What is quantum computing? Temple researchers explain computing’s next frontier

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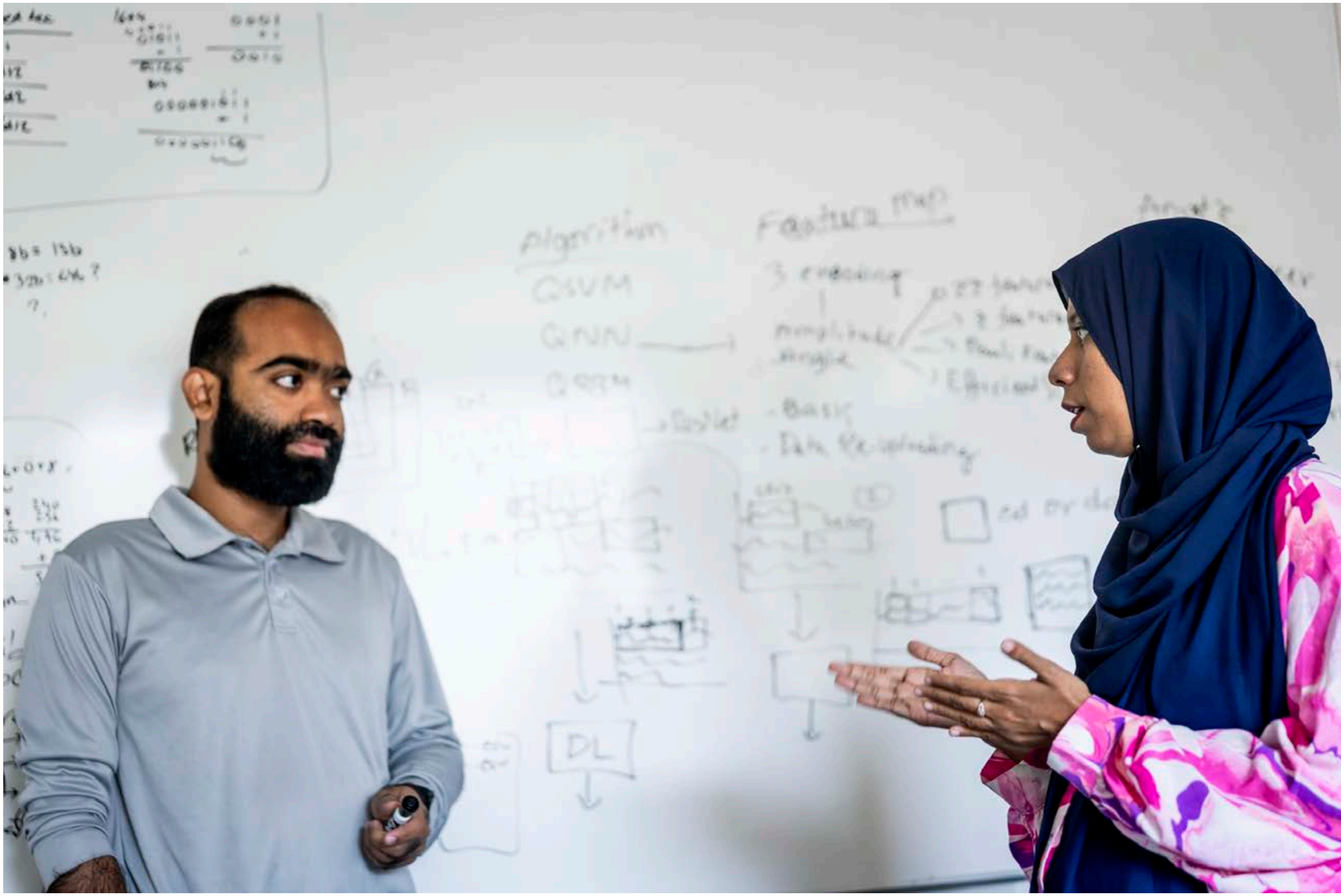
When most people think of quantum computing, they think of a futuristic technology capable of solving our most complex problems. Two graduate researchers from the College of Engineering

discuss what quantum actually is and how it differs from traditional computing.



On Friday, Aug. 14, Temple University will host the Quantum Machine Learning Workshop, a one-day hands-on experience introducing individuals to quantum computers for machine learning.

Photo by Ryan S. Brandenberg

On Friday, Aug. 14, College of Engineering researchers hope to answer some of the questions below during the Quantum Machine Learning Workshop, introducing individuals to quantum computers for machine learning. With virtual spots still remaining, the workshop, co-sponsored by the Neural Engineering Data Consortium, the Temple University Office of the Vice President for Research and the IEEE Philadelphia Section, aims to make quantum an approachable topic for researchers and students alike, with no prior experience necessary.

Quantum computing is often associated with futuristic science and mathematics, but what it actually is, and what it can do, remains a mystery to many people outside the field. Beyond its reputation for solving complex problems, how does quantum computing differ from the computers we use every day? And how can it be used in conjunction with AI, machine learning and other forms of accessible technology?

PhD candidate Sadia Afrin Purba and electrical and computer engineering graduate student Md Abdullah Al Mamun spoke with Temple Now ahead of the university's Quantum Machine Learning Workshop to answer frequently asked questions about quantum computing and what workshop attendees can expect to gain from the experience.

Temple Now: What is quantum computing, and how does it differ from traditional computing and personal computers?

Sadia Afrin Purba: The real difference lies in how computation is performed. Classical computers process information using bits, where each bit can be either 0 or 1. Every operation performed by a classical computer is ultimately based on manipulating these binary values. Quantum computers make use of unique properties of the quantum world, particularly superposition and entanglement. Instead of bits, they use quantum bits (qubits). A qubit is not limited to being only 0 or only 1. Due to superposition, it can exist in a combination of both states simultaneously until it is measured. One way to think about this is as a cloud of possibilities rather than a single definite value.

The advantage becomes clearer when we consider multiple bits. With two classical bits, there are four possible states: 00, 01, 10 and 11. A classical computer typically needs to evaluate these possibilities through separate computational paths. In contrast, two qubits can represent all four states simultaneously through superposition. This does not mean we instantly get all answers at once, but it allows quantum algorithms to explore a solution space in a fundamentally different way. Combined with elegant mathematical techniques, this can lead to significant speedups for specific problems.

Another important property is quantum entanglement. Entanglement creates correlations between qubits that have no direct equivalent in classical computing. For example, if two qubits are entangled, measuring one instantly provides information about the state of the other, regardless of the distance between them. Classical systems can show correlations too, but entanglement is stronger than anything classical systems can produce. So, quantum algorithms can take advantage of it to perform computations more efficiently than classical approaches in certain scenarios.

TN: What types of problems can quantum computing help solve?

Md Abdullah Al Mamun: Quantum computers can solve problems that are basically impossible for normal computers because the possibilities are insane. Examples could include simulating molecules for drug discovery, optimizing crazy complex logistics problems, breaking/improving cryptography, material science problems. Anything where you'd have to brute force through billions of combinations, quantum can (theoretically) speed that up a lot.

TN: What are some misconceptions you've seen about quantum computing?

Purba: One of the biggest misconceptions about quantum computing is that it is simply a much faster version of a classical computer. Many people imagine a quantum computer as a "super-PC" that can perform every task millions of times faster than today's computers. In reality, quantum computers are not universally faster. They are specialized machines designed to solve certain classes of problems more efficiently than classical computers.

I also think many people underestimate how difficult it is to build and operate a quantum computer. Depending on the technology, most quantum processors must be cooled to temperatures extremely close to absolute zero and all of them require highly specialized hardware and control systems. When people hear the word "computer," they often imagine something that could sit on a desk, but current quantum systems look more like scientific instruments than personal computers.

Quantum computing is less about replacing classical computing and more about complementing it. A future scientist, engineer or researcher may use both classical and quantum resources together, selecting the right tool for the right problem.

TN: Who should attend the Quantum Machine Learning Workshop and what can attendees expect?

Purba: This workshop is designed for anyone who wants to gain a high-level understanding of quantum computing and learn how its concepts can be applied to machine learning problems. Whether you are a student, researcher, engineer, data scientist or simply someone curious about technologies, you are welcome to join. No prior background in quantum computing is required.

We will focus on the practical ideas that make quantum computing relevant for real-world machine learning applications. By the end of the workshop, participants with no prior experience in quantum computing should have enough knowledge and hands-on exposure to begin running their own experiments using quantum machine learning algorithms and available quantum computing frameworks.

The workshop will also provide an excellent networking opportunity, with the chance to connect with researchers, practitioners and students who are actively working on challenging problems in quantum computing and machine learning.

TN: What does the future of quantum computing look like?

Purba: I am optimistic about the future of quantum computing. I believe that, eventually, we will have large-scale, error-corrected quantum computers capable of solving problems that are beyond the reach of today's classical computers.

When classical computers were first developed in the 1940s, very few people could have predicted what computing would look like in 2026. From those early machines came personal computers, the internet, smartphones and AI systems such as ChatGPT. I expect quantum computing to follow a similarly transformative path, even though it is difficult to predict exactly where it will lead.

Al Mamun: There's still a long way to go, but progress is steady. We'll probably see more hybrid systems first (classical + quantum working together) before full-on quantum takes over anything. The main hurdles right now are error rates and scalability, but companies are pouring money into it, so it may be 10–15 years before it's mainstream for real-world problems.

- Casey Tinney

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