Researchers release roadmap for the development of quantum information technologies

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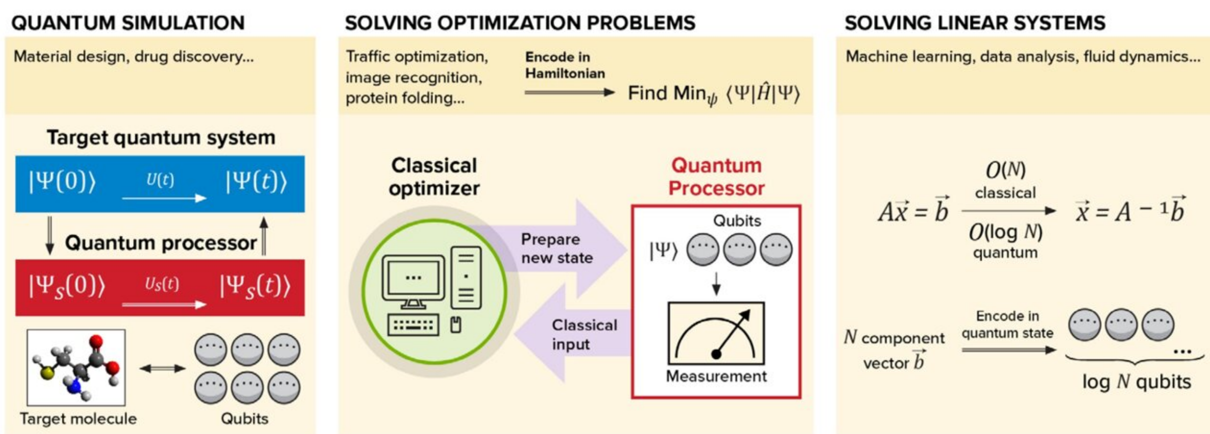

Application of quantum computing. Left (quantum simulation): A target quantum system (blue box) evolves in time according to U(t), while the quantum processor (red box) evolves according to US(t). The quantum processor is designed such that there is a mapping between the two systems. Measurements of the quantum processor then yield information about the target quantum system. For example, the difficult electronic structure problem of a target molecule can be mapped onto the qubits of the quantum processor. Center (solving optimization problems): The solution of an optimization problem can be encoded into the ground state of a Hamiltonian, H. This ground state can be found using an iterative, quantum-classical algorithm illustrated at bottom. A state |Ψ> of the quantum processor is prepared. The energy of the state is measured and fed into the classical computer. A classical optimization algorithm then suggests a new quantum state, which is then prepared. The algorithm iterates until the ground state is found. Right (solving linear system): Linear systems of the form Ax=b, where A is an NxN sparse matrix, are ubiquitous in science, engineering, finance, etc. A classical computer can find the solution in O(N) operations, while a quantum computer yields the solution in O(log N) operations, an exponential speedup. This quantum speedup is possible by being able to encode the N component vector b in the state of only log N qubits. Credit: *Department of Energy* (2022). DOI: 10.2172/1900586

Quantum technologies are expected to become part of our everyday lives in the coming decades. Researchers in the emerging area of quantum information science (QIS) are rapidly developing many of these technologies, including ultraprecise quantum sensors that could propel fundamental science and medicine forward by leaps and bounds; powerful quantum computers to tackle insoluble problems in finance and logistics; and quantum communications to connect these machines as part of long-distance networks.

To guide the development of these devices, the Q-NEXT quantum research center has published a new report, "A Roadmap for Quantum Interconnects," which outlines the research and scientific discoveries needed to develop the technologies for distributing quantum information on a 10- to 15-year timescale.

Q-NEXT is a U.S. Department of Energy (DOE) National Quantum Information Science Research Center led by DOE's Argonne National Laboratory.

In QIS, researchers manipulate the quantum features of nature for practical applications such as computing. The roadmap is intended to guide the QIS community as it navigates the challenges and opportunities afforded by advances in QIS.

The roadmap specifically focuses on quantum interconnects, devices that link and distribute quantum information between systems and across distances to enable quantum computing, communications and sensing.

"The role of Q-NEXT and the other DOE National QIS Research Centers is to do the science that will be useful for the public good," said Supratik Guha, who led the roadmap effort and who is also the Q-NEXT chief technology officer, a senior advisor to Argonne's Physical Sciences and Engineering directorate, and a professor at the University of Chicago's Pritzker School of Molecular Engineering. "That's why we need a roadmap. It captures the major challenges going forward and what should be done to address them."

The roadmap comprises three sections, focused on quantum interconnect use in quantum computing, communication and sensing. Each section identifies the science and technology imperatives needed to advance the research area over the next decade; lays out the components and systems they use; poses questions that need to be addressed by the community; and outlines the developments necessary to turn the technology to practical advantage.

"Quantum information research has been mostly about the science until recently. Now, especially over the past decade, there's been increased interest in turning the science into technology," Guha said. "We've tried to be nonprescriptive, but we do say what needs to happen to build the technologies. We've tried to identify areas of science that need to be advanced and describe engineering challenges that need to be tackled."

Thirty-nine experts from 15 institutions across the national labs, academia and industry contributed to the report.

"The roadmap was an excellent way to get together scientists and engineers, industry-focused and academic-focused people, to provide all points of view and learn from each other's perspectives," Guha said.

"We expect this roadmap will be a guide for the global QIS community as we design and develop viable quantum technologies," said Jennifer Dionne, who is a report co-author, one of the leaders of the Q-NEXT collaboration and a professor at Stanford University.

"The roadmap brings together the insights of experts spanning a broad range of disciplines. We hope it provides an integrated view to inform the strategies of national science agencies, academia and industry as they invest in this burgeoning field."

More information: David Awschalom et al, A Roadmap for Quantum Interconnects, *Department of Energy* (2022). DOI: 10.2172/1900586

Provided by Argonne National Laboratory

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