Teaching Beyond Classical Bits:

Quantum Computing for the Next Generation of Computer Scientists

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Institution: KTH Royal Institute of Technology - Dept. of Computer Science

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> *For many companies and organizations today, quantum computing is surrounded by a mix of fascination and expectation. It is often presented as the technology that will solve everything faster. It will solve everything from optimization problems to cryptography, often within very optimistic timelines. As teachers, we are at the intersection of expectation and the reality of what students can and should learn in a university course.*
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> *From our perspective, quantum computing is not a magic accelerator. It is a beautiful new computing paradigm. It challenges students to embrace reasoning about computing in terms of superposition, interference, and entanglement. Teaching quantum computing is therefore not only about preparing students for future jobs in quantum computing. It is also about training their minds to think in fundamentally new ways.*

Beyond the Hype: Teaching Under the Pressure of Expectations

Expectations for quantum computing within the industry and organizations are high. Companies read about quantum advantage, see roadmaps from hardware vendors, and ask, "*When can we use this in production?"* Students hear the same messages and arrive in the classroom expecting revolutionary breakthroughs.

One of our first responsibilities as teachers is to help students distinguish between promise and reality. We explain that today's quantum devices are noisy and still limited in size, and without error correction on a large scale. Practical quantum advantage will likely be problem-specific. At the same time, we highlight that this does not diminish the importance of learning quantum computing. Instead, it clarifies how and why they should learn it.

In courses "Quantum Computing for Computer Scientists", "Applied Quantum Machine Learning", and "Quantum Neural Networks" at KTH, supported by the ACHIEVE project, we

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leverage this tension constructively. We present students with real research prototypes. We also discuss current limitations, open problems, and unsolved engineering challenges. In this way, they learn not only to utilize quantum technologies but also to manage expectations effectively. This is a critical skill when they will be the ones explaining to managers what quantum can and cannot do.

From Physics to a Computer Science Discipline

Historically, quantum computing has been a topic mainly for physicists. Many introductory textbooks assume a background in quantum mechanics. Often, the focus was on physical realizations of qubits and fundamental experiments. Computer scientists were mostly spectators.

This is now changing. As quantum devices move toward larger scales and more stable architectures, a computer science perspective becomes critical. Quantum algorithms must be analyzed with the same rigor as classical ones. Quantum software must be designed, optimized, tested, and maintained using computer science methodologies.

In other words, quantum computing is no longer only about understanding how a qubit is physically built. It is now about deciding what to do with thousands/millions of qubits once they become available. It is also about how to organize the software layers that drive them.

A New Computing Paradigm in Class

Introducing quantum computing to computer science students means inviting them to question their assumptions about how computations are carried out. Bits can now be in superposition. Operations can interfere. Many classical intuitions about copying data or debugging programs simply no longer apply.

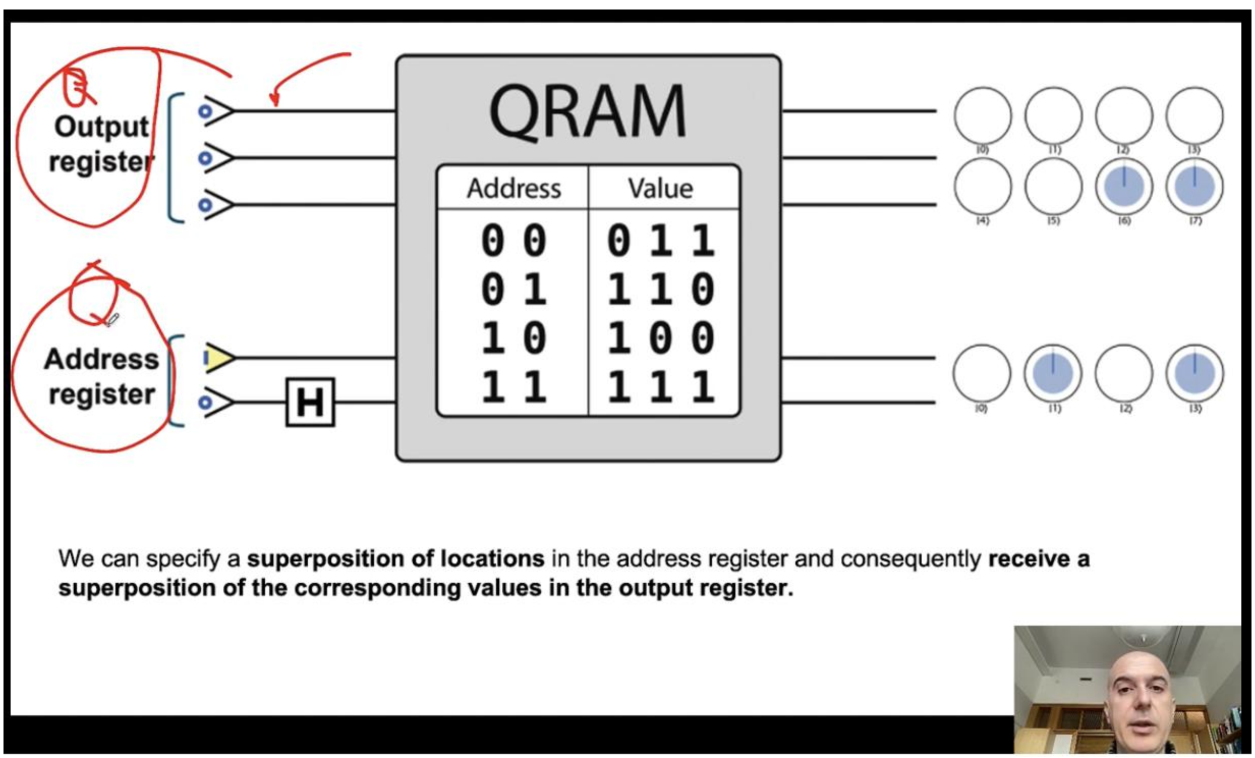
In the classroom, we turn this conceptual novelty into a learning opportunity. We begin with familiar ground, e.g., linear algebra, logic, and classical algorithms. We then progressively extend these concepts into the quantum world. Quantum circuits are presented as a new kind of program. Quantum algorithms are treated as carefully constructed patterns of interference. Quantum states are manipulated using matrices and vectors that students are already familiar with.

Our goal is not to transform computer science students into physicists, but to provide them with the appropriate level of abstraction. They learn enough physics to understand what qubits and measurements are. But the emphasis stays on algorithmic thinking, software design, and system-level reasoning.

Conclusions

Modern Quantum computing is portrayed as a disruptive technology that will change everything. From the perspective of teaching, we see it as an important opportunity to change how students think about computation.

At KTH, the courses “Quantum Computing for Computer Scientists” and “Quantum Machine Learning”, supported by the ACHIEVE project, are designed to form this new generation of professionals. They are not promised immediate quantum speedups. Instead, they are given the tools to critically assess what quantum computing can really offer, to design algorithms and software that respect the constraints of current and future hardware.



Video lecture from “Quantum Computing for Computer Scientists”, supported by ACHIEVE, at KTH Royal Institute of Technology.

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