Quantum applications based on the IBM QX platform

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ABSTRACT

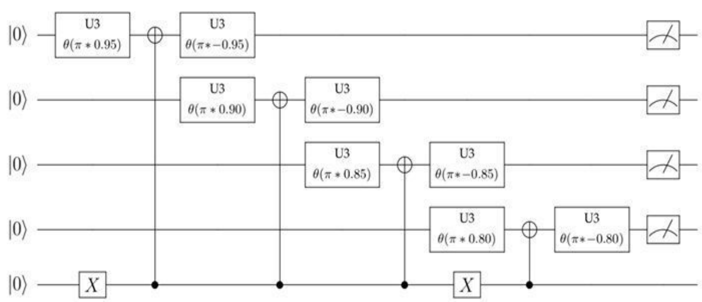
This thesis presents a set of works that were chosen to be decomposed to individual algorithms and solved using a quantum computer, which is available publicly through the IBM QX platform. The objective was to demonstrate a fundamental change in the way of thinking about problems when working with a quantum computer as opposed to solving a computational problem on a classical computer.

EXPERIMENTS

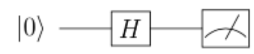
I first tested out the quantum computer on simple programming problems, such as encoding strings of characters. The below circuit is a quantum algorithm for encoding a four letter word using the values: 0.95, 0.90, 0.85 and 0.80.

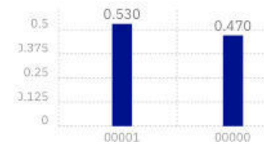
- Rotations U3 (+ and -) on the quantum bits encode the letters on the first four qubits
- CNOT (+ vertical line) operations 'copy over' the information about the rotation on the last 'control' qubit
- X quantum gates on the control quantum bit denotes the start and the of the 'control'. Whenever X is executed, the results comprise those values and by stopping the control with another X gate, the results do not contain any other encoded value.

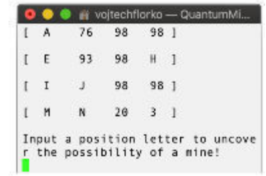
The results from the circuit below should contain only the first three 'letters'. In other words, the results should contain the 0.95; 0.9 and 0.85 values, which I have received.



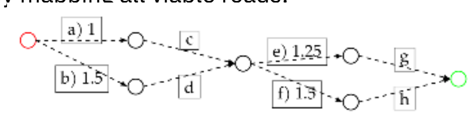
Quantum computers also provide absolute and unpredictable randomness. To demonstrate this, I have created a quantum powered version of a popular game Minesweeper. The 4x4 board is generated using the simple algorithm using a single Hadamard gate, with the following random result. The numbers are hidden behind the letters and the mines are denoted as numbers above 90. Whenever the user uncovers a letter, he sees the probability of a mine around the position. In the case of the game in the third picture, the mine is clearly located behind the letter H as seen in the screenshot from the game picture above

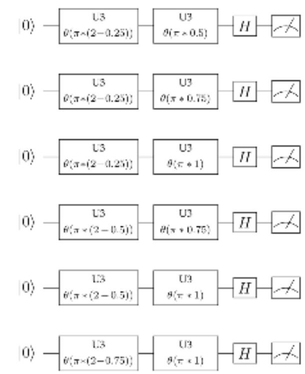




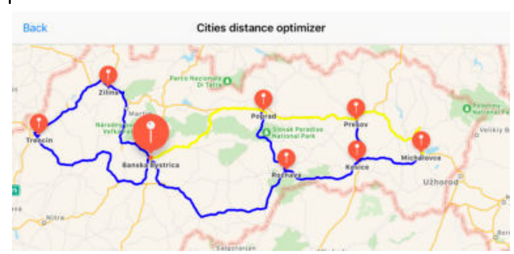


The comparing algorithm developed to determine the explosion after uncovering in the Minesweeper game is its key part. The pathway optimization problem is a great way to utilize the comparing as well and of course to use quantum computing, as the execution of the algorithm is instant and the quantum computer knows and presents immediately all of the results, in this case pathways. The only real challenge is how to **map** the network of nodes and pathways onto a quantum circuit, so that the results are readable. The comparing algorithm takes two values and a Hadamard rotation and the results are immediately visible. One solution for the following pathway is easily solved for example by mapping all viable roads:





During the completion of this thesis, I have ported the official software development kit provided by IBM Q to Swift programming language, which allowed me to create mobile quantum applications. By chaining multiple aforementioned comparison quantum algorithms, I was able to create an iOS application which allows user to choose two cities in Slovakia on a pre-determined grid and the quantum computer calculates the optimal path:



CONCLUSION

Quantum computing is nowadays popular subject in the realm of information technologies, but its principles are still mostly unknown to the mainstream software community, because the number of viable use cases and algorithms is still very low. This thesis provides an entry gateway to the world of quantum computing from a programmer's perspective. It shows how to think differently when attempting to solve a certain problem and it offers multiple types of problems which can be offloaded to the quantum computer with some form of advantage. The problems I have worked on in this thesis also underline the possibilities of expansion and ways on how to solve the bigger problems in the future.