PHYS ORG

On the origin of (robot) species

August 12 2015, by Sarah Collins

Researchers have observed the process of evolution by natural selection at work in robots, by constructing a 'mother' robot that can design, build and test its own 'children', and then use the results to improve the performance of the next generation, without relying on computer simulation or human intervention.

Researchers led by the University of Cambridge have built a mother robot that can independently build its own children and test which one does best; and then use the results to inform the design of the next generation, so that preferential traits are passed down from one generation to the next.

Without any human intervention or computer simulation beyond the initial command to build a robot capable of movement, the mother created children constructed of between one and five plastic cubes with a small motor inside.

In each of five separate experiments, the mother designed, built and tested generations of ten children, using the information gathered from one generation to inform the design of the next. The results, reported in the open access journal *PLOS One*, found that preferential traits were passed down through generations, so that the 'fittest' individuals in the last generation performed a set task twice as quickly as the fittest individuals in the first generation.

"Natural selection is basically reproduction, assessment, reproduction, assessment and so on," said lead researcher Dr Fumiya Iida of Cambridge's Department of Engineering, who worked in collaboration with researchers at ETH Zurich. "That's essentially what this robot is doing – we can actually watch the improvement and diversification of the species."

For each robot child, there is a unique 'genome' made up of a combination of between one and five different genes, which contains all of the information about the child's shape, construction and motor commands. As in nature, evolution in robots takes place through 'mutation', where components of one gene are modified or single genes are added or deleted, and 'crossover', where a new genome is formed by merging genes from two individuals.

In order for the mother to determine which children were the fittest, each child was tested on how far it travelled from its starting position in a given amount of time. The most successful individuals in each generation remained unchanged in the next generation in order to preserve their abilities, while mutation and crossover were introduced in the less successful children.

The researchers found that design variations emerged and performance improved over time: the fastest individuals in the last generation moved at an average speed that was more than twice the average speed of the fastest individuals in the first generation. This increase in performance was not only due to the fine-tuning of design parameters, but also because the mother was able to invent new shapes and gait patterns for the children over time, including some designs that a human designer would not have been able to build.

"One of the big questions in biology is how intelligence came about – we're using robotics to explore this mystery," said Iida. "We think of robots as performing repetitive tasks, and they're typically designed for mass production instead of mass customisation, but we want to see robots that are capable of innovation and creativity."

In nature, organisms are able to adapt their physical characteristics to their environment over time. These adaptations allow biological organisms to survive in a wide variety of different environments – allowing animals to make the move from living in the water to living on land, for instance.

But machines are not adaptable in the same way. They are essentially stuck in one shape for their entire 'lives', and it's uncertain whether changing their shape would make them more adaptable to changing environments.

Evolutionary robotics is a growing field which allows for the creation of autonomous robots without human intervention. Most work in this field is done using computer simulation. Although computer simulations allow researchers to test thousands or even millions of possible solutions, this often results in a 'reality gap' – a mismatch between simulated and real-world behaviour.

While using a computer simulation to study artificial evolution generates thousands, or even millions, of possibilities in a short amount of time, the researchers found that having the robot generate its own possibilities, without any computer simulation, resulted in more successful children. The disadvantage is that it takes time: each child took the robot about 10 minutes to design, build and test. According to Iida, in future they might use a computer simulation to pre-select the most promising candidates, and use real-world models for actual testing.

Iida's research looks at how robotics can be improved by taking inspiration from nature, whether that's learning about intelligence, or finding ways to improve robotic locomotion. A robot requires between ten and 100 times more energy than an animal to do the same thing. Iida's lab is filled with a wide array of hopping robots, which may take their inspiration from grasshoppers, humans or even dinosaurs. One of his group's developments, the 'Chairless Chair', is a wearable device that allows users to lock their knee joints and 'sit' anywhere, without the need for a chair.

"It's still a long way to go before we'll have robots that look, act and think like us," said Iida. "But what we do have are a lot of enabling technologies that will help us import some aspects of biology to the engineering world."

More information: "Morphological Evolution of Physical Robots through Model-Free Phenotype Development" *PLOS One* (2015). DOI: 10.1371/journal.pone.0128444

Provided by University of Cambridge