

Could quantum give us the generative AI we're looking for?

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Images created in [DALL·E](#)

Quantum computing and artificial intelligence (AI) might seem as distant from each other as New York and Los Angeles. But according to Duke Quantum Center (DQC) director Chris Monroe, the two subjects are practically next-door neighbors.

"Quantum and AI are often spoken about together, and it makes sense because quantum will accelerate the next generation of AI," said Monroe, the Gilhuly Family Presidential Distinguished Professor at Duke University with appointments in electrical and [computer engineering](#) and physics. "Even ChatGPT, the current poster child for state-of-the-art AI technology, is currently limited in its ability because computers can't make correlations among a trillion objects. There's just not enough memory in a computer to do that."

Monroe is speaking, of course, about traditional bit-leveraging computers that make yes/no evaluations. Quantum systems of the type that Monroe and his colleagues at the DQC are building have the potential for infinitely more computing power—which could theoretically translate to infinitely more capable AI tools.

"Machine learning and AI is so interesting because it's highly empirical," said Jungsang Kim, the Schiciano Family Distinguished Professor of Electrical and Computer Engineering at Duke who, with Monroe, co-founded the [quantum computing](#) company IonQ, which caters to industry collaborators.

"We throw a lot of data and models and computational power at the problem, but we have limited insight about how and why the AI technology works. Nevertheless, it's available for use and has already had

huge impact. In the [machine learning](#) and AI space, the really interesting question is, 'Are there opportunities for quantum to really make a difference?'"

Large language models (LLMs) are certainly adept at summarizing mountains of data or presenting highly stylized text. But at this juncture, LLMs cannot keep up with specialized knowledge—according to ChatGPT, its last update on advances in quantum computing was made in September 2021—nor can it synthesize ideas or generate new ones.

Here's a quick example. Currently, if a user queries ChatGPT about why Juliet is likened to the sun in the balcony scene of Romeo and Juliet, the tool returns this response:

"By comparing Juliet to the sun, Romeo is conveying several meanings:

- **Radiance and Beauty:** The sun is often associated with light and beauty. Romeo is expressing how Juliet's presence illuminates his world and fills it with beauty.
- **Warmth and Comfort:** The sun provides warmth and comfort. In a similar way, Juliet's love and affection bring warmth and comfort to Romeo's heart.
- **Center of Attention:** The sun is the center of the universe in the geocentric model, around which everything revolves. In this context, Romeo is emphasizing how Juliet is the center of his universe, and his world revolves around her.
- **Vitality and Life:** The sun is essential for life on Earth. Romeo may be suggesting that Juliet is his source of life and vitality, without whom he would be lost.
- **Unattainable Distance:** Just as the sun is distant and unattainable, Juliet is seemingly unattainable due to the feud between their families. This adds to the dramatic tension of their love."

It's quite a satisfactory summary of what is surely a vast body of literature on the subject. When invited to write a new simile comparing Juliet to a different planetary body, however, the LLM's shortcomings are made clear in its response: "Juliet's presence in my life is like a [distant planet](#), captivating and mysterious, with an orbit that pulls at the very fabric of my being."

The problem with that AI-generated simile—aside from it reading more like "The Notebook" than "Romeo and Juliet"—is that an orbit does not exert any pull, a fact that ChatGPT acknowledged when pressed.

Language models like ChatGPT are probabilistic, meaning that they generate strings of words based on the probability of which word is likely to sequentially follow the next—which likely resulted in the incorrect language in the example above. Given the vast number of words and configurations in which they are arranged and rearranged to form sentences, the internal mathematical models that underpin them, and the amount of data required to train them, are enormous.

The myriad correlations that the models must make are difficult to capture with classical computers, but there's a dawning realization that quantum computers' superior ability to recognize patterns and predict multiple simultaneous outcomes could give AI models a leg up.

"If you use quantum models to capture the structure of data like images, they're very effective—even right now, with the small quantum computers we have," said Kim.

Generative AI comprises just a small sliver of machine learning applications, and there are innumerable opportunities for businesses to automate tasks or make them more efficient with machine learning—semiconductor chip design is one example.

It's one reason why quantum initiatives are still proliferating around the world. But a significant challenge for these new players is leveling up on a field that's been dominated for decades by a few key teams.

The U.S. has invested significantly in quantum computing research and development since the mid-1990s, and the United Kingdom and Singapore quickly followed suit. Now, a host of other countries are standing up their own quantum initiatives—but with the early adopters so far ahead on the research and development front, newcomers are taking alternate routes.

"In quantum, there are makers and takers," said Kim. "Makers develop technologies and build devices. The U.S. has a lot of makers, from startups to large companies building quantum computing devices, because we developed the technology here. Then there are takers—these people are not necessarily interested in making quantum computers themselves but want to figure out how to use the makers' technology to benefit their businesses. They have the opportunity to win through partnerships, and they should not be shy about leveraging advances made by industry in other countries."

"Some people worry that quantum computing technology is overhyped, that we're headed for a 'Valley of Death,' where the [vertical axis](#) is the amount of investment or interest in the technology and the horizontal axis is time," said Monroe. "It's also called the hype cycle. When you get to the very top and the technology is still years away from being realized, people become disillusioned."

The National Quantum Initiative, which was launched in 2018, endowed the National Science Foundation, the Department of Energy, and the National Institute of Standards and Technology with new programs to advance quantum computing, of which Duke has captured a significant slice. And IARPA made a \$31 million investment in the partnership

among Monroe, Kim and Michael J. Fitzpatrick Distinguished Professor of Electrical and Computer Engineering Ken Brown; the funding allowed the trio to procure the multichannel optical modulators that catch and steer atoms, making the forward leaps and bounds of their ion trapping research possible.

Now, Congress is considering the National Quantum Initiative for renewal. Kim is currently serving as a special advisor to Korea, which is laying the foundations of its own \$2.5 billion quantum computing program. Brazil, Spain, South Africa and the U.K. all created new quantum computing initiatives last year.

If these investments are any indicator, interest in the technology hasn't reached its peak. But you don't have to take Kim's and Monroe's word for it; just ask ChatGPT itself.

"Quantum computing has the potential to bring about significant advancements in various fields, including machine learning and natural language processing, which could potentially improve models like myself. However, the extent to which quantum computing will directly impact my capabilities depends on the specific developments that occur in the field. As the field progresses and challenges are addressed, we may see more concrete and significant improvements in AI and other technologies."

Provided by Duke University

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