Quantum Machine Learning for Conspicuity Detection in Production

Team BASTET
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Team Introduction - BASTET

About Us:

We are two students from Egypt, proud to present our work under the team name BASTET, inspired by the Egyptian cat goddess.

Why BASTET?

- Bastet symbolizes protection, grace, and nurturing, much like our approach to advancing technology and science.
- The iconic "Schrödinger's cat" thought experiment, which illustrates the concept of superposition in quantum mechanics, also features a cat. This connection beautifully bridges our cultural heritage with the frontier of quantum science, reflecting our blend of tradition and innovation.

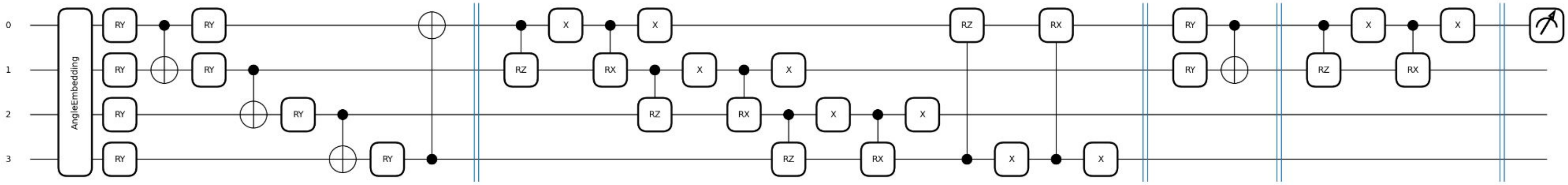
Problem Statement

- Classifying industrial dataset with quantum convolutional neural networks (QCNNs).
- Doing classification on the TIG dataset
  - Dataset divided into 6 classes. First class is good weld, and the rest are variations of bad weld.
  - For binary classification, we take good weld (labeled by 0) and the rest as bad weld (labeled by 1).
- Work is based on the following python libraries: pennylane, scikit learn and pytorch.

Quantum Circuit Design

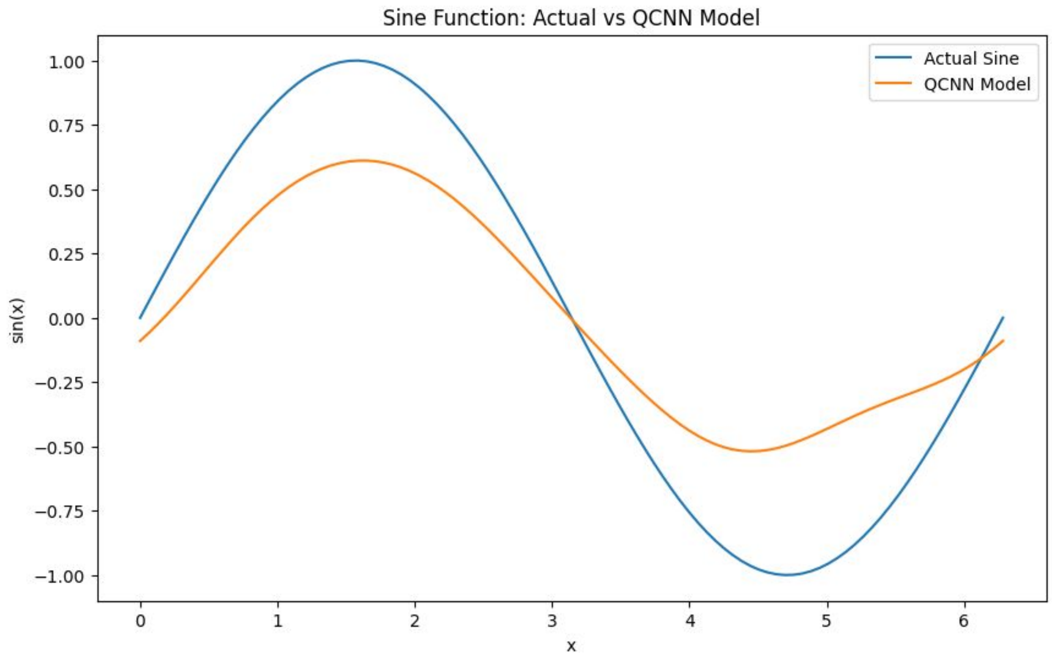
- Circular Nearest Neighbor Connection.
- 4 qubits
- 2 Layers:
  - 1 convolutional layer and 1 pooling layer, applied on all 4 qubits.
  - 1 convolutional layer and 1 pooling layer, applied on the first 2 qubits.
- Measuring the first qubit.
- Compute the expectation value of Pauli Z.

Quantum Convolutional Neural Network Circuit



QCNN for Sine Function Approximation

- Goal: Approximate Sine function
- **Mean Squared Error**: 0.105
- This amplitude discrepancy could be enhanced by changing the quantum *circuit's expressiveness* or adjusting the *data encoding* strategy.



Results

- **Test accuracy**: 67%
- Due to data imbalancing, the model is biased
- Consider undersampling the dominating class

Target	Predicted	Probability
1	1	0.5993
0	1	0.5993
1	1	0.5153
1	1	0.6964
1	1	0.6110
0	1	0.5153
0	1	0.6432
1	1	0.6964
1	1	0.6218
1	1	0.6323

Results (Undersampled)

- Good weld class 50% - bad weld class 50%
- **Test accuracy**: 54%
- Unlike the previous trial, the model is less biased, yet needs more improvement.

Target	Predicted	Probability
1	0	0.4809
1	1	0.5408
0	1	0.5182
1	0	0.4809
0	0	0.4401
0	0	0.4529
0	0	0.4809
0	0	0.4809
1	0	0.4424
0	1	0.5302

Success

- **Novelty**: Successfully implemented a QCNN using only 4 qubits and a shallow circuit on a real welding dataset, demonstrating the feasibility of quantum machine learning for industrial applications.

- **Challenges**: Highlights the need for balanced datasets and more expressive quantum circuits for practical use.

Future Outlook

- **Expand Training Data**: Increase the dataset size to improve model accuracy, though this requires significant computational resources.
- **Data Optimization**: Implement advanced techniques such as shuffling and balanced sampling to mitigate the impact of data imbalance.
- **Multi-Class Classification**: Extend the model to differentiate between various types of bad welds, enhancing its versatility and practical application.

Thank You

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