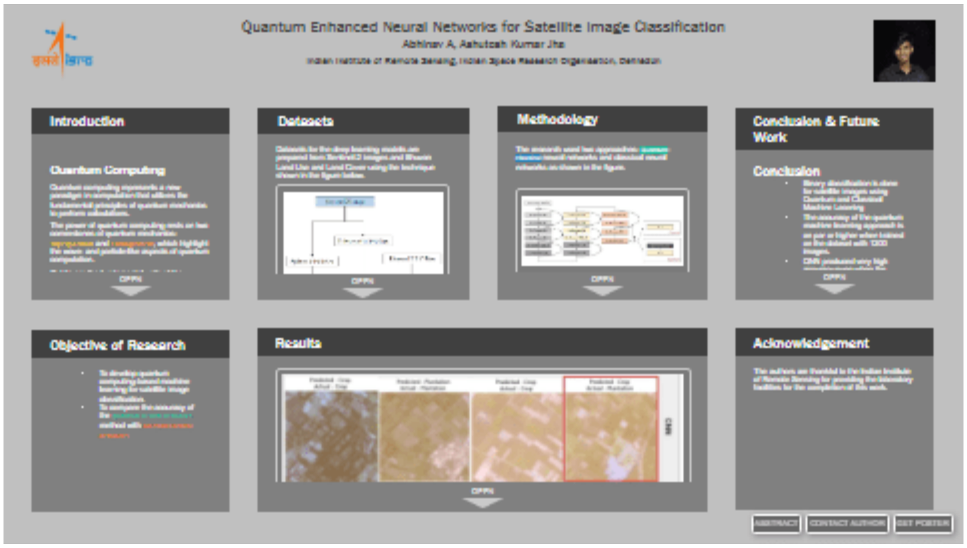
Quantum Enhanced Neural Networks for Satellite Image Classification



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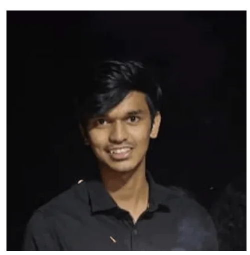
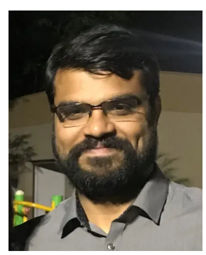




PRESENTED AT:

INTRODUCTION

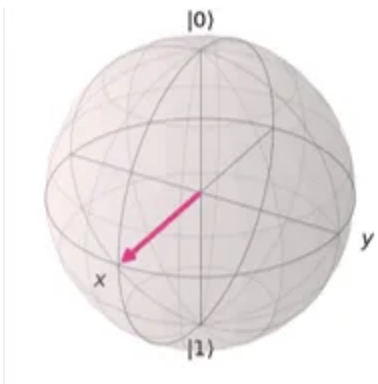
Quantum Computing

Quantum computing represents a new paradigm in computation that utilizes the fundamental principles of quantum mechanics to perform calculations.

The power of quantum computing rests on two cornerstones of quantum mechanics: **superposition** and **entanglement**, which highlight the wave- and particle-like aspects of quantum computation.

Qubits are the fundamental units of the information held in quantum computers. A qubit exists in a superposition of 0 and 1. The state of the qubit is expressed by the equation:

$$|\psi> = \alpha\ |0> + \beta\ |1>$$



Qubit

Need for Quantum Machine Learning

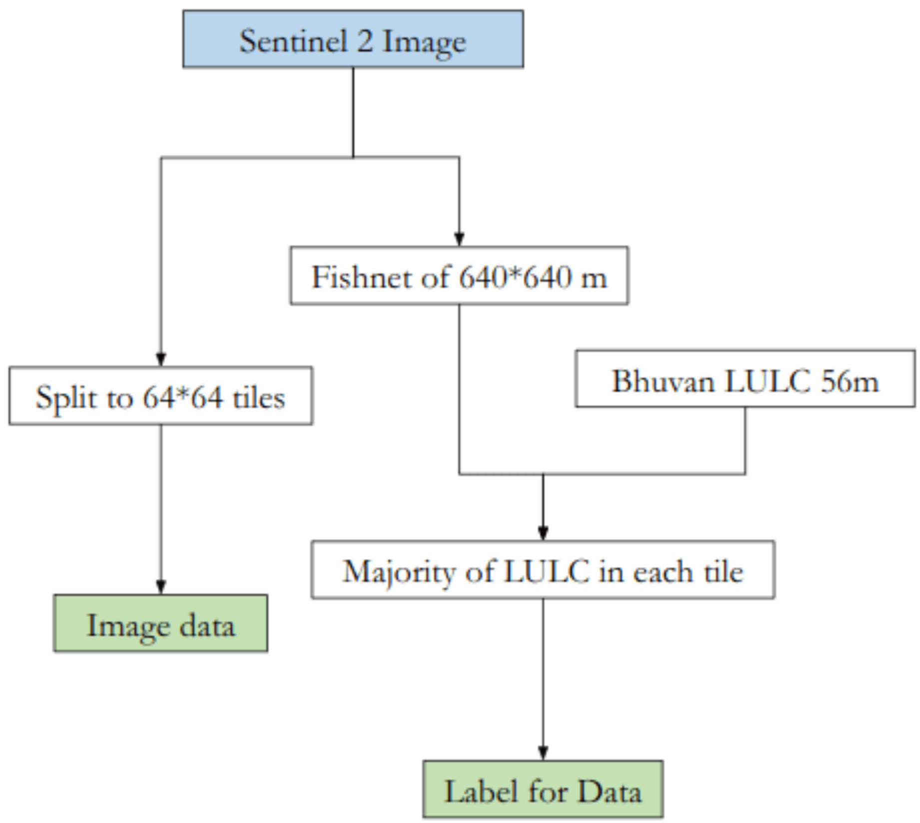
- **Learning efficiency improvements: less training information or simpler models needed to produce the same results or more complex relations can be learned from the same data.**

- Improvements in run-time: obtaining faster results.

- Learning capacity improvements: increase of the capacity of associative or content addressable memories

DATASETS

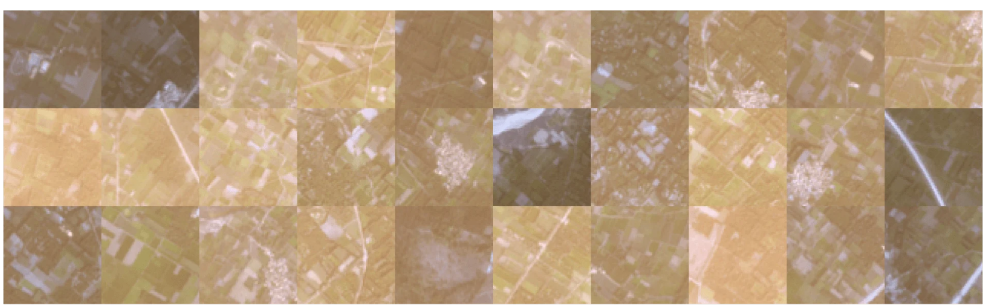
Datasets for the deep learning models are prepared from Sentinel-2 images and Bhuvan Land Use and Land Cover using the technique shown in the figure below.



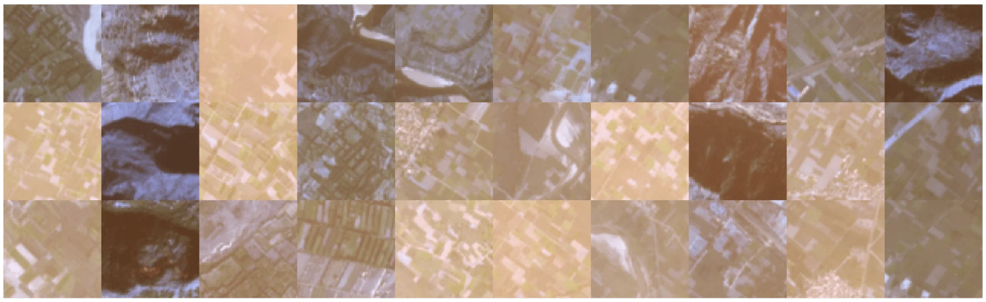
Data Preparation

Bhuvan is Geoportal of ISRO.

Dataset for the model



Plantation



Crop

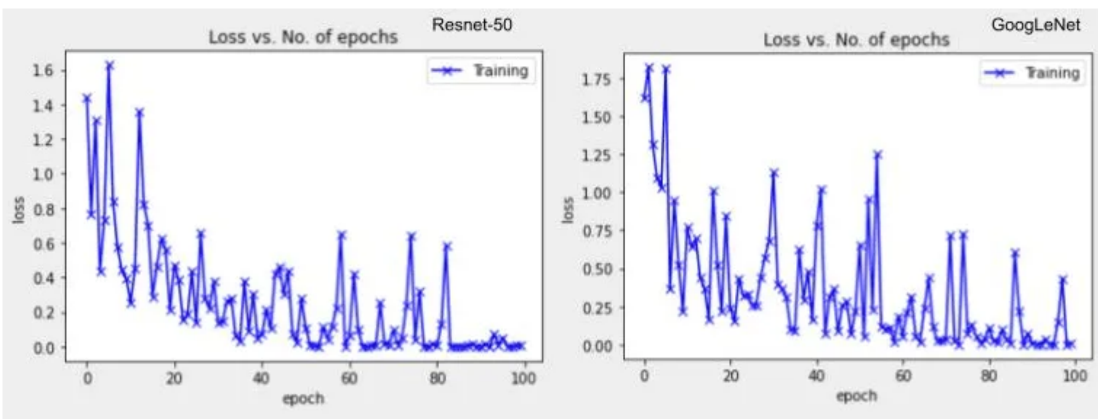
Dataset Consistency Check

Datasets are trained with ResNet 50 and GoogLeNet deep learning architectures.

Accuracies

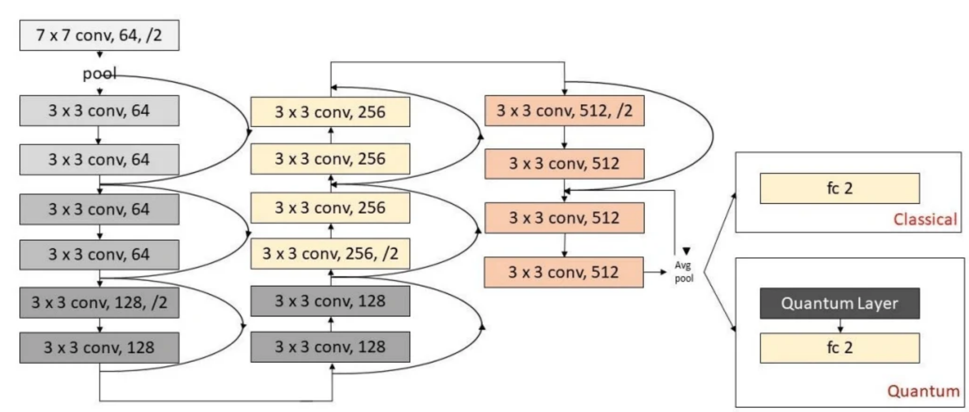
Resnet-50: 99.18%

GoogLeNet: 99.38%



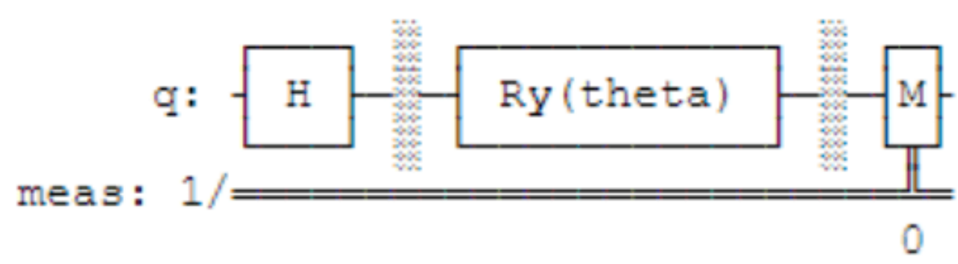
METHODOLOGY

The research used two approaches: Quantum-classical neural networks and classical neural networks as shown in the figure.



Methodology

The quantum layer consists of a Ry circuit, as shown in the figure below, that induces the quantum behaviour to the circuit.



Ry Gate

The quantum circuit used in this approach consists of three gates; namely Hadamard gate, RY gate and measure gate. The hadamard gate takes the classical bit as input and induces superposition to it and produces a qubit. Hadamard gate can be expressed mathematically as:

$$H = \frac{1}{\sqrt{2}} \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix}$$

The output from the hadamard gate is given to the Ry gate. Ry gate is a single qubit gate like the hadamard gate and it rotates the qubit about the Y axis. It is expressed mathematically as:

$$RY(\theta) = exp(-i\frac{\theta}{2}Y) = \begin{pmatrix} \cos\frac{\theta}{2} & -\sin\frac{\theta}{2} \\ \sin\frac{\theta}{2} & \cos\frac{\theta}{2} \end{pmatrix}$$

The output from the RY gate is given as input to the measure gate which converts the qubit to classical bits. Then the measure value is given to the fully connected layer which acts as the final layer of the model.

CONCLUSION & FUTURE WORK

Conclusion

- Binary classification is done for satellite images using Quantum and Classical Machine Learning
- The accuracy of the quantum machine learning approach is on par or higher when trained on the dataset with 1200 images.
- QNN produced very high accuracy even when the training data is low.
- Quantum Machine learning can be used to generate useful outputs when the number of training samples are low.

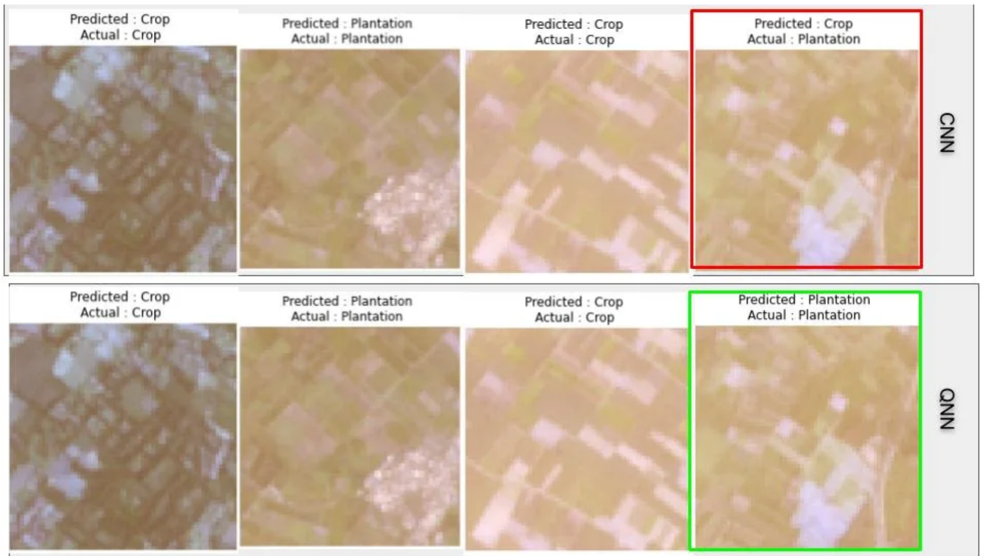
Future Work

The future work includes generation of quantum neural networks exploiting quantum entanglements for remote sensing applications as well as testing these archiectures on multi-class data.

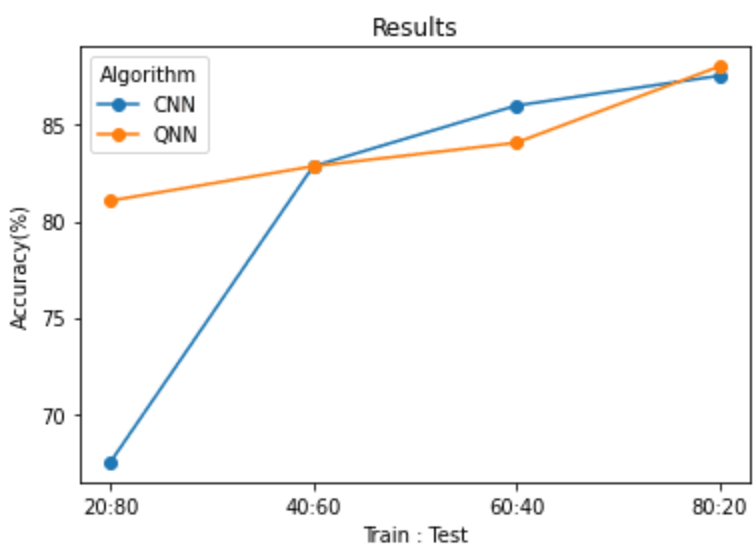
OBJECTIVE OF RESEARCH

- To develop quantum computing-based machine learning for satellite image classification.
- To compare the accuracy of the **quantum neural networks** method with **classical neural networks.**

RESULTS



Results of Classification



Accuracies of algorithm in different train:test ratio.

ACKNOWLEDGEMENT

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ABSTRACT

Deep learning algorithms like convolutional neural networks gained significant prominence in digital image processing, especially in object detection, semantic segmentation, and image classification applications. However, convolutional neural network algorithms require extensive training data and computational facilities to optimize the training parameters. Quantum computing is a new field of research at the intersection of computer science and quantum mechanics using various quantum mechanical properties for information processing in quantum computers and can be efficiently used for performing computationally demanding tasks of deep learning. In this work, a classical-quantum hybrid convolutional neural network is designed by modifying the state-of-the-art ResNet 18 architecture by adding a quantum layer to it for satellite image classification. Binary classification of crops and plantations is done using both hybrid classical-quantum neural networks and ResNet 18 neural network on a dataset of 1200 images and the results are compared. Training and testing of both models are done using two approaches. In the first approach, training and testing data are split in the ratio of 80:20, and the hybrid and classical deep learning algorithms produced an accuracy of 88.04% and 87.56% respectively. The second approach was by splitting the training and testing data in the ratio of 20:80, where the classical and quantum deep learning algorithms produced an accuracy of 67.48% and 81.07% respectively. The study demonstrates the efficiency of the quantum neural networks even when the training data is very minimal for a classical deep learning model for training and optimization.