Researchers sniff out AI breakthroughs in mammal brains

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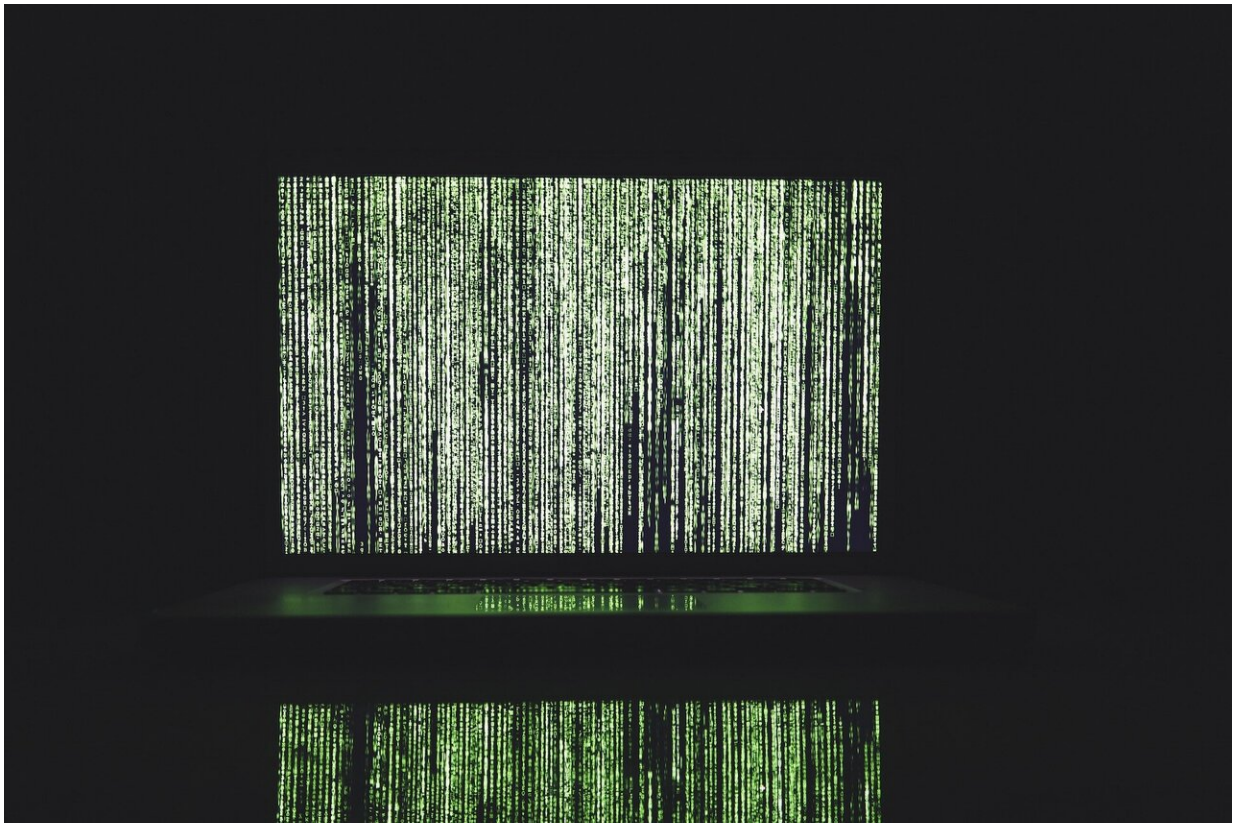

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When you smell an orange, the scent is most likely combined with several others: car exhaust, garbage, flowers, soap. Those smells bind simultaneously to the hundreds of receptors in your brain's olfactory bulb, obscuring one another, yet you can still recognize the smell of an orange, even when it's blended with a totally different pattern of other scents.

The precise mechanics of how mammals learn and identify smells have long eluded scientists. New Cornell research explains some of these functions through a computer algorithm inspired by the mammalian olfactory system. The algorithm both sheds light on how the brain works and, applied to a computer chip, rapidly and reliably learns patterns better than existing machine learning models.

"This is a result of over a decade of studying olfactory bulb circuitry in rodents and trying to figure out essentially how it works, with an eye towards things we know animals can do that our machines can't," said Thomas Cleland, professor of psychology and senior author of "Rapid Learning and Robust Recall in a Neuromorphic Olfactory Circuit," which published in *Nature Machine Intelligence* March 16.

"We now know enough to make this work. We've built this computational model based on this circuitry, guided heavily by things we know about the biological systems' connectivity and dynamics," Cleland said. "Then we say, if this were so, this would work. And the interesting part is that it does work."

Cleland and co-author Nabil Imam, Ph.D. '14, a researcher at Intel, applied the algorithm to an Intel computer chip. The research chip, known as Loihi, is neuromorphic—meaning it's inspired by the way the brain functions, incorporating digital circuits that mimic the way neurons communicate and learn. For example, the Loihi research chip is based on many parallel cores which communicate via discrete spikes, and the effects delivered by each of these spikes can change based solely on local activity. This architecture requires fundamentally different strategies for algorithm design compared with existing computer chips.

Using neuromorphic computer chips, machines could learn to identify patterns or perform certain tasks a thousand times faster than by using the computer's central or graphics processing units, as most programs do. Running certain algorithms on the Loihi research chip also uses about a thousand times less power than traditional methods, according to Intel.

The chip is the optimal platform for Cleland's algorithm, which can accept input patterns from an array of sensors, learn multiple patterns rapidly and sequentially, and then identify each of these meaningful patterns despite strong sensory interference. The algorithm can successfully identify odors even when their pattern is 80% different from the pattern the computer originally learned.

"The pattern of the signal has been substantially destroyed," Cleland said, "and yet the system is able to recover it."

The mammalian brain is stunningly adept at identifying and remembering smells, with hundreds or even thousands of olfactory receptors and complex neural networks rapidly analyzing the patterns associated with odors. Our brains also retain what we've learned even after we've acquired new knowledge—something that's easy for mammals but difficult for artificial intelligence systems. Particularly in deep learning approaches, everything must be presented to the network at the same time, because new information can distort or destroy what the system learned before.

The brain-inspired algorithm solves this problem, Cleland said.

"When you learn something, it permanently differentiates neurons," he said. "When you learn one odor, the interneurons are trained to respond to particular configurations, so you get that segregation at the level of interneurons. So on the machine side, we just enhance that and draw a firm line."

It also explains a previously misunderstood phenomenon: why the olfactory bulb of the brain is one of the few places where mammals can create new neurons after they've reached adulthood.

"The computational model turns into a biological hypothesis for why adult neurogenesis is important," Cleland said. "Because it does this thing that otherwise would make the system not work. So in that sense, the model is feeding back into biology. And in this other sense, it's the basis for a set of devices for artificial olfactory systems that can be constructed commercially."

The brain's complexity motivated Cleland to focus his neuroscience research around a theoretical approach guided by explicit computational models.

"When you start studying a biological process that becomes more intricate and complex than you can just simply intuit, you have to discipline your mind with a computer model," he said. "You can't fuzz your way through it. And that led us to a number of new experimental approaches and ideas that we wouldn't have come up with just by eyeballing it."

More information: Imam, N., Cleland, T.A. Rapid online learning and robust recall in a neuromorphic olfactory circuit. *Nat Mach Intell* 2, 181–191 (2020). doi.org/10.1038/s42256-020-0159-4 , nature.com/articles/s42256-020-0159-4

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