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Quantum computing: Plotting for the pivot

Fujitsu Laboratories Advanced Technology Symposium 2017

Mountain View, Calif., USA; Oct. 11, 2017

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Quantum computing has the potential to execute complex algorithms 100 million times faster than classical computing instances, but this potential will not be developed overnight. Technology Business Research, Inc. (TBR) believes commercial quantum computing remains five to seven years from having reliable instances that outperform classical computing performance capabilities. As the world waits for quantum computers to become mainstream, companies such as IBM (NYSE: IBM), Atos and Fujitsu have intermediate quantum offerings that facilitate the development and testing as well as human training to speed creation and commercialization ahead of quantum supremacy. For example, Fujitsu announced a new category of quantum-inspired systems based on proprietary Digital Annealing (DA) technology that can be applied to solve complex real-world social problems. Traditional computing vendors and startups strive to solve the technological challenges on the hardware side while also supporting emerging software assets to allow the world's brightest minds to begin establishing a base of quantum-ready utilities, tools and algorithms. Plotting the pivot to quantum will also be accelerated by industry partnerships, such as the recent Fujitsu announcements with University of Toronto and 1QBit.

Leaders in academia, technology and business agree quantum computing will ultimately change our world — algorithm by algorithm — at a rate and pace we can only imagine as we sit at the dawn of the commercial quantum computing era.

Event overview

Fujitsu Laboratories Advanced Technology Symposium 2017 (FLATS 17) focused entirely on the current state of quantum computing, the obstacles to commercialization and the near-term use cases ripe for the technology. Fujitsu assembled an impressive collection of quantum experts to share their challenges

and aspirational objectives for quantum hardware, software and application areas in a highly engaging, day-long conference held in Mountain View, Calif., and attended by approximately 400 people.

Fujitsu competes in the current quantum arena with its quantum-inspired technology based on DA

At the core of Fujitsu's development investments is the recognition that as the current computing technology nears its physical limits, based on Moore's Law, the world needs the compute power quantum development has the potential to deliver. On the road to quantum computing, Fujitsu envisions new advances in compute infrastructures, including what it calls a hyper-connected cloud that can empower human collaboration and decision making as well as emerging digital technologies heavily reliant on artificial intelligence (AI), big data and analytics.

Fujitsu describes its current quantum solution as "quantum inspired" technology infrastructure. DA underpins the architecture that can be applied to solve combinatorial optimization problems in a realistic time frame. Fujitsu works closely with the University of Toronto and with quantum software startup 1QBit, with all three stakeholders sharing the IP developed through the collaboration. Key benefits to Fujitsu's DA technology include:

- The DA architecture relies on highly parallelized architecture based on current CMOS technology that does not require the sophisticated cooling systems of some of the general-purpose alternatives under development.
- The DA architecture should be easier to scale as the algorithm demands increase in complexity, allowing for expansion as applications begin shifting to the platform.
- Using an architecture inspired by quantum computing, the DA finds the "sweet spot" between speed of computation and accuracy of the solution, enabling it to rapidly solve combinatorial optimization problems that were previously out of reach for classical systems.

Impediments persist around reliability and accuracy with different quantum architectures

Quantum computing introduces the concept of superposition, or the ability of atoms to be in two states at once, which translates into a profound shift in the way compute processing will occur by operating at atomic scale. According to the morning keynote speaker, Professor Daniel Lidar from the University of Southern California, current technological challenges revolve around reducing calculation errors caused by superposition interference, or "decoherence." However, cooling the quantum computer to 1 kelvin slows the movement of these particles and improves the processing accuracy, to a point, but vendors must continue to innovate to address the number of qubits in operation as well as limit the number of errors or decoherence inherent in the structure.

The consensus suggests greater quantum scaling, and therefore faster computation of probabilistic outcomes, will limit errors. In the near term, firms will innovate around quantum simulation, which allows for the utilization of quantum processing in reliable states that are not yet superior to conventional computing technology. Simultaneously, firms will continue to seek hardware solutions that will enable the technology to achieve quantum supremacy.

Quantum hardware vendors discuss their different architectural approaches and the ongoing challenges to reaching quantum supremacy

Competing architectural approaches are being developed around quantum computing. One is deemed more general purpose, while another utilizes annealing technology to allow for superior performance around single-purpose functions. Gate quantum processors show the most promise; D-Wave uses annealers to address use cases with high-variable, incalculable algorithms; Fujitsu has a unique proprietary approach.

IBM (as well as Google [NASDAQ: GOOGL] and Rigetti) devotes its energies to developing universal or general-purpose architectures. These architectures rely heavily on cooling the instance to approximately 1 kelvin, requiring simultaneous innovations around cryogenics to stabilize the computing environment. Scaling the number of qubits likewise presents a challenge given the need for RF generators and their associated multiplexers.

D-Wave has a different technological approach that can be described as single purpose of single function based on annealing technology. An annealing computer is a type of quantum processor that solves a finite set of problems.

Fujitsu has taken an innovative approach with its DA architecture, which employs conventional semiconductor technology with flexible circuit configurations. Multiple computation circuits can be run in a parallel hierarchical structure to perform optimization computations, enabling scalability in problem size and processing speed. This structure minimizes the volume of data moved between basic optimization circuits, making it possible to implement them in parallel at high densities using conventional semiconductor technology. In addition, thanks to a fully connected structure that allows signals to move freely within and between basic optimization circuits, the architecture is able to handle a wide range of optimization problems.

Software development cannot wait for quantum supremacy, hence quantum cloud and the need for a quantum PaaS layer

Cloud delivery underpins early quantum approaches by using a hybrid architecture with quantum computing accelerator modules for specific functions, which represents the best near-term possibility

for successfully commercializing quantum computing. 1Qbit, offers an abstraction layer and APIs, allowing users to quickly leverage the power of quantum computing.

The near-term quantum software market highlights the fundamental difference between the development and commercialization of quantum architecture and the arc classical computing took in the 1950s, 1960s and 1970s. Abstracting the IP development into the software layer, relying on open standards and benefiting from the ecosystem effect of developer communities sharing IP to build out a platform of enabling utilities and tools will advance quantum commercialization faster than realized with classical computing.

1QBit has industry attention as much for its offerings as for its partners, which include Fujitsu and Accenture Labs, and would appear to have the early lead on building the foundational open platform software layer for quantum. The Fujitsu partnership with 1QBit represents one of several 1QBit partnerships expected to accelerate the development of these software offerings that leverage the power of quantum.

Quantum use cases: Known-knowns store pent-up demand for quantum computing

A range of "killer apps" will accelerate exponentially once the industry achieves quantum supremacy, including:

- Exponentially faster simulation of quantum mechanics, enabling discovery and first-principles design of novel materials and pharmaceuticals; medical research, healthcare research and chemical research all require quantum computing to speed their development efforts.
- Cybersecurity, or breaking public key cryptography and secure encryption; this has direct applicability to governments for national security and for industry regulation as well as within the industries facing those regulations (e.g., financial services and healthcare).
- Optimization speedup, which will accelerate machine learning and the verification and validation of supply chains (enabling blockchain, for example), financial trading algorithms and financial regulatory stress testing algorithms

The near-term approach, as in the case with Fujitsu DA, deploys hybrid computation utilizing classical computing to narrow down the queries before moving them to a quantum computer. Specific examples of this hybrid approach include the following:

- Search for molecular similarities in chemistry and drug discovery where the DA enables rapid and accurate searches of the entire molecule

- In financial services, instantly calculate the computationally intensive hierarchical risk parity equation; highly correlated stocks can be identified, enabling investments to be diversified with the objective to maximize returns while lowering risk
- In chemistry, a conventional model can narrow down the problem to currently allowed qubits.
- In cancer treatment, analysts can combine Monte Carlo dose calculations with quantum computing for greater dosage precision and accuracy.

Within these traditional fields, the ability to more rapidly discover new materials and composites can generate billions of dollars worth of value, which is a business model dynamic unchanged since the days of classical computing that will only accelerate global innovation as quantum computing commercializes.

Quantum adoption: Similar process, faster time to commercialization

The development of high-performance computing that has advanced along the Moore's Law Economics curve for over 50 years provides many lessons to consider when evaluating how quantum computing will advance. The known-knowns are the ways in which government, financial services and healthcare will deploy the technology for cryptography, trading algorithms and medical research. The factors that will compress the time to commercialization include:

- **Demonstrate ROI value** of quantum computing; as we wait for commercial quantum hardware and software systems over the next several years, it is important to demonstrate the power of quantum computing today to sustain market interest. Fujitsu's quantum-inspired DA technology represents a unique breakthrough and can power a range of applications that can solve real-world social problems today while showcasing the promise of a quantum tomorrow.

- **Cloud economics** will enable an iterative opex approach for fast failure or sandboxing projects for early adopters seeking to learn how to harness the power of quantum computing for competitive advantage once quantum supremacy becomes a reality. The ability to gain first-mover advantage in quantum computing using cloud access to quantum computers and quantum simulators will be monumental to enterprises seeking to address intractable problems and to educate their labor force on the new tools and programming constructs needed to exploit quantum computing.

- **FANG** (Facebook [Nasdaq: FB], Amazon [Nasdaq: AMZN], Netflix [Nasdaq: NFLX] and Google) utilization of quantum computing represents an entirely new factor not economically viable under the early stages of classical computing development in the 1950s, 1960s and 1970s. Google has taken a leadership position in concert with NASA and D-Wave around quantum development, with quantum use cases for search optimization anticipated as a major focal point for FANG companies addressing the vast set of consumer applications made available by the persistently declining price points associated with classical computing power.

- **The power of open communities** and the contribution of IP for the enabling layers associated with bridging the classical computing world to the quantum computing world will be one of the biggest enabling activities accelerating the rate and pace of adoption. The availability of quantum simulators as appliances and as cloud subscription services from firms such as IBM, Atos and Fujitsu, coupled with academic research being conducted at leading universities such as the University of Toronto, will be some of the most practical and effective ways enterprises and developers can begin preparing for the profound capabilities quantum will bring to bear on solving the world's intractable problems.

The advancement in global knowledge, which has accelerated rapidly since the advent of classical computing in the late 1940s, sits poised to explode one algorithm at time, as quantum computing calculates algorithms as much as 100 million times faster. Firms that start plotting their pivot to quantum computing in these early commercial stages with development test beds on platforms such as the Fujitsu's quantum-inspired DA technology will gain a distinct, first-mover advantage.