Quantum Convolutional Neural Network:

- A CNN is a type of deep learning algorithm especially used for image classification. A convolutional neural network is inspired by the human brain, it's based on a series of interconnected nodes, or *neurons*, organized in a layered structure, with parameters that can be trained by applying deep learning training strategies. In quantum each node is a qubit. In the training process the algorithm learns to assign weights to the parameters passed to the qubits and shrinks the amount of data points through pooling.

<u>Training and Testing</u>

- When given a dataset we randomly split the set in two with 75 % going to the training data, and 25 % for the testing data. The algorithm is then trained with the training data learning to assign importance to specific features as it constantly guesses and checks the given answers, this is expressed through a series of parameters and weights. Obviously, the more training data the better the result, but it is computationally costly to train the circuit on a simulator and the noisy state of today's quantum computers make it unable to converge.

<u>Circuit</u>

- The quantum circuit consists of a feature map, then layers of convolution and pooling components, lastly all the decisive information is stored in the minimal number of qubits needed to enumerate classification. Their measurement gives us our result.

<u>Feature Map/Encoding the Data</u>

- A feature map is a function which maps data from its natural encoded space to the feature encoded space. To encode the data we used Zfeature maps and ZZfeature maps. The ZZFeatureMap offers a higher level of expressiveness due to the inclusion of entangling gates, whereas ZFeatureMap provides a simpler, first-order approach.

<u>Convolution layer</u>

- The objective of the convolutional layer is to extract the *high-level features*. *N* pairs are created then by using the parameter weights from the training, the decisive features are stored using less qubits. This is known as a convolved feature.

<u>Pooling layer</u>

- The pooling layer decreases the dimensions of the convolved feature, to limit the computational power needed. This is done while retaining as much information as possible from previously learned data. For this project we are using a technique called max pooling which simply gets rid of the least significant qubits. Because of the way our circuit is structured this always means keeping the bottom *N/2* qubits.

Binary classification

- We trained and tested our QCNN and VQC on an open source, benchmarking dataset for that consisted of raw Sonar data and asked them to classify whether a given sonar return was a rock or mine. In this circuit we began with 16 qubits, representing 16 different features of the Sonar data. The baseline performance of predicting the most prevalent class is a classification accuracy of 53%. The top performer achieved an accuracy of 78%.