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UNDERSTANDING THE CAPABILITIES OF MODERN QUANTUM COMPUTERS

A plain language summary of some of Booz Allen's recent quantum research

What will this quantum computer be able to do?

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Link to paper:

Number-Theoretic Characterizations of Some Restricted Clifford+T Circuits

Executive Summary

Today's data-driven organizations run on the computer programs that interpret and translate code written by engineers into a form modern computers understand. To use quantum computers, we have to understand how to efficiently write code these new machines can execute. The process of translating code from what humans write to instructions machines can perform is called compiling, and a team of Booz Allen researchers lead by Dr. Andrew Glaudell has begun to tackle this problem. Targeted research along these lines enables mission stakeholders to understand how emerging capabilities and tooling will evolve as these technologies become available to disrupt and support various status quos.

Quantum computers promise new and radically different ways of solving common, persistent, and emerging problems in cybersecurity, materials engineering, chemical simulation, and beyond—approaches and solutions that simply aren't accessible to current computers. Ultimately, the breadth of problems that today's computers can solve is limited by the set of the simplest instructions they can execute. Collections of these instructional building blocks, known as "gates," create more complex processes that build up to solutions. We think of quantum computers the same way, combining simple operations to execute complicated algorithms, but the fundamental "gates" are different.

Predicting the capabilities of future quantum computers requires studying the relationship between their basic operations and the breadth of capabilities those operations can build. To understand what quantum computers might be capable of, we have to look at a specific problem or use case and ask: What do we need to teach a quantum computer in order for it to be able to solve the challenge we have in mind?

In a recent paper, the research team proposes doing quantum calculations using a nonstandard set of fundamental gates. From this novel starting point, the team draws an exact parallel between the simple building blocks we allow the computer to use and the types of instructions it can perform, relating gates we add to the gateset to specific increases in the computer's ability to build more complicated operations using more than one gate. We exploit this new framework to show that in some instances, the approach can be used to execute commonly used algorithms in much simpler ways.

HOW DO THE BASIC PIECES DETERMINE WHAT WE CAN BUILD?

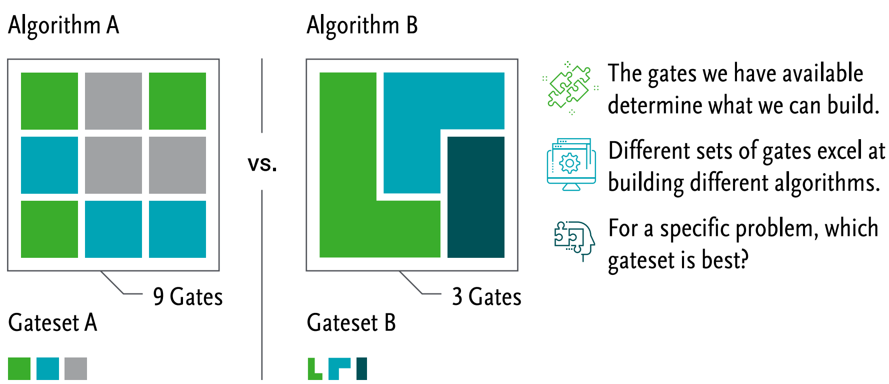

Figure 1: The efficiency of a given solution depends on the pieces used to build it. Simplifying a computer's building blocks can reduce the number of steps to perform the same operation—a necessity as quantum computing becomes more advanced.

The Booz Allen quantum team demonstrates that if we know the operation we need to perform, we can build the necessary quantum circuit (the flow-chart-like sequence of simple gates) that performs it. That is, if we understand how the quantum computer needs to manipulate what we give it, we know how to do this more complex procedure using only the basic operations the computer is allowed to use.

By establishing this framework, we characterize previously unexplored collections of quantum operations and circuits. For scientists, this research maps out how theoretical results and seemingly minor advances build up to the capability leaps we expect from quantum computers. For people who build new solutions and tooling for quantum computers, it provides unique clarity about the advantages their architecture provides by showing when and how additional basic operations enable these new capabilities.

Link to read the full paper:
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WHAT BUILDING BLOCKS DO OUR QUANTUM COMPUTERS NEED?

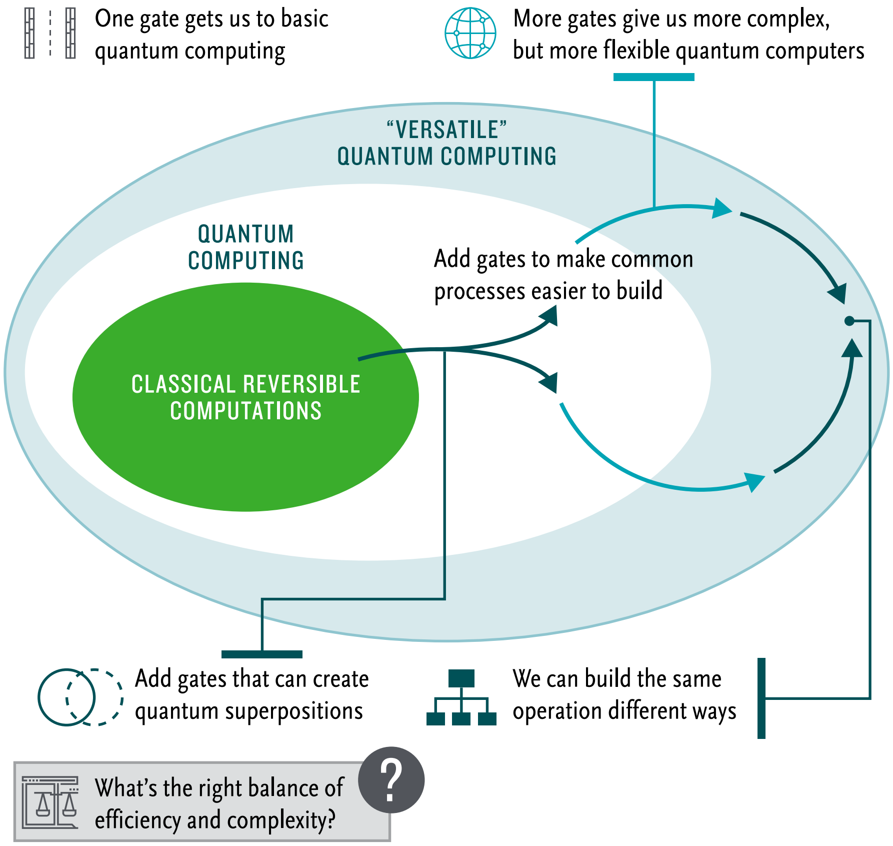

Figure 2: Quantum computing's basic gatesets often yield more complex circuits compared to other gate choices. As a result, the addition of relatively few basic operations can result in powerful new computing paradigms and increasingly flexible and efficient solutions.

Booz Allen's Quantum Research

Booz Allen's quantum research team is focused on basic, theoretical research addressing client needs not prioritized by academic researchers. Through this targeted, original research, the team focuses on bringing deep quantum expertise and mission-minded experience directly to clients to identify and fill capability gaps across the defense, civil, and commercial spaces.

Learn more at **boozallen.com/quantum**.

REFERENCES

[1] M. Amy, A. N. Glaudell, and N. J. Ross. Number-Theoretic Characterizations of Some Restricted Clifford+T Circuits. Quantum, 4:252, Apr. 2020. (see also arXiv: 1908.06076)

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