EVOLUTION (/TAG/EVOLUTION)

To Create Advanced Robots, Let Them Evolve in Complex Environments

By Derek Mead (/author/DerekMead)

A control organism, showing very simple structure and movement, courtesy Auerbach and Bongard

Life, borne of a primordial soup, has spent the last couple billion years blossoming into a kaleidoscope of incredibly complex organisms. Why? The question of what causes organisms to become more complex has been contested since Darwin's days.

In fact, the very idea that life inherently becomes more complex—think of those evolution of man cartoons—is a source of debate. For one, if there was pressure on all life to increase in complexity, why do single-celled organisms and simple viruses still exist? Why have some creatures actually evolved to be simpler?

A new study offers some interesting insight, and it doesn't involve studying living creatures as you might expect. Instead, a pair of researchers have studied how complexity arises in evolving robots. The results are fascinating: Computer creatures, allowed to compete and evolve much as natural organisms do, become more complex in response to more complex environments. Stick a virtual being in a virtual box, and it's not likely to become too advanced. But stick it in an environment with myriad challenges and opportunities, and it will become far more specialized.

The work, published in *PLOS Computational Biology (http://www.ploscompbiol.org/article/info%3Adoi%2F10.1371%2Fjournal.pcbi.1003399#pcbi.1003399-Sims1)*, is a fascinating look at the so-called "arrow of complexity" hypothesis (http://www.ncbi.nlm.nih.gov/pubmed/18489250), which argues that organisms tend to become

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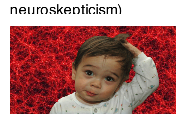
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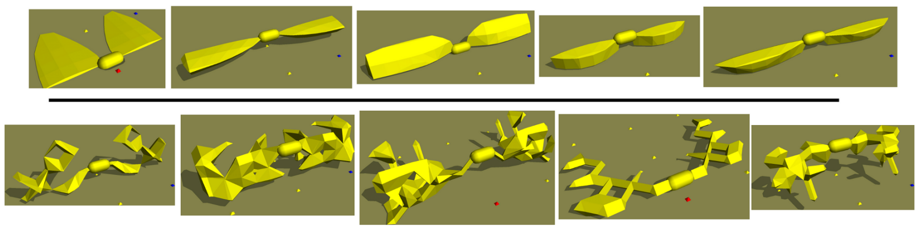
more complex over time as they're shaped by evolutionary pressures. To test this, he research duo of Joshua E. Auerbach and Josh C. Bongard developed a computer model of evolution, in which virtual organisms were tested in their ability to move around varying environments.



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The five robots with the least amount of change on top, and the five with the most complex structures on bottom. Via Auerbach and Bongard

Such work has been done before, but Auerbach and Bongard argue that their model is more valuable because it allows for varied terrain. So unlike some previous models, which modeled the evolution of locomotion on flat virtual terrain, their model saw how organisms responded to terrain of varying complexity.

The terrain models consisted of two types of ground: a high-friction surface, and a very low-friction surface like ice. A control group evolved on purely flat, high-friction ground, while experimental models involved high-friction surfaces with rows of ice. Because the ice was so slippery, the only way to move across it was to reach into the gaps between ice bars and pull across, requiring more advanced appendages.

To provide a basis for the organisms' evolution, the team developed both single- and multi-objected selection models, based on the CPPN-NEAT method for robotic evolution, a topic the pair have written about before (http://www.cs.uvm.edu/~jbongard/papers/2011_GECCO_Auerbach.pdf). In the new study, they found that in highly complex environments, the complexity of the virtual creatures skyrocketed.

"Our work supports the idea that the morphological complexity of organisms is influenced by the complexity of the environments in which they evolve," Auerbach said in a release. "While our work does not prove anything about biological complexity, it does provide a new methodology for investigating questions about the evolution of complexity in silico."

A combination of icy and high-friction environment produced a far more complex creature

So while it's not proof that complex environments beget organismal complexity, the study does lend more support to the idea. And while the arrow of complexity might not be a one-way affair, it is fairly intuitive. Speciation is driven by organisms finding (or being pushed into) new niches, and more complex environments tend to play host to more species. Of course, figuring out which came first is the big question.

But Auerbach and Bongard's study has huge implications in another space: the evolution of robots. Along with the National Science Foundation, the research was funded by DARPA, which is quite interested in robot development. Similar work done last year, and funded by the same set of NSF and DARPA grants, also demonstrated a platform for simulated robot construction and evolution (http://www.cs.uvm.edu/~jbongard/papers/2012_GECCO_Beliveau.pdf).

It's fascinating work because it allows for parameter-based development in an autonomous fashion. Reverse-engineered with a specific goal in mind, a virtual model of evolution thus becomes a rather cutthroat prototyping and problem-solving program. In the latest study, robots responded to fairly simple tasks—moving across a varied environment—but even then, the result is highly efficient designs.

Imagine putting such design processes to use on a larger scale, for more real-world design challenges, and you get an idea of why the work is so compelling. What if, instead of developing engineers solutions to robotics challenges, we could solve them evolutionarily? How about using virtual evolution to create advanced AI?

Of course, all of that requires incredible computing resources. According to the authors, "all of the experiments were carried out on a 7.1 teraflop supercomputing cluster and required a total of over 100 CPU-years of distributed compute time," which isn't exactly cheap. So while I wouldn't expect to be modeling evolution at home any time soon, these are the early stages, and the process will get cheaper and more refined over time.

By Derek Mead (/author/DerekMead) | 1 day ago

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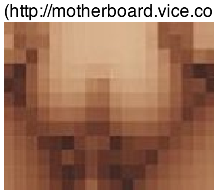

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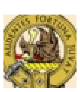

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These results are not unexpected. In fact it is well established that any replicative system provided with a source of variation (mutation, for instance, in the case of biology) and a selective (competitive) mechanism which can filter the variants, those so produced will tend to be more complex than those of the previous generation.
This gross trend is inevitable.

In the case of apparently retrograde biological evolution, the virioids and viruses for instance it must be realized that where a niche is there to be filled it almost certainly will be. Moreover we must remember that in such cases it is not really sensible to consider the parasitic organism alone. Because it is entirely dependent upon its host. So we really have to view it in the context of a composite host-parasite system.
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