

Chapter 2

Fundamentals of Quantum Computing, Quantum Supremacy, and Quantum Machine Learning

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ABSTRACT

When we aim to demonstrate that a programmable quantum device can solve complex problems which cannot be addressed by classic computers, this fundamental goal is known as quantum supremacy. This concept has changed every fundamental rule of computation. In this chapter, the detailed concept of quantum computing and quantum supremacy is explained along with various open source tools and real-time applications of this technology. The major base concepts, quantum computing, the difference between classical and quantum computer on physical level, programing quantum device, and the experiment-quantum supremacy are explained conceptually. This chapter also includes an introduction of the tools Cirq and OpenFermion plus the applications like quantum simulation, error mitigation technique, quantum machine learning, and quantum optimization, which are explained with illustrations.

INTRODUCTION TO QUANTUM SUPREMACY

Scientists and physicists were pointing out about quantum computing science last 30 years, but the question with this innovation is “where is it useful? Is it worth investing time, money and resources in this?” To answer this, follow the good engineering practice; formulate decisive short-term goals that demonstrate whether the design is going in right direction. Thus to demonstrate that a programmable quantum device can solve a problem that no classical computer can solve; this experiment and demonstration is known

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as Quantum Supremacy. Many directions were discerned to overcome technical challenges inherent in quantum system to make a computer that is both programmable and powerful.

Here in the concept of quantum computers, the computer does not refer to Laptop, desktop, mobile phone or any such device which are prevalent in the current market. The word “Quantum Computer” is quite misleading as it contains the word “computer”. Computer starting from the smallest device such as mobile phone to the largest device like super computer working on the same fundamental rules. These all the devices do work on classic bits. Where’s Quantum Computer work on Qubits.

Scientists across the globe are working to demonstrate quantum supremacy. The famous scientist Hartmut Neven said about the experiment during the demonstration:

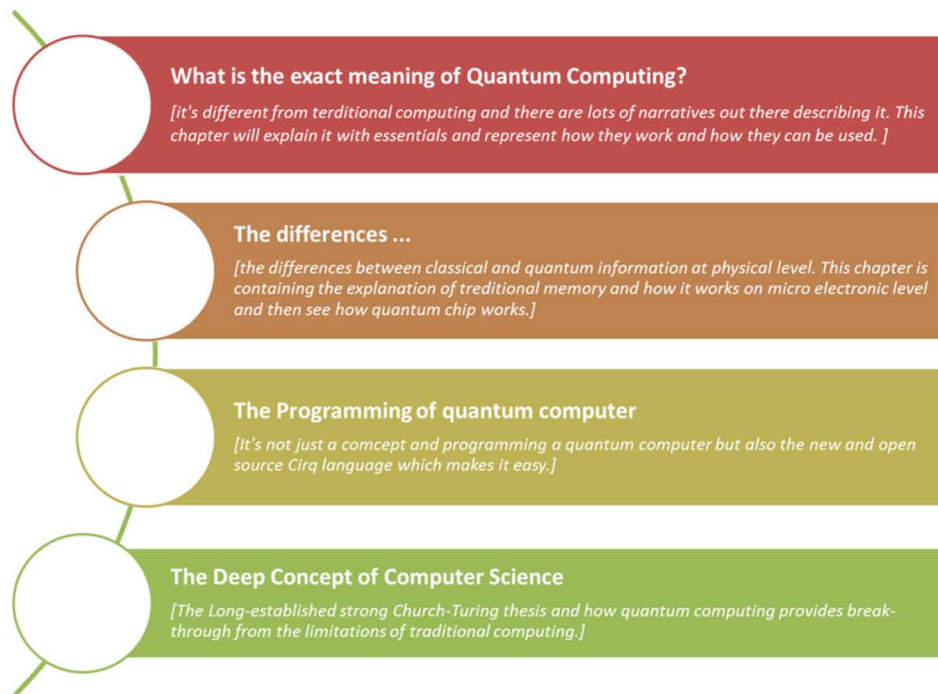
“The nice thing about Quantum supremacy is that, this is a very well defined engineering milestone” - Hartmut Neven [Engineering Director – Lead Google AI Quantum]

Hartmut Neven is clearly indicating the power of quantum supremacy, as it is the well-defined milestone. Thus, to achieve this; various people has contributed into the experiment. (Neven, 2020)

In a nut shell, this experiment shows that the experimental quantum computers can surpass the largest and best computers in the world. The processor which is created to achieve quantum supremacy is known as “Sycamore Processor”. It processes 2^{53} states simultaneously.

According to the scientist Marris a Gustina, this innovation is really exiting for mankind as it can be given to the researcher as a tool and they can come out with the best results.

Figure 1. The base concept of quantum computing



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