Quantum Computers

Where Physics and Computer Science Intersect

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My interest in physics was first sparked in childhood. During my elementary and junior high school years, I visited research institutions like JAXA, AIST, and KEK. For example, I participated in some talks by astronauts and launched water rockets. It was thrilling and amazing to see a simple plastic bottle blast high into the sky and disappear far beyond the open field, just through the power of water. I realized the incredible physics behind it. Also, I learned that everyday objects, like water and fire, behave very strangely in zero gravity. I wondered how huge the particle detector at KEK was. Scientists there use a massive accelerator stretching dozens of kilometers to accelerate tiny electrons and positrons to nearly the speed of light and then capture their collision with the huge detector as tall as a five-story building. I was fascinated by the depth of science through these experiences.

A programming class in high school was the beginning of my curiosity about computer science. I made some websites and applications as a hobby. At first, it was a constant battle. A single missing semicolon or a tiny typo could break everything, and I would spend hours staring at the screen, feeling like I was solving a mystery without any clues. To be honest, it was much harder and more frustrating than I had ever imagined. However, that struggle was exactly what made it so addictive. The moment I finally fixed a ‘bug’ and my program came to life, I felt an incredible rush of joy. I felt as if I could create anything in the world with my computer, fueled by a passion to improve my programming skills. It is very satisfying to build solutions with my own hands.

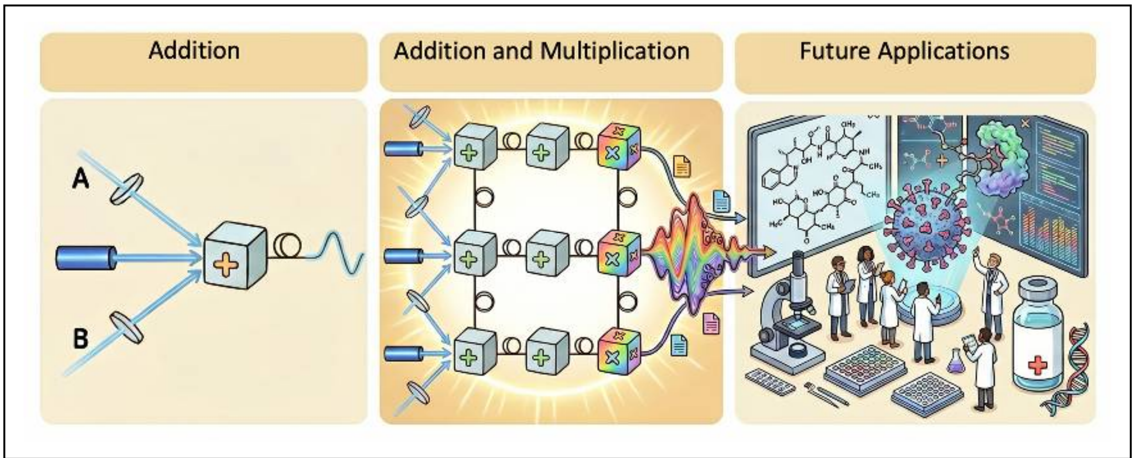
At university, I was introduced to the exciting field of quantum computing, where physics and computer science intersect. I It felt inevitable that I would choose to conduct research in this field. A science magazine which I had read in junior high school first introduced the concept of quantum mechanics. Electrons, atoms and lasers at a very low energy level obey a weird principle: quantum mechanics. For example, an atom does not exist at a particular point. There are only probability distributions, and we cannot predict where the atom will be. Imagine leaning against a wall. You would not expect to fall right through it. However, if you were an atom, there would be a tiny, but non-zero, probability of existing on the other side of the wall, and you might pass through it.

In my current research, I am working to realize ‘multiplication’ in optical quantum computing. Quantum computers use the weirdness of quantum mechanics as a principle of computing, and by doing so, we can calculate in a totally different way from classical computers which we are using now. It is often explained that while classical computing processes patterns one by one, quantum computing can calculate all patterns at once. As a result, quantum computing is expected to be faster than current classical computing for certain types of problems, such as finding a new molecule suitable for medicine. To find the best molecule, we must search through billions of molecules. It takes a very long time with classical computers, but it might take only a second with quantum computers.

Optical quantum computers use the quantum properties of light. Light is the fastest messenger in the universe, so we can create very fast computers with it. Additionally, it is practical and energy-efficient because we do not need extremely low temperatures or a vacuum to utilize the quantum nature of light. Currently, optical quantum computers experimentally can experimentally perform ‘addition’ but cannot execute ‘multiplication’. We expect that ‘computers’ can perform arbitrary calculations, but quantum computers cannot do so without ‘multiplication’. Also, as you know, ‘addition’ is very simple operation and ‘multiplication’ is more complicated. Theoretically, it has been proven that quantum computers cannot be faster than classical computers using only ‘addition’. Therefore, we need ‘multiplication’ to surpass classical computers, and I am trying to realize it experimentally.

In my lab, we use infrared lasers, which are invisible to the human eye. To ‘see’ them, we must use detectors that convert the intensity of the light into voltage. My daily work involves adjusting the angles of tiny mirrors, bit by bit, with extreme precision. The calculation fails by even less than a degree. However, when everything is perfectly aligned, the quantum operation works completely, and the light reaches exactly the state I intended. This process of constant adjustment and tuning is actually very similar to the trial and error I experienced in programming. It can be exhausting, but it is also an incredibly exciting process because it feels like I am slowly uncovering a hidden path.

Looking back, the awe of the water rockets and the patience built at the



computer screen were the twin paths that led me here, merging physics and computer science into quantum computing. Science is a journey of endless trial and error. It is through this patient, passionate exploration that we turn the impossible into reality, one reflection at a time.

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