Evolution of learning is key to better artificial intelligence

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Anselmo Pontes, MSU computer science researcher. Credit: Michigan State University

Since "2001: A Space Odyssey," people have wondered: could machines like HAL 9000 eventually exist that can process information with human-like intelligence?

Researchers at Michigan State University say that true, human-level intelligence remains a long way off, but their new paper published in *The American Naturalist* explores how computers could begin to evolve learning in the same way as natural organisms did—with implications for many fields, including artificial intelligence.

"We know that all organisms are capable of some form of learning, we just weren't sure how those abilities first evolved. Now we can watch these major evolutionary events unfold before us in a virtual world," said Anselmo Pontes, MSU computer science researcher and lead author. "Understanding how learning behavior evolved helps us figure out how it works and provides insights to other fields such as neuroscience, education, psychology, animal behavior, and even AI. It also supplies clues to how our brains work and could even lead to robots that learn from experiences as effectively as humans do."

According to Fred Dyer, MSU integrative biology professor and co-author, these findings have the potential for huge implications.

"We're untangling the story of how our own cognition came to be and how that can shape the future," Dyer said. "Understanding our own origins can lead us to developing robots that can watch and learn rather than being programmed for each individual task."

The results are the first demonstration that shows the evolution of associative learning in an artificial organism without a brain.

"Our inspiration was the way animals learn landmarks and use them to navigate their environments," Pontes said. "For example, in laboratory experiments, honeybees learn to associate certain colors or shapes with directions and navigate complex mazes."

Since the evolution of learning cannot be observed through fossils—and would take more than a lifetime to watch in nature—the MSU interdisciplinary team composed of biologists and computer scientists used a digital evolution program that allowed them to observe tens of thousands of generations of evolution in just a few hours, a feat unachievable with living systems.

In this case, organisms evolved to learn and use environmental signals to help them navigate the environment and find food.

"Learning is crucial to most behaviors, but we couldn't directly observe how learning got started in the first place from our purely instinctual ancestors," Dyer said. "We built in various selection pressures that we thought might play a role and watched what happened in the computer."

While the environment was simulated, the evolution was real. The programs that controlled the digital organism were subject to genetic variation from mutation, inheritance and competitive selection. Organisms were tasked to follow a trail alongside signals that—if interpreted correctly—pointed where the path went next.

In the beginning of the simulation, organisms were "blank slates," incapable of sensing, moving or learning. Every time an organism reproduced, its descendants could suffer mutations that changed their behavior. Most mutations were lethal. Some did nothing. But the rare traits that allowed an organism to better follow the trail resulted in the organism collecting more resources, reproducing more often and, thus, gaining share in the population.

Over the generations, organisms evolved more and more complex behaviors. First came simple movements allowing them to stumble into food. Next was the ability to sense and distinguish different types of signals, followed by the reflexive ability to correct errors, such as trying an incorrect path, backing up and trying another.

A few organisms evolved the ability to learn by association. If one of these organisms made a wrong turn it would correct the error, but it would also learn from that mistake and associate the specific signal it saw with the direction it now knew it should have gone. From then on, it would navigate the entire trail without any further mistakes. Some organisms could even relearn when tricked by switching signals mid-trail.

"Evolution in nature might take too long to study," Pontes said, "but evolution is just an algorithm, so it can be replicated in a computer. We were not just able to see how certain environments fostered the evolution of learning, but we saw populations evolve through the same behavioral phases that previous scientists speculated should happen but didn't have the technology to see."

Other MSU co-authors include Robert Mobley, Charles Ofria and Christoph Adami. This project was developed through the BEACON Center for the Study of Evolution in Action, which brings together biologists, computer scientists and engineers to illuminate and harness the power of evolution.

"Pontes and colleagues have evolved associated learning in a computer from the raw ingredients of mutation, inheritance and competitive selection," said George Gilchrist, program director at the National Science Foundation, which funds the BEACON science and technology center. "This opens the door to creating artificial intelligence systems without the limitations imposed by human design."

More information: Anselmo Pontes et al. The Evolutionary Origin of Associative Learning, *The American Naturalist* (2019). DOI: 10.1086/706252

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