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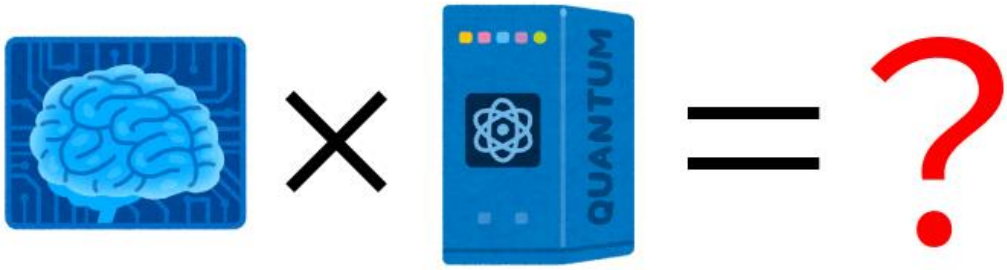
Title: **Quantum Machine Learning: AI with a Completely New Computer**



You may have used Chat-GPT, which is one of the most famous artificial intelligence (AI) in the world. If you ask a question, it answers very quickly and naturally. Recently, the AI technology is growing rapidly, and it will continue in the future.

AI is based on a technique called machine learning. Computers tune their algorithms automatically depending on their purpose. To understand this technique, let's take an image recognition task to distinguish dog breeds as an example. First, we prepare a training data set comprising dogs' images and labels. Each Label indicates a dog's breed (Bulldog, Pomeranian, and so on) in the corresponding image. In short, it's a correct answer. Next, the machine learning model receives input images and outputs the answers. Then, it calculates loss which shows the difference between the labels

and the model's answer. Finally, we change the model's parameters to reduce the loss. By repeating the process, we get a powerful model that can correctly answer a dog's breed from its image. This is the basic mechanism of machine learning.

I'm very interested in machine learning. Computers learn how to do their tasks well by trial and error. It's like a human! This technology has already been used for translation, self-driving cars, and so on. It's improving our daily lives.

So far, machine learning has been done by usual computers (we call them classical computers), but nowadays completely new computer is proposed. It's a quantum computer which is driven by quantum mechanics. Quantum mechanics emerge only on a very tiny scale, but it has some interesting features which I'll explain in the next paragraph. Then, can quantum computers enforce machine learning?

In my opinion, the answer is Yes. To show the possibility of a quantum computer, I'll introduce two interesting and unique concepts of quantum mechanics.

One is superposition. As its analogy, you may have heard of a thought experiment called "Schrödinger's cat." Suppose I put a cat and a little toxic gas in a box, is the cat dead or alive? (Of course, it's a thought experiment and I never do such a thing! I love cats.) Both possibilities exist simultaneously, and we can't know it until we open the box. This is superposition. In a classical computer, information is always processed by bits which can be 0 or 1. It's always determined which state each bit is in. However, in a quantum computer, we can make a state which has both possibilities of 0 and 1. Strangely, the state of the bit of the quantum computer (qubit) is not determined until we measure the qubit. When a qubit is measured, its state is determined probabilistically.

Another concept is entanglement. For example, we can prepare two qubits' state

which can be only 00 or 11. In other words, the state can't be 01 or 10. If you measure one qubit and get the result "0", another qubit's state is always "0". Similarly, if you get the result "1", another qubit's state is always "1". It means that when you measure one qubit, you can know the state of another qubit without measuring it. I note that this state is also an example of superposition because it has both possibilities of 00 and 11.

I'm inspired by these mysterious characteristics, and I believe they empower machine learning. It's already proved that quantum computers can solve some problems much faster than classical computers. One example is prime factorization. Classical computers can't solve it efficiently, but quantum computers can do that by using Shor's algorithm.

Another reason is that I'm planning to research quantum many-body systems which follow quantum mechanics. Quantum computers also follow quantum mechanics, so I think quantum computers can execute simulations of quantum many-body systems more efficiently than classical computers.

Many people have done research to realize quantum computers, but they still have many errors, so we can't execute accurate calculations on quantum computers now. However, according to IBM Quantum Computing's roadmap [1], we may get an error-corrected quantum computer in the next 10-20 years.

If so, a quantum computer will be used for various tasks. It will be used not only for advanced academic research but also for commercial uses. Airbus and BMW Group are holding The Quantum Mobility Quest [2], which is a contest of quantum computing including quantum machine learning for real-world industrial applications. Shortly, quantum computers may be used for tasks that are directly related to our daily lives.

Another influence on our society is the way of thinking of quantum mechanics.

Its unique concepts (e.g. superposition, entanglement) may affect the way of thinking in not only natural science but also social science and humanities. Of course, quantum mechanics itself emerges on a very tiny scale, so it isn't directly related to a research area that deals with other things such as human society. However, if more people become familiar with quantum mechanics' way of thinking, some people may use its concept as an analogy in another research area.

Machine learning has already affected our lives in various aspects such as AI, and I believe quantum computers enforce it. I'm excited about the possibilities of quantum machine learning.

I would like to thank Dr. Kate Harris and Yosuke Nakashima for useful comments to revise this essay. I used Grammarly to check my writing.

The image is made by me, using いらすとや(https://www.irasutoya.com/).

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[1] IBM. (n.d.) Our roadmap to advance useful quantum computing. In *Technology for the quantum future*. Retrieved June 29, 2024, from https://www.ibm.com/quantum/technology

[2] AIRBUS and BMW GROUP. (n.d.) Quantum Computing Challenge. Retrieved June 29, 2024, from https://qcc.thequantuminsider.com/#slide-2