QML Womanium Quantum+AI Project

QML for Conspicuity Detection

Hussein Shiri, Martyna Czuba

WOMANIUM | QUANTUM

The Detection Duo team members

Martyna Czuba

Full stack developer

Currently pursuing PhD in computer science

Teaches university courses on optimization fundamentals, algorithmic techniques, and quantum algorithms

Hussein Shiri

ML Engineer intern

Graduated from physics major

Currently Computer science undergraduate

Project Tasks:

Task 1

Notebooks from PennyLane

Task 2

Variational Classifiers

Task 3

Quantum Convolution layers

Task 4

Quantum Model for predicting the Sine Function.

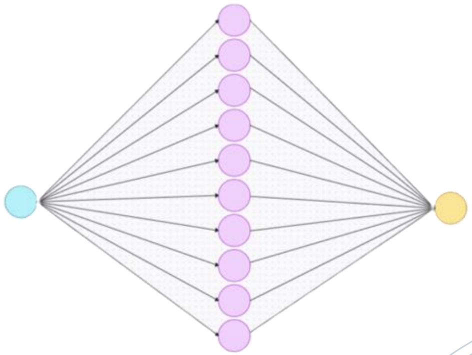
Task 5

Implement a Quantum Machine Learning model to detect a defective production part.

TASK 4 – Sin Function

01

Classical Model



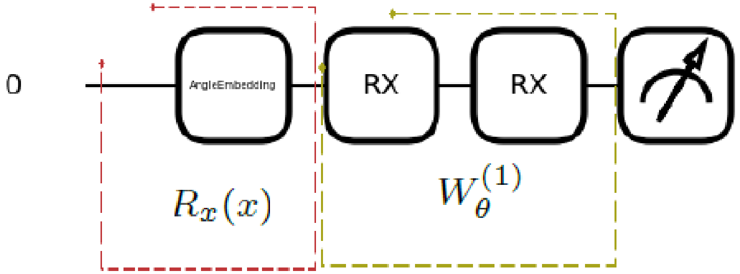
02

Quantum Model 1

$$f_\theta(x) = \langle 0|U^\dagger(x,\theta) M U(x,\theta)|0\rangle$$

,where $|0\rangle$ is a single qubit, $M = \sigma_z$,

$$U(x,\theta) = W_\theta^{(1)} R_x(x)$$

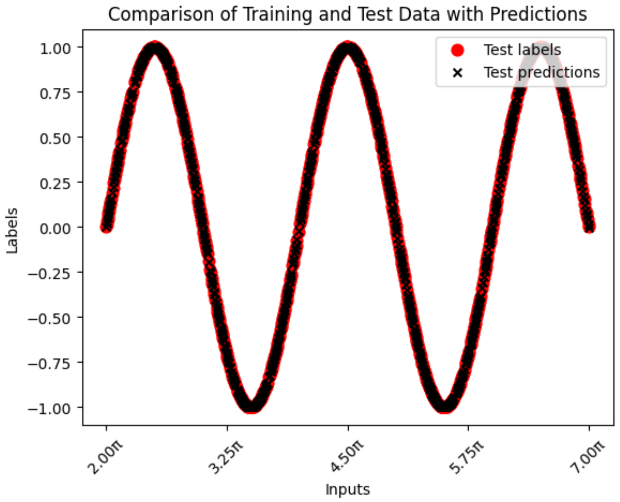


03

Adjustment of points

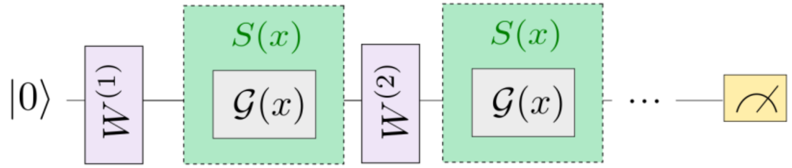
We run the training process on different numbers of data.

*Min. **4 points,** we need do learn sine function.*



TASK 4 - Function with larger frequency spectrum

Source: [1]



01

Quantum Model 2

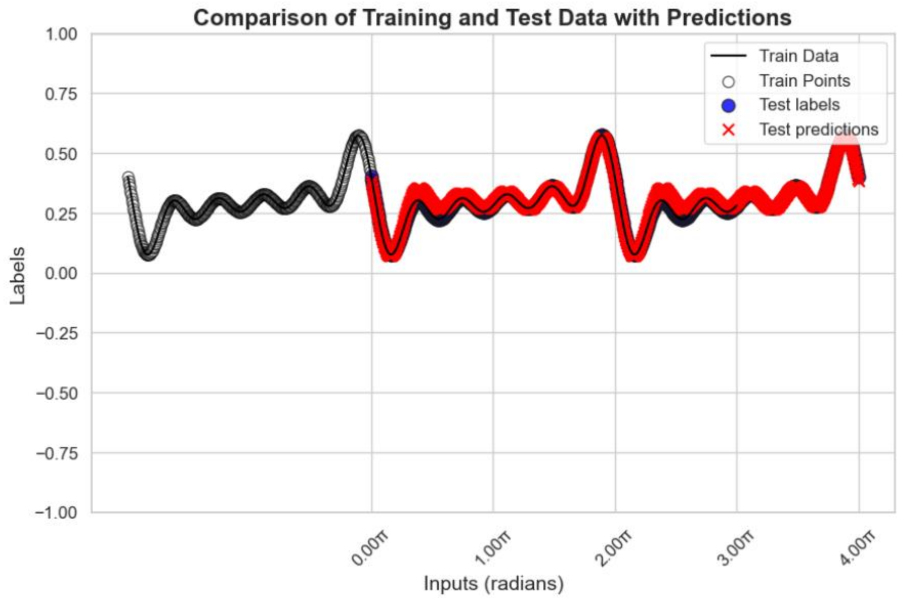
$$f_\theta(x) = \langle 0|U^\dagger(x,\theta) M U(x,\theta)|0\rangle$$

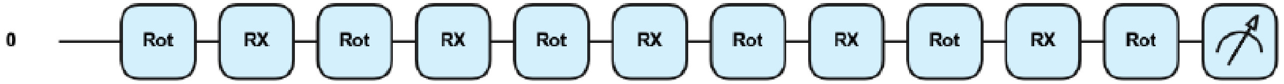
,where $|0\rangle$ is a single qubit, $M = \sigma_z$, and.

$$U(x,\theta) = W_\theta^{(L+1)} \underbrace{S_L(x) W_\theta^{(L)}}_{\text{Layer L}} \cdots W_\theta^{(2)} \underbrace{S_1(x) W_\theta^{(1)}}_{\text{Layer 1}}$$

,where $L = 5$, $S(x) = e^{-ixH} = R_x(\phi)$,

$$W_\theta = RZ(\omega) RY(\theta) RZ(\phi)$$





[1] Maria Schuld, Ryan Sweke, and Johannes Jakob Meyer. The effect of data encoding on the expressive power of variational quantum machine learning models. Physical Review A, 103(3):032430, 2021.

TASK 5

Images crop and resize

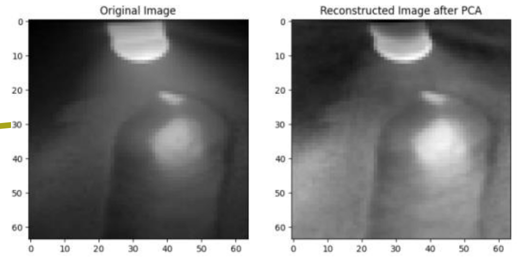
Dimensionality reduction

VQC
using 4 and 8 qubits.

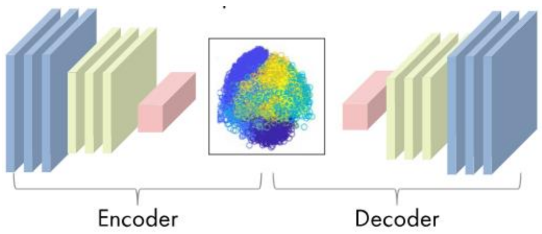
Training using diffrent loss function

Calculate the metrics

PCA



Autoencoder



Exponential loss:

$$loss = \sum_i (1 + 10e^{7p_i})^{-1}$$

Binary cross entropy loss:

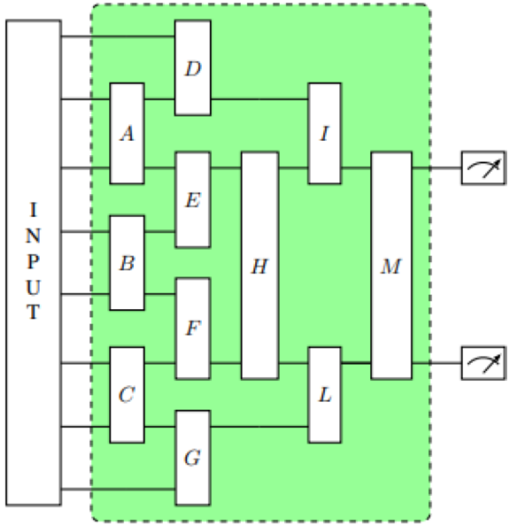
$$\text{Loss} = -\sum_{i=1}^{\text{output size}} y_i \cdot \log \hat{y}_i$$

Focal loss:

$$\text{FL}(p_t) = -(1 - p_t)^{\gamma} \log(p_t)$$

Results TASK 5

Source: [2]



(b) Variational classifier based on a MERA.

Quantum Model

Quantum Tensor Neural Network in MERA architecture

Train set	Test set	Validation set	Loss	epochs	Validation acc	Test acc
2393,2407	303,297	304,296	cross entropy	200	88.17%	86.0%
2393,2407	303,297	304,296	exponential	200	92.67%	89.83%
2393,2407	303,297	304,296	FL, gamma=1	200	89.33%	86.0%
2393,2407	303,297	304,296	FL, gamma=2	200	92.33%	80.83%

Table 2: table showing the results for circuit with 8 qubits.(Binary classification)

[2] Daniel Gonzalez, Lukasz Cincio, Mikkel Kjaergaard, and et al. Multi-class quantum classifiers with tensor network circuits for quantu phase recognition. arXiv preprint arXiv:2110.08386, 2021.

Challenges and future scope

Challenges

- Computational resources
- Big images dimensions
- Trying to implement a novel approach
- Trying to create maintenance and reusable code. Designed to be extended

Future scope

- Comparing with other models
- Extending for multiclassification
- Evaluate model on Hardware
- Detect anomalies by analyzing frequency pattern in image

❮ WOMANIUM | QUANTUM ❯

THANK YOU

https://github.com/Martyna94/The_Detection_Duo