Ready-to-run
Quantum Software

Why Classical vs. Quantum Computing Is the Wrong Question

Understanding and capitalizing on the differences between the two

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Quantum and classical computing are as different as night and day. The choice isn't one or the other, but how we need and can use both in business to achieve our objectives.

Quantum's promise is to solve complex computational problems that classical cannot—or to speed up solving them faster and better than we ever imagined. As our data expands, quantum promises to rise to the challenge of solving even bigger problems—those unknown today—faster, while providing more accurate and diverse solutions to choose from.

It's important for business leaders to understand the differences between classical and quantum computing as you prepare to take advantage of the value quantum brings. This will help you understand how to think about the types of problems and business decisions where quantum can bring competitive advantage, as well as to see the possibilities for using a combination of classical and quantum computing moving forward.

A key difference is how data is analyzed in classical computing as a binary stream vs. multi-dimensional analysis in quantum computing.

Binary Data Analysis in Classical Computing

With classical computing, today's data volumes limit the performance and results that a classical application can achieve. As data grows, the volumes overload classical resources.

- Serial processing in a binary space can't handle the large and dense solution sets of many problems. That limits the size and validity of analytics. This forces subject matter experts (SMEs) and programmers to compress/reduce and limit the data that is processed, resulting in a lower quality solution.
- Classical computing results can be reproduced since the results are always computed from the same exact "state."
- Classical computers generally return one result, limiting the flexibility of decisions when multiple solutions are present.

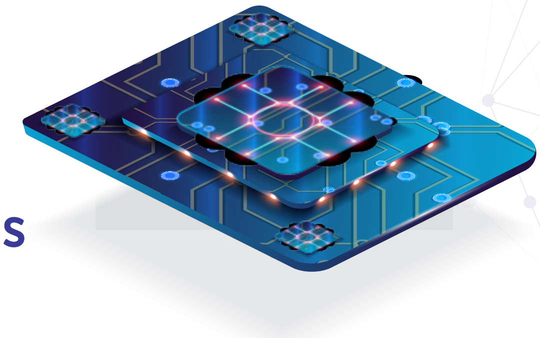
Multi-dimensional Analysis in Quantum Computing

Quantum approaches accelerate complex analysis since they can handle larger and more dense solution spaces [as qubits become available], while accelerating time-to-results and the quality of results.

- Multi-dimensional, simultaneous analysis structures data to accelerate performance, better mirroring the natural multi-dimensional state of most problems. The world we live and act in is multi-dimensional. That means solving our real-world problem in the same state better reflects what happens in our environment.

- Limitless size leads to increased validity of analytics and better-quality results.
- Quantum computers return a diversity of highly accurate results, offering more and better opportunities to find the best possible solution in different situations, or states.

The difference between linear binary programming and sequential, multi-dimensional presentation and optimization is one reason quantum requires highly trained quantum experts to define the problem and its processing to extract full benefit from the quantum computer.



How Software Programming Differs from Classical to Quantum

Quantum approaches accelerate complex analysis since they can handle larger and more dense Quantum software programming is critical to make quantum computers process actual results. Understanding how to create quantum software, and the implications for your business, is vital to getting the most out of quantum computers.

In many ways, quantum software programming is the bigger challenge vs. the hardware itself.

That's because programming quantum software requires a significant and new level of expertise. Expertise that classical programmers, subject matter experts, and others don't have. Only a rare few know right now to create quantum software. It's a different programming paradigm, including extremely low-level coding that's proprietary to each QPU (Quantum Processing Unit) manufacturer.

The differences between classical and quantum software programming are vast.

Here are three fundamental shifts to help you think about how to build quantum software to address your complex business problems.

1. Quantum Software Programming Isn't Classical

Programming quantum computers is nothing like programming the CPUs running your business today. It's not about simply making existing programs run faster. Rather, quantum programming is a completely new paradigm.

If you choose a software development kit (SDK) approach to build new quantum software programs, it will take a lot of time and resources before you can build, test, tune and successfully run a quantum program. In addition to the PhDs in math and physics and quantum experts—expensive investment—they'll have to do extremely low-level coding for each QPU type to manage the QPUs for the program execution. And it goes on from here...

2. Qubits are Inherently Probabilistic

With quantum, you must think about your problem, or request, in a completely different manner. Quantum processing reflects the multi-dimensional, multi-state nature of our world vs. the binary bits and serial processing for classical.

Quantum algorithms work in terms of probabilistic factors, seeking out all probable outcomes that meet whatever constraints and objectives your optimization problem requires. Creating a program from scratch to solve those problems is a long and complex process. It's an even larger programming paradigm shift than the move from vector processing to parallel vectors, and to massively parallel and beyond.

The implications are threefold:

1. You can't use classical programming paradigms and skills.
2. You'll have to write code at a lower, more technical level than before. (Think assembly language on steroids.)
3. You'll have to visualize the problems and create programs to solve them differently.

This gets complicated fast. Here's why:

In classical programs, bits of 1s and 0s represent data in states that are repeatable. Bits are binary—either on or off—and can be measured or read without changing the state.

In quantum programming, qubits are inherently probabilistic, meaning that two identical qubits can have different measurements based on their states. Qubits are vectors of 1s and 0s and can exist in the same state, different states, or in multiple states at the same time (that's called superposition.) These outcomes are based on the moment in time when they are measured, and the probabilities present at that exact moment. You can only measure a qubit once. As it is measured, it begins to go through a state called decoherence, and it collapses into one of two states – just like a bit.

Running a problem in multi-dimensional space with multiple, probabilistic, answers being "true" at the same point in time is a lot to get your head around. The beauty is that with qubits, you can simulate the real world and all its diverse probabilities, versus only a binary scenario. You just need to be able to transform your business problem and its story into the mathematical terms that represent them as qubits.

3. Quantum Software is Discrete

Classical computers have difficulty calculating what are known as discrete problems, meaning the answers are in whole numbers vs decimals. The appropriate quantum software techniques empower both classical and quantum computers to solve these discrete problems, accurately and with good performance.

This is another reason why quantum is enticing. Classical programs use a variety of advanced heuristics to find the best solutions to constrained optimization on binary variables. The software solutions are usually aligned with floating-point results – meaning you can have a result of 1.278 crates of toilet paper per load to meet your constraints for optimizing your stock in different warehouses or stores.

That's not exactly helpful when you need to optimize trucking deliveries to stores. How are you supposed to load .278 of a crate? And by the way, you can't just round up or round down. That further reduces the accuracy of the result, and the decisions you make about your supply chain optimization.

Quantum software techniques can process decimal or whole numbers, processing continuous or discrete variables in discrete measurements – meaning an answer must be a discrete number, not a floating-point decimal. This means every single problem variable, constraint and goal must be processed as a discrete number. The result? When you run your logistics problem on a computer using quantum techniques – you can get results that map to solving your business problem. No more partials for people, crates, packages, or planes.

Will Quantum Replace Classical?

Quantum computing is the next step in the evolution of information technology. All the hype out there has led some to think this means we'll all be shifting from the laptops we have today to a new, upscaled quantum version.

That's not true.

The potential for quantum computing to transform the way businesses use complex computational techniques to fuel more informed decisions is staggering–once quantum hardware can scale to handle it. This doesn't mean quantum computing will replace how most of us use the computers we have now, every day—even when functional quantum computers become available.

Here's the thing. Classical computers process transactional data very well. So, when you need to buy something, order something, update your revenue projections or headcount costs, or virtually any other data that resides in a database – you will do it with a classical computer. In fact, classical computers will create and store much of the data that quantum computers will analyze.

Quantum computers will augment classical computers for most of the work they will do for the foreseeable future.

Since quantum computers can't yet scale to process our enormous real-world datasets, we still need classical systems to do the large-scale processing. Even when quantum computers do scale to meet the vast sizes of enterprise data sets, we'll still use classical systems for much of the processing work related to anything transactional, among other jobs.

The more likely scenario is that quantum computers will augment classical computers. There are many thoughts and scenarios about "hybrid" or enhancement across different use cases. Here's one example focused on optimization.

Quantum computers simulate real world scenarios in ways that classical computers simply cannot. Their 3-dimensional processing enables complex analysis of multi-dimensional problems thanks to capabilities like superposition and entanglement. These features allow them to investigate what happens in complex situations as different elements change, simulating all related changes in the scenario. They are especially accurate at identifying "where" the best answers are most likely to be within vast data sets, based on the problem you're trying to solve. They're more accurate than classical systems, and they find all results that meet the problem criteria, offering a diversity of results that provide better insights for the business or organization.

Classical computers do well at searching the data itself to find the best answer to the problem. The challenge is they must work through volumes and volumes of data in a serial fashion, reviewing large amounts of data that often has no relevance to the problem. This is why we hear about problems that run forever and never find a solution.

When you combine a quantum computer with a classical computer, the QPU can help locate the most likely positions in the data to find the best answers. The classical computer can then search for the very best solution or for a diversity of results in those prime data locations.

Another example of hybrid processing would be using the quantum computer to process the more difficult sub-problems of the data set, while focusing classical resources on the simpler sub-problems.

This results in accelerated performance, more accurate results, and a diversity of results to choose from. In contrast to the potential to never solve the problem, less accuracy, and a single result with todays' approaches.

The Bottom Line

The question of "will quantum computers replace classical computers" is not relevant.

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There's a need for both classical and quantum computers, individually andworking together.

Each has its own strengths and use cases today. As we expand our quantum knowledge in the future, we'll find more ways to use quantum with classical, and on its own.

All the hype about quantum computers often misleads people into believing that they are ready for production and will take over the world. That's not the case. As with any new technology, they need time and vendor effort to evolve to become production ready. Similarly, they have a specific arena of useful applications, an arena that includes many unsolvable problems and unknown potentials todaay.

Here at QCI, we have an extended meaning – embracing both classical and quantum processing and how to apply quantum techniques to either of them, or across a hybrid architecture.

QCI believes that quantum approaches and techniques can be applied to classical processing to capture business value today. Instead of focusing purely on quantum for quantum's sake, our technologists focused on applying quantum techniques to classical and quantum computing. Qatalyst is designed to create a seamless bridge between the two, harnessing quantum power immediately within classical systems, to help you start using quantum techniques today.