RADemics

Hybrid Algorithms for Image Processing Leveraging Quantum Computing for Enhanced Performance

Ramprabu J, S. Prabhavathy
KUMARAGURU COLLEGE OF TECHNOLOGY, CHRIST THE ENGINEERING COLLEGE

Hybrid Algorithms for Image Processing Leveraging Quantum Computing for Enhanced Performance

Ramprabu J, Assistant Professor, Department of EEE, Kumaraguru College of Technology, Coimbatore 641049, ramprabu.j.eee@kct.ac.in

S. Prabhavathy, Assistant Professor, Department of ECE, Christ The Engineering College, Karamadai, Coimbatore, India, prabhavathysundaram@gmail.com

Abstract

The integration of quantum computing into image processing represents a significant advancement in computational technology, offering transformative capabilities that enhance performance, efficiency, and accuracy. This chapter explores hybrid quantum-classical algorithms, focusing on how quantum subroutines can be integrated into classical image processing workflows. A comparative analysis of various quantum image encoding techniques highlights their strengths and limitations, paving the way for optimized applications across diverse fields. Key advantages of quantum-enhanced image processing, such as improved speed in high-resolution data analysis and superior optimization methods, are discussed in relation to real-world applications, including medical imaging and computer vision. The chapter anticipates future developments in quantum technology, emphasizing the need for interdisciplinary collaboration to unlock the full potential of quantum computing in digital image applications. By addressing the critical gaps in current methodologies, this work aims to inspire further research and innovation in the realm of quantum-enhanced image processing.

Keywords:

Quantum Computing, Image Processing, Hybrid Algorithms, Quantum Subroutines, Optimization, Digital Applications.

Introduction

The emergence of quantum computing marks a revolutionary shift in computational paradigms, offering unprecedented capabilities for processing complex data [1]. Among its various applications, quantum computing holds particular promise for enhancing image processing techniques [2,3]. Traditional image processing relies on classical computing methods, which, while effective, often struggle to manage the ever-increasing complexity and size of modern image datasets [4,5,6,7]. The integration of quantum algorithms into image processing workflows offers a new avenue for overcoming these challenges, providing the potential for faster processing times and improved accuracy in image analysis [8,9].

Quantum computing operates on fundamentally different principles compared to classical computing [10,11]. While classical computers use bits as the smallest unit of data, representing information in binary states (0 or 1), quantum computers utilize quantum bits or qubits [12]. Qubits can exist in multiple states simultaneously, thanks to the phenomena of superposition and entanglement [13]. This unique property enables quantum computers to perform parallel computations, dramatically accelerating the processing of large datasets [14]. Such advancements are particularly beneficial in image processing, where tasks such as filtering, segmentation, and recognition can be significantly expedited through the use of quantum algorithms [15,16,17].

The application of hybrid quantum-classical algorithms represents a significant trend in the field of image processing. These algorithms combine the strengths of classical computing with the enhanced capabilities of quantum systems, allowing for the execution of complex image processing tasks more efficiently [18]. For instance, quantum subroutines can be embedded within classical frameworks to accelerate specific operations, such as optimizing image features or performing complex searches [19]. This integration not only preserves the reliability of classical systems but also harnesses the unique advantages offered by quantum technologies, paving the way for innovative solutions to image-related challenges [20,21].

Various quantum image encoding techniques have been developed to represent and manipulate image data effectively in a quantum environment [22]. Each encoding method presents unique strengths and weaknesses, influencing its applicability in different scenarios [23]. For instance, while Quantum Pixel Representation (QPR) offers simplicity, techniques like Flexible Representation of Quantum Images (FRQI) and Novel Enhanced Quantum Representation (NEQR) provide improved efficiency for high-resolution images [24]. Understanding these encoding techniques was critical for optimizing image processing algorithms and ensuring that they can handle the diverse requirements of modern imaging applications [25].