Applications and Challenges of Quantum Image Processing – A Comprehensive Review

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Abstract

The tremendous parallel processing capability of quantum computers allow quantum image processing, a multidisciplinary field combining image processing and quantum computing, to expand the potential outcomes for image processing. The problem of quantum computation is to create effective quantum algorithms since quantum computers need extremely effective algorithms than classical algorithm. Additionally, information storage, communication, and computing power are increasing in relevance with the number and importance of processing digital images. Some of these issues might be resolved by encoding the visual data in quantum-mechanical systems as opposed to classical methods and by switching from classical to quantum information processing. Moreover, the quantum image processing is analysed based on the recent research works and is summarized. This study projects the application of quantum image processing and challenges.

Keywords: Quantum Image Processing (QuIP), Image Processing, Quantum Computing

1. Introduction

Quantum image processing (QuIP) is an emerging technology that analyses quantum computing and quantum information. A large majority of researchers and engineers devote their scientific research to finding and developing cross-fertilization projects for quantum information processing in different fields, in addition to furthering the theoretical and physical

fundamentals of quantum information and computing. The new concept, that is quantum computing was introduced to overcome the inefficient task of classical computation. Quantum computing aims to enhance the overall performance of computation by integrating these quantum mechanics and quantum physics.

Image processing is related to the quantum mechanics, that focused on how to recognize the orthogonal images using quantum system. In quantum image processing, different quantum images can be used for various process. Now the research implements the quantum images using quantum computer and also implements with various methods like quantum images with an artificial intelligence, machine learning algorithm, using qubits, etc.

The primary activities involved in image processing are image storage, analysis, and restoration. The pixels and parameters of an image are recorded in the computer in separate bits in a classical computer. If there are significant correlations between one portion of the image and other portions, the classical computer must use additional storage capacity to store this correlation in order to preserve them. Hence, the classical computers need lot of storage space to store the images, and this storage method affects how effectively the images function in parallel computing. Quantum computing is faster than classical computing in terms of data storage and similar computation due to its intrinsic features, including quantum coherence, fragmentation and superposition of quantum states. As a result, researchers can enhance the effectiveness of image processing and computational performance by combining it with quantum computing. The classical bit represents the classical computing and qubit represents the quantum computing as shown in figure 1.

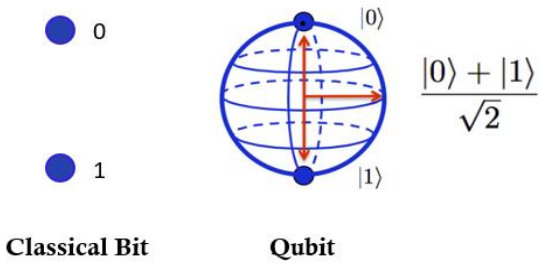

Figure 1. Classical Bit Vs Qubit

2. Related Works

There are a lot of novel mechanisms being developed today. The application of quantum image processing is a recent innovation and a practical technique for advancement. As stated in table 1, some research is concentrated on QuIP.

Liu et al., [1] investigated the quantum sobel edge detection algorithm, which is a specific form of quantum mechanism-based technique for image edge identification, to achieve a more circuit complexity and edge information. This algorithm's advantage is that it requires less storage space.

Pachuau et al., [2] proposed a method of quantum algorithms for constructing the quantum image filters with a nonspecific structure to accommodate various filters. It was used to obtain the edge detection and smoothing operation and produced better images compared to the classical filer.

Fan et al., [3] described a novel enhanced quantum edge detection algorithm that integrates the Laplacian operator and Zero-cross method. It reduces the circuit complexity and also increases the image intensity and provides the image edge extraction in real time problem.

Elaraby et al., [4] claimed a quantum algorithm that provides an efficient image and explained the operation of executing the encoding and enhancing procedures for medical image processing on a quantum computation system as opposed to a conventional one. In medical field, quantum computation improves the image pigments and clarity.

Ranjan et al., [5] studied quantum computing techniques to achieve accuracy using 54 qubit quantum computing and discussed how to improve the quantum image processing method.

Sajeev et al., [6] analysed quantum computing platform to obtain the fast calculation and accuracy using maximum qubits and also provide high prediction accuracy. In medical filed, the thyroid cancer can be predicted using quantum image processing with higher accuracy.

Wei et al., [7] investigated a quantum convolutional neural network (QCNN) to obtain the less noisy image recognition. It means integrating with quantum image processing and handwritten number recognition to achieve noise free and more accurate images.

Table 1. Literature Review

S. No	Reference	Algorithm	Operation	Output	Advantage
1.	Liu et al. [1]	Quantum sobel edge detection algorithm	Sobel operator's vertical and horizontal direction restrictions resulting in less edge data being provided	Achieves more circuit complexity and edge information	It gives less storage capacity
2.	Pachuau et al. [2]	Quantum algorithms	Constructing quantum image filters with a nonspecific structure to accommodate various filters	Obtains edge detection and smoothing operation	It gives better images compared to classical filter
3.	Fan et al. [3]	Novel enhanced quantum edge detection algorithm	This algorithm integrates the Laplacian operator and zero-cross method.	Reduces the circuit complexity and also increases the image intensity	It clarifies the image edge extraction in real time problem
4.	Elaraby et al. [4]	Quantum algorithm	Implementing the encoding and enhancement processes for medical image processing on quantum computation system instead of a classical one	In medical field, quantum computation improves the image pigments and clarity	It provides an effective image
5.	Ranjan et al. [5]	Quantum computing techniques	Focuses on quantum computing for orthogonal image processing	Achieves accuracy using 54 qubit quantum computing	Discusses how to improve the quantum image processing method.
6.	Sajeev et al. [6]	Quantum computing platform	In medical filed, to predict the thyroid cancer using quantum image processing for accuracy.	Obtains fast calculation and accuracy using maximum qubits	It provides high prediction accuracy
7.	Wei et al. [7]	Quantum convolutional neural network	Using QCNN, to obtain the less noisy image recognition.	Integrating with quantum image processing and handwritten number recognition to	Compared to the classical algorithm, it reduces the complexity

				achieve noise free and more accurate images.	
8.	Mastriani et al. [8]	Quantum algorithms	Using Quantum Boolean Image Processing with CBS, it is easy to operate with threshold value. This function is not affected by quantum measurement.	Achieves high-resolution images in grey and colour.	It measures the equivalent noise measurement and avoids the quantum measurement problem
9.	Cai et al. [9]	Quantum algorithms	Describes the image representation, processing algorithm, etc.	Obtains high-resolution images and colour images.	It just requires less memory and has fast computation.
10.	Su et al. [10]	Quantum algorithms, quantum image representation	The stored image is normalised when the quantum state occurs in the quantum superposition state.	The preparation of the volume of quantum bits and quantum images, is made less computationally complex.	Quantum superposition state increases the security of quantum cryptographic protocols.

3.Quantum Image Processing

One of the main types of information that is transferred and stored in digital technology is images. They are commonly employed in daily life situations where multimedia is necessary, such as social networking, medical problem, and satellite communication. Quantum image processing refer to the manipulation of images using a quantum computer as opposed to digital image processing, which is the processing of digital images using a digital computer. A part of quantum information processing is quantum image processing.

Due to the rapid advancement of quantum processing and quantum information, it may be a useful approach to comprehend how visual information behaves. Superposition, synchronization, cohesiveness, and entanglement are just a few of the peculiar aspects of

quantum mechanics that are used in quantum image processing to demonstrate how to store and describe an image in a quantum system.

An architectural similar to the one shown in Fig. 2 is invariably implied by a standard QuIP system. Evidently, this method isn't all that different from the one's quantum computers uses for other tasks. Figure 2 illustrates the need to enter the classical image (digital) into the quantum computer for further processing, which is the job of a quantum algorithm assigned within a quantum computer.

Assuming that the below processing involves filtering out the noise that the digital image introduces from its traditional source, such as a camera, the network it was received across, etc., the quantum algorithm will therefore have the task of eliminating said interference. Incorporating a quantum version of the initial classical information into the quantum computer is obviously the issue.

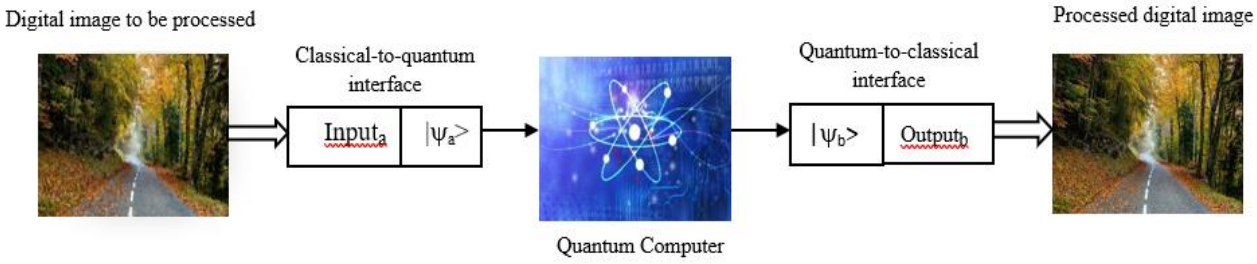

Figure 2. Scheme of Quantum Image Processing

Representations of QuIP

In this study, some aspects of the quantum computing environment's image representation are described.

Simple Quantum Representation

On the basis of the fact that infrared images represent objects' infrared photons energy, a Simple Quantum Representation (SQR) of infrared images is proposed. The Qubit Lattice representation for image features serves as the basis for the SQR model. In this model, the radioactive energy value for each pixel is stored using probability of prediction measuring device rather than the angle variable of a qubit as in qubit lattice recognition. The proposed model is made clearer because the connection between radiation value obtained and probability values can be collected for the limited radioactive energy values. The performance of the proposed with the most recent flexible interpretation of quantum images shows that SQR can

achieve a quadratic increase in speed in quantum image preparation. In the process of image preparation, only simple quantum entrances are used.

Flexible Representation of Quantum Images

A Flexible Representation of Quantum Images (FRQI) is suggested to provide images on quantum computers a recognition in the type of a normalised state that captures data on colours and their relating positions in the images. A quantum video compression algorithm is introduced, and processing operations for quantum images are combined to create a comprehensive framework for quantum image processing on FRQI.

Novel Enhanced Quantum Representation

A Novel Enhanced Quantum Representation (NEQR) method uses the basis states of a qubit pattern to store the grayscale value systems of each pixel within an image. The color features of pixels are not encoded using the angle variables. NEQR uses two entangled qubit sequence data to store the grayscale values and positional details of all the pixels within an image. In this method, a binary sequence that encodes the grayscale value is used to represent the grey spectrum of an image.

Caraiman's Quantum Image Representation

The colour image of the quantum image was encoded using the same pattern of quantum bits used in NEQR by Caraiman's quantum image representation, or "CQIR." The key element of Caraiman's method is its capacity to produce a corresponding histogram of the quantum image, which offered a more efficient method for processing multiple operations like negative energy and binarization.

Multi-Channel Quantum Image

The reconfigured FRQI approach is used to represent the Multi-Channel Quantum Image (MCQI) methodology. The FRQI technique is actually represented in colour by the MCQI. As suggested by its name, MCQI represents the different colour information of an image using R, G, and B channels and maintains the normalized state. In this method, the colour information of an image is encoded using three qubits. In such security and image processing, algorithms are based on phase coding; it is highly flexible because the colour image is realized by a managed phase gate. Moreover, it also uses probability in its image retrieval.

3. Applications

- In the field of medicine, quantum computing techniques and different data mining methods may be combined to recognise diverse visual patterns, image and video processing, automatically monitor environments, and more. Analysis of medical images software that uses morphological image processing also uses quantum information and quantum computation algorithms.
- In military applications, quantum computing and quantum information analysis might be crucial. For instance, a quantum image processing technique (QIMP) can be used to create quantum radar.
- In the fields of astrophysics, QIMP share toward resolving all tasks assigned in image processing.
- In the future, it is possible to create a neural filter that uses NNs to remove noise while also performing mathematical analysis on the statistical characteristics of quantum noise. This method can be used to handle different NN models in the future, including the radial basis function networks and others.
- Researchers must concentrate on a model that is able to use multi qubit states that require dividing pixels with various colours (RGB) to apply unique transformations in order to eliminate the drawbacks associated with the many well-known models discussed. Designing quantum devices for image processing applications is made simpler.

- One of the areas that can use the many aspects of quantum computing to produce better compressed images that really are ideal for storage and processing is quantum image cryptography.

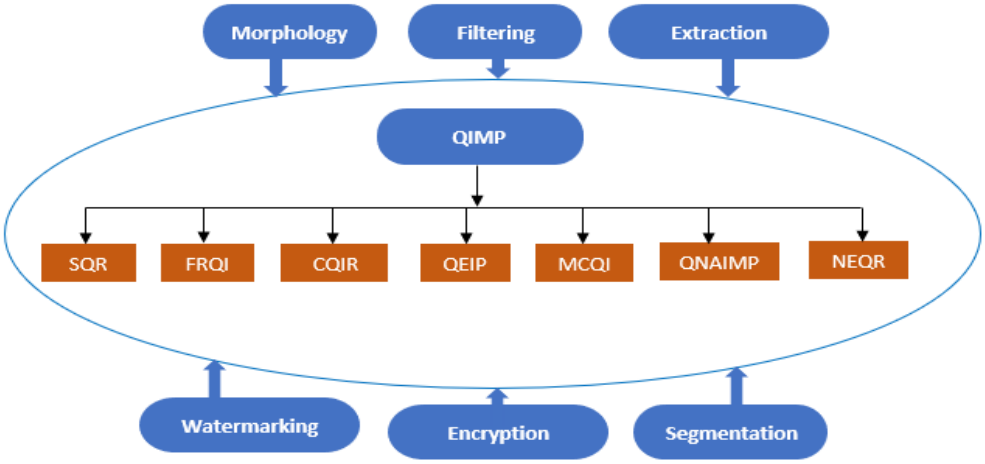

Figure 3. Qir Algorithms and their Applications

QEIP- Quantum Entangled Image Processing

QNAIMP- Quantum Normalized Amplitude Based Image Processing

4. Conclusion

Quantum mechanics has been thoroughly investigated to demonstrate, store, and process images in order to obtain high image processing methodology. The current state of data analysis in the quantum image processing is briefly surveyed in this study. The most recent findings in quantum image representation research are analysed and examined in this review. All these activities are required to bring about the development of QIMP technologies that will enable mankind to fully tap into the enormous potential of quantum information processing as well as quantum computing.

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