# QUANTUM EDGE DETECTION

QUANTUM EDGE DETECTION USES QUANTUM COMPUTING TO PROCESS LARGE, HIGH-RESOLUTION IMAGES FASTER THAN CLASSICAL METHODS BY ENCODING PIXEL DATA INTO QUANTUM STATES. IT PROMISES BREAKTHROUGHS IN FIELDS LIKE MEDICAL IMAGING AND AUTONOMOUS SYSTEMS, DESPITE HARDWARE LIMITATIONS.

## GROUP MEMBERS

Mohammad Yehya 21k-3309
Hasan Iqbal 21k-3297
Daniyal Haider 21k-3433

## AFFILIATIONS

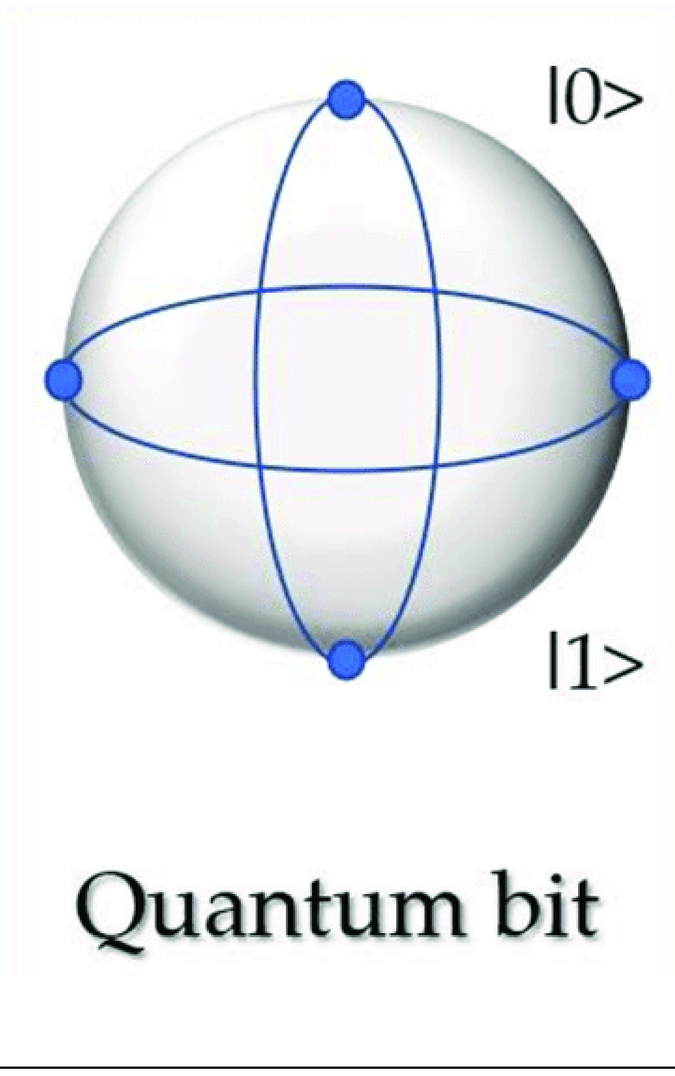
FAST NUCES

## INTRODUCTION

Edge detection is a fundamental image processing technique used to identify boundaries within images, playing a vital role in applications like computer vision, autonomous vehicles, and medical imaging. Classical methods, however, often struggle with high computational costs and limitations in handling large-scale or complex datasets. Quantum edge detection leverages the power of quantum superposition to efficiently detect image boundaries. By applying the Hadamard gate, pixel intensity variations are encoded into quantum states, enabling parallel processing of large image datasets. This approach emphasizes intensity gradients to highlight edges, offering faster and more scalable processing compared to classical methods. This project explores advanced quantum edge detection techniques such as QPIE (Quantum Probabilty Image Encoder), FRQI (Flexible Representation of Quantum Images), and QHED (Quantum Hadamard Edge Detection), aiming to evaluate their potential for accurate, efficient, and scalable edge detection, paving the way for advancements in quantum-enhanced image processing.

## METHODOLOGY

- **Encoding using QPIE and FRQI:**
  - QPIE (Quantum Pixel Image Encoding): Encodes image pixel data into quantum states, typically using amplitude encoding, to represent image intensities in qubits.
  - FRQI (Flexible Resource-efficient Quantum Imaging): A technique used to encode the image data efficiently, reducing the resource requirements of quantum systems while maintaining accuracy in representing image features.
- **Gradient Calculation via Amplitude Permutation Unit Operation:**
  - After encoding, an amplitude permutation unitary operation D2n+1 is applied to shift down the elements of the state vector by one row. This operation enables simultaneous gradient calculation for both even and odd pixel pairs, facilitating the detection of edges.
- **Post-processing of Image:**
  - After quantum edge detection, the image's quantum states are measured and converted back to classical data.

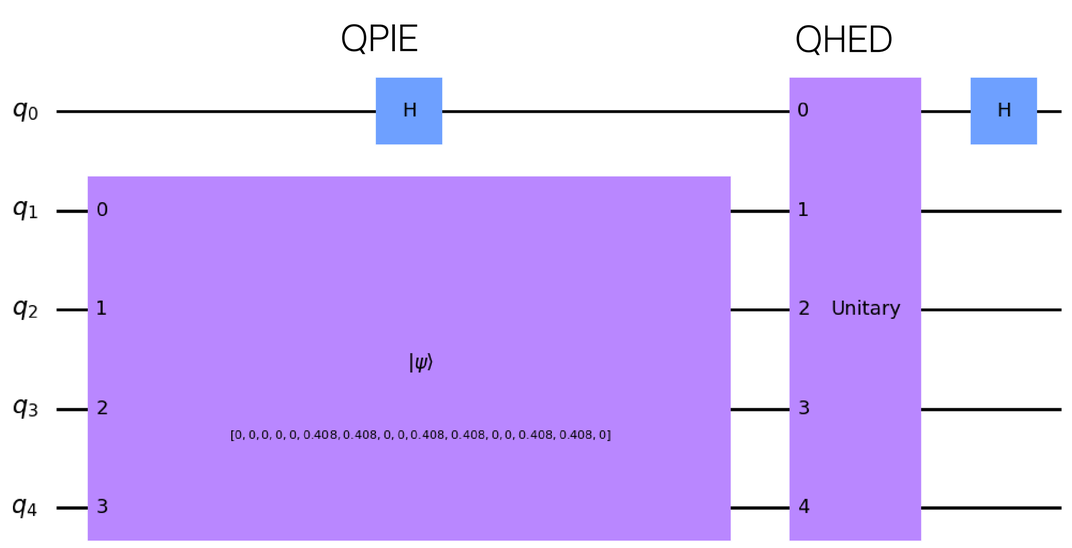



## RESULTS/FINDINGS

The comparison between the classical Sobel operator and the quantum solution using QPIE revealed that the quantum approach outperforms the Sobel method in accuracy, especially in detecting finer edges. However, due to current hardware limitations, only quantum simulations can be run, restricting the use of quantum computing to smaller image datasets. As a result, only small images could be tested, but even with these limitations, QPIE demonstrated superior edge detection accuracy compared to the classical Sobel operator.

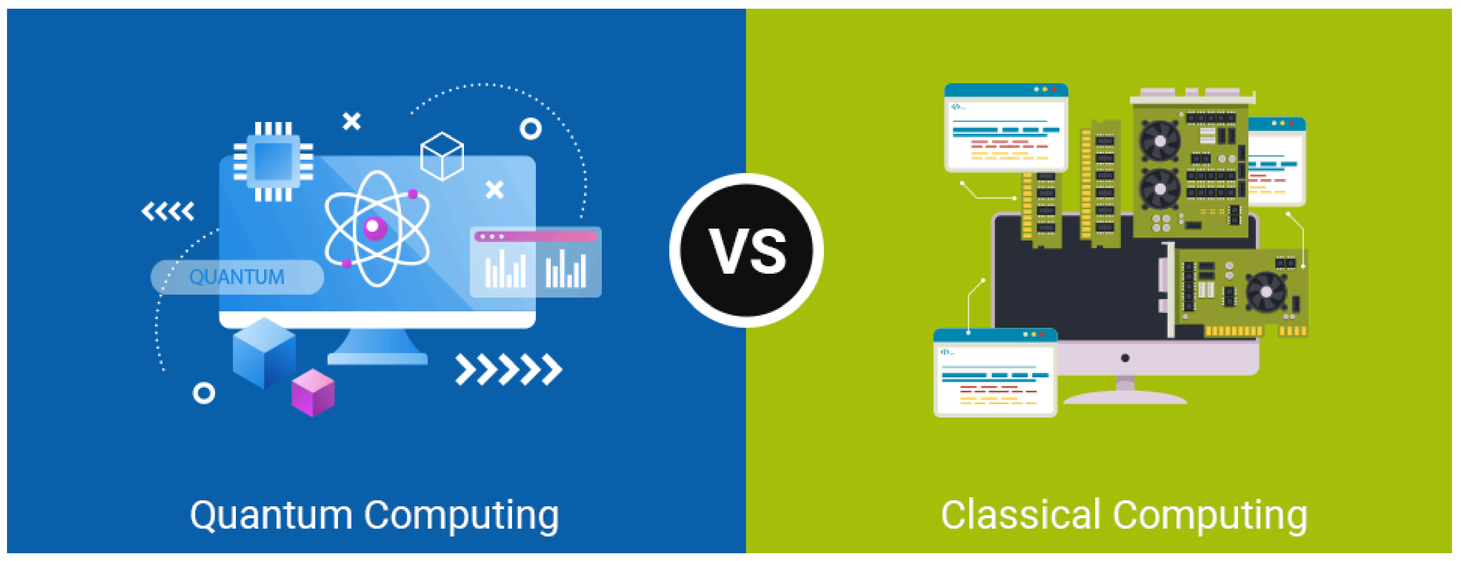
## RECOMMENDATION

we suggest optimizing quantum algorithms like QPIE, FRQI, and QHED to enhance computational efficiency and accuracy. Advancements in quantum hardware are crucial to support the demands of these techniques. Integrating quantum and classical methods can leverage the strengths of both paradigms for real-world applications, such as medical imaging, autonomous vehicles, and surveillance systems.




## CONCLUSION

Despite hardware limitations, the quantum edge detection method using QPIE shows strong potential for edge detection tasks, offering better accuracy than classical Sobel on small images. The ability of quantum computing to handle image data with parallelism and improved gradient calculation paves the way for future advancements. Once quantum hardware evolves to handle larger datasets, this approach could revolutionize image processing in fields such as medical imaging and autonomous systems.




## REFERENCES

Edge Detection Quantumized: A Novel Quantum Algorithm for Image Processing - Research Article
Quantum Image Processing: Quantum Probability Image Encoding (QPIE) and Quantum Hadamard Edge Detection - Blog on Medium