Ecology and artificial intelligence: Stronger together

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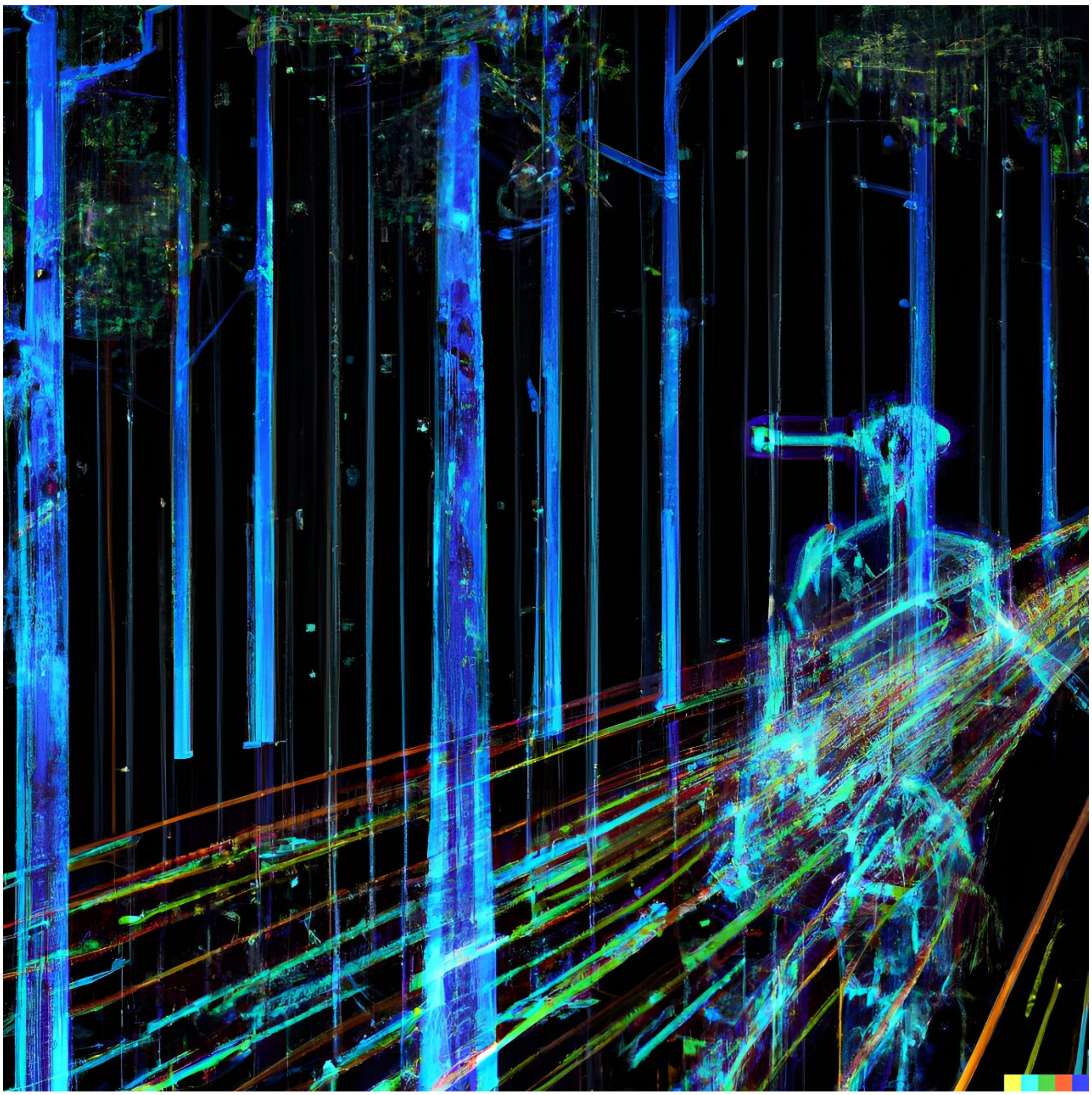

An image generated by the AI system DALL-E using the prompt, “a synergistic future for artificial intelligence and complex ecological systems”. Credit: Barbara Han

Many of today's artificial intelligence systems loosely mimic the human brain. In a paper published in *Proceedings of the National Academy of Sciences*, researchers suggest that another branch of biology—ecology—could inspire a whole new generation of AI to be more powerful, resilient, and socially responsible.

The paper argues for a synergy between AI and ecology that could both strengthen AI and help to solve complex global challenges, such as disease outbreaks, loss of biodiversity, and climate change impacts.

The idea arose from the observation that AI can be shockingly good at certain tasks, but still far from useful at others—and that AI development is hitting walls that ecological principles could help it to overcome.

"The kinds of problems that we deal with regularly in ecology are not only challenges that AI could benefit from in terms of pure innovation—they're also the kinds of problems where if AI could help, it could mean so much for the global good," explained Barbara Han, a disease ecologist at Cary Institute of Ecosystem Studies, who co-led the paper along with IBM Research's Kush Varshney. "It could really benefit humankind."

How AI can help ecology

Ecologists—Han included—are already using artificial intelligence to search for patterns in large data sets and to make more accurate predictions, such as whether new viruses might be capable of infecting humans, and which animals are most likely to harbor those viruses.

However, the new paper argues that there are many more possibilities for applying AI in ecology, such as in synthesizing big data and finding missing links in complex systems.

Scientists typically try to understand the world by comparing two variables at a time—for example, how does population density affect the number of cases of an infectious disease? The problem is that, like most complex ecological systems, predicting disease transmission depends on many variables, not just one, explained co-author Shannon LaDeau, a disease ecologist at Cary Institute. Ecologists don't always know what all of those variables are, they're limited to the ones that can be easily measured (as opposed to social and cultural factors, for example), and it's hard to capture how those different variables interact.

"Compared to other statistical models, AI can incorporate greater amounts of data and a diversity of data sources, and that might help us discover new interactions and drivers that we may not have thought were important," said LaDeau. "There is a lot of promise for developing AI to better capture more types of data, like the socio-cultural insights that are really hard to boil down to a number."

In helping to uncover these complex relationships and emergent properties, artificial intelligence could generate unique hypotheses to test and open up whole new lines of ecological research, said LaDeau.

How ecology can make AI better

Artificial intelligence systems are notoriously fragile, with potentially devastating consequences, such as misdiagnosing cancer or causing a car crash.

The incredible resilience of ecological systems could inspire more robust and adaptable AI architectures, the authors argue. In particular, Varshney said that ecological knowledge could help to solve the problem of mode collapse in artificial neural networks, the AI systems that often power speech recognition, computer vision, and more.

"Mode collapse is when you're training an artificial neural network on something, and then you train it on something else and it forgets the first thing that it was trained on," he explained. "By better understanding why mode collapse does or doesn't happen in natural systems, we may learn how to make it not happen in AI."

Inspired by ecological systems, a more robust AI might include feedback loops, redundant pathways, and decision-making frameworks. These flexibility upgrades could also contribute to a more 'general intelligence' for AIs that could enable reasoning and connection-making beyond the specific data that the algorithm was trained on.

Ecology could also help to reveal why AI-driven large language models, which power popular chatbots such as ChatGPT, show emergent behaviors that are not present in smaller language models. These behaviors include 'hallucinations'—when an AI generates false information. Because ecology examines complex systems at multiple levels and in holistic ways, it is good at capturing emergent properties such as these and can help to reveal the mechanisms behind such behaviors.

Furthermore, the future evolution of artificial intelligence depends on fresh ideas. The CEO of OpenAI, the creators of ChatGPT, has said that further progress will not come from simply making models bigger.

"There will have to be other inspirations, and ecology offers one pathway for new lines of thinking," said Varshney.

Toward co-evolution

While ecology and artificial intelligence have been advancing in similar directions independently, the researchers say that closer and more deliberate collaboration could yield not-yet-imagined advances in both fields.

Resilience offers a compelling example for how both fields could benefit by working together. For ecology, AI advancements in measuring, modeling, and predicting natural resilience could help us to prepare for and respond to climate change. For AI, a clearer understanding of how ecological resilience works could inspire more resilient AIs that are then even better at modeling and investigating ecological resilience, representing a positive feedback loop.

Closer collaboration also promises to promote greater social responsibility in both fields. Ecologists are working to incorporate diverse ways of understanding the world from Indigenous and other traditional knowledge systems, and artificial intelligence could help to merge these different ways of thinking. Finding ways to integrate different types of data could help to improve our understanding of socio-ecological systems, de-colonize the field of ecology, and correct biases in AI systems.

"AI models are built on existing data, and are trained and retrained when they go back to the existing data," said co-author Kathleen Weathers, a Cary Institute ecosystem scientist. "When we have data gaps that exclude women over 60, people of color, or traditional ways of knowing, we are creating models with blindspots that can perpetuate injustices."

Achieving convergence between AI and ecology research will require building bridges between these two siloed disciplines, which currently use different vocabularies, operate within different scientific cultures, and have different funding sources. The new paper is just the beginning of this process.

"I'm hoping that it at least sparks a lot of conversations," says Han.

Investing in the convergent evolution of ecology and AI has the potential to yield transformative perspectives and solutions that are as unimaginable and disruptive as recent breakthroughs in chatbots and generative deep learning, the authors write. "The implications of a successful convergence go beyond advancing ecological disciplines or achieving an artificial general intelligence—they are critical for both persisting and thriving in an uncertain future."

More information: Han, Barbara A. et al, A synergistic future for AI and ecology, *Proceedings of the National Academy of Sciences* (2023). DOI: 10.1073/pnas.2220283120. doi.org/10.1073/pnas.2220283120

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