Quantum Convolutional Neural Networks based Image Compression technique using Image Processing

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Abstract

The image compression technique is famous for down-sampling images while preserving the image features. Several methods were proposed earlier for image compression; however, those techniques have some disadvantages, and they lost important features while down-sampling the image. This paper proposed an image compression technique based on the Gaussian pyramid filter image processing technique for Quantum Convolutional Neural Networks (QCNN) in the IBM quantum computing framework for binary image classification. The image is compressed using a Gaussian pyramid filter and fed into QCNN's quantum circuits for state preparation, quantum convolution, and quantum pooling. The proposed QCNN model is trained and evaluated on the MNIST three-dimensional (RGB channel) and one-dimensional (GRAY-scale channel) dataset, and the performance of the QCNN model feature extraction method outperformed the classical convolutional neural network (CNN) in terms of accuracy.

Keywords: Quantum convolutional neural networks, Image classification, Gaussian filter, Image processing, Convolutional Neural Networks.

1. Introduction

Quantum computing and deep learning have shown great promise in recent years, providing previously unheard-of chances to advance image processing methods. Image classification has long been a popular application area for supervised learning, with applications ranging from facial recognition [1] to medical diagnosis [2]. The image classification method generally involves two primary stages: feature extraction and classification based on the extracted features. Before the rise of convolutional neural networks, feature extraction was predominantly accomplished using methods such as scale-invariant feature transformation [3], SURF algorithm [4], and FAST algorithm [5]. In 2023, Guiming et al. [6] proposed two novel local feature extraction techniques inspired by scales that utilize the QCNN within the Tensorflow quantum framework. This study aims to use image compression technique using image processing for QCNN. Therefore, the main contribution is the image processing technique for image compression using the Gaussian pyramid filter. This study proposes a method for improving the retention of image features while downsampling images for binary image classification tasks by including the Gaussian pyramid filter. Finally, the idea is implemented, and the effectiveness of the proposed model is verified to show its effectiveness.

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2. Methodology

The suggested methodology presents a novel technique for compressing images by effectively incorporating the Gaussian pyramid filter into a QCNN structure. The essential aspect of the suggested approach is incorporating a 4-qubit QCNN model into the image compression process. The QCNN utilizes quantum circuits for state preparation, convolution, and pooling tasks. These quantum processes introduce a processing paradigm that is inherently parallel and based on superposition, which may give advantages compared to conventional equivalents. The output image is recreated in the final layer using the acquired features and quantum-processed data. Using quantum entanglement and superposition in the convolutional and pooling layers of the QCNN enhances extracting features from images,

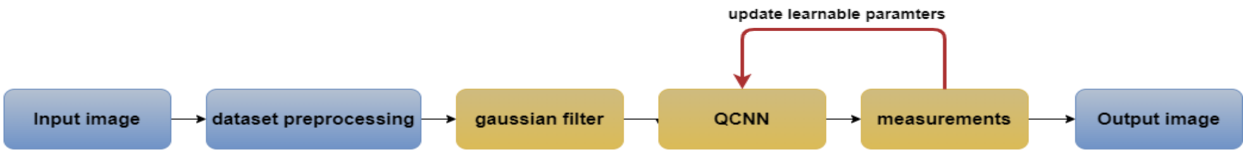

Figure 1. Flowchart of overall process of proposed method.

possibly resulting in higher performance in image classification.

Figure 1 provides a visual representation of the general structure of the suggested technique. This comprehensive methodology integrates traditional image processing methods with the quantum capabilities of a QCNN, demonstrating a promising pathway for increased image compression and feature extraction in the field of quantum-enhanced machine learning.

3. Experimental Analysis

In the training phase, images undergo a distinctive pre-processing stage in which they are compressed and down-sampled using a Gaussian pyramid filter. After the images have been compressed and down-sampled, the altered dataset is fed into the QCNN model, which utilizes quantum circuits. The model incorporates quantum circuits specifically engineered to execute quantum convolutions and extract complex characteristics from the down-sampled images using the distinctive computational capacities provided by quantum computing.

The training routine consists of iterating over 200 epochs, during which the QCNN model adjusts its learnable parameters to enhance accuracy. The model demonstrates exceptional accuracy, achieving a remarkable rate of 98.54% in successfully identifying handwritten digits, as shown in Fig 6. The QCNN architecture reflects its ability to manage the MNIST dataset's complexity accurately, even after undergoing compression and down-sampling steps. This study compared classical CNN with the QCNN model. As shown, the QCNN outperformed and achieved high accuracy against CNN, as demonstrated in Fig.2.

4. Conclusion and Future Work

This research presents a new Gaussian pyramid filter for Quantum Convolutional Neural Networks (QCNN) in image processing. The primary goal is to decrease the computing workload of the QCNN, enhancing its efficiency in image classification. This novel method improves classification accuracy and corresponds with

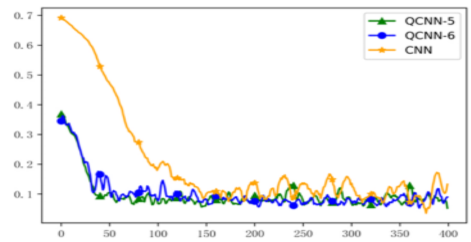

Figure 2. Overall QCNN training results compared with CNN classifier.

the primary objective of resource-efficient quantum image processing. Using the Gaussian pyramid filter is a viable approach to achieve efficient image classification with reduced processing demands in quantum computing.

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References

[1] D. Zeng, R. Veldhuis, L. Spreeuwers, A survey of face recognition techniques under occlusion, IET Biom. 10 (2021) 581–606.

[2] A.J.A. AlBdairi, Z. Xiao, A. Alkhayyat, A.J. Humaidi, M.A. Fadhel, B.H. Taher, L. Alzubaidi, J. Santamaría, O. Al-Shamma, Face recognition based on deep learning and FPGA for ethnicity identification, Appl. Sci. Basel 12 (2022) 2605.

[3] C. Zhang, A.A. Mousavi, S.F. Masri, G. Gholipour, K. Yan, X. Li, Vibration feature extraction using signal processing techniques for structural health monitoring: a review, Mech. Syst. Signal Process. 177 (2022), 109175.

[4] M. Bansal, M. Kumar, M. Kumar, 2D object recognition: a comparative analysis of SIFT, SURF and ORB feature descriptors, Multimed. Tool. Appl. 80 (2021) 18839–18857.

[5] W. Pang, G. Wu, Fast algorithms for incremental and decremental semi-supervised discriminant analysis, Pattern Recogn. 131 (2022), 108888.

[6] Chen, G., Chen, Q., Long, S., Zhu, W., Yuan, Z., and Wu, Y. (2023). Quantum convolutional neural network for image classification. Pattern Analysis and Applications, 26(2), 655-667.