Contributors

Iren Okminyan and Lilit Adamyan.

Project description and questions

Begin by reading Section 3 through Section 6 of *The Economist's* 2017 article "Quantum Technology is Beginning to Come into Its Own."

This article addresses the past, present, and future of quantum computing, and includes perspectives from Prof. Aram Harrow and Prof. David Kaiser from MIT, among many others in the business, engineering, science, and technology fields. The four sections you are to read discuss quantum communications, quantum computation, software for quantum computers, and the uses of quantum technology.

1. **According to the article, how do ambitions for quantum networks differ across nation-states around the world, and why? Include your own convictions about what role quantum networks should play.**
2. **Give four reasons why corporations and governments believe "the time for investment, all agree, is now" for quantum computation, according to the article. Comment on which of the reasons you believe are most convincing.**
3. **The article quotes IBM vice president Dario Gil saying, "The power of quantum computing is rediscovering all the problems that computers cannot solve, and having a path to solving them." Discuss three ways "quantum software" addresses this idea, and argue whether one should believe Dr. Gil's statement (or not).**
4. **The article states "subjects that used to be mere footnotes to physics will rule, and engineers (and perhaps even consumers) will have to learn to speak quantum." How is this point presented in the article (cite corporate and government examples), and can you give examples from your own experience?**

Question 1

As nation-states, we selected Europe, Asia, and Australia. We will compare the innovations and how these nation-states handle the major problem of quantum networks - the distance.

Besides having QKD (Quantum Key Distribution) and Heisenberg's uncertainty as components of quantum communication, there are also Quantum networks. Being an infrastructure that connects senders and receivers, quantum networks are the base of quantum communication. The absolute leader in terms of quantum networks is Asia thanks to China. China's 70 square kilometers quantum network is funded by the government, links Shanghai with Beijing, and has a metro network consisting of 50 nodes. Besides China, South Korea also has a government-funded project for a metro network of 250 kilometers. In Europe, Britain is working on a similar project connecting Bristol and Cambridge. Australia also works on a quantum network project in Canberra, but for government usage.

Now, let us discuss the main restriction the quantum networks face. Fiber length that is longer than 200 kilometers can result in mixed quantum states and lost information. There are two possible solutions to this problem - by land and by air. In this discussion, we will compare Europe, Asia, and North America.

The land option includes usage of some a quantum version of a repeater and requires teleportation in its reproduction steps. Two research groups are working on this technique on a network connecting Calgary (Canada, North America) and Hefei (China, Asia).

The other, air option also uses teleportation. Here we can notice a collaboration of nation-states as well. In 2012, 143km apart two Canary Islands (Europe) attempted quantum-encrypted messaging. China (Asia) launched a quantum-key-distribution-enabled satellite backed by tech companies including Huawei and Lenovo called Micius. It aims to develop a 3.000km long network. Singapore and Japan (Asia), Italy (Europe), and Canada and the USA (North America) have plans for satellites too.

The opinions on quantum networks differ across different nation-states and inside them. While in the USA (North America) an MIT expert expresses a positive opinion on the potential of quantum networks, research teams of the US army and navy doubt that quantum networks have vast advantages over classical alternatives. In Europe however, The European Telecommunications Standards Institute (ETSI) has big plans on quantum networks.

To sum up, Asia has done big steps in building and investigating quantum networks to which China has a big contribution. Europe also shares the belief that quantum networks will play a life-changing role in the future and does research. North America works on quantum network projects, however, it has both optimistic and pessimistic views on the efficiency of the technology (the US in particular).

We do think that quantum networks have the potential to overcome current technologies and make a big change. However, it will take time and quality research. We think that in case of success, they will be widely used by the governments and authorities for security purposes. The never-ending search for secure communication by the authorities and current government fundings support our assumption.

Question 2

We will present our reasons, provide supporting examples, and discuss the most convincing one in detail:

I. Quantum technologies show potential to solve problems that classical computers, even supercomputers cannot do. (Is fully covered in task 3. Was the top choice, but as it is discussed in another task, we will discuss here our second top choice.)

II. Atomic clocks - an underrated investment proved to be a lost business opportunity. (Discussed below.)

III. Quantum technologies are new to the market and possibilities to invest early and become leading in the market of the future is tempting. (The interest of big giants like Microsoft, Intel, and IBM implies it. These companies are leaders in IT that have made their way to the top by making the right decisions at the right time. In the case of quantum technologies too, they want to gain their leading positions in a newly emerging and very promising industry.)

IV. Curiosity for the “weird” technology that works differently. (The working principles of quantum technologies are based on quantum physics and are different from classical approaches. For a century, quantum physics was just a theory, with no available technologies to help engineers construct quantum products. If the question once was “Can we do it?”, it eventually became “How can we start?” and is currently transitioning to “How can we improve it?”. Questions need answers, and people are interested in finding them.)

Point II. The atomic clocks.

As the article states, although it is hard to compare them with quantum computers or other quantum technologies, atomic clocks can be considered as the first quantum product, as their work is based on the behavior of small particles. The article discusses the example of atomic clocks, thus making parallels with their story and the emerging story of quantum technologies. Being different from classical approaches, it took time to see the significance and work quality of atomic clocks. Despite being developed in Britain, they were commercialized only a year later by an American firm. Underrating them was a big mistake as history showed. Later, similar technology was developed to use in GPS and the magic of quantum technologies became visible for possible investors. In the end, the point of investments is the expectation of satisfying outcomes and profit. The early form of quantum technologies showed that it was worth fighting for.

Question 3

We will present those ways, provide supporting statements and examples.

I. Implementing algorithms that classical computers cannot solve or improving classical algorithms.

II. Evolving ML, DL, and AI with newly developing quantum computing can be powerful.

III. Revolutionary effect on Cryptography: breaking any code.

(I) The article presents an excellent example. a 100-logical-qubit computer needs a few hours or days to solve a problem that supercomputers would solve for billions of years. The reward of this problem is a cut of 1-2% in global natural-gas consumption. This problem can at least partially solve an important environmental issue. According to the article, many algorithms cannot be solved by classical alternatives, but are possible to solve by quantum ones. Solving these and many other problems can open doors to their implementations that were closed, and result in important outcomes like solving environmental problems, for instance. Also, quantum technologies can enhance classical algorithms. “By taking the lens of how you would formulate an algorithm on a quantum computer you often find very good improvements on classical algorithms,” - these are the words of Landon Downs, a co-founder of 1Qbit, a firm that links other firms with quantum experts. In this way, quantum methods optimize classical solutions to the problems.

(II) Besides, quantum computers can be used in machine learning, deep learning, and artificial intelligence - fields that are becoming more popular by each date. They are currently in the development process. As data gets more, new techniques and innovations in data analysis may be needed in the future. The limit of classical computers is more or less known, while the potential of quantum computers is not discovered yet and will take a reasonable time to find out. Combining data analysis and its possible implementations with quantum technologies sounds promising. The combination can be very powerful and result in important inventions.

(III) Shor's algorithm is worth a separate discussion. It solves the biggest cryptographic challenge - cracking any system. Possible only with quantum computers, this brilliant technique both supports and questions Dr. Gil's statement. The fact that cryptographic problems become solvable supports the statement. The fact that the problem of having secured systems gets enormous contradicts it. Now, we can crack any system, but how about defending those systems? The algorithm can cause big problems in terms of security. So yes, current problems can be solved, but new problems will come to replace them.

Of course, there is truth in Dr. Gil's statement, quantum computing truly can solve some unsolvable classical computer problems, however, there is the other side as well. It creates new problems and in some way worsens some, like the security of classical systems. Therefore, yes, we should believe in his words, but we should also be ready for new and even greater challenges.

Question 4

The first three examples below are corporate and government examples, the last ones are our ones.

I. One big example is that Microsoft tries to build quantum software, to have it when quantum hardware comes in use. This big corporation has a leading position in the software of classical systems, and yet, it considers working also on quantum software. This successful company sees the need to investigate new technologies and is ready to ‘learn’ to speak quantum too.

II. Bosch is another corporate example, but in this time quantum technologies are used in household products, to make them more innovative and widen their usage. The applications of quantum technologies are wide and not limited to computers. Thus, learning quantum technologies becomes an excellent task for engineers of this industry.

III. Corporate example of NVision, which uses quantum technologies that have MRI techniques that make much faster and at the same time -cheaper. This is an example of the usage in medicine. Even in here, quantum technologies can make considerable improvements.

IV. A government example: Australia’s government investing in a laboratory at the University of New South Wales in Sydney. Also, the same Australian government investing in closed government quantum networks in Canberra. It tries to benefit from quantum technologies too for various purposes, including security.

V. Another government example. American government's funding of the lab at the University of Sydney as part of LogiQ, as a part of Intelligence Advanced Research Projects Activity.

VI. (Iren) I decided to take our class as I read about quantum technologies and their possible ‘revolution’ in the IT industry, and even daily life. Its promising collaboration with ML and AI got me even more interested because I want to continue my education and career in that direction. I want to be open to the usage of quantum technologies in the future, and the best is to start as soon as I have a chance.

7. (Lilit) As a software engineer, I want to understand the best tools for my job and this means that it would be sensible for me to at least understand quantum computing, what range of problems it can help to solve, and when I should consider it on my project.
My initial interest was the fact that for NP-Hard problems a quantum algorithm can often yield a polynomial or quadratic speedup relative to classical ones. But as you learn it becomes more promising. What makes it more absorbing is the possibility that the next scientific breakthrough in just a couple years will make quantum computing something accessible to the general public, or even worse, cybercrime syndicates. This is one probable shot that forces me to be aware of what awaits us and dive into quantum computing and maybe have my contribution to our country in the future.

Links

https://www.economist.com/news/essays/21717782-quantum-technology-beginning-come-its-own

https://researcher.watson.ibm.com/researcher/view.php?person=us-dgil