could breach the Geneva Convention.

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