QUANTUM COMPUTING

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INTRODUCTION

Richard Feynman, the celebrated physicist once said: "If you think you understand quantum mechanics, then you don't." Quantum computing is a hot topic today and will likely produce some eyebrow-raising responses in conversation. Quantum computing studies computation systems (quantum computers) that make direct use of quantum-mechanical occurrences to perform operations on data. In this Tech Insight, we present an overview of the emerging next-generation computing technology (Quantum Computing) and its related impact on Artificial Intelligence (AI), healthcare, and technology in-general, as well as how it's impacting the Department of Veterans Affairs (VA).

QUANTUM COMPUTING OVERVIEW

Moore's Law, referred to as the "golden rule for the electronics industry and a springboard for innovation," refers to the five paradigm of computation. Quantum computers may well be the sixth paradigm as they work in a fashion that is entirely different from "classical" computers. A classical computer performs operations using classical "bits" that can be in only one of two states: "0" or "1." In contrast, a quantum computer uses "quantum bits," or "qubits," due to a principle called quantum superposition. A qubit is a unit of quantum information. The qubits can have a value of "0", "1," or both "0 AND 1." This capability allows quantum computers to solve certain types of complex problems that are too challenging for conventional computers.

Qubits' properties can be intertwined through the quantum phenomenon of entanglement. A measurement of one qubit in an entangled pair instantly reveals the value of its partner, even if they are far apart — what Albert Einstein called, "spooky action at a distance." The power of qubits is that they scale exponentially. A two-qubit machine allows you to do four calculations at once. A three-qubit machine can do eight calculations at once, and so on. To put it simply, Peter Lee, the corporate vice president and head of Microsoft Research, said quantum computing "is like that old story problem from math in school where you offer kids a thousand dollars right now, or to give them one penny today, two pennies tomorrow, and continue to double that every day for 30 days. Most kids want the thousand bucks, but the pennies doubled daily over 30 days eventually add up to more than $10.7 million."

PRACTICAL USES OF QUANTUM COMPUTING

A Fast Company Magazine article carried a feature on quantum computing pointing out that quantum mechanics holds the potential to provide us with more information about human biology. According to Dr. Peter Diamandi, Chairman and CEO of the X PRIZE Foundation, there are five top applications of quantum computing:

Machine Learning: Machine learning (ML) is an application of AI that provides systems the ability to automatically learn and improve from experience without being explicitly programmed. ML focuses on the development of computer programs that can access data and use it learn for themselves. Much of ML is about "pattern recognition." With quantum computing, we'll be able to do this by processing orders of magnitude more effectively than with classical computing. Quantum computing will allow a user to compare more data in parallel, simultaneously, and all permutations of that data, to discover the best patterns that describe it. This will lead to fundamentally more powerful forms of AI much more quickly than we expect. Quantum computing can cause a positive inflection point (upward) for the speed at which the world develops AI, which is quickly becoming a top solution strategy for industry and governments, as evidenced by massive AI investments.

Medicine: Quantum computing will also allow us to model complex molecular interactions at an atomic level. This will be particularly important for medical research and drug discovery. Soon, we'll be able to model all 20,000+ proteins encoded in the human genome and start to simulate their interactions with models of existing drugs or new drugs that haven't been invented yet. Based on the analysis of these drug interactions, we'll be able to find cures and hopefully accelerate the time to market for new drugs. Quantum computation is ideally suited to the task as the processes that govern chemical interactions are fundamentally linked to those that would allow for the existence of a quantum computer. This, at least in theory, would make a universal quantum computer an ideal approach to drug discovery, and could potentially result in faster drug production and more precise drugs. The pharmaceutical benefits are substantial, because quantum computation essentially eliminates the need for guesswork in building up a model of the human body and how it reacts to stimuli.

Chemistry (and Climate Change): Worried about the climate crisis? Wondering what we can do about it? Quantum computers may be our newest tool to understand what is going on and to fight it. They will allow us to unlock "simulation-driven" solutions, perhaps design new catalysts that capture carbon from the atmosphere and turn it into new and valuable products at low cost and energy use.

Material Science & Engineering: Since we can simulate atomic interactions, we can explore and invent entirely new and better materials. We might find better superconductors, magnets, and

materials that will allow us to create much higher energy density batteries, and so on. Since 2011, the U.S. federal government has granted over $250 million to the Materials Genome Initiative to "discover, manufacture, and deploy advanced materials twice as fast, at a fraction of the cost."

Biomimetics, Energy Systems & Photovoltaics: Scientists believe that much of the world is built atop quantum systems. Processes like photosynthesis, for example, are likely dependent on quantum mechanical systems. Thus, as we look to the natural world for inspiration to build better energy systems or stronger materials, we'll only fully realize their potential when we can model these processes with quantum computers. Quantum computing will enable the very building blocks of the universe to be controlled.

DEVELOPMENT OF QUANTUM COMPUTERS

In the U.S., five major players are developing quantum computers right now: Google, IBM, Microsoft, Rigetti Computing, and D Wave Systems. Both Rigetti Computing and Google believe they will reach "quantum supremacy" in the next 12 to 18 months. Google started working on a form of quantum computing that harnesses superconductivity in 2014. Google hopes that this year or shortly after, they will be able to perform a computation that is beyond even the most powerful classical supercomputers — an elusive milestone known as quantum supremacy. IBM issued a press release in November 2017 saying they had built the world's first 50 qubit quantum computer for commercial application. They previously made their five-qubit computer accessible online for free. Microsoft is betting on an intriguing but unproven concept, topological quantum computing, which depends on excitations of matter that encode information by tangling around each other like braids. Information stored in these qubits would be more resistant to outside disturbance and would make error correction easier.

D-Wave has developed chips with qubits, but they haven't been proven to operate as a quantum computer. They are building the world's first functioning quantum computer contained within a refrigerator-like casing. It's the coldest refrigerator ever assembled at -273 Celsius degrees or as close to absolute zero as the known universe gets. The supercooled environment is necessary to maintain coherent quantum activity of superposition and entanglement, the state in which particles begin to interact.

IMPACT ON VA

VA researchers have harnessed the potential of ML and Cognitive Computing through work with IBM Watson. Speedier and more accurate cancer diagnosis is the goal of a VA-Watson partnership announced last summer, which put the supercomputer to work on sequencing tumors for thousands of Veterans.

The Department of Energy (DOE) and VA are establishing a scientific computing environment called MVP-CHAMPION (Computational Health Analytics for Medical Precision to Improve Outcomes Now) that will house and provision MVP data to researchers nationally as well as create a big data environment to foster transformational science. In addition to the unparalleled health data on 24 million Veterans who have used VA for healthcare over the past two decades, data will be obtained from the Department of Defense (DoD), Centers for Medicare and Medicaid Services (CMS), and the Center for Disease Control's (CDC) National Death Index. The MVP, which has already enrolled over 560,000 Veterans, will enhance these rich health data resources with genetic and self-reported lifestyle and military exposure information making this among the most valuable health care data repositories in the world.

Senior leadership at important private sector companies for next generation computing, data analytics, and health care are taking note of this joint effort. This partnership has the potential to bring in the private sector to share risk, develop prototypes, and accelerate advances. The U.S. is the only country in the world with the opportunity to partner such a large-scale health database with world leading data analytics capabilities. With this partnership, the U.S. can drive cutting edge technology in next generation data analytics and improve quality of life for Veterans and all Americans.

Evidence of this can be seen via the collaboration already taking place with the DOE and VA to more broadly support the Precision Medicine Initiative by applying advanced supercomputing capabilities and data analysis to the nearly half a million veterans' records from one of the world's largest health research cohorts, and the aforementioned Million Veteran Program (MVP). This five year partnership is now underway and the first phase will focus on cardiovascular health, mental health issues, and prostate cancer.

CONCLUSION

Quantum scientists are trekking into a new, uncharted realm of computation, bringing computer programmers along for the ride. The capabilities of these fledgling systems could reshape the way society uses computers. Eventually, quantum computers may become part of the fabric of our technological society. Quantum computers could become integrated into a quantum internet, for example, which would be more secure than what exists today. If you would like to read more about some of the topics, please check out some of our recent TS Tech Insights and on Virtual Reality in Healthcare, AI in the Workforce and Blockchain. Additionally, TS has also delivered an Enterprise Design Pattern (EDP) on the Impact of Internet of Things and has several EDPs developed around cloud computing.

TECH INSIGHT SERIES

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