about a person's eating patterns: "It measures how fast someone is eating, and how many chews they take for each bite," he says. He wants to create a consumer device that can deliver this information to users in real time and thus help them change their food habits. "Some eating behavior is automatic," he says. "Imagine you're sitting in front of the TV next to a bowl of chips—you grab the chips and shove them into your mouth," he says. "Our sensors could help people be more mindful."

SODIUM SENSOR

With more than 1 billion people around the world now living with high blood pressure—a major risk factor for heart disease and strokes—doctors are keen to get people to reduce their sodium intake. But sodium, the primary component of table salt, is everywhere in our modern diets—it's in snack foods, in restaurant meals, and in beverages. Even when people want to follow doctors' advice, they may not realize how much sodium they're taking in.

W. Hong Yeo, an assistant professor of micro- and nano-engineering at Georgia Tech, is tackling the problem with a flexible electronic sodium sensor that sits in the mouth. His first prototype is battery powered and embedded in a dental retainer: "We wanted to offer easy handling and cleaning capability," he says. But future versions could do away with the battery, instead receiving power remotely via inductive coupling, and could be small enough to stick directly to the tongue or a tooth. When users gulp down tomato juice or crunch on potato chips, the sodium sensor sends info via Bluetooth to their smartphones, giving them instant data about whether they're busting their low-sodium diets.

> "Our sensors could help people be more mindful"
>
> —Edward Sazonov, University of Alabama

DENTAL ANTENNA

A research team from Tufts University's department of biomedical engineering designed a tiny tooth-mounted device that can monitor people's consumption of all sorts of toothsome things, including alcohol, salt, and sugar.

Fiorenzo Omenetto led the team that developed the sensor, which is composed of an inner layer of polymer film sandwiched between two gold rings that act as antennas. When the film absorbs certain chemicals, such as ethanol, sodium, and glucose, it swells and pushes the gold rings apart. Each substance causes the film to thicken up to a different degree, so the distance between the gold rings indicates which chemical passed over the tooth. Omenetto's system bounces radio waves off the tooth and records the spectrum and intensity of the wave that returns from the antenna. While alcohol, salt, and sugar are high on the list of problematic foods that consumers want to track, the sensor's film could theoretically be tuned to detect all manner of different comestibles.

—ELIZA STRICKLAND

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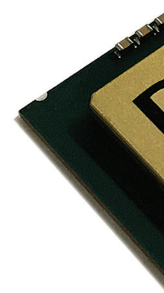
SILICON CHIP DELIVERS QUANTUM SPEEDS

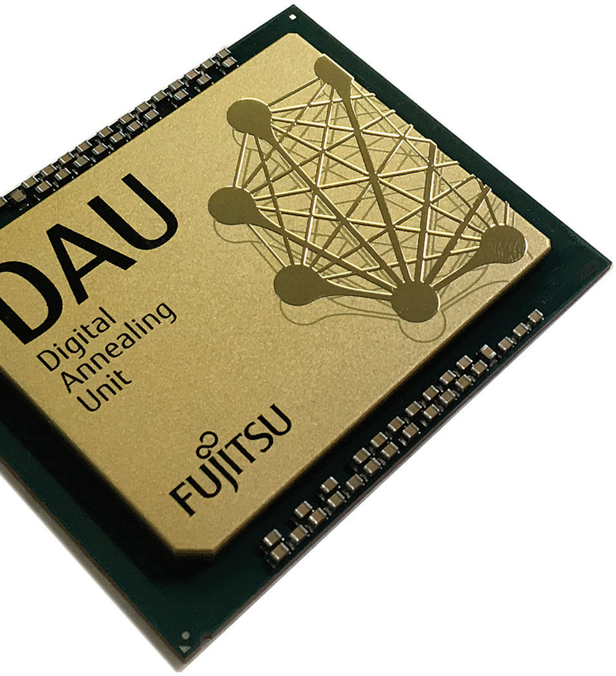


Fujitsu says its Digital Annealer will outperform today's commercial quantum computers

Fujitsu has designed a new computer architecture running on silicon—dubbed the Digital Annealer—which the company claims rivals quantum computers in utility. Fujitsu began offering cloud services in Japan in May, employing the technology to resolve combinatorial optimization problems, such as finding similarities among patterns of molecules to speed drug discovery.

The service comes as activity in the quantum computer field ramps up. D-Wave Systems, based in Burnaby, B.C., Canada, is marketing its latest 2000Q quantum annealing computer and is racing to introduce a 5,000-qubit model within the next two years, according to industry press reports. Quantum annealing is a mathematical tool designed to find a good solution to a complex optimization task that has more possible answers than conventional computing can manage.

Meanwhile, companies and research institutes are creating "universal" quantum computers. These use quantum gates to handle quantum bits, or qubits, and run more sophisticated algorithms than quantum annealing machines can. However, given the design of these universal computers and requirements for highly controlled superconducting envi-



FUJITSU

MONEY MAKER: Fujitsu's new chip will support cloud services anticipated to generate US $900 million in revenues by 2022.

ronments, the number of qubits these machines can practically support is relatively small at present, typically up to 50 qubits, compared with D-Wave's 2,000 qubits.

IBM and Microsoft are taking this quantum gate approach, while Google is working on both quantum gate and quantum annealing systems. In 2016, IBM made its 5-qubit superconducting quantum computer available online for researchers. Since then, IBM has also made 16-qubit and now 20-qubit machines available. At CES 2018, Intel unveiled a 49-qubit superconducting quantum test chip called Tangle Lake.

While all these approaches have the potential to deliver unprecedented computing power, quantum computers require a lot of overhead and have expensive price tags. They must maintain near absolute zero temperatures and remain free from magnetic interference, thermal noise, and mechanical vibration in order for qubits to maintain superposition—the ability to hold dual states of 0 and 1—which forms the basis of quantum calculations.

Fujitsu, working with the University of Toronto, has developed its Digital Annealer as an alternative to current quantum annealing computers, such as the D-Wave machines. Whereas the latter requires a carefully controlled cryogenic environment, Fujitsu employs conventional semiconductor technology that operates at room temperature and can fit on a circuit board small enough to slide into the rack of a data center.

The Digital Annealer is a dedicated chip that uses non-von Neumann architecture to minimize data movement in solving combinatorial optimization problems. It is composed of 1,024 "bit-updating blocks" with on-chip memory that stores weights and biases, logic blocks to perform "bit flips," and interfacing and control circuitry, explains Hirotaka Tamura, a Fujitsu senior fellow.

Unlike classical computers, the Digital Annealer doesn't require programming. Rather, a problem is uploaded in the form of weight matrices and bias vectors so as to convert it into an "energy landscape." Fujitsu has teamed up with 1QB Information Technologies, a leader in quantum computing software based in Vancouver, B.C., to provide the software for the system and a development kit for customers, so they can write their own energy landscapes.

To solve a problem, "each bit block uses its one-to-all connections via the 1,023 weights stored in memory," explains Tamura. The Digital Annealer makes full use of this parallelism to assume many possible states based on the weight matrices and bias vectors. Then, the bit blocks collectively run a stochastic search—an estimation technique to minimize the value of a mathematical function—to produce candidates for the next sequence in the process. This continues until the lowest energy state in the energy landscape is realized.

Hidetoshi Nishimori, a professor of physics at the Tokyo Institute of Technology and an author of one of the first papers proposing the idea of quantum annealing, explains the operation by way of analogy: "In digital annealing, the system hops from one state to another sequentially in search for better solutions, like a person wandering around a complicated landscape filled with hills and valleys, looking for the lowest point." This is in contrast, Nishimori adds, with quantum annealing, "where the system looks for the best solution in a massively parallel way with all the states taken into account simultaneously."

So is the CMOS-based Digital Annealer, with its 1,024 bit blocks capable of matching or outperforming the D-Wave quantum annealing system, with its 2,000 qubits, as Fujitsu claims?

"At the moment, most likely it can," says Nishimori. He notes that the weights between bit blocks on the Fujitsu machine enable a problem to be expressed with a higher degree of precision than the D-Wave system has. Nevertheless, "quantum annealers will surpass the Digital Annealer in the long run because of their supermassive quantum parallelism," he adds. Meanwhile, Fujitsu says it aims to introduce a Digital Annealer with 8,192 bit blocks next year, followed by a 1-million-bit block machine later.

Fujitsu is working with the University of Toronto to research applications for the Digital Annealer, and later this year, the company will begin marketing Digital Annealer servers, towers, and chips for on-site installation. Fujitsu also plans to roll out cloud services in North America, Europe, and Asia before the end of the year and is targeting 100 billion yen (about US $900 million) in revenues for the service by 2022. —JOHN BOYD

An extended version of this article appears in our Tech Talk blog.

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