RESEARCH PROJECT SYNOPSIS

A New Way to Store and Use Digital Images on Quantum Computers

Organization:
Suvidha Foundation (Suvidha Mahila Mandal)

Proposal submitted for
Competitive Research & Technical Grant
Project Cycle [2025-2026]

RESEARCHER

Abhi Pandey
Suvidha Foundation (Suvidha Mahila Mandal)

Suvidha Foundation (Suvidha Mahila Mandal)
India

1. Introduction

Quantum Image Processing (QIMP) is a multidisciplinary field that leverages quantum mechanics to store, process, and retrieve visual information. As classical computing approaches its physical limits, quantum computing offers a paradigm shift in performance through superposition, entanglement, and interference. This project focuses on the efficiency of **Quantum Image Representation (QIR)**, which is the foundational step for all quantum vision tasks.

QIR defines the mapping between classical pixel data and quantum states. While modern frameworks like FRQI and NEQR have introduced exponential storage advantages, the "loading problem"—the high complexity of state preparation—remains a significant bottleneck for practical application on current quantum hardware.

2. Emergence of the Problem

Existing models face a critical trade-off: FRQI offers high qubit efficiency but is probabilistic, requiring massive measurement counts for reconstruction. Conversely, deterministic models like NEQR provide high fidelity but involve complex circuit depths that often exceed the coherence time of current Noisy Intermediate-Scale Quantum (NISQ) devices. There is an urgent need for a novel representation that optimizes qubit utilization while reducing gate complexity.

3. Justification of the Problem

Improving representation efficiency directly enhances the feasibility of advanced tasks such as quantum image encryption and medical imaging analysis. By developing a more efficient QIR technique, we can reduce the computational overhead on physical quantum processors (e.g., IBM Q). This research aims to provide faster, more secure data handling capabilities for future quantum-integrated industries.

4. Statement of Problem

"A study of a novel technique for Quantum Image Representation and its effect on computational efficiency, image reconstruction fidelity, and information security in simulated and hardware-based environments."

5. Variables of the Study

- **Independent Variable:** Quantum Image Representation Technique (Proposed Novel Technique vs. FRQI/NEQR).

– **Dependent Variables:**

(a) Computational Efficiency (Circuit Depth and Gate Count)

(b) Image Reconstruction Fidelity (MSE and PSNR)

(c) Information Security (Key Space and Resistance to Attacks)

(d) Quantum Volume Utilization

6. Objectives of the Study

1. To determine the criteria for evaluating efficient Quantum Image Representations.
2. To design a novel QIR technique using optimized quantum logic gates.
3. To implement the proposed technique on the IBM Quantum (Qiskit) or Azure Quantum platform.
4. To compare the novel technique with existing models regarding circuit depth and qubit count.
5. To study the effect of the proposed representation on security and steganographic capacity.

7. Hypotheses of the Study

1. The proposed technique will significantly reduce circuit depth compared to traditional NEQR.
2. The reconstruction fidelity of the novel technique will remain comparable to or exceed that of existing deterministic models.
3. The proposed QIR will show improved resistance against quantum noise and decoherence during state preparation.

8. Methodology

The study will adopt an experimental research design using quantum simulators and physical quantum processors.

8.1 Sampling Procedure

A dataset of benchmark images (e.g., Lena, Peppers, and medical MRI scans) of sizes ranging from 32×32 to 256×256 will be utilized to test scalability.

8.2 Procedure of the Study

- **Stage I:** Benchmarking existing models (FRQI/NEQR) on the IBM Q interface.
- **Stage II:** Development of the novel QIR algorithm using multi-controlled rotation gates and optimized state preparation.
- **Stage III:** Integration of Hilbert scanning and chaotic mapping to enhance information security.
- **Stage IV:** Comparative analysis and resource estimation for fault-tolerant hardware.

9. Statistical Techniques

The performance will be analyzed using:

- **Descriptive Statistics:** Mean and Standard Deviation for Peak Signal-to-Noise Ratio (PSNR).
- **Inferential Statistics:** ANOVA to compare execution times and gate counts across various representation models.

10. References

1. Lisnichenko, M., & Protasov, S. (2022). "Quantum Image Representation: A Review." *Innopolis University*.
2. Su, J., Guo, X., Liu, C., & Li, L. (2020). "A New Trend of Quantum Image Representations." *IEEE Access, Volume 8*.
3. Khandelwal, A., & Chandra, M. G. (2022). "Quantum Image Representation Methods Using Qutrits." *arXiv:2207.09096v2*.
4. Haider, G. R., & Rizwan, W. (2023). "Quantum Image Representation- FRQI Image." *LUMS SSE*.
5. Le, P. Q., Dong, F., & Hirota, K. (2011). "A flexible representation of quantum images." *Quantum Information Processing, 10, 63*.
6. Zhang, Y., et al. (2013). "NEQR: a novel enhanced quantum representation." *Quantum Information Processing*.
7. Sharma, V. K., et al. (2022). "Hilbert quantum image scrambling and graph signal processing-based steganography." *Multimedia Tools and Applications, 81*.