Qiskit Advocate Mentorship Mid-Term Checkpoint

Lossy Image Compression using Unity and real Quantum Computer

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Introduction

Encoding Images without loss as quantum circuits

Idea of the Project

- Implement lossy image compression/encoding method in Unity
- Smaller circuits for encoding and decoding

Target

- Tested on real devices with 15 qubits
- Resulting image should be comparable to the base images
- Image of ideal size in 128x128

Pixel and bitstring

32x32 = 1,024 = 2^10, 10 qubits for manipulation, 10 bit strings long

Bit string represent the position of the pixel

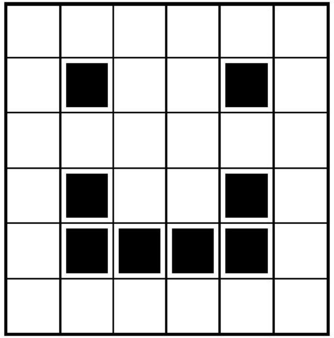
The bigger the image, the longer the size of a bit string

First pixel: |0000000000>

All qubits with the outcome 0

Probability: 0 refers to black, 1 refers to white

$$
\begin{aligned}
(x+1, y) &\rightarrow 1000 \\
(x-1, y) &\rightarrow 0100, \\
(x, y+1) &\rightarrow 0010, \\
(x, y-1) &\rightarrow 0001.
\end{aligned}
$$



```
1 1 1 1 1 1
1 0 1 1 0 1
1 1 1 1 1 1
1 0 1 1 0 1
1 0 0 0 0 1
1 1 1 1 1 1
```

Probability Amplitude and Brightness

Brightness is encoded in the probability of an outcome

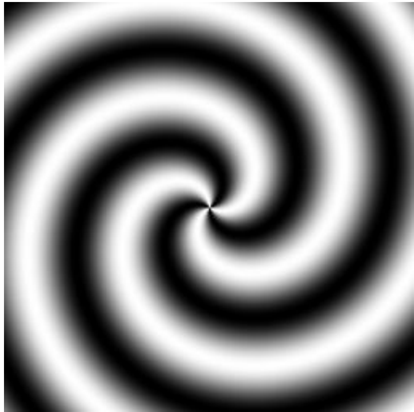
Amplitude of the quantum circuit to store this probability

- Amplitude is the square root of the probability.
- 1,024 pixels: 1,024 possible outcomes
- Each possible outcome is representing 1 pixel
- We only want the real part of the amplitude for the outcome

Original (256 colors) 8 colors 4 colors

we don’t know the certain probability correspond to the brightness

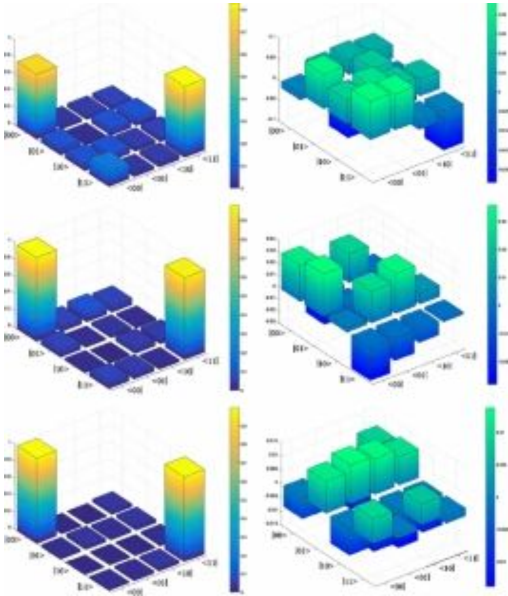
- Assume Brightness 1: White, 0: Black, Grey: 50% = 0.5
- Normalize the circuit to give total probabilities as 1



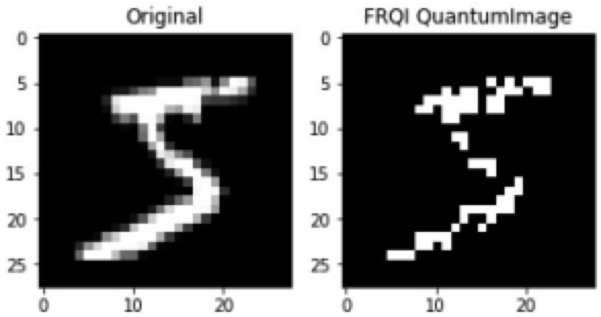
Challenge-Not ideal to work on real device

Initializing quantum circuit by setting the amplitudes in it is inefficient

- The transpilation to gates leads to these amplitudes is slow
- Lot of quantum gates, which is not suitable for real devices
    - Large depth of quantum circuit



Possible Solutions



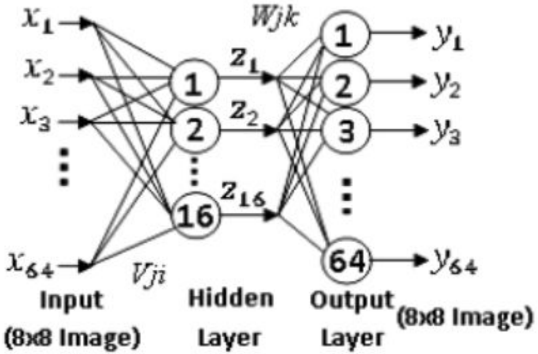
Flexible Representation of Quantum Image (FRQI)

Novel Enhanced Quantum Representation (NEQR)

- from classical image to quantum state to represent the image
- Leveraging the basis state of a qubit sequence to store the grayscale
- Run on a real device by feeding the transpiler with a device coupling map

Train a neural network with Variational circuit

- Create a quantum circuit which encode an image
- The circuit generated can represent the amplitudes
- Not too many gates



Plan for the Final Presentation

1. Encode the image in a circuit via FRQI, NEQR
2. Transform the circuit back into a texture
3. The construction of circuit
    a. Only gates, without initialisation of probability amplitude
    b. Approximate a quantum state with simple quantum circuit
4. Test the efficiency of the quantum compression
    a. Depth (number of gates in a circuit)
    b. Cost (number of primitive gates in a circuit)
    c. Number of qubits for the preferred dimension of image

Reference

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