Qiskit

Quantum GPT Model

https://github.com/qiskit-advocate/qamp-spring-23/issues/31

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Outline

1. Goal
2. Outcomes
3. Classical & Quantum Self Attention models
4. Quantum Model for Text and image classification
5. Results of Each
6. QRNN model for text and image classification
7. Further work

Goal Quantum Sequential models

1. We wanted to work on Quantum GPT models
2. First step for that was to look at sequential models in quantum as is to process Text/Image.
3. To do a literature survey on Self attention quantum models for text and images.
4. To generate a Survey Paper on Quantum sequential models

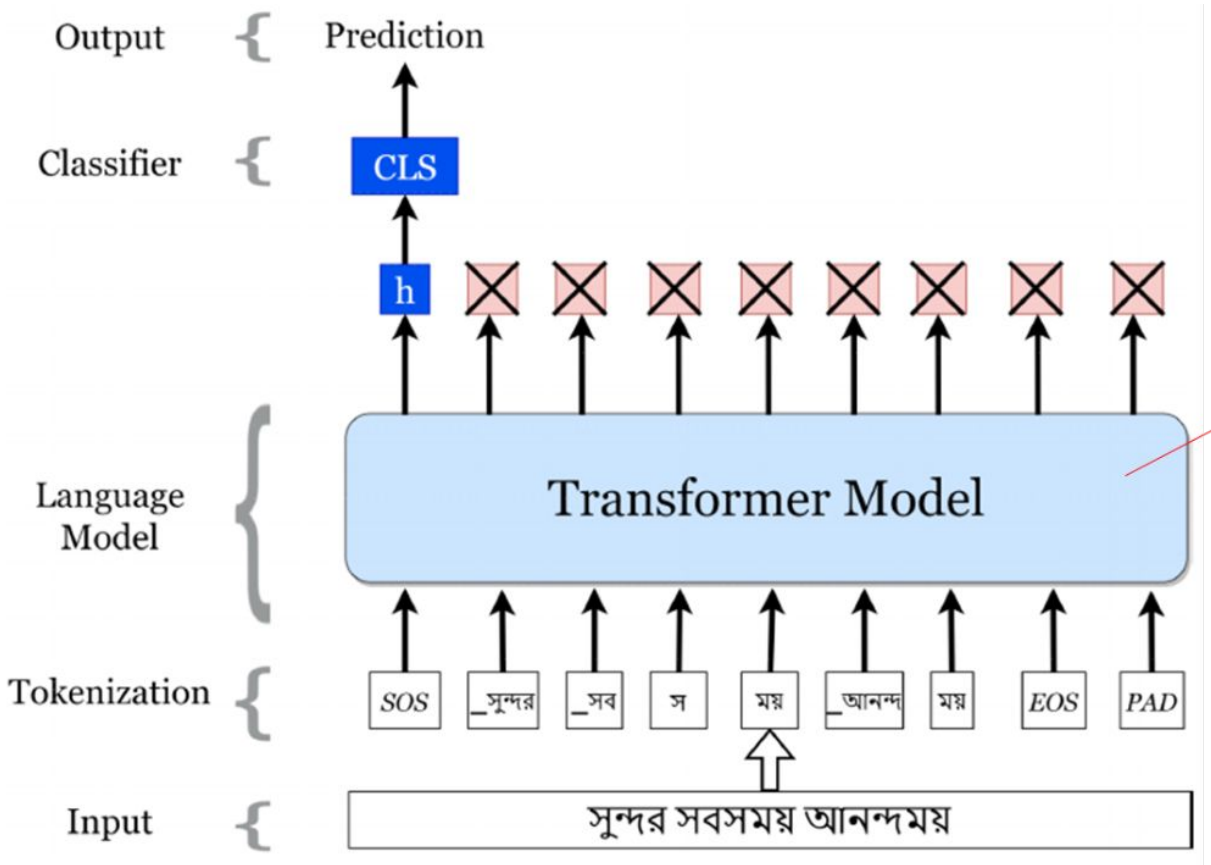
Literature Survey

- An improved novel quantum image representation and its experimental test on IBM quantum experience
- Quantum Vision Transformers
- Quantum Self Attention Models for Text Classification
- Quantum Self-Attention Neural Networks for Text Classification
- QRNNs

Outcomes

1. **Developed a Qiskit version** Quantum Self attention Neural Network (**QSANN**) models for Text and Images with/without Positional Encoding.
2. We also developed **Qiskit version QRNN model** for text and images.
3. We have **results for 2-3 datasets on all the 3 models** we built during this time frame.
4. We are still in the process of comparing all 3 models
5. We are documenting our results and working on a survey paper
    a. The scope of this literature survey is to produce a survey Paper on quantum self-attention models and QRNNs, for image and text classification.

Classical and Quantum Self-Attention for Sequential Data



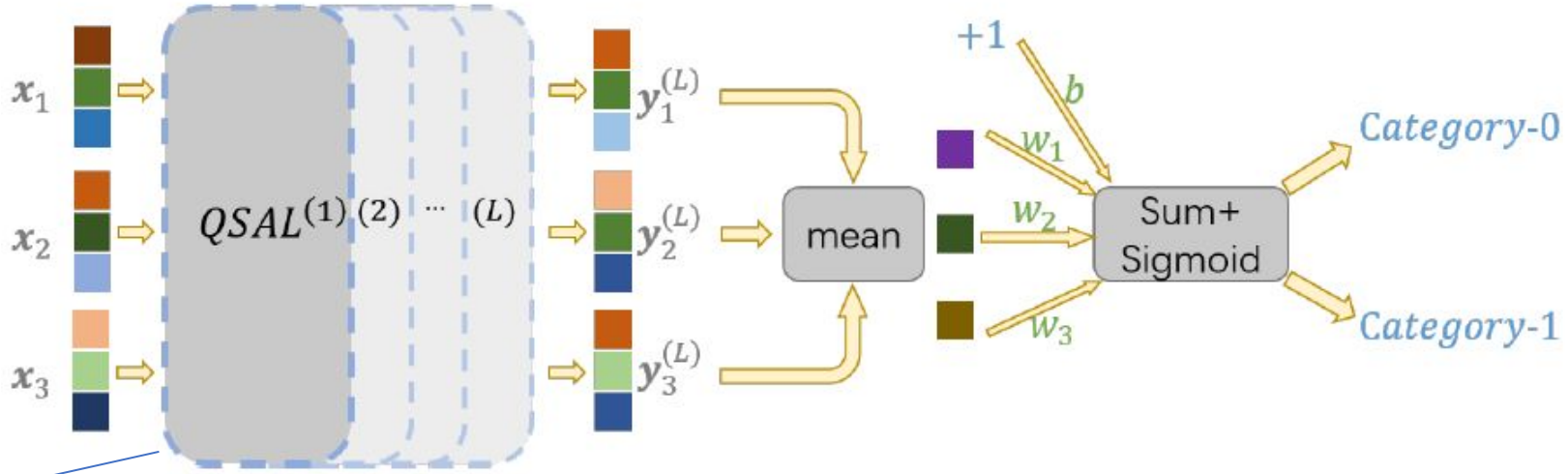
Scaled dot product attention

$$Attention = softmax\left(\frac{QK}{\sqrt{d}}\right)V$$

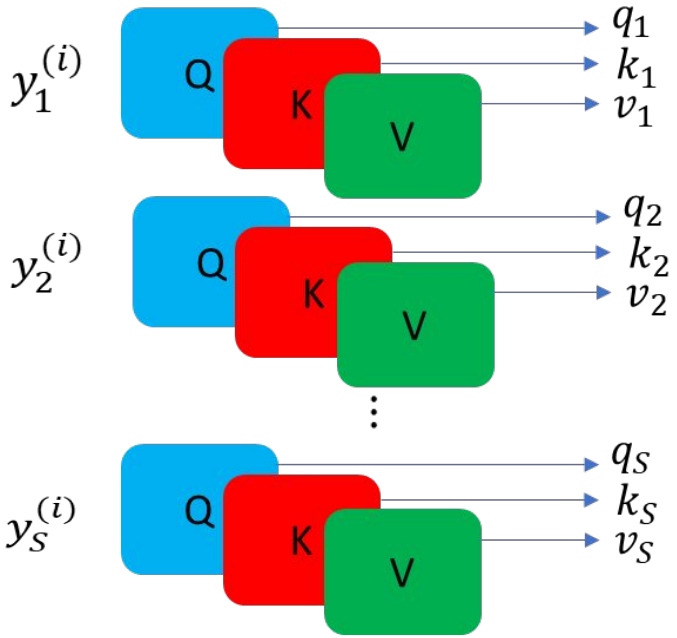
$\sqrt{d}$ is the scaling factor

arXiv: 2011.04446

QSANN for text classification



PQC



Gaussian Projected Quantum Self-Attention

$$\alpha_{lj} = e^{-(q_l - k_j)^2}$$

$$y^{(i+1)} = y^{(i)} + \sum_j \bar{\alpha}_{lj}\, v_j$$

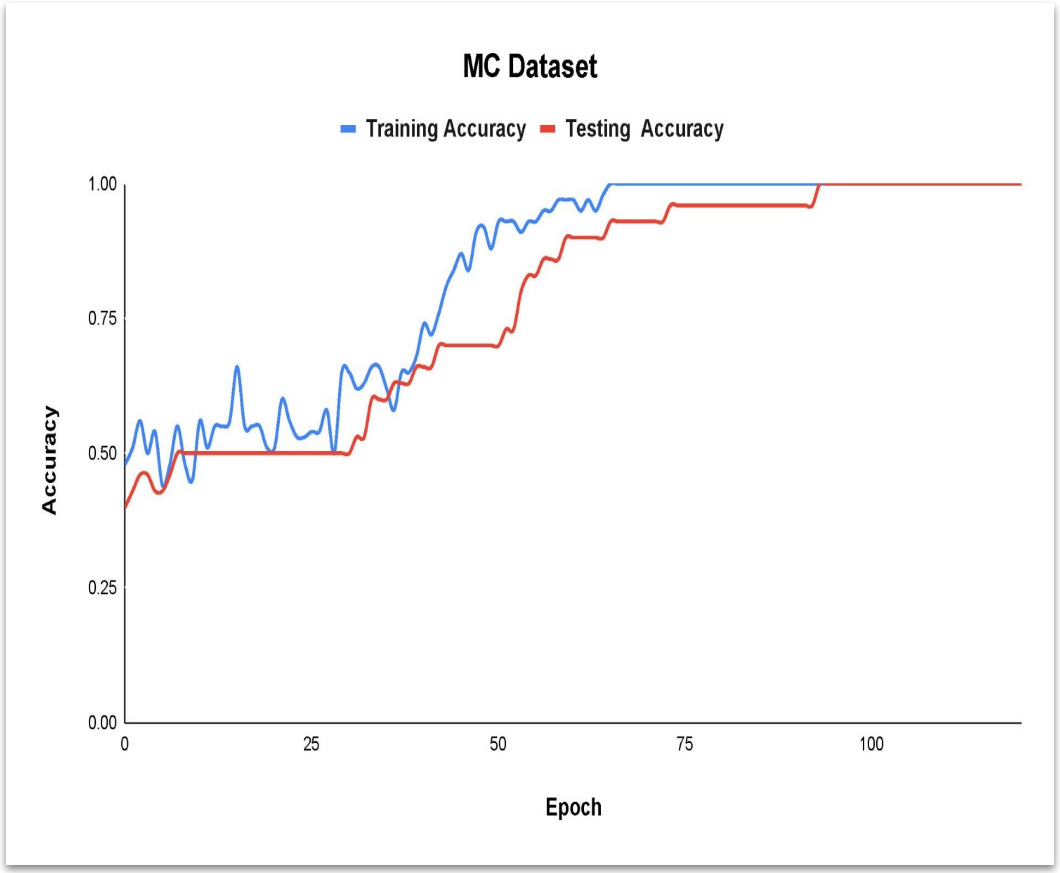
with $\bar{\alpha}_{lj} = \dfrac{\alpha_{lj}}{\sum_l \alpha_{lj}}$

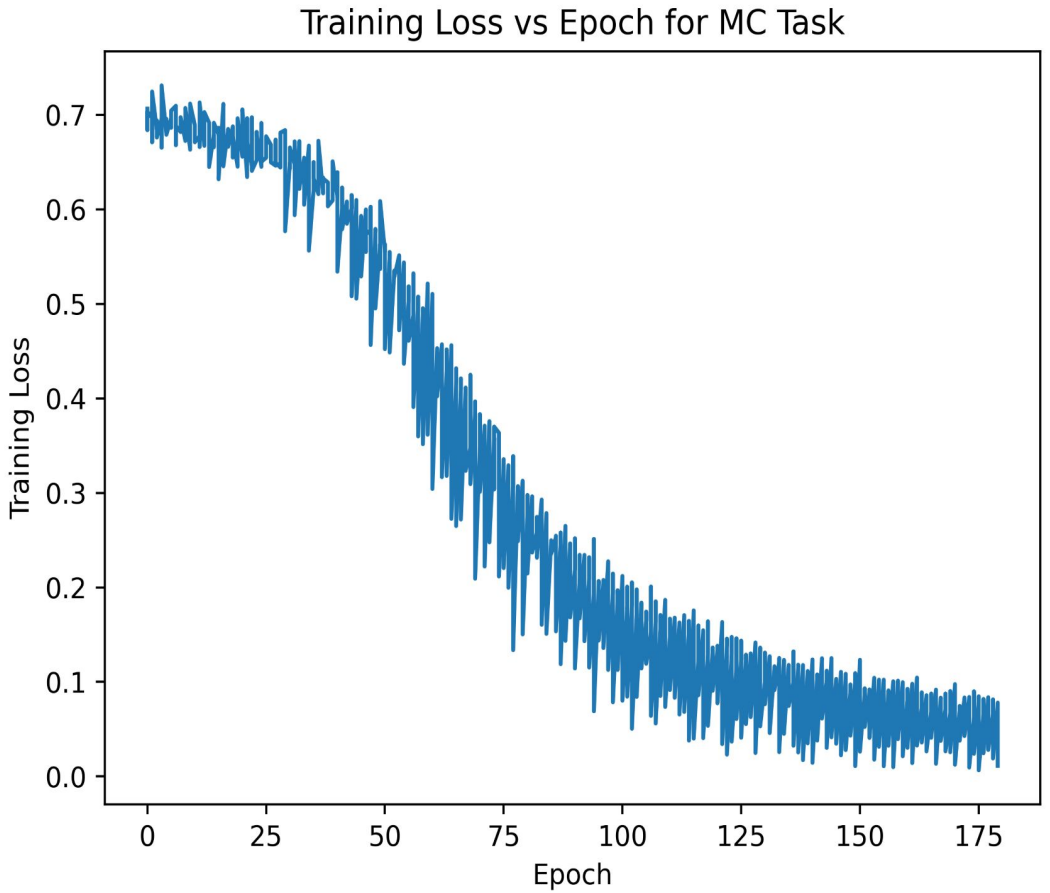
arXiv:2205.05625

QSANN Code Review

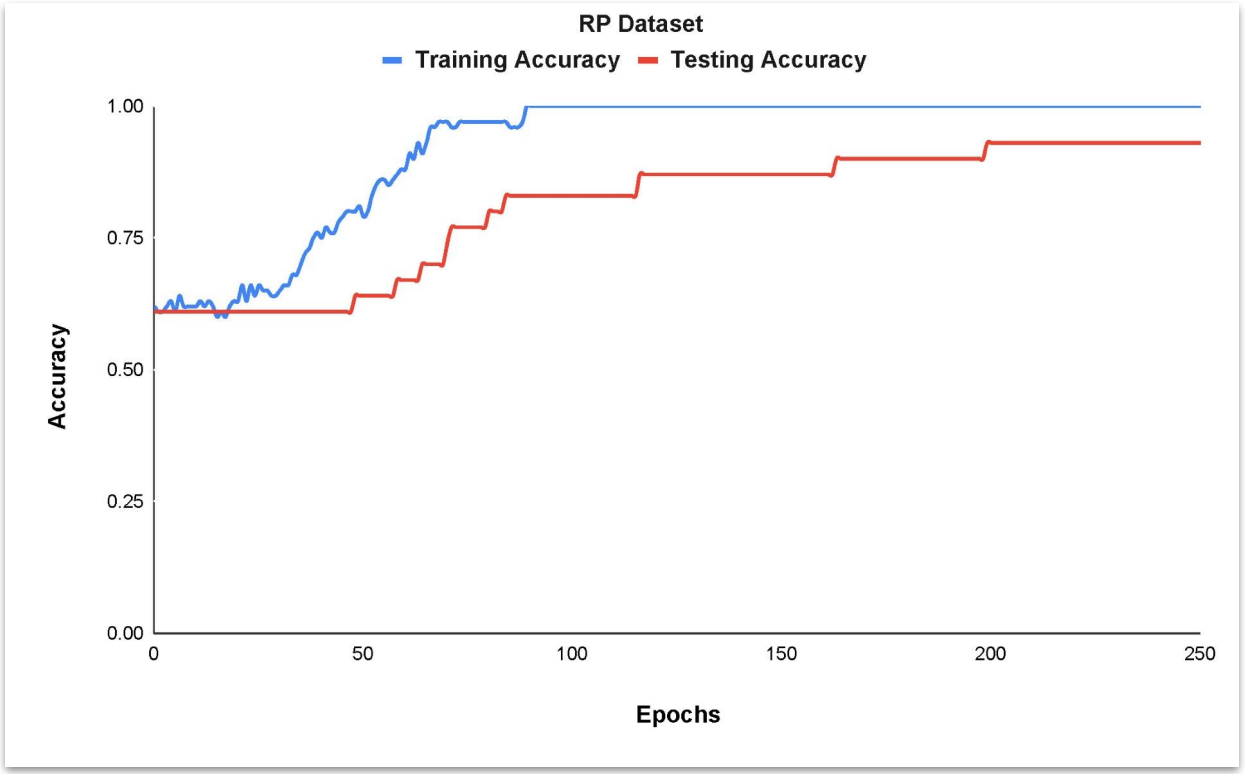
- qgpt-issue-31/QSANN codes/QSANN_qiskit.ipynb at main · AnuVadali/qgpt-issue-31 · GitHub

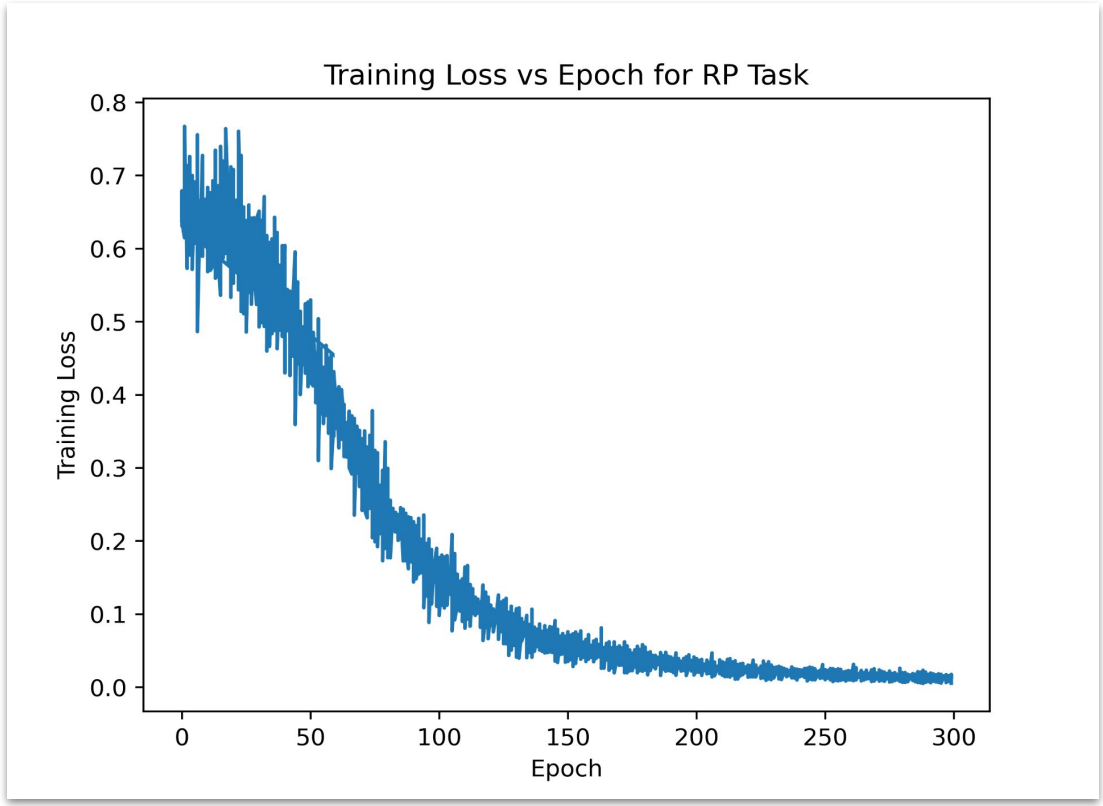
QSANN for text Classification : MC





QSANN for text Classification : RP





QSANN for text classification - Results

Dataset	Samples	Accuracy	Classes
MC	100 (70 train + 30 test)	100%	2
RP	105 (74 train + 31 test)	93.5%	2

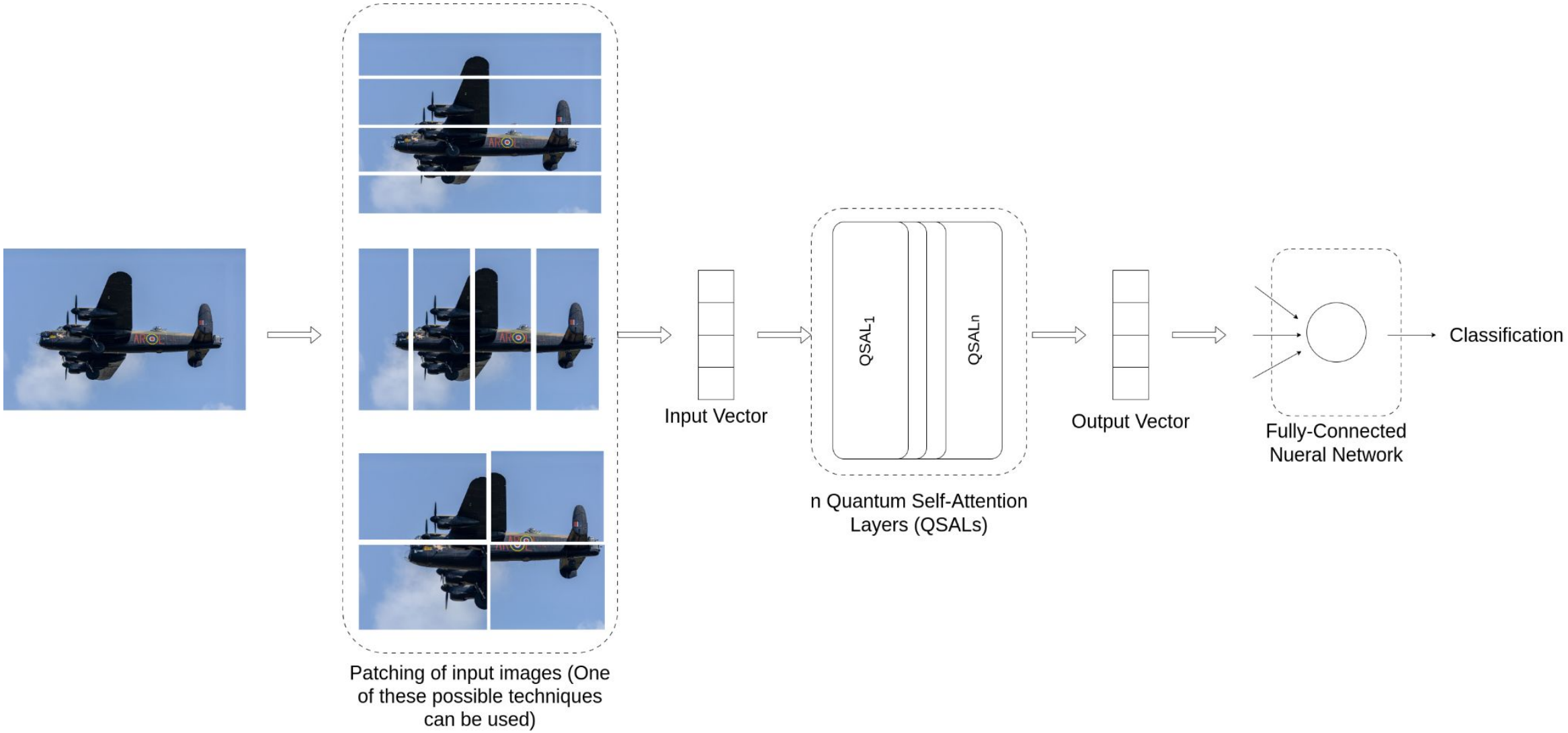
Link to dataset paper :
https://dl.acm.org/doi/pdf/10.1613/jair.1.14329

Image Classification with QSANNs

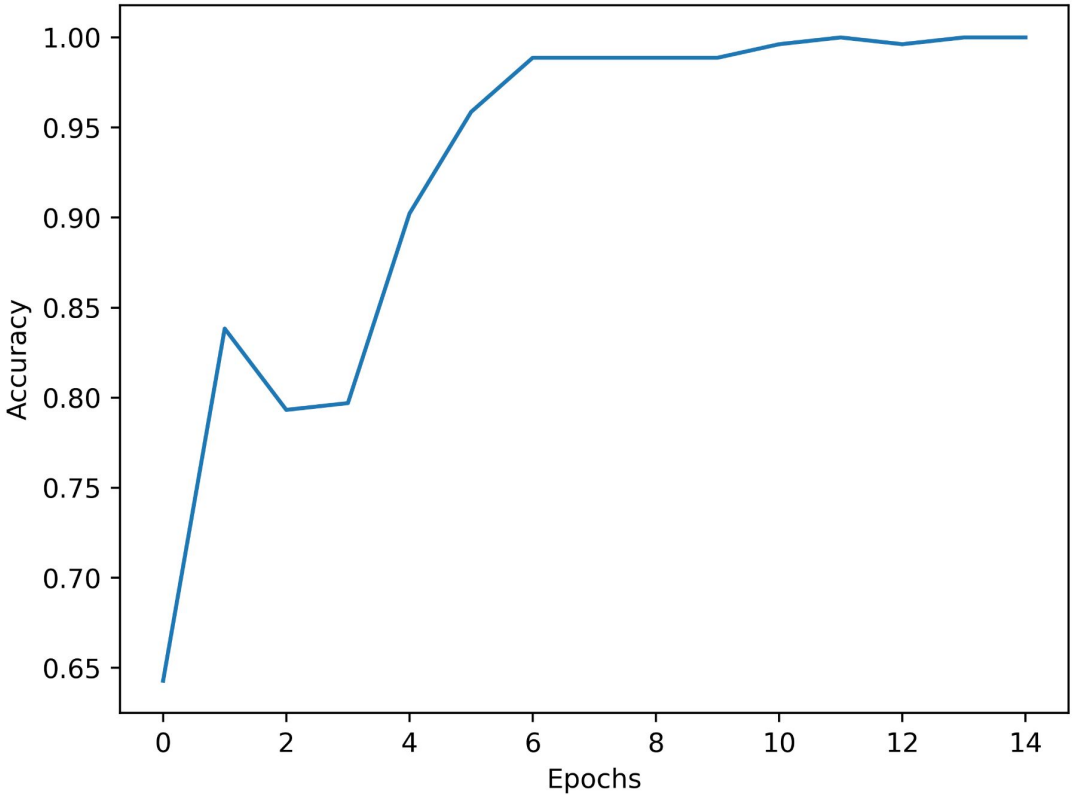
Image classification can be done with quantum self-attention neural networks in a similar way to text classification and the process can be explained in the following steps:

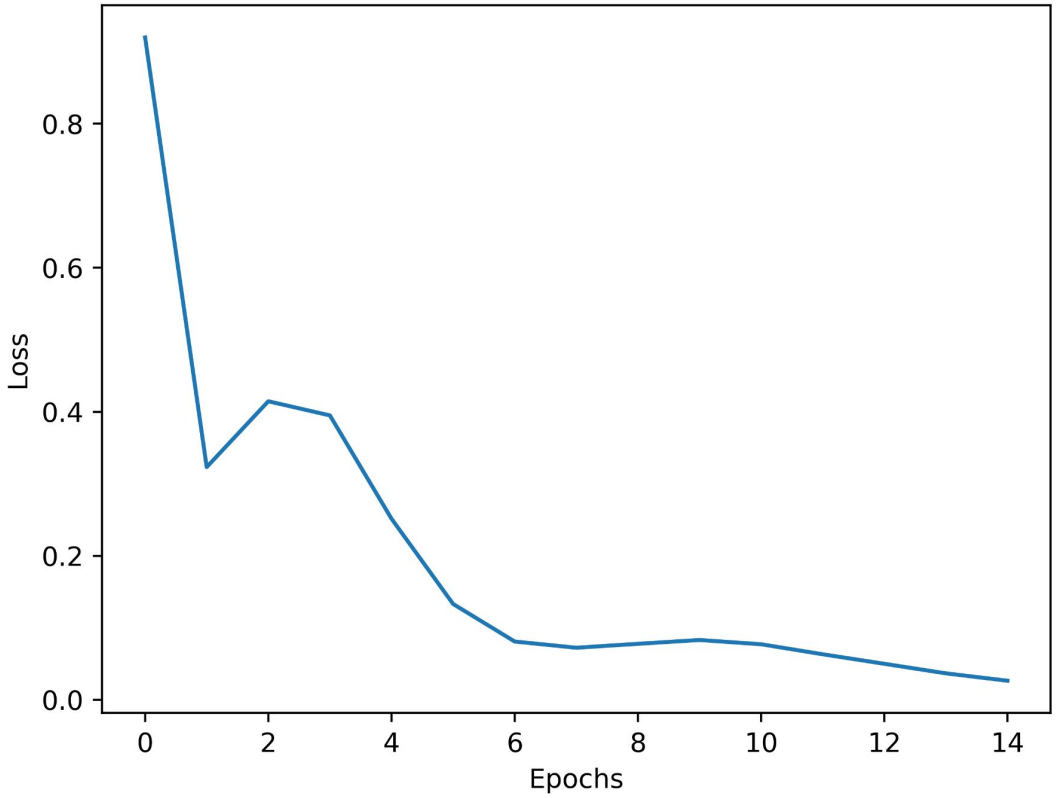
- Patching: The patching can be done in three different ways: row-wise, column-wise, and block-wise. For this particular study and the results presented ahead, row-wise patching was used.
- Encoding: The patched image is then embedded into the quantum circuit.
- QSALs: The input vectors are then passed through multiple layers of quantum self-attention layers (QSALs).
- Classification: The output from the QSAL is then fed to a fully-connected neural network for classification

Image Classification with QSANNs



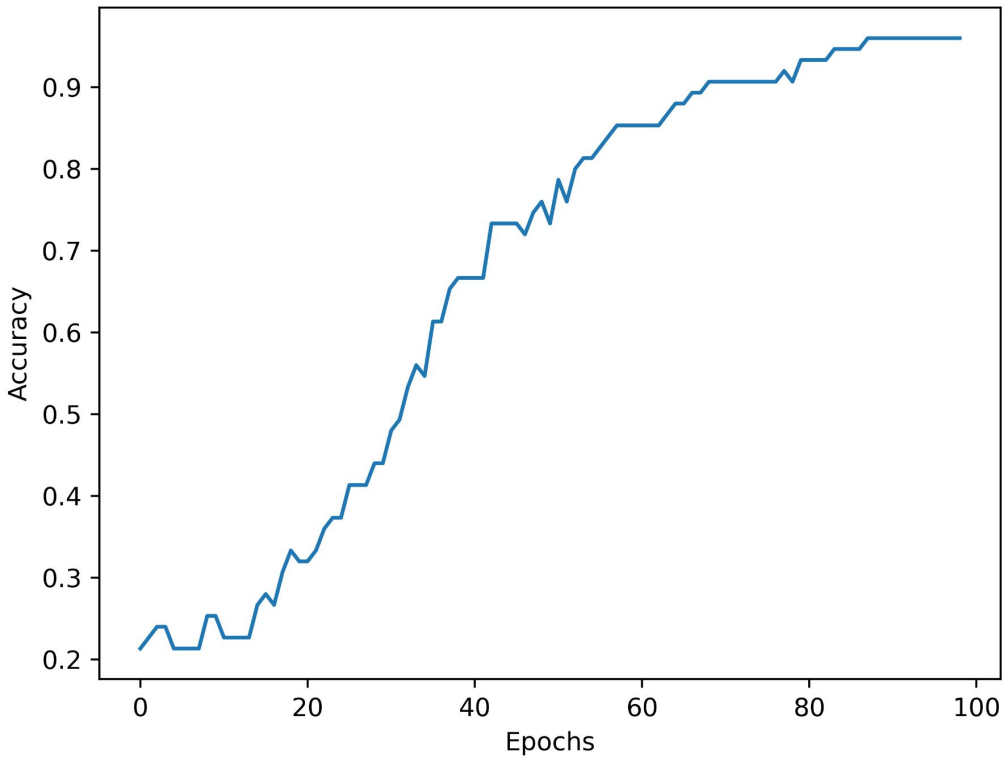
Step 1: Binary Image Classification with QSANNs

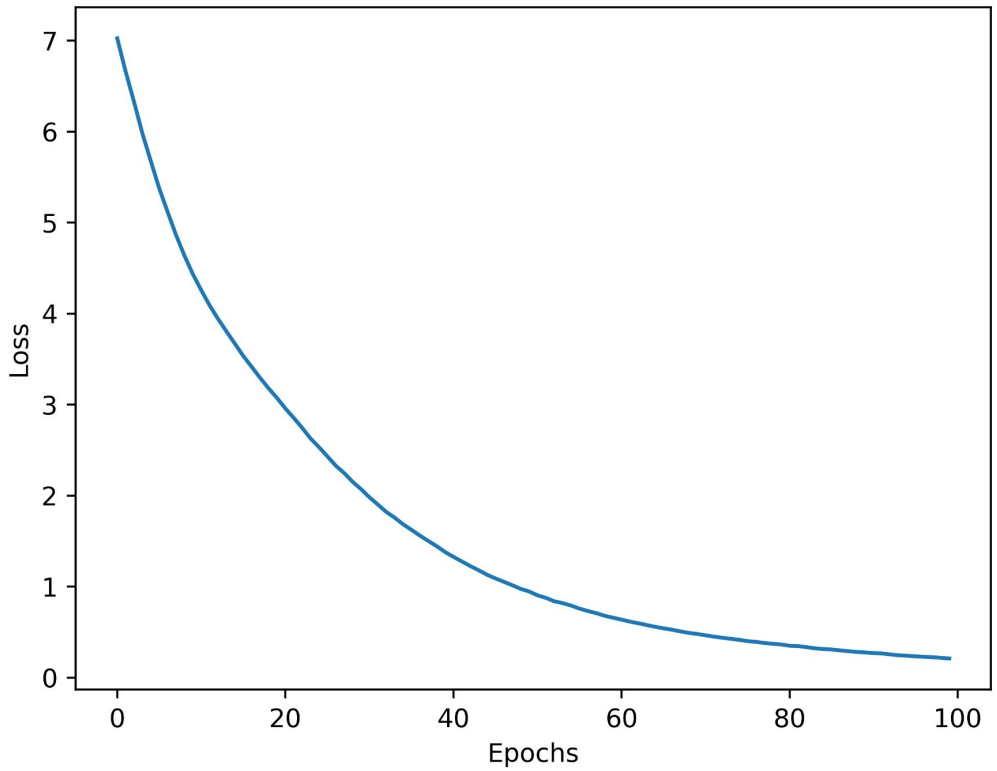




Dataset: Sklearn Digits Dataset
Number of Patches: 4
Number of Qubits: 4
Number of Repetitions: 2
Number of Self-Attention Layers: 1

Step 2: MultiClass Image Classification with QSANNs





Dataset: Sklearn Digits Dataset
Number of Patches: 4
Number of Qubits: 4
Number of Repetitions: 2
Number of Self-Attention Layers: 1

Image Classification with QSANNs

Dataset	Number of Images	Number of Classes	Training Accuracy	Test Accuracy
Sklearn Digits	270	2	1.0	0.98
Sklearn Digits	100	10	1.0	0.90
Sklearn Digits	500	10	0.96	0.84
MNIST	500	10	1.0	0.78
FashionMNIST	1000	10	0.88	0.65

Challenges for Image Classification with QSANNs

Image classification can be done with quantum self-attention neural networks in a similar way to text classification and the process can be explained in the following steps:

- Size of the problem
- Lack of employment of efficiency techniques like positional encoding, etc.
- Different Attention Mechanisms

Image Classification with QSANNs- including Positional Encoding

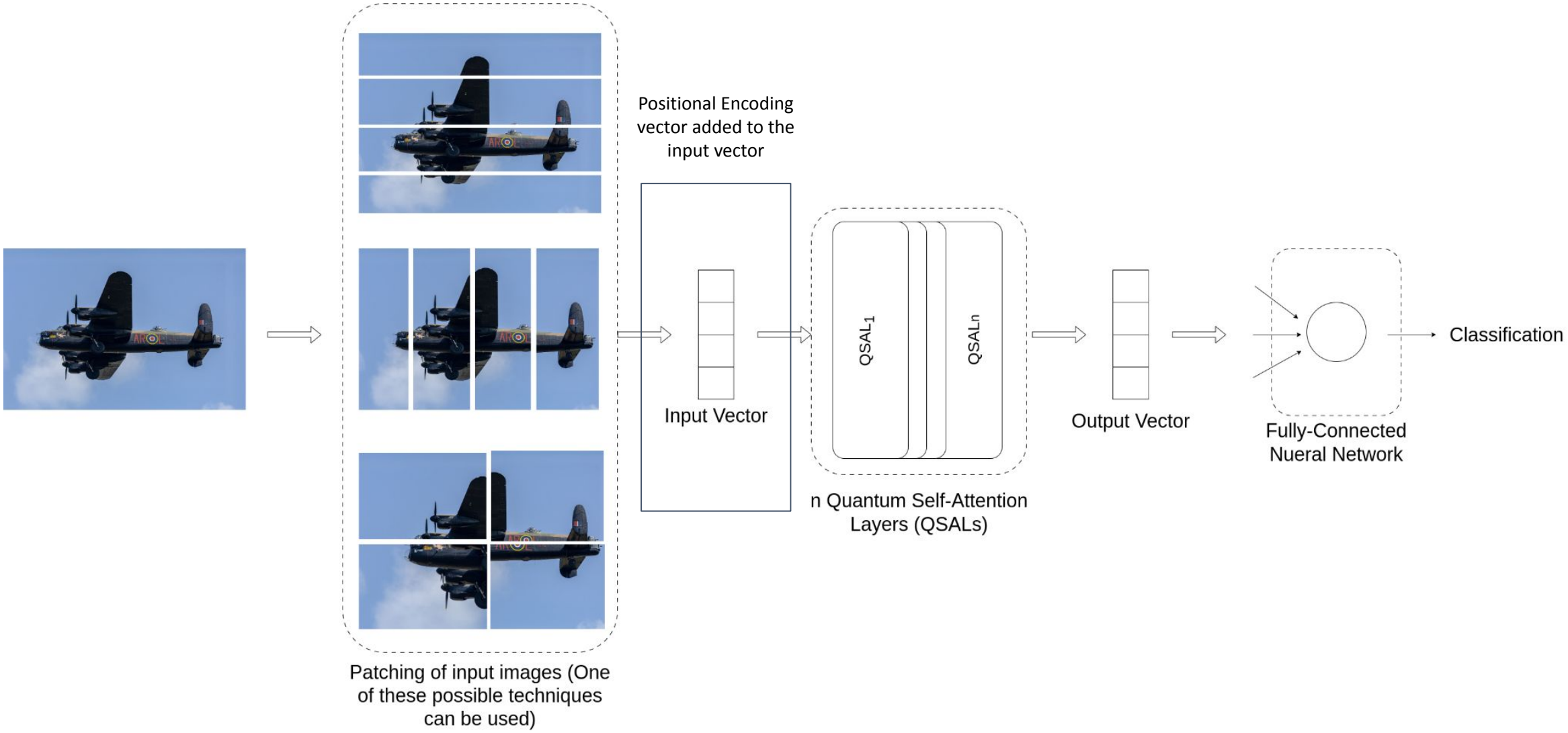
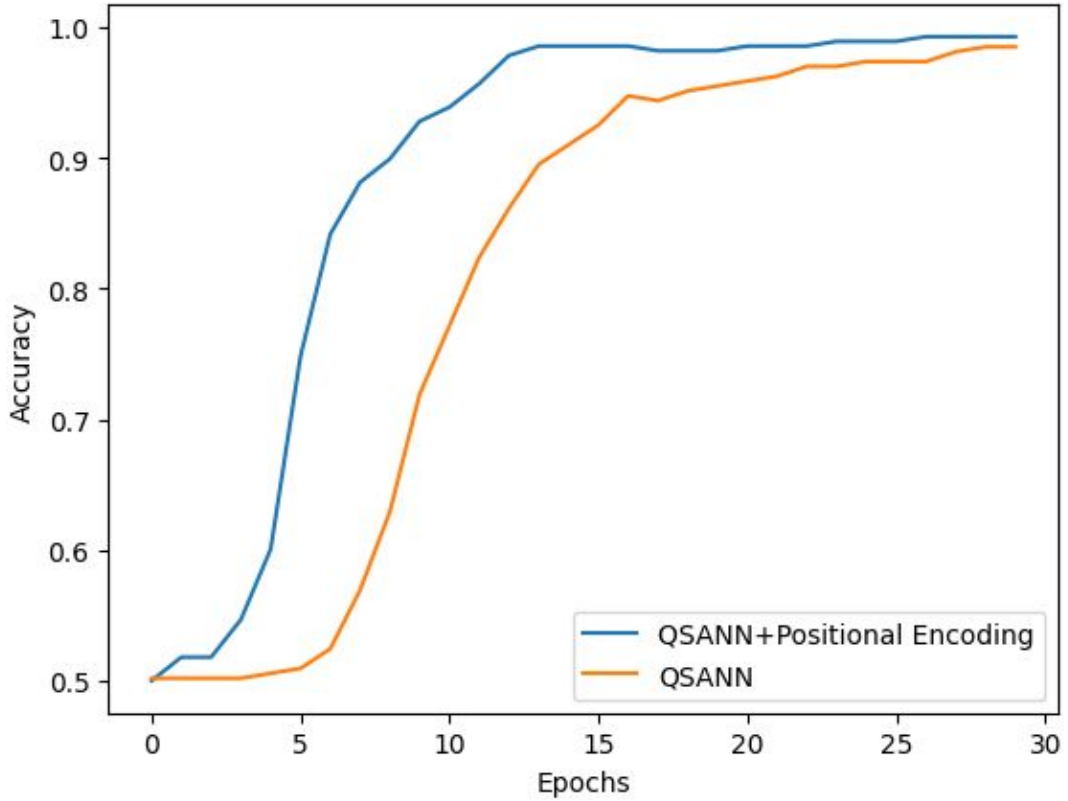


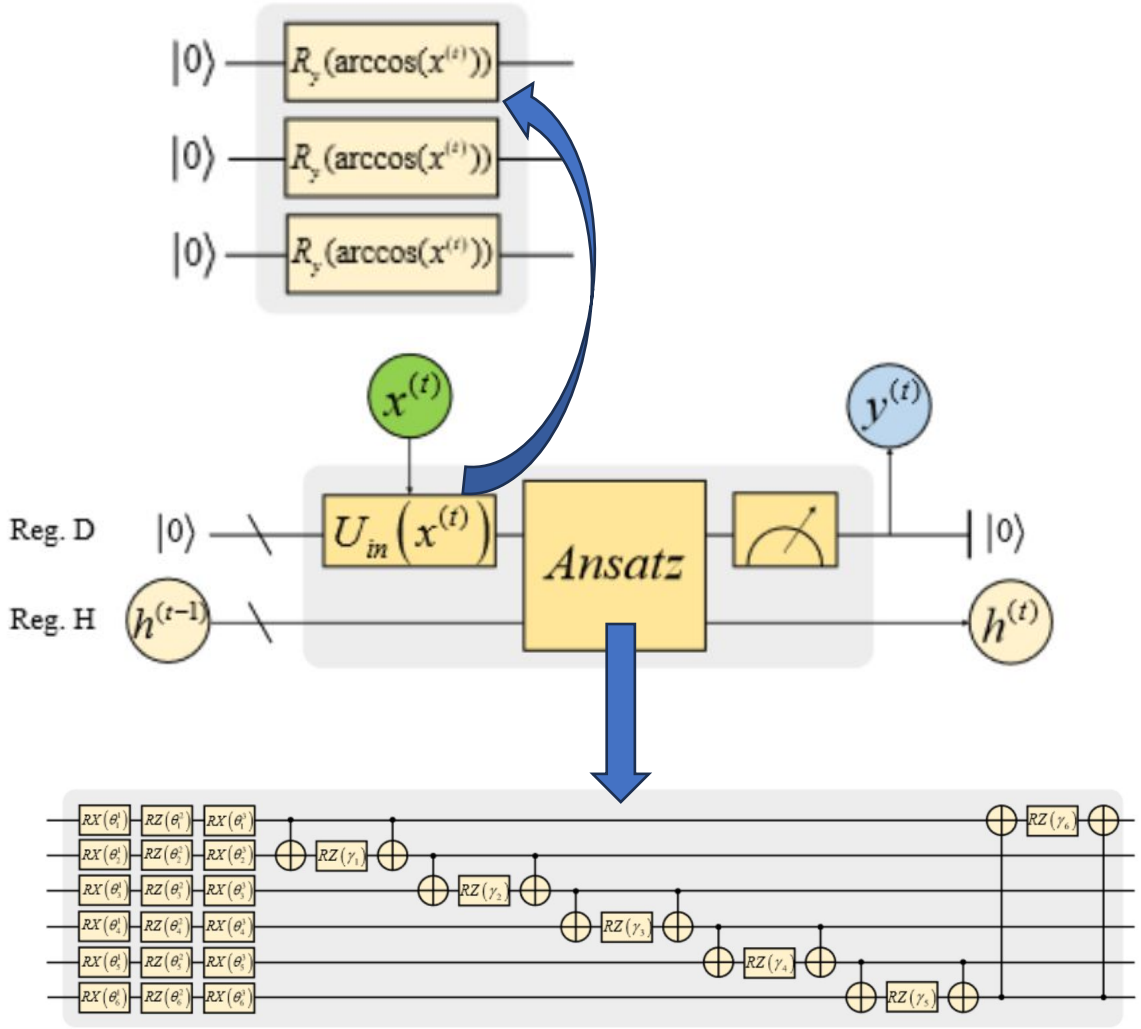
Image Classification with QSANNs- including Positional Encoding



Dataset: Sklearn Digits Dataset
Number of Patches: 4
Number of Qubits: 4
Number of Repetitions: 2
Number of Self-Attention Layers: 1

QRNN Architecture for Sequential Data

- The proposed architecture consists of three parts : data encoding, ansatz circuit and partial measurement
- The paper uses angle encoding to encode data and feed to ansatz
- The ansatz is hardware efficient which consists of layers of two qubit and single qubit gates
- The rotation angles of the RZZ gates inside the ansatz are the learnable parameters
- Circuit block config is used for the ansatz



QRB Block with encoding and ansatz

https://github.com/AnuVadali/qgpt-issue-31/blob/main/QRNN/QRNN.ipynb

Results of QRNN for text data

Dataset	Train Accuracy	Test Accuracy
MC dataset	74.7%	66.9%
RP dataset	67.1%	60%

MC - Meaning Classification
RP - Relative Pronoun

Link to paper mentioning the dataset : https://dl.acm.org/doi/pdf/10.1613/jair.1.14329

Remaining Work

- Comparison of all 3 models on the same dataset
- Write a survey paper

Thank You