Lessons from the Brain: Toward an Intelligent Molecular Computer

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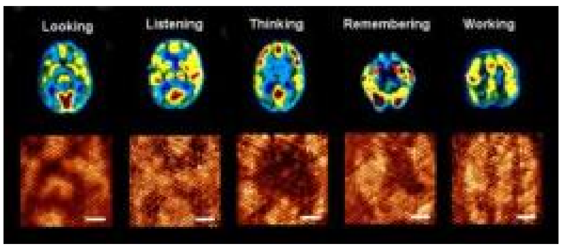

Magnetic resonance images of human brain during different functions appear on top. Similar evolving patterns have been generated on the molecular monolayer one after another (bottom). A snapshot of the evolving pattern for a particular brain function is captured using Scanning Tunneling Microscope at 0.68 V tip bias (scale bar is 6 nm). The input pattern to mimic particular brain function is distinct, and the dynamics of pattern evolution is also typical for a particular brain operation. Credit: Anirban Bandyopadhyay

(PhysOrg.com) -- Information processing circuits in digital computers are static. In our brains, information processing circuits—neurons—evolve continuously to solve complex problems. Now, an international research team from Japan and Michigan Technological University has created a similar process of circuit evolution in an organic molecular layer that can solve complex problems. This is the first time a brain-like "evolutionary circuit" has been realized.

A team of researchers from Japan and Michigan Technological University has built a molecular computer using lessons learned from the human brain.

Physicist Ranjit Pati of Michigan Tech provided the theoretical underpinnings for this tiny computer composed not of silicon but of organic molecules on a gold substrate. “This molecular computer is the brainchild of my colleague Anirban Bandyopadhyay from the National Institute for Materials Science,” says Pati. Their work is detailed in “Massively Parallel Computing on an Organic Molecule Layer,” published April 25 online in *Nature Physics*.

“Modern computers are quite fast, capable of executing trillions of instructions a second, but they can’t match the intelligent performance of our brain,” says Pati. “Our neurons only fire about a thousand times per second. But I can see you, recognize you, talk with you, and hear someone walking by in the hallway almost instantaneously, a Herculean task for even the fastest computer.”

That’s because information processing is done sequentially in digital computers. Once a current path is established along a circuit, it does not change. By contrast, the electrical impulses that travel through our brains follow vast, dynamic, evolving networks of neurons that operate collectively.

The researchers made their different kind of computer with DDQ, a hexagonal molecule made of nitrogen, oxygen, chlorine and carbon that self-assembles in two layers on a gold substrate.

The DDQ molecule can switch among four conducting states—0, 1, 2 and 3—unlike the binary switches—0 and 1—used by digital computers.

“The neat part is, approximately 300 molecules talk with each other at a time during information processing,” Pati says. “We have mimicked how neurons behave in the brain.”

“The evolving neuron-like circuit network allows us to address many problems on the same grid, which gives the device intelligence," Pati says. As a result, their tiny processor can solve problems for which algorithms on computers are unknown, especially interacting many-body problems, such as predictions of natural calamities and outbreaks of disease. To illustrate this feature, they mimicked two natural phenomena in the molecular layer: heat diffusion and the evolution of cancer cells.

In addition, their molecular processor heals itself if there is a defect. This property comes from the self-organizing ability of the molecular monolayer. “No existing man-made computer has this property, but our brain does,” Bandyopadhyay says. “If a neuron dies, another neuron takes over its function.”

“This is very exciting, a conceptual breakthrough,” Pati says. “This could change the way people think about molecular computing.”

An abstract of “Massively Parallel Computing on an Organic Molecule Layer” is available at *Nature Physics.*

Provided by Michigan Technological University

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