Face Patterns Analysis and Recognition System Based on Quantum Neural Network QNN

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Abstract—The past few years have witnessed a huge increase in the application of facial recognition, detection, and analysis technology. However, face recognition systems remain the most popular among the general public. The facial recognition system can detect the presence of a face when exposed to one. The accuracy and fairness that can be derived from such systems necessitate their use, because humans, particularly security personnel can be tired and target the wrong person as a suspect. However, artificial intelligence systems that are properly trained are capable of efficiently identifying and classifying faces without errors. In this work, the use of Matlab language was employed in building a software system that is capable of recognizing and differentiating different face patterns. The proposed system is equipped with a camera that serves as the practical aspect of the software that captures different shots that are sent to the theoretical part of a special program that is designed to recognize faces by comparing them with a database stored within the program. The practical part of the work involved the use of Quantum Neural Network. In this work, the training dataset is made up of features vectors that were obtained from a well-known set of face images of different people. Here, Principle Component Analysis (PCA) was used for the extraction of feature vectors from images and then prepared for the next training step. The experimental results revealed that efficient face recognition can be achieved through the use of well-trained Quantum Network.

Keywords—artificial intelligence, facial recognition, feature extraction, QNN, PCA

1 Introduction

Academics and industry professionals are increasingly becoming interested in the accuracy of computerized identification systems, due to the increasing security challenges around the world [1]. This interest has resulted in a drastic increase in the number of security applications and systems. A wide variety of algorithms ranging from simple to complex ones have been developed to this end [2, 3]. However, the main question here is "how accurate is the facial recognition algorithm for security applications?"

Over the years, a wide range of commercial products has been developed by the Academic Computer Science Resellers [4, 5]. These products have improved the efficiency of automated identification algorithms in different fields where faces recognition tasks are required. Consequently, the field has advanced with a view of producing systems of high resolution that can effectively perform the task of face identification. Hence, this field appeared to be developed to get a very high-resolution system to identify the faces, which in turn is a final number of applications that begin with children's education programs and end with global security systems [6, 7]. Below is a summary of the steps involved in facial recognition systems:

1. ACQUIRING: Obtain image by capturing.
2. DETECTING: face image is extracted from the entire image.
3. ALIGNMENT: at this stage, the image is subjected to the processes of alignment and image sclerosis, whereby, the facial angle is adjusted to the camera angle.
4. EXTRACTING: the most significant features of the acquired image are extracted at this stage.
5. MATCHING: at this stage, the required image and photo store are matched.
6. REPORTING: The stage of issuing a report closer to the image or dissimilar.

Out of the different measures of biometrics, the most natural is facial recognition. Naturally, this can be regarded as reasonable, because humans are typically able to recognize themselves just by looking at each other's, rather than through irises and thumbprints. More than half of the world has been estimated to be influenced by facial recognition technology in one way or the other [8–10]. The automated facial recognition system works by identifying an individual based on a given picture of that person which was previously stored in the memory of the system [11, 12]. The memory of the facial recognition system is created and extracted from a training dataset. The feature vector refers to any collection chosen from the matrices of the original image. More so, the features vectors are representative of the most significant and critical values in the original images, and hence the reduction of the images' size to vectors that summarize the images. Therefore, the recognition is performing the task of identifying the feature vector which is very similar or closest training set to the feature vector extracted from the image presented for testing (i.e., the image whose identity must be known using the recognition system. A person's identity can be known and differentiated by inputting the person's image into the system; the image that is inputted into the system for identification is referred to as the test image [13–16]. One of the most efficient statistical techniques that have been employed in the field of image recognition and image compression, is the PCA algorithm, whose role is centered on the reduction of large dimensions of data space to smaller dimensions spaces. Under normal conditions, the new spaces are feature spaces, containing the essential and most relevant features of the data within their original spaces. Thus, the size of the data is reduced and made portable through the reduction of dimensions. The reduction of the dimensions is much appreciated at a later stage. The reason why reducing the dimensions is important is that the face recognition systems normally encounter problems when dealing with spaces of large dimensions such as images. There are several ways through which this issue can be addressed; extant data can be matched and transferred to data within a less dimensional [17–19]. Therefore, the process of reducing the dimensionality begins from the original space of large dimensions and then moves to the new space containing smaller dimensions.

Assuming that the following vector in a space of N dimension:

$$x = \left[x_1, x_2, x_3, \ldots.., x_N \right]^T \tag{1}$$

After the reduction of dimensions, it will become another vector in another space of K dimension:

$$y = \left[y_1, y_2, y_3, \ldots.., y_K \right]^T \tag{2}$$

Where K < N

The PCA algorithm is mainly used for the reduction of the data's dimensionality, while as much as possible relevant information is retained within the original data [20]. The process is almost the same as keeping as many variations and modifications as possible in the original data. The data within the space of higher dimensionality is mapped out by the PCA to the matching information within the lower-dimensional subspace; the PCA achieves this through a linear transformation as shown below:

$$y = T_x \tag{3}$$

Where T denotes the transformation in which the value of $\|x - y\|$ is smaller.

The areas of quantum information and quantum computation have witnessed rapid growth, thereby increasing the potentials of quantum neural networks (QNN's. The actualization of QNN has been stimulated by the drastic advancement of quantum computer hardware. Given the quantum properties possessed by the QNN, it is computationally efficient and has greater storage capacity as compared to its counterparts. The areas of disease prediction, image processing, speech recognition, as well as other fields have seen extensive use of QNN. In academia, there are several definitions of QNN, but there is no consensus on a specific definition. However, the most acceptable one defines QNN as a computing paradigm that is a combination of neuroscience and quantum computing [21]. Particularly, quantum theory and neural network model are connected by QNN; QNN achieves this by considering the similarity between the basic quantum computing, two-level qubits, and the active/idle states within the complex process of signal transmission in the nerve cells. It is clear that the system evolves based on quantum effects and it is in conformity to the principle theories of quantum mechanics. Nevertheless, the majority of the QNN models proposed are centered on the aspect of mathematical computations. Such models have failed to address impending issues like the ambiguous physical feasibility of QNN. Also, some of them do not follow the changes that have occurred in the area of quantum effects and are not designed with the characteristics of neural network computing. For this reason, the actual QNNs have not been actualized in real life. Based on a historical development view, there are approximately two phases through which QNN has passed; early-stage and near-term quantum processor stage. previously, it was impossible to implement QNN on quantum computers because of the conditions of the hardware. At that time the proposals of several models were made based on the physical process associated with quantum computing, without any description of particular quantum processor structures like quantum circuits and qubits. The classic example of these kinds of QNNs includes QNN based on dissipative quantum gates, QNN based on multiple world views, QNN analogous to CNN, QNN based on interactive quantum dots, etc. In comparison to results from early studies, the QNN proposed in recent times is broader in meaning. Usually, the concept of QNN is used when referring to a computational model that is characterized by a networked structure and parameters that can be trained, and are implemented through a quantum system and quantum circuit. Furthermore, recent studies have addressed the problem of the model's physical feasibility, as the emphasis is now placed on that aspect of the model. There are several advantages that the QNN offers. Nevertheless, at the current stage of QNN development, the inconsistency between unitary dynamics in quantum computing and dissipative dynamics in neural computing is an area that is begging for a more comprehensive study. In addition, the present QNN is limited by the fact that it can only be trained for larger samples at low latitudes, and the accuracy of prediction and generalization of performance remains a problem yet to be solved. More so, the parameter space of the QNN exponential level experiences the easy formation barren plateau phenomenon.

2 Related work

For the first time in 1980, the concept of quantum computation was introduced by Benioff [22], while the quantum neural computing concept was introduced in 1995 by Kak [4]. Subsequently, a study was conducted by Kak [23] who investigated the concept of quantum neural computing from the perspective of different new directions in neural network research. Also, in 1995, in a study carried out by Menneer and Narayanan [5] quantum-inspired neural network (QINN) was proposed. In another study, Perus [6] presented a discussion on the absorption comparability between quantum parallelism and neural networks. In [24], the use of optical interference was employed in proposing a hypothetical model. To provide in-depth insight into the quantum neural network, the authors [25, 26] presented a comprehensive description as well as a systematic review of the quantum neural network. In the work of Ventura and Martinez [9] which was carried out in the year 2000, the quantum implementation of the associative memory model was proposed. Similarly, Behrman and his associates [27] introduced the idea of physically implementing the QNN as a collection of dots. By means of simulation and experiments, Narayanan and Menneer [28] demonstrated that quantum ANN is not only more. A quantum perception model was introduced by Altaisky [29], who named the model "network with a teacher". Presently, the majority of the models of QNN proposed are self-organized network that does not require human intervention. Also, in the work done by Gupta and Zia [30], a new computational model was defined; the authors named it QNN based on the concept of Deutsch's model of the quantum computational network. In 2003, Kouda et al. [31] proposed Qubit neural network. Karayiannis et al. proposed a model based on multi-level transfer function

Quantum Neural Networks [32]. The multilevel transfer function is adopted by the transfer function of neural cell within hidden layer since the feature of fuzziness is possessed by the network. The model which is based on multi-level transfer function QNN has proven to be of great importance in solving indetermination and crossed pattern problem. In the study carried out in [33], the prediction of weather has been successfully carried out using multi-level transfer function QNN. Similarly, [34, 35] have also used it for voice recognition and diagnosis of disease, etc. QNN is also known as a feed-forward neural network with multiple layers. With the QNN, indeterminate data can be effectively classified [36–38]. The transfer function of the quantum neural network is expressed as a linear superposition of the multi-sigmoid function. Hence it is referred to as a multi-level transfer function [39]. A deep neural network consisting of nine layers was used in the model, which was afterward tested. The model achieved an accuracy rate of 97.35%. The use of three databases was employed in training the model, and the databases include, Youtube Faces (YTF), Labelled Faces in the Wild (LFW), and Social Face Classification (SFC) [28]. The authors in [40, 41] performed the tasks of extracting pattern recognition through the use of an algorithm referred to as Local Vector Projection Classification (LVPC). Six face databases (UMIST, AR, ORL, Yale B, FERET, and Yale). An average recognition rate of 89.48% was achieved by the system [42]. In another study, the authors tested a model designed based on the dictionary learning method. In their work, the model learned features by using Bilinear Discriminative Dictionary Learning (BDDL) [43], while the Collaborative representation-based classification (CRC) was used for image classification in the model. In 2015, the authors in [40] enhanced the CNN model's performance to 0.8763 by combining a fusion network with Joint Bayesian. Nevertheless, the CNN layers are dependent on the size of the data, and as such, there are 2 models used for small size and medium sizes. In other to minimize the training time, the GPU was used in operating the model. The model was tested using public database LFW (Labeled Faces in the Wild) which consists of 13,233 images [44]. It was observed that the extant commercial systems are faced with challenges whenever they are faced with real life tasks. Many authors have made efforts to solve this problem using many software such as Convolutional Neural Networks which has been used for estimation of age, gender, and emotion. The dataset was created by collecting 4 million images from 40,000 people. Nevertheless, human annotators have labelled the images with parts of emotion and gender labels. The proposed software, achieved age classification accuracy of 96.2%, while the score for mean absolute error was 5.76 when the images were annotated, and an accuracy rate of 61.3% when the data was not annotated [45].

2.1 Normalization of transforming image data

Several factors influence the extraction of features, including offset of data and peak-to-peak magnitudes. These occur as a result of the surrounding physiological conditions, artifacts, psychological state, and the parameters of the measurement system. To address the issue, the process of normalization is applied so that the effects of undesirable offset and parameters can be minimized. The process of normalizing transformed image data involves the following steps:

1. Set transformed data's mean value to zero value.
2. Subtract the mean value from the original image data.
3. The mean value of the produced image data after subtraction should be zero or close to zero.

3 Proposing work outline

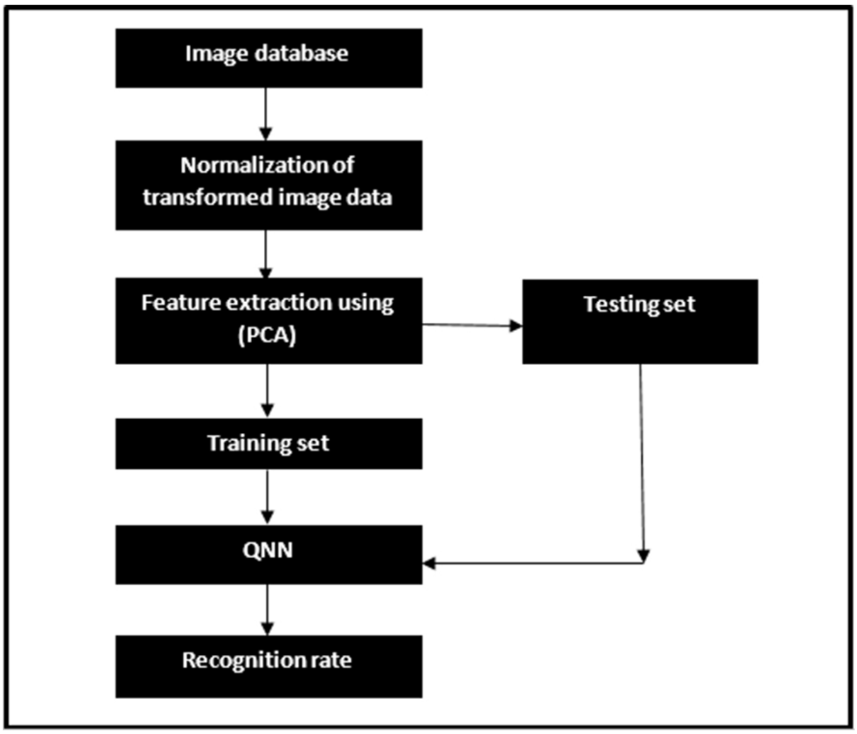

Fig. 1. Block diagram of proposed work

3.1 Project requirements

Two requirements were needed for the completion of this research project. The first is an image that was obtained using cameras. The captured images were saved and obtained from the LFW Face Database. The second requirement involved the construction of special programs through the use of QNN technology as well as Matlab language for the recognition of faces. The software achieves this by sending the images after they have been processed and their most relevant details extracted to the program for the analysis and comparison between the database stored to analyze and compare them with the database stored within the program.

Fig. 2. LFW face database used in this work

3.2 Implementation

The programs used in this study were built and implemented using the Matlab language. The PCA was used to extract the critical features from the image during the preprocessing, while the training set was used to train the quantum neural network; it was trained to differentiate faces using the database with which it was fed. Lastly, the testing set was used in testing the performance of the model, and the corresponding score was recorded.

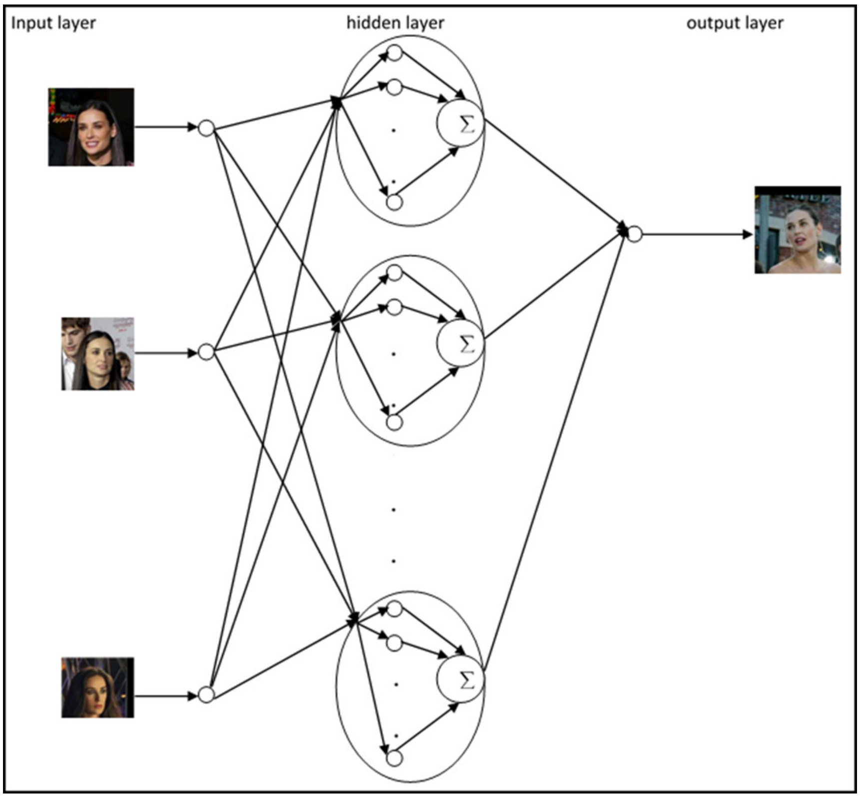

Fig. 3. Structure of QNN for face recognition

3.3 Results and discussion

The QNN's ability to recognize images was examined using the faces of five people. The results obtained have been compared using statistical methods. The performance of the model was evaluated based on the following parameters: Sensitivity (SE), positive predictivity (PP), and Total Classification Accuracy (TCA). The parameters are defined as following [46–48]:

$$\text{Sensitivity (SE)} = \frac{TP_i}{TP_i + FN_i} \tag{4}$$

$$\text{Positive Predictivity (PP)} = \frac{TP_i}{TP_i + FP_i} \tag{5}$$

$$TCA = \sum_{j=1}^{5} \frac{TP_i}{T_r} \tag{6}$$

Where
(TP_i) is the number of images i that have been correctly recognized.
(FN_i) is the number of miss recognition of image i.
(FP_i) is the number of correctly recognized images as another person of image i.
(T_r) is the number of all images in the testing set.

Table 1. Recognition results obtained using QNN and PCA

	TP	FN	FP	Se	PP
Person 1	**4**	**1**	**0**	**0.8**	**1.0**
Person 2	**5**	**0**	**0**	**1.0**	**1.0**
Person 3	**5**	**0**	**0**	**1.0**	**1.0**
Person 4	**4**	**0**	**1**	**1.0**	**0.8**
Person 5	**4**	**0**	**1**	**1.0**	**0.8**
TCA	**89%**				

The effect of the number of epochs on the training phase of the network, is one of the results that were obtained, because there is a certain level of balance between the error rate emanating from the correct non-recognition and the number of those epochs, as shown in Figures 4, 5, 6.

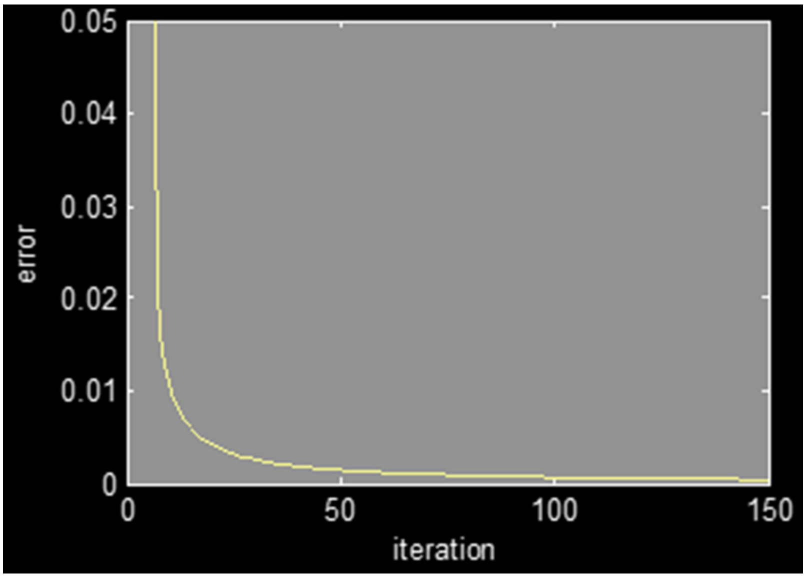

Fig. 4. Error value versus number of iterations (150 epochs)

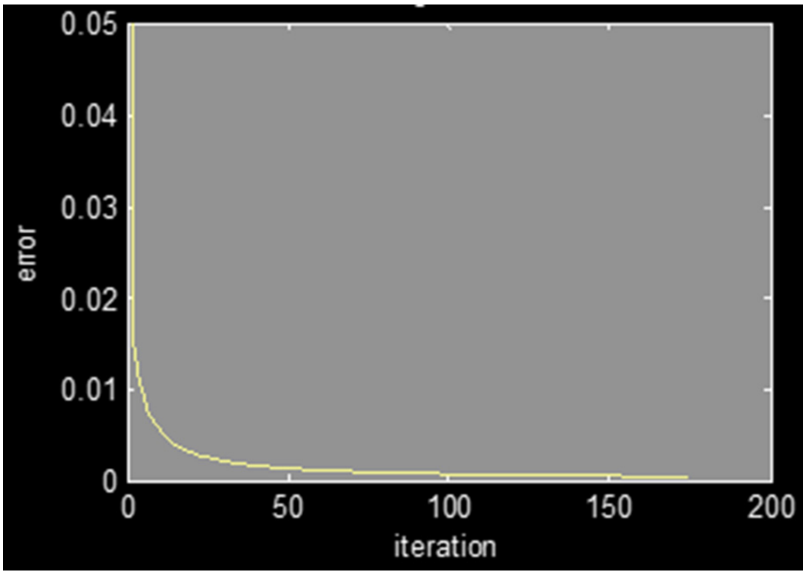

Fig. 5. Error value versus number of iterations (200 epochs)

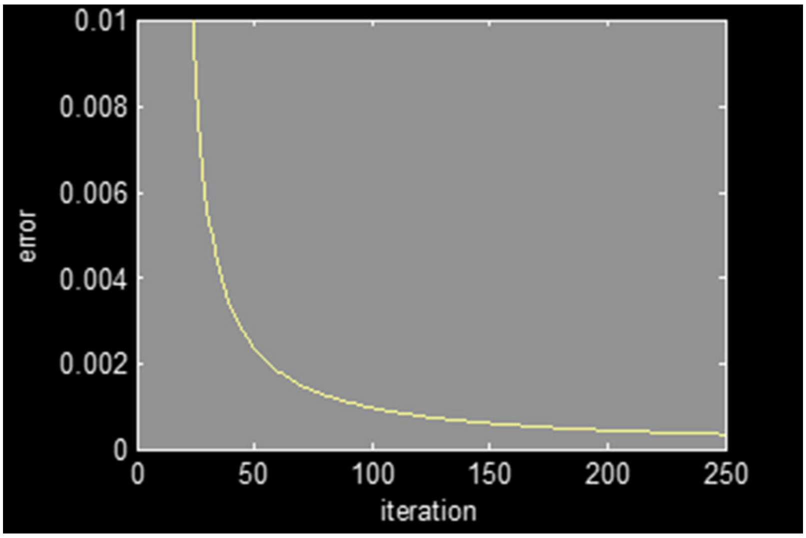

Fig. 6. Error value versus number of iterations (250 epochs)

4 Conclusions

This article presents a system that was specifically designed for the recognition of face patterns through the use of a quantum neural network as well as one component transformed by the PCA so that the most significant facial features can be extracted. Based on the results presented in the tables and figures, the quantum network is capable of achieving correct recognition at a high percentage, even though, the database was not large enough to make generalizations. This is indicative of how efficient the quantum network is as well as the training accuracy. The PCA has demonstrated superior performance in terms of the extraction of the most significant features of the face pattern so that a correct dataset can be built at the training phase. It is noteworthy that the training time represented by the number of epochs is proportional to the error rate which may cause the discrimination process.

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