Analysis of Noise Effects on Chest X-ray Images Using Quantum Fourier Transform in the Frequency Domain

B.Tech (AIDS)
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CONTENTS

Introduction

- Chest X-ray imaging is widely used for diagnosing respiratory conditions
- Image quality is often affected by noise during acquisition and transmission
- Noise can obscure minute details and affect diagnostic reliability
- Frequency-domain analysis helps understand how noise alters image characteristics
- Quantum computing introduces the **Quantum Fourier Transform** (QFT) as an innovative approach for frequency-domain analysis
- Alongside quantum techniques, the **Classical Fourier Transform (FFT)** remains the widely used and reliable method for frequency-domain analysis in medical imaging
- In this work, both **classical FT and Quantum FT** are used to study and compare how noise alters the frequency characteristics of chest X-ray images

Objective of the Project

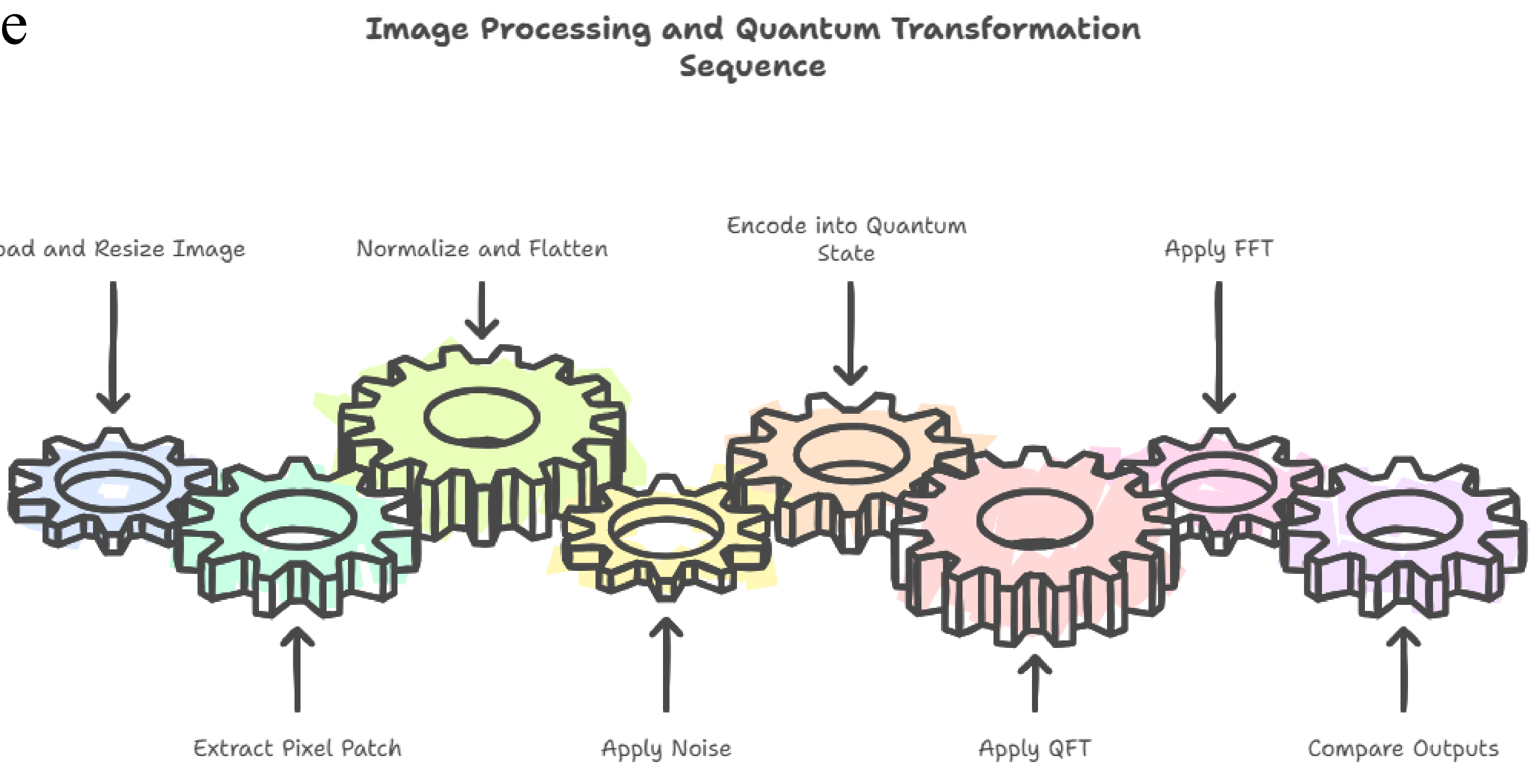
- To analyze the impact of noise on chest X-ray images in the frequency domain
- To encode a 4×4 image patch into a quantum state using amplitude encoding
- To apply Quantum Fourier Transform on clean and noisy images
- To compare the frequency-domain behaviour under:
- Gaussian noise
- Salt-and-pepper noise
- To study how noise redistributes frequency components using both classical and quantum frequency-domain framework
- To apply Classical Fourier Transform (FFT) on the same image patch and use it as a benchmark for comparison with QFT results

Literature Review

- Classical Fourier Transform techniques have been extensively used for frequency-domain analysis of images, enabling the identification of low- and high-frequency components related to image structure and noise.
- Prior studies in image processing report that **Gaussian noise** introduces smooth and distributed spectral variations, primarily affecting low- and mid-frequency components.
- In contrast, **salt-and-pepper noise**, being impulsive in nature, introduces abrupt intensity changes, resulting in strong high-frequency components in the frequency domain.
- Recent advancements in quantum computing have led to the exploration of the **Quantum Fourier Transform (QFT)** for image and signal processing applications, demonstrating its effectiveness in frequency-domain representation.
- However, existing literature shows **limited work on applying QFT specifically to analyze noise effects in medical images**, particularly chest X-ray images.

Proposed Methodology

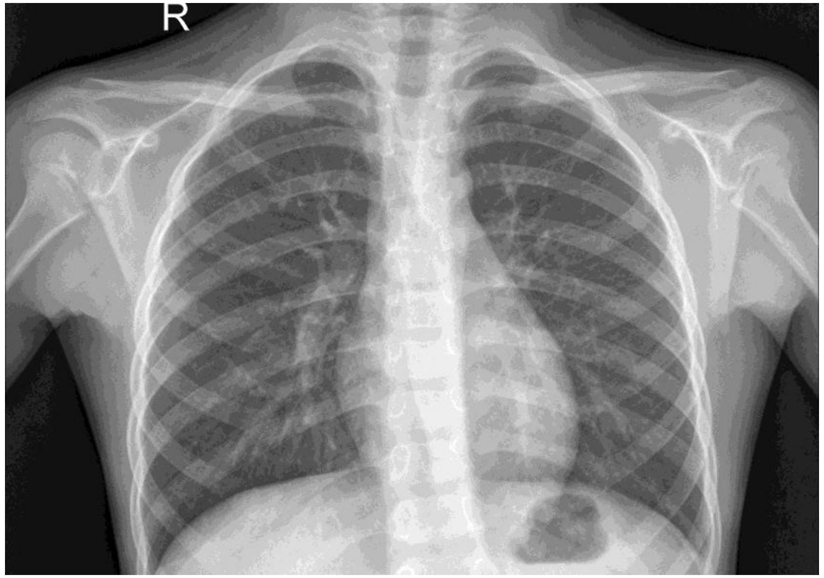
1. Load and resize chest X-ray image
2. Extract 4×4 pixel patch
3. Normalize & flatten pixel values
4. Apply two types of noise:
5. Gaussian
6. Salt-and-pepper
7. Encode patch into 4-qubit state (Amplitude Encoding)
8. Apply QFT on quantum circuit
9. Apply FFT on classical vector
10. Compare frequency-domain outputs



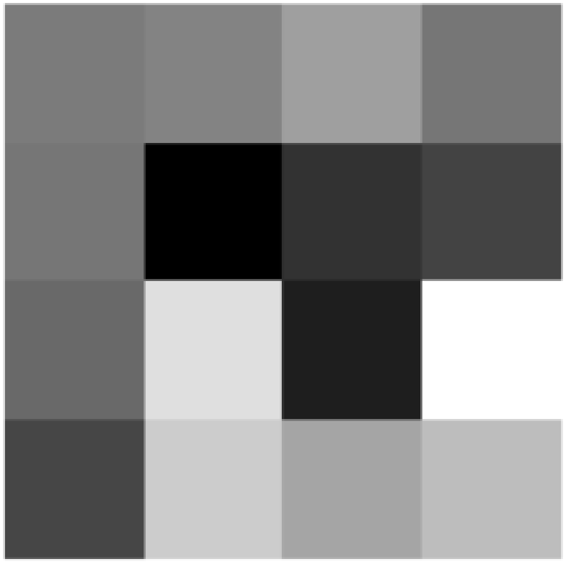
Results

Effect of Noise on Image Patch

- Gaussian noise introduces mild random fluctuations
- Salt-and-pepper noise introduces abrupt intensity changes
- Visual differences indicate varying frequency content



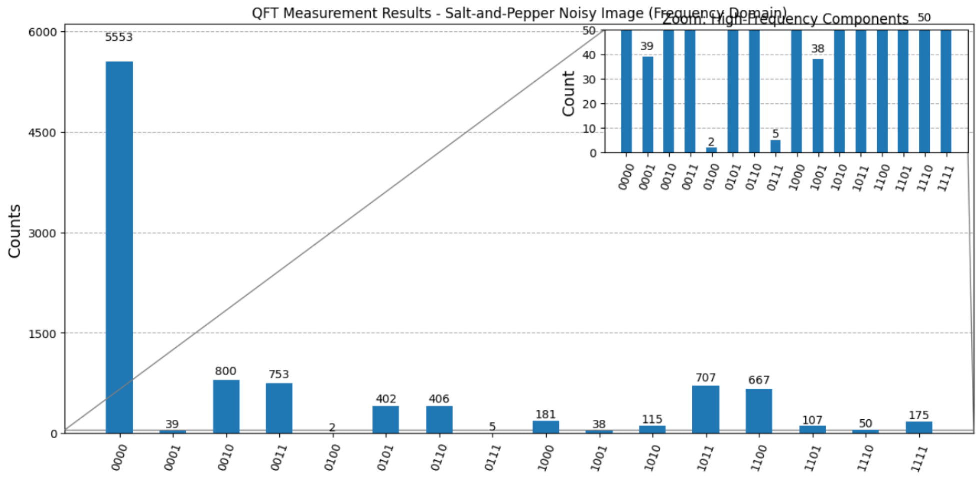
Gaussian Noise Image (4×4 Patch)

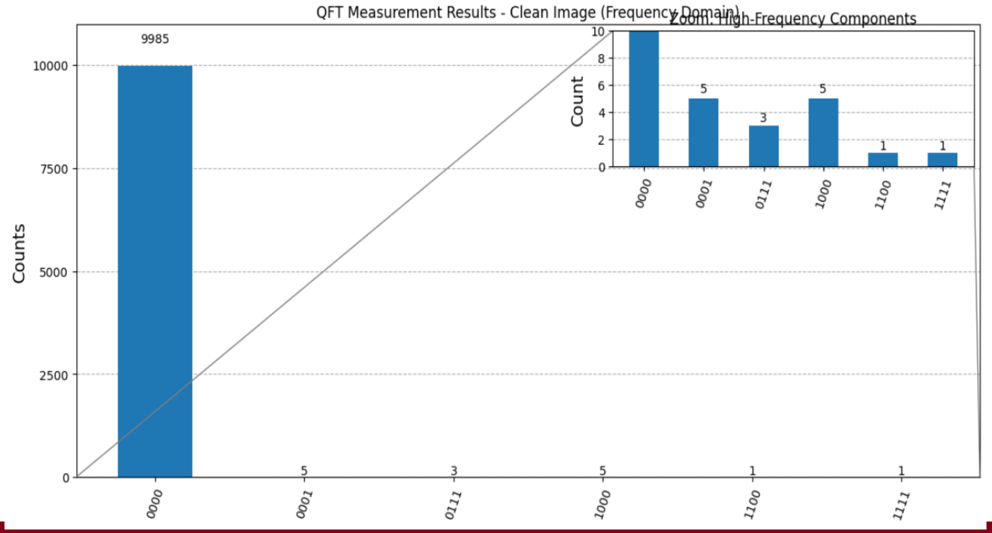


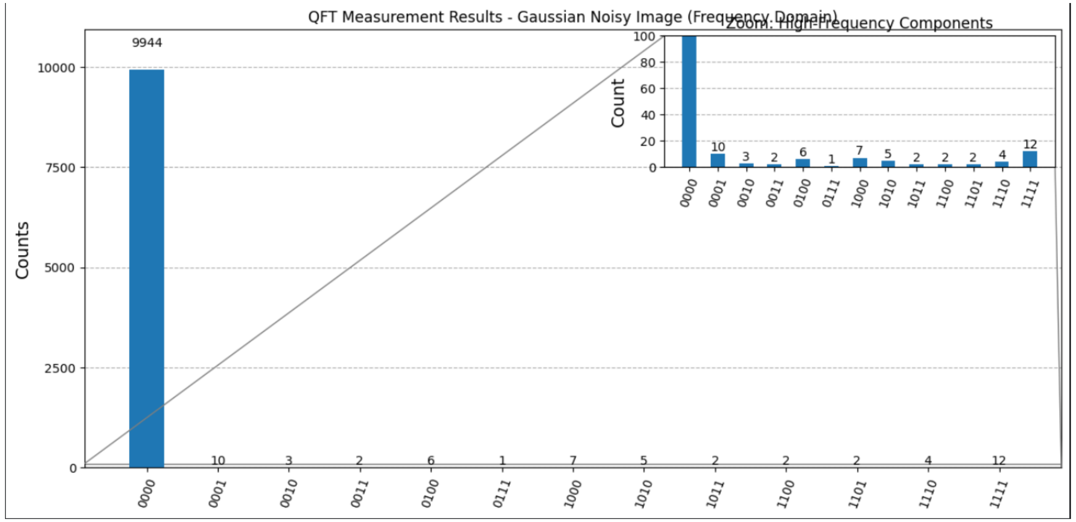
Salt-and-Pepper Noise Image (4×4 Patch)

QFT Analysis

- Clean image:
  - Dominant low-frequency state |0000⟩
- Gaussian noise:
  - Minor leakage into higher-frequency states
- Salt-and-pepper noise:
  - Significant spread across multiple frequency states
  - Indicates increased high-frequency components due to impulsive noise

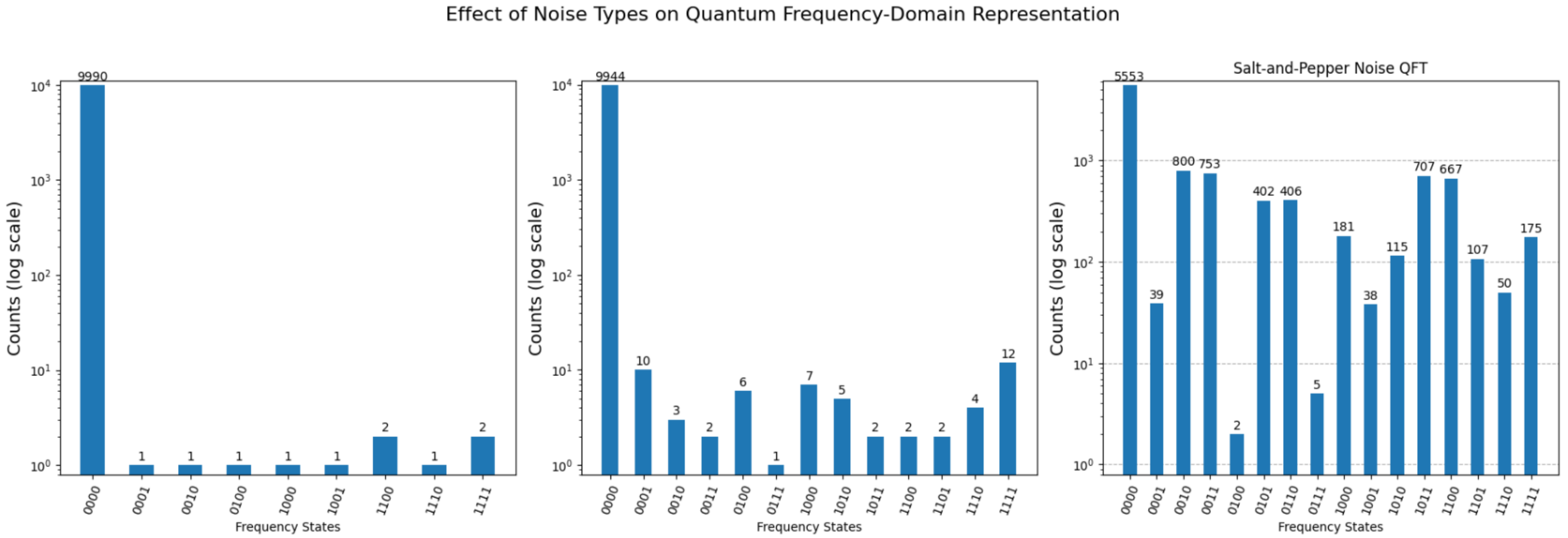






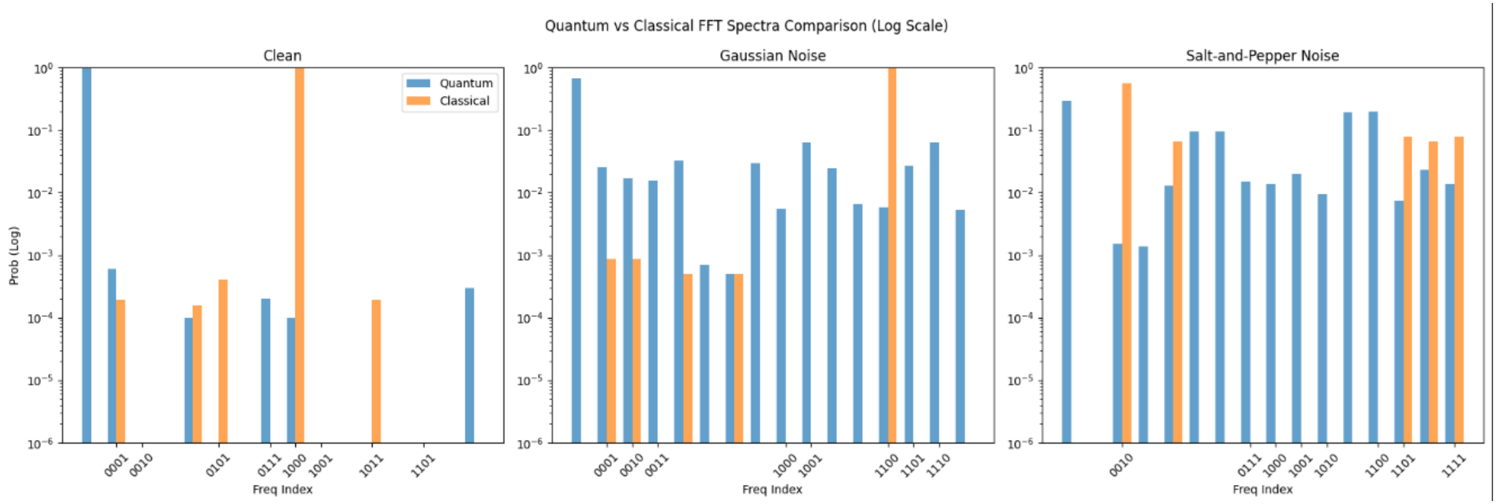
Comparative Frequency-Domain Analysis

- Clean and Gaussian cases dominated by low-frequency components
- Salt-and-pepper noise shows strong frequency spreading
- Log-scale visualization highlights differences clearly
- Observations align with classical signal processing principle.



Quantum vs Classical Comparison

- Agreement Between Results
  - QFT follows FFT frequency distribution
  - Minor variations only due to:
    - Quantum sampling noise
- Key Insight
  - Classical FT
    - Fast
    - Accurate
    - Scalable
  - Quantum FT
    - Conceptually correct
    - Limited by NISQ hardware
    - Useful for small-scale experiments



Applications and Future Scope

Applications :

- Noise analysis in medical image processing
- Educational demonstrations of quantum image processing
- Basis for quantum-assisted image enhancement
- Hybrid quantum–classical medical imaging systems

Future Scope :

- Extend to larger image patches using more qubits
- Explore additional noise models
- Test on real quantum hardware
- Apply to disease-specific X-ray datasets
- Investigate quantum-based image denoising techniques

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THANK YOU