Decoding and Enconding of an 8x8-pixels image using different quantum computing techniques

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Introduction

One of the most basic uses of programming is data communication and visualization, and with the introduction of qubits this task has been exponentially improved. Nonetheless, the reach of the technology nowadays is still a bit too short, since the strongest computers only have a couple dozens of qubits. Because of that, we need to develop new techniques for data compression, error correction and so on.

Now speaking about real world problems, with classical binary programming we used to need 8 bits of precision (values from 0 – 255) to represent a grayscale, but with the 3-dimentionality of the qubits we can express all this information into one single "quantum bit". Knowing this, our task is to encode an 8x8-pixel image into a quantum circuit to make it readable for a quantum computer. Then we have to retrieve the imagen trying to lose the minimum quality in the process.

Conditions

- The scope of the problem is transmitting an 8x8-pixel imagen.
- As stated during the presentations, the problem should be solvable with 6 qubits.
- Our physical limit is the real-world simulator that we will use (Jakarta), which has 7 qubits of power.
- There's no initial code, therefor we will have to look for the best strategy and try to implement it

First steps

Our initial work throughout the hackathon was related to learning more about the tools and the theory behind quantum computing. Since our team was formed of three computer science students and two computer science graduates, we had very little knowledge about qubit theory and IBM's qiskit. Even though, that didn't make us lose hope.

Being honest, at first, it was a bit overwhelming, but with our knowledge in programming and experience at passing exams without having studied, we went on. Perseverance is a key value we must grow.

The first algorithm we tackled was NEQR-Image Repesentation. We read and followed an example from the qiskit's documentation page and, thanks to it, we learnt more about qubits. We understood a bit better how quantum circuits worked and saw how we could represent the image.

Even with that, there was an underlying problem the we didn't know about: using one circuit to represent the using positions needed and another one to express the data into the quantum computer makes it a "very tall" circuit. This was a problem, because with this strategy we need 8 qubits to represent positions and 8 qubits to express the color of the pixel. As stated before, our project had a physical limit of 7 qubits, making this way useless.

After a lot of hours, we were a bit lost in the sea of "quantum theory". But inside this deep and undetermined darkness one thing helped us: friends. We would like to talk about the two teams by our sides: 'Mike's & Co.' and 'Black School', because they lent us a hand even though they didn't do the same challenge. Some persons of their team used some of their time to explain us the theory behind superposition, how to use it in our advantage and how we could face the problem.

With this new data, we searched ways to optimize the representation and compression of information. For example, knowing that the image was 8x8-pixels, we concluded that we could represent each position with 6 qubits of precision. On the other hand, the 8-bits needed to express grayscale was "transposable" to only 1 qubit, taking advantage of its imaginary component. Therefore, we jumped into FRQI with a new strategy of using this limit of 7 qubits.

With this new algorithm, our work was to create a circuit with 6 qubits. Firstly we had to create a state of superposition and then play with the cos and sin values of the qubit to save data into it. With these two variables, we can express the proximity of one value to |0> or |1>, information we can translate into its proximity to black and white. Then, when we needed to extract this data we had to use an arctan to retrieve the angles of both components.

This looked to be a good strategy that was within our quantum computer's physical limitations, but the lack of knowledge was once again a problem. We didn't know how to use in real life how to escalate a problem from a 2x2 image (used in most problems and examples), into a 8x8 one. Then, with some more questions and help from staff and other team's we jumped into QPIE, the last one that gave us some results.

QPIE was the last algorithm we tackled and it was quite late in the night. This context made it a bit harder to learn, but we continued anyways. This new algorithm was very theory-heavy and we went through a lot of problems when we wanted to implement it, but we though that we could do something out of that.

With QPIE, we normalize the intensity of the data using the value of all the cells, then we try to play with the components of the imaginary part. Nevertheless, we ran into a problem in which we were unable to convert the image into a 7-qubit circuit, since the math complexity was too high. For context, a 2x2 image gave us a 8x8 matrix, making a 8x8 image a worldwide-class problem.

Even though, we used other strategies to represent data and try to codify the image. Losing some information in the process, we chose to ignore the last row and column of the data. This allowed us to have an easier way of processing the data using quantum fourier transform resulting in a histogram representing each pixel with a count of how white a pixel is.