QUANTUM IMAGE PROCCESING AND ML APPLICATIONS

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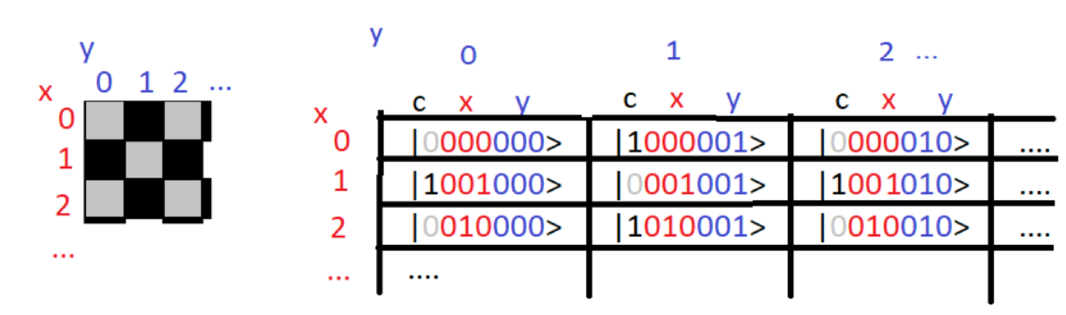
Quantum machine learning is a branch of machine learning that combines classical and quantum computing. It has the potential to revolutionize computer science, and could help us solve some of the most important problems we face as a society. With a strong motive to create a better and healther world, I decided that for my graduation project will be about quantum computing.

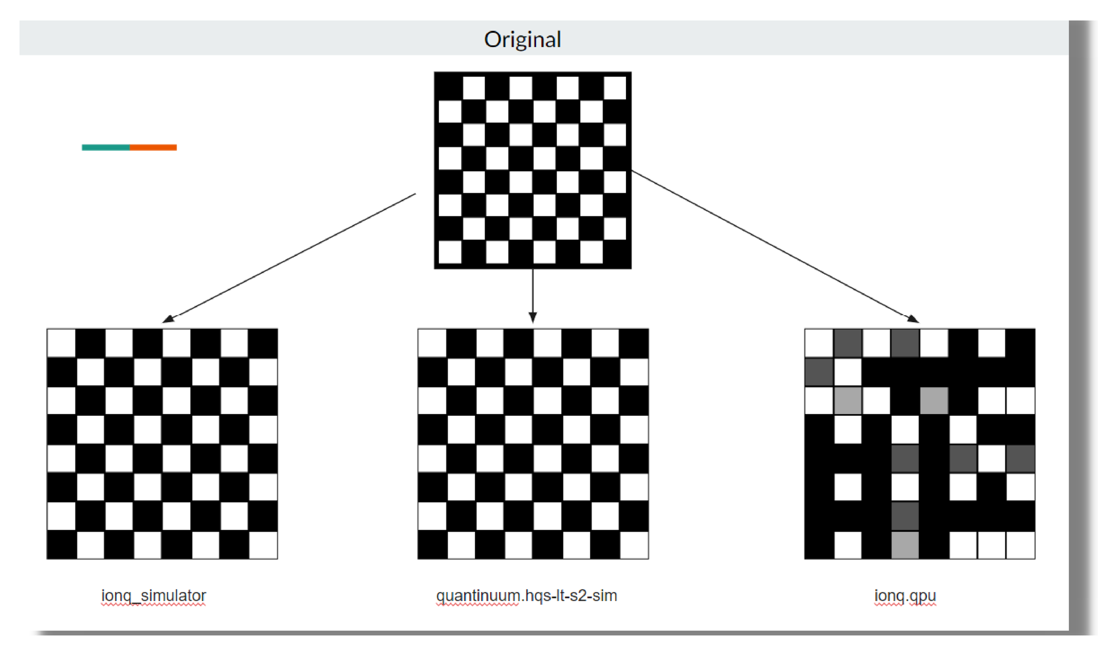
INTRODUCTION

In Quantum Machine Learning qubits are used to model abstractions, like images or patterns found in nature. The goal is to use them to model complex relationships between variables that classical computers couldn't do without losing all their information and becoming useless. In this project, first the quantum computer server had to be decided. Then with the best server an CNN application had been done.

RESULTS

FRQI: Flexible Representation of Quantum Images Example





DIFFERENT IMAGE RESULTS ON DIFFERENT QUANTUM SERVERS
in order; IonQ Simulator, Quantinuum, IonQ QPU

Quantum computers work with quantum bits, which use the concept known as superposition in quantum physics, instead of classical binary (where a bit can take the value 1 or 0) systems. Quantum bits, called qubits, can be both 0 and 1 at the same time. Thus, quantum computers make a serious difference in their computational capacity.

Mathematatically, the state of a qubit is written as a complex-valued vector with two elements. These vectors, or "state vectors" are denoted by the symbol "|.)" called ket.

Qubits of state 0 and 1 in order:

$$|0\rangle = \begin{pmatrix}1\\0\end{pmatrix}, \quad |1\rangle = \begin{pmatrix}0\\1\end{pmatrix}$$

Frameworks and Library Examples:
Pennylane (Xanadu)'s quantum machine learning on a classical simulator,
QuantumCircuits is an open-source library for working with quantum computers at the application level, especially for Quantum Machine Learning and Quantum Finance. The library is listed in Qiskit Ecosystem,
Qiskit Library by IBM.

ANALYISIS

FRQI: Flexible Representation of Quantum Images

Proposed by Phuc Q. Le, Fangyan Dong & Kaoru Hirota. (2009)

Generic form:

$$|I>= N* \sum_{i=0}^{2^{2*n}-1} |c_i > \bigotimes |i>$$

Where:
Image size: 2^n x 2^n
Color of pixel i is ci, qubit rotated by an angle

Our specific case:

$$I = \sum_{i=0}^{2^8-1} |c_i i> , \; c_i \in \{0, 1\}$$

Image size: 8x8 (23x23)
Only 2 different colors:

- |0> -> blank pixel
- |1> -> colored pixel

Translation

Maps pixel (x, y) to (x, y+1).
Increments y coordinate.

```
%%qsharp
open Microsoft.Quantum.Arithmetic;
operation ShiftImageRight(Color:Qubit, Coords:Qubit[]): Unit
{
    let N = Length(Coords)/2;
    let yCoord = LittleEndian(Coords[N..2*N-1]);
    IncrementByInteger(1, yCoord);
}
```

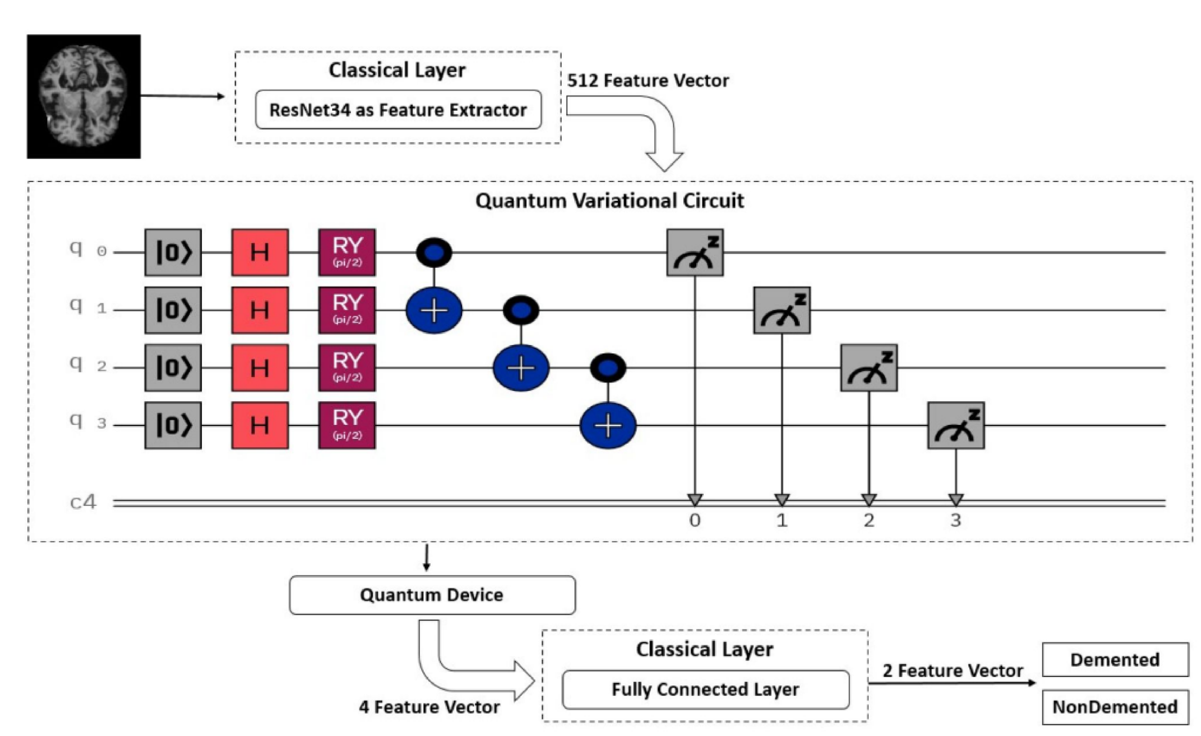
Rotation

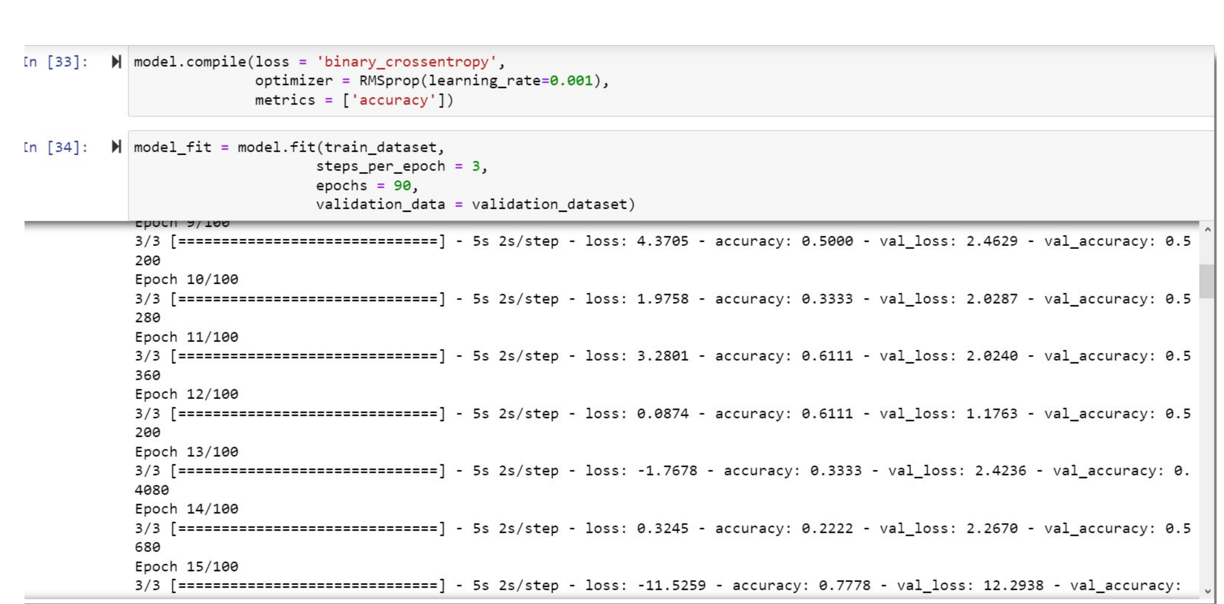
Maps pixel (x, y) to (y, x).

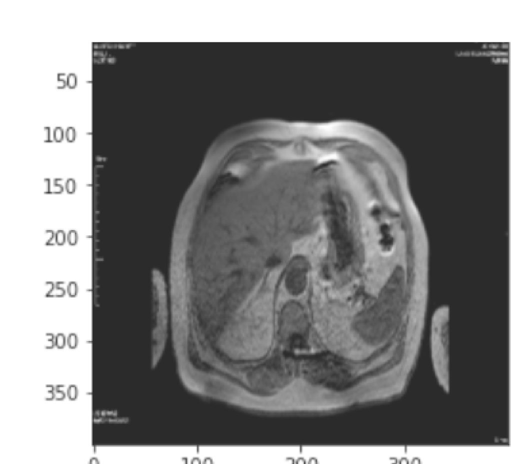
```
%%qsharp
operation RotateImageRight90(Color:Qubit, Coords:Qubit[]): Unit
{
    let N = Length(Coords)/2;
    for i in 0..N-1
    {
        SWAP(Coords[i], Coords[i+N]);
    }
}
```

Test

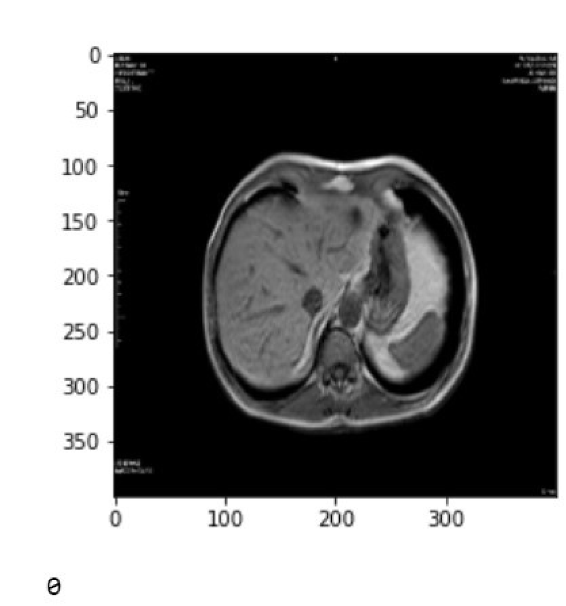
Sample image: XR images of human body parts
Perform a rotation and a translation
1000 shots
Each shot measures the color of one pixel
On average 1000/(8*8) , so 15-16 measurements per pixel







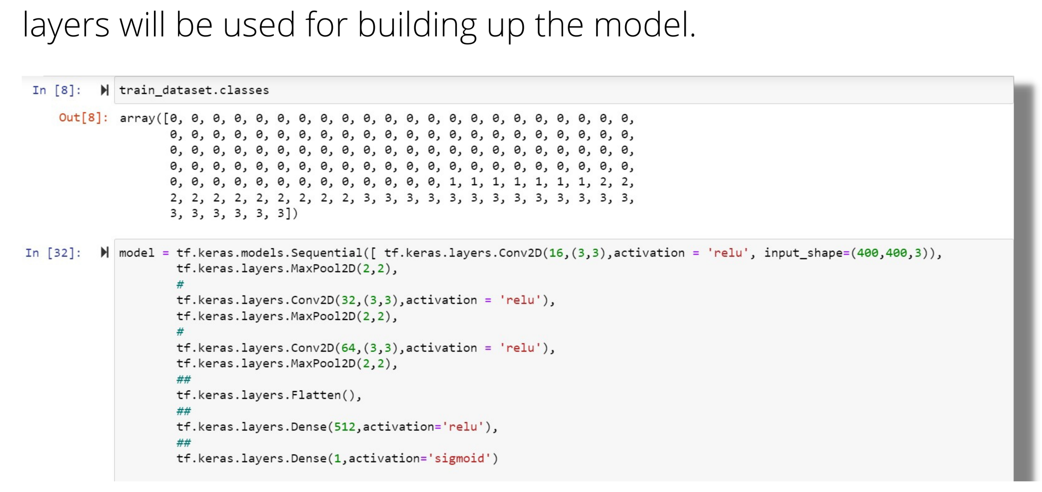
Label 0 - Label 1



METHODOLOGY

In this project, we will create CNN, use it on a a quantum computer, train it with images of the noisy medical images scaling from 0 to 3. Then, we will categorize the images with new given data, then indicate which noisy category it depends.

Tensorflow Keras and ImageDataGenerator to build the network and to label data will be used. CNN with max pooling as dense layers will be used for building up the model.



CONCLUSION

In conclusion;

Machine Learning corrects artifacts during image acquisition and reconstruction,
Neural network layer structures are used for coherent image structures,
Reconstruction methods require thousands of high-quality acquired signals in large datasets,
With the help of quantum computers and the advantage of using them from there local servers, image processing results are taken faster and better for large datasets.

"Beginner's Guide to Quantum Machine Learning." Paperspace Blog, 30 Nov. 2020, blog.paperspace.com/beginners-guide-to-quantum-machine-learning/
Patyuchenko, A. (2019) Medical Image Processing: From Formation to Interpretation. Analog Devices
D. R. Sarvamangala, Raghavendra V. Kulkarni Convolutional neural networks in medical image : understanding survey