Chapter 10
Quantum Discrete Transform for Real-Time Object Detection in Today's Smart Era

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ABSTRACT

The application of quantum technology for remote sensing has been considered for at least the last 20 years. An active imaging information transmission technology for satellite-borne quantum remote sensing is proposed, providing solutions and a technical basis for realizing active imaging technology relying on quantum mechanics principles. Quantum technology is also used in interferometric synthetic aperture radars. A residue connection problem in the phase unwrapping procedure as quadratic unconstrained binary optimization problem can be solved by using the D-Wave quantum annealer. A quantum annealer application has been explored in the past for subset feature selection and the classification of hyperspectral images. In this chapter, quantum discrete transform is proposed and analyzed, which can be used for real-time object detection in distinct fields.

INTRODUCTION

Sensor data has consistently leveraged technological and computational advances helping in developing novel techniques to characterize and model the human environment (Rodriguez-Donaire et al., 2020 and Sudmanns et al., 2019). Given that many remote sensing missions are currently operative, carrying on board multispectral, hyperspectral, and radar sensors, and the improved capabilities in transmitting and saving a continuously increasing volume of sensor data, nowadays estimated in over 150 terabytes per day, the amount of data from sensor applications have reached impressive volumes so that they are

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referred to as Big Data. At the same time, advances in computational technologies and analysis methodologies have also progressed to accommodate larger and higher resolution datasets. Data classification techniques are constantly being improved to keep up with the ever expanding stream of Big Data, and as a consequence, artificial intelligence (AI) techniques are becoming increasingly necessary tools.

Given the need to help expand the processing techniques to deal with these high-resolution Big Data, sensor data processing is now looking toward new and innovative computation technologies (Riedel et al., 2021). This is where quantum computing (QC) will play a fundamental role. Today, there is a number of differing quantum devices, such as programmable superconducting processors, quantum annealers, and photonic quantum computers. However, QC still presents some technological limitations, as reported by (Shettell et al., 2021) with a special concern with noise and limited error correction. Specific algorithms, namely, the noisy intermediate-scale quantum (NISQ) computing algorithms, have been designed to tackle these issues.

Quantum computers promise to efficiently solve important problems that are intractable on a conventional computer. For instance, in quantum systems, due to the exponentially growing physical dimensions, finding the eigen values of certain operators is one such intractable problem, which can be solved by combining a highly reconfigurable photonic quantum processor with a conventional computer.

Another example is the case of the variational quantum eigensolver (VQE) algorithm used to solve combinatorial optimization problems such as finding the ground state energy of a molecule. The algorithm finds a bound to the lowest eigenenergy of a given Hamiltonian. This is, in essence, a kind of cost function, which is defined by the expectation of the molecular Hamiltonian of a given prepared eigenstate. The goal of the VQE is to minimize this cost function by varying the parameters θ used to prepare the ansatz eigenstate often representative of a molecule. This hybrid algorithm prepares and determines eigenenergies through quantum circuits, and then, it varies the parameter classically. By iterating through these classical variations and quantum calculations, a hybrid minimization process is established. This approximation of critical minima is analogous to the gradient descent.

In QC, a qubit or quantum bit is the basic unit of quantum information, i.e., the quantum version of the classic binary bit. A qubit is one of the simplest quantum systems that display the peculiarity of quantum mechanics. Indeed, it is a two-state quantum mechanical system, e.g., an electron in two possible levels (spin up and spin down) or a single photon in one of the two possible states (vertical and horizontal polarization).While in a classical system, a bit can be in one state or the other, qubit exists in a coherent superposition of both states simultaneously, a property that is fundamental to quantum mechanics. Quantum computers utilize the principles of superposition and entanglement to streamline computation. For every n qubits, 2n possible states can be represented. This is an exponential improvement with respect to the classical systems, which can only represent n states for every n bits. Moreover, quantum systems exist in a high-dimensional space, known as a Hilbert space, whose inherent properties lend themselves to a complex linear optimization.

RELATED WORK

With the vigorous development of emerging sensor technologies the huge volume of data gets generated every day. Identification of the intended objects from this huge volume of data is tedious task. Following sections describes various mechanisms developed in recent years for object detections in the data collected from sensors. The comparative analysis of all these reviewed literature is given in table 1.

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