Brain-Inspired Computing: Using the Brain’s ‘Technology’ to Solve Complex Problems

‘IF I ONLY HAD A BRAIN’

With a population of roughly 50 million people, England has an estimated 4.2 million closed-circuit cameras operating around the clock, sentries on watch to monitor the happenings, some harmless, others significant and potentially threatening, that unfold in city streets and across the countryside in the course of a day. That’s about one camera for every 12 of the country’s citizens.

It’s estimated that under optimal conditions it would take 12.6 million people to monitor the camera feeds 24 hours a day. That would be about 25 percent of the country’s population watching video feeds that are captured by the second — and having to make spot decisions about suspicious behavior, patterns of activity, or events that could trigger hostile action.

Of all the tasks machines have been programmed to do, it seems plausible that computers could be applied to track these raw, unedited video images that flow in daily and analyze them…but as well as humans? The human brain can do things that have not yet been accomplished with machines, and identifying patterns from a wide array of behaviors is one of them.

The HUMAN BRAIN can do things that have not yet been accomplished with machines...

That’s where research on “brain-inspired computing” takes front stage. Engineers at Lockheed Martin’s Advanced Technology Laboratories are working on solutions that will enable a machine to, in doing certain tasks, think like a brain. But, forget about building a brain, they say — the workings of the mind still hold many mysteries. Instead, they are applying to computer science what is understood about the hundreds of brain circuits that illicit intelligence in humans, says Jon Darvill, senior engineer in ATL’s Distributed Systems Laboratory.

Human brains have an easier time than machines in working with messy, real-world problems, and are able to draw from knowledge stores derived from life experiences and “fuzzy logic” to find solutions.
Brains can determine, for instance, the intent of friendly or enemy forces based on any type of intelligence data whether it’s voice, visual, or written text. Prediction and association of behavior patterns and events are easy for the human mind, says Darvill.

Machines, however, typically focus their resources to solve a single problem at a time and with defined parameters. They often use stovepipe solutions that solve a narrow, well-defined problem rather than learn, as humans do, to solve several problems simultaneously, based on potentially fuzzy parameters.

Robust approximation versus brittle precision are the common differentiators between a human brain and a computer.

What is Brain-Inspired Computing?

Brain-inspired computing takes it cue from the intricate network of neural pathways of the human mind to accomplish tasks that are performed easily by the brain, such as recognizing patterns, processing incomplete or vague information, and applying life experiences to improve on actions and tasks. The brain is able to manipulate more complex and abstract concepts than computers, which excel in performing specific tasks with well-defined parameters, such as calculation or rule-based reasoning.

Projects Behind the Brain

Lockheed Martin’s research into brain-inspired computing focuses on defense applications of the technology, though it is possible that any government agency dealing with an overload of data could use it. Each of these research areas attempts to solve the general learning problem of teaching machines to think like humans.

Teaching Computers to Learn

As sensor data, including video surveillance feeds, pours into various command centers, intelligence analysts rely on computer-automated pattern recognition tools to monitor, detect, and extract important events. However, the traditional methods of machine learning that are used for this aren’t flexible and must be designed by hand for specific tasks or situations.

A change in tasks or situations requires an entirely new learning model to capture new machine learning concepts. The brain, on the other hand, uses a single set of general-purpose learning models to achieve highly effective pattern recognition across many tasks and situations.

The Advanced Technology Laboratories’ “Brain Box” is a prototype system capable of performing dynamic space- and time-event recognition through life-long learning inspired from the complex circuitry and interconnecting networks in the brain. This research is based on the idea that teaching a computer to learn relies on basic concepts in a fashion similar to having building blocks as foundations to understand more abstract concepts.

Through this approach Brain Box can learn increasingly abstract concepts in the same way that calculus builds on addition or paragraphs are built from sentences. This style of learning from foundation blocks gives the system an ability to adapt previously learned concepts to new situations. It does that by reusing simple concepts that have meaning and relevance in new situations. For example, children have a much easier time tying a bow on a gift if they have already learned to tie their shoes.

Managing the Overload

When faced with an overload of data, whether visual, voice, or written text, our brains focus on specific features of the data that would be important to the task or situation. Computer algorithms that answer questions about the surrounding environment in an image or video, such as those that discriminate between different objects in an image — trees from lampposts, for instance — are known as “classifiers.”

Classifiers, however, are unable to work on raw data. Rather they work in a more abstract space of “features” that are extracted from data by humans. Eliminating unnecessary information in making decisions is a task humans routinely perform. With Sensor Box technology, ATL’s researchers will design a dynamic “feature extraction” formula capable of detecting prominent patterns in raw data and transforming them into single characteristics — called “feature vectors” — that can be used to classify data. For instance, in a simplified world, height and weight could be used as feature vectors to help classify basketball players from football players. Still, unimportant information, such as hair color, would have to be eliminated in order to provide the classifier with the salient data features: height and weight. As Sensor Box suggests feature vectors to classifiers, it observes which features are important to the classifiers and those patterns that are obvious in the data.

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To understand a computer’s use of brain-inspired mechanisms, a basic primer of the mechanics of the brain is required. It is a web of neurons and synapses. When a stimulus activates a neuron, it sends messages to other neurons through synapses, which act as conduits in this case. These messages may either excite or inhibit the recipient neurons and cause others to activate. The result is a cascade of activity, which may eventually lead to an identification of familiar patterns or the learning of new ones.

For example, a person walks down a street and spies a large, blue-painted metal box with an eagle on its side, which causes a certain set of brain neurons to fire. At this same time, a voice can be heard to say “mailbox,” causing a second set of neurons to fire, says Darvill. As this happens, the circuits connecting them becomes stronger, forming a collection of neurons that tend to fire when any mailbox features are present.

The example offers clues for how patterns are recognized, but it glosses over the intricate mechanisms that the brain uses to achieve truly robust recognition. It is those underlying mechanisms — hierarchically-organized memory, distributed coding, attention, surprise, inhibition, prediction and others — that brain-inspired computing uses to build smarter machines.

**Benefits of Brain-Inspired Computing**

The benefits of human intelligence programmed into machine computing could not only revolutionize a civilian security sector needing to determine patterns among non-stop streams of video, but could greatly increase the speed and efficiency of intelligence analysis for the U.S. military, says Darvill.

Brain-inspired systems could be programmed to handle the staggering amount of sensor data collected throughout the world in areas of interest, or even areas that aren’t yet of interest, he says. With numerous sensors collecting vast amounts of data, building a complete operating picture of an area is difficult due to time and resource limitations. Humans can’t even comprehend the volume of data available, yet alone analyze it, says Darvill.

Of all the technologies, brain-inspired computing could have the most widespread effects on concepts of operations. Unmanned aircraft could be made smart enough to tell each other what they see, and if it’s worthwhile to surveil a particular area. Computers could be programmed to alert commanders when a weather pattern could affect their missions. Networks could automatically predict when a likely cyber attack could occur, based on patterns of use.

Some of the most capable minds are working on brain-inspired computing, which seems fitting. But even the research community does not know everything about how the human brain works. “Advances in brain-inspired research are helping us understand the brain a bit more every day,” says Darvill. “Lockheed Martin is investing resources in ground-breaking technologies based on our newfound understanding of the mind, and it’s exciting to be a part of that work.”

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**Attentional Analysis: What’s in That Image?**

With more visual data coming into command centers than can be reviewed by intelligence analysts, filtering out portions of imagery that aren’t important could save time, money, and mean mission success.

ATL’s Attentional Analysis program uses features such as color, line orientation, and brightness to determine the relative importance of an image just as the human visual attention system chooses where to point our eyes as they dart around a room just after turning on the lights. Using this program, many computers could run in parallel to analyze huge volumes of imagery and only present analysts with the most relevant images.

**Brain-Inspired Attentional Search: Mind Reading That Works**

When searching an image database, a user typically enters a set of key words that apply to the content of the image: helicopter, molecule, engine. Images tagged with those key words are returned in the search. With any image database, a human must annotate the image for it to be found, and at the rate of visual data coming into command centers, annotating every image is an almost impossible task.

Take an aircraft, for example. It could be the latest fighter jet, maybe a World War II-era bomber, or even the Wright brothers’ first flying machine. Unless there are key terms that differentiate these planes, and unless the person annotating images in the database made such a distinction, it is likely an analyst will sort through every image tagged “plane” to find the exact one.

Using sensors to measure electrical activity in the brain, Brain-Inspired Attentional Search, or BIAS, will — in effect — read a person’s mind for the image that is being searched as images are quickly flashed before them. With the BIAS system, sensors that indicate electrical activity in the brain will chart a spike when the image is seen, even if the analyst didn’t consciously “see” it. Moving at a rate of 10 images per second, an image analyst could search 600 photos in one minute. Over the course of a search, BIAS refines the resulting candidates to those identified as images of interest.