ID: 21241010 **Name:** Sk Saif Ibna Ezhar Arko **Course Code:** CSE424 **Section:** 02
Review: Quantum pattern recognition on real quantum processing units
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Midterm Assignment Concept Paper

1.1 Motivation/Purpose/Aims/Hypothesis

The primary aim of the paper is to investigate the effectiveness of quantum pattern recognition protocols using real quantum devices, specifically IBMQ's noisy intermediate-scale quantum (NISQ) processors. The authors hypothesize that swap tests could be used to efficiently compare quantum states representing classical images for pattern recognition. However, they note that noise in real quantum systems can limit performance, particularly for systems with three or more qubits.

1.2 Contribution

The paper contributes to the field by experimentally verifying the feasibility of quantum pattern recognition using swap tests on real quantum devices. It introduces the destructive swap test as an alternative to mitigate noise, allowing for better performance in quantum systems. The study also presents a segment-wise approach to applying quantum pattern recognition on larger images, and proposes a protocol inspired by quantum associative memory for supervised learning tasks.

1.3 Methodology

The authors conducted experiments using IBMQ NISQ devices, where binary and grayscale images were encoded as quantum states. They implemented the swap test to determine the overlap between quantum states, evaluating its efficiency. Due to noise challenges, a destructive swap test was used, which requires fewer gates. This improved the performance, especially for three-qubit systems. Additionally, the segment-wise approach was employed to test higher-dimensional images. The images used included MNIST numbers, fashion MNIST, and MRI scans of blood vessels.

1.4 Conclusion

The paper concludes that while swap tests struggle with noise beyond three qubits, the destructive swap test can improve performance on noisy quantum devices. It also highlights that the destructive swap test can be a viable tool for pattern recognition in binary and grayscale images, including potential applications in biomedicine.

2.1 1st Critique/Limitation

The swap test's performance degrades significantly with increasing qubit count, due to noise in quantum processors. The destructive swap test offers some improvement, but it also has limitations as the number of qubits increases.

2.2 2nd Critique/Limitation

The study primarily focuses on relatively simple binary and grayscale images. More complex image data, such as high-dimensional RGB images, were not tested, limiting the scope of the study in terms of practical applications.

2.3 3rd Critique/Limitation

The destructive swap test increases the complexity of classical post-processing, particularly when segment-wise approaches are used for larger images. This adds computational overhead and could reduce the overall advantage of using quantum methods for large-scale image recognition.

3.1 1st potential/idea of a new/follow-up/extension paper

Future work could explore ways to combine the destructive swap test with quantum error-correction techniques to further mitigate the effects of noise in higher qubit systems. Another direction could involve testing the performance of quantum pattern recognition protocols on more complex image data, such as RGB images used in real-world applications.

3.2 2nd potential/idea of a new/follow-up/extension paper

An extension paper could investigate the integration of machine learning techniques with quantum pattern recognition protocols to enhance performance. Quantum neural networks could be applied to improve pattern recognition accuracy, especially for biomedical images, as the study hints at possible applications in medical diagnostics.