Metamorphosis key to creating stable walking robots

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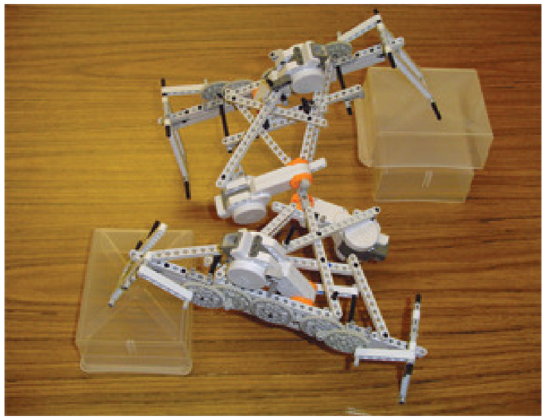
Virtual robots learning to walk are steadiest on their feet when they start out with no legs and are allowed to evolve limbs over time. As well as helping to design more stable robots, the implication is that creatures whose body plans morph as they grow may have an evolutionary advantage.



Learning how to walk (Image: Josh Bongard/UVM)

Programming robots to walk without falling over is arduous, so Josh Bongard at the University of Vermont in Burlington set out to find the quickest way to evolve walking behaviours. To do this, he ran simulations of several types of robots and gave each the same goal: to seek out a virtual light source and evolve a walking gait to reach it.

Bongard added another twist to the simulation, though. Some of his virtual bots could change their body plan over time, "in much the same way that an initially legless tadpole develops into a legged frog over its lifetime", he says. One slithered along the ground like a snake, but gradually grew four vertical legs. Another began with four legs splayed out horizontally in lizard fashion – its legs gradually shifted into a vertical position beneath its body. A third type of virtual bot had four upright legs to start with and lacked the ability to evolve its body plan.

Each bot used a software routine called a genetic algorithm to evolve a slithering or walking gait that would best get it to the light source given its current body plan. Once each bot had evolved to the point where it could walk upright on four legs and reach the light source within a fixed time period, Bongard ran the algorithms on a real four-legged walking robot to assess the results (see movie).

No pushover

He found that the four-legged robot was stable when programmed to walk like any of the virtual bots that had metamorphosed with time. "Metamorphosed robots were able to continue walking even if they were randomly pushed around," he says. However, when the four-legged robot adopted the walking style of a virtual bot with a fixed body plan, it was far more prone to falling over when pushed. Bongard thinks that's because the morphed robots had to remain balanced and on course through many body plans, so the gait they finally adopted had greater stability.

In terms of biology, evolving behaviours like locomotion may be easier if the animal progresses through body plans that allow for gradual learning over time, says Bongard. "This is what human infants do: they progress from crawling to walking gradually, even as the bones in the legs and feet change to accommodate the change in behaviour."

The results are useful for engineers, says Hod Lipson, a roboticist at Cornell University in Ithaca, New York: "We may now need to examine new ways to allow robots to automatically adapt their hardware, not just their software, if we are to achieve higher levels of performance."

Bongard agrees, but thinks Lipson's call to action might be premature. "We need advances in materials to realise robots that can grow new legs," he says.

Four legs good

Even without those advanced materials, though, roboticists have begun to experiment with some of these concepts by manually altering the body plans of their robots. In 2009, Chris MacLeod at Robert Gordon University in Aberdeen, UK, used a similar algorithm to teach a simple two-legged walking robot how to adjust its gait to cope with the addition of an extra pair of legs – a step towards more advanced and adaptive robots, MacLeod thinks.

He is interested by Bongard's "embryological approach" – the way that his simulations mimic the changes seen in some animals between birth and adulthood. "It is certainly worthy of further study," he says.

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