Comparative Analysis Report

Quantum RNN vs Quantum LSTM for Sentiment Analysis

1. Introduction

A Quantum RNN and a Quantum LSTM, both models are tested on Amazon review dataset consisting of 1000 labeled sentences (500 positive, 500 negative).

2. Model Architectures

2.1 Quantum RNN

- **Encoding**: Amplitude + angle encoding (32-dimensional embeddings split into 16 amplitude + 16 angle)
- **Qubits Used**: 8
- **Quantum Circuit**: Single QNode per time step
- **Hidden State**: Updated via quantum observable from QNode
- **Trainable Parameters**: 14 input weights + 2 hidden weights
- **Output Layer**: Linear classifier + learnable bias

2.2 Quantum LSTM

- **Encoding**: Amplitude + angle encoding (32-dimensional embeddings split into 16 amplitude + 16 angle)
- **Qubits Used**: 8 (per gate)
- **Quantum Circuits**: Four separate QNodes per time step, one for each gate (input, forget, candidate, output)
- **Trainable Parameters**: 4 x 7 gate weights = 28 total (no shared weights)

- **Output Layer**: Linear classifier on final hidden state

3. Training Performance

Model	Epochs	Training Accuracy	Training Loss	Convergence
Quantum RNN	100	~53%	~0.69-0.70	Stagnated
Quantum LSTM	100	~53%	~0.69-0.70	Stagnated

- Both models showed early stagnation around random guess performance.
- No signs of overfitting despite long training.
- Loss plateaus after ~10-15 epochs.

4. Test Performance

Model	Test Accuracy
Quantum RNN	46.5%
Quantum LSTM	46.5%

- Classification reports and confusion matrices showed near-random behavior.
- Slight negative class bias observed.

5. Model Behavior Diagnostics

5.1 Prediction Distribution

- Both models predicted each class almost equally (~50/50)
- However, prediction confidence was low (many probabilities near 0.5, mean logit is negative – hovering around zero)

5.2 Bias & Stagnation

- Few unique probabilities (~3-5), indicating saturation or convergence failure
- Low logit and probability standard deviation (~0.01-0.02)

5.3 Confusion Matrix Insights

- Most predictions were wrong or borderline (~50% misclassification)
- Predicted class distribution did not significantly deviate from true class distribution

6. Conclusion

Both the Quantum RNN and Quantum LSTM achieved similar performance, stagnating at guess-level accuracy. Despite LSTM's added complexity (both cell and hidden state), it did not outperform the RNN.

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