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Murphy Niu receives NSF CAREER award for quantum computing innovation

UC Santa Barbara computer science assistant professor Murphy Yuezhen Niu, who is also a physicist, has been awarded a prestigious CAREER Award from the National Science Foundation to support her work in quantum computing.

The five-year, $630,000 grant will fund Niu's project, "Quantum Pulse Processing — Robust and Programmable Quantum Control for Near-Term Quantum Simulation," which is aimed at advancing a new paradigm in quantum computer engineering.

"We are leveraging advancements in the emerging area of quantum signal processing to introduce a new paradigm, called quantum pulse processing, to bridge the gap between existing gate-based approaches and purely analog approaches to quantum computing," Niu wrote in her proposal.

A physicist by training, Niu aims to connect how quantum computers are built and how they are programmed. Current machines operate in a noisy, error-prone range known as the "intermediate scale," typically consisting of 100 to 100,000 qubits. While they are usually programmed using discrete digital gates, their underlying operations are governed by continuous analog control pulses.

Niu’s work focuses on developing techniques to make this analog layer more robust and programmable, helping to unlock the full potential of near-term quantum technologies.

Gate-based quantum computing requires significant overhead in terms of the number of extra qubits required to scale up digital error correction. In contrast, alternative computing paradigms — such as analog simulation, reservoir computing and quantum neural networks — offer a path to robustness without relying on error correction. These approaches could enable faster scaling toward systems with tens of thousands of qubits in the near future. In her NSF CAREER project, Niu is exploring novel hybrid quantum-computing paradigms beyond the traditional gate model, in which the analog nature of quantum dynamics is combined with the programmability of digital approaches.

The goal of developing new quantum-control techniques and algorithmic frameworks grounded in quantum signal processing is to enhance robustness and error resilience of large-scale quantum computation without relying on the overhead of conventional digital error correction.

Niu’s hybrid approach aims to combine the strengths of both paradigms: the structured programmability of digital gate sequences with the flexibility and efficiency of direct, continuous pulse-level control..

“The goal is to engineer quantum dynamics having both enhanced flexibility and robustness against errors, without sacrificing the crucial element of programmability required for complex algorithms,” she said.

A transformative proposal, Niu builds upon her unique full-stack experience in both academia and industry, covering the entire spectrum of quantum-computing research, from foundational physics to practical applications.

By developing sophisticated multi-qubit control optimization protocols, hybrid digital-analog algorithms and scalable system characterization methods, the project holds the promise of significantly enhancing the performance of near-term quantum computers, thereby accelerating the timeline for achieving a practical quantum advantage in fields such as materials science and drug discovery.

In her CAREER award project, Niu will also support her commitment to building a strong quantum workforce by developing open-source tools, new interdisciplinary courses, undergraduate research programs, K-12 outreach and a free online textbook dedicated to quantum control.

Tags
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