Building Smarter Machines

Engineers have made impressive strides in creating artificial intelligence systems, autonomous vehicles and robots, and smart electronics. But these systems still lag far behind what living organisms can accomplish. No vehicle can navigate its environment the way a rat can, or fly easily in a crowd like a swarm of bats. No device can learn, remember, or interpret information like a human brain—or even like the brain of a small mammal or insect.

Now, a growing movement at Boston University and beyond is bringing together the disciplines of biology, computer science, and engineering to dramatically advance the state of engineered systems and push the boundaries of what human designs can do. The goal: to learn from biology to make smarter machines.

Machines That Can Multitask

Imagine a world in which each person could only perform one task. One excels at sensing other people’s facial expressions, another at a specific kind of surgery, and another can recognize and avoid objects. No one can adapt and learn the tasks that other people know. Despite the hope that’s surrounded artificial intelligence over the years—the promise that robots and computers could do all the things humans and other animals do—artificial systems are more like this scenario of vastly limited abilities.

Designing a robot that can sense, learn, make decisions, and move on its own is the ambitious goal of a project led by Massimiliano Versace, head of the Neuromorphics Lab, which is part of the multi-institution Center of Excellence for Learning in Education, Science & Technology (CELEST), funded by the National Science Foundation and hosted at Boston University. Most robots, he explains, are designed for one particular problem.

“We’re not interested in special-purpose intelligence,” says Versace. The group’s leading project, Modular Neural Exploring Traveling Agent (MoNETA)—co-funded by Hewlett-Packard (HP) and CELEST—is a comprehensive software program referred to as a “brain on a chip.” MoNETA, as Versace and his team envision it, would eventually be an autonomous robot that can sense its surroundings, identify important information, and use that information to make decisions and perform tasks. The group’s research was recently published in IEEE Spectrum as the cover article, written by team member Ben Chandler.

The Neuromorphics Lab is developing brain models—biologically inspired algorithms that mimic the way brains work—and, in collaboration with HP, the operating system that will run on the chip. The hardware is based on an innovative type of electrical component only a few atoms wide, called a memristor. Versace explains that this technology will enable more lifelike intelligence by processing information faster and more efficiently, similar to how synapses in the brain work. Memristors are used to...
The Math Behind Vision

Scientists have long known that the brain uses shortcuts to glean information from the senses. In vision, for instance, we don’t need to see all the details of an object to recognize it. Marr postulated that humans determine information about images by finding edges, that is, lines of contrast that delineate one object from another. The line drawing thus represents what the brain is already doing—outlining the world using edges separating discrete objects.

Looking at an aerial view of a city, for instance, different structures come into view at different heights, from the gross outlines of neighborhoods to the fine borders of individual yards. Or consider the way that different edges emerge when you blur an image to different degrees. Marr made a conjecture: that by locating only a picture’s edges at various levels of blurring—what are called multiscale edges—it would be possible to reverse-engineer mathematically this so-called edge information and reconstruct the image.

The Long Way Home

People grabbed onto this as a mathematical conjecture,” says Mark Kon, professor of mathematics and statistics at BU. Several scholars attempted to prove or disprove the conjecture for real images, which have finite boundaries. Kon’s research deals with statistics and applied mathematics, so he was able to use the language of mathematics to reframe the problem in terms of probability and information theory. Kon’s approach and work, he says, shows how we know about the street smarts of rats to help robots find their way.

Kon’s research is part of a broader effort to use ideas from neuroscience to improve computer science. Kon has found that grid cells are constantly active as an animal navigates its environment, and that they are analogous to the way that different edges emerge when an image is blurred to different degrees. Kon and his colleagues have found that grid cells are highly correlated with the way that an animal navigates its environment, and that they are analogous to the way that different edges emerge when an image is blurred to different degrees. Kon and his colleagues have found that grid cells are highly correlated with the way that an animal navigates its environment, and that they are analogous to the way that different edges emerge when an image is blurred to different degrees. Kon and his colleagues have found that grid cells are highly correlated with the way that an animal navigates its environment, and that they are analogous to the way that different edges emerge when an image is blurred to different degrees.