Improvement Airport Security System with Face Recognition Using Neural Network Based on the Arduino Uno Microcontroller

Sarah W. Abdulmajeed[1, a)], Arwa A. Moosa[2,b)]

[1]Computer Department, Collage of Engineering, Al-Iraqia University, Baghdad, Iraq.
[2]Network Department, Collage of Engineering, Al-Iraqia University, Baghdad, Iraq.

Corresponding E-mail: sara.waleed@aliraqia.edu.iq [a)]
arwa.amir@aliraqia.edu.iq [b)]

Abstract
The aim of this study is to implement an algorithm for face recognition, based on the Arduino uno microcontroller. This paper presents it as an airport security system to detect passenger's face and compare the result with the database of unwanted people. The system combines laser trigger circuit for image capturing and artificial neural network for image recognition. The laser trigger circuit has many benefits such as avoiding camera shakes or taking a picture without a timer. The captured image will be analyzed and processed in MATLAB using an artificial neural network to recognize the passenger's face from the real captured images after the training phase. Many experiments have been conducted on our face databases with various numbers of iterations. The recognitions' accuracy and efficiency of the proposed model are 93.33% and 2.67 respectively with 0.696530 seconds as execution time. The result shows the robustness of the developed model in terms of mean squared error, execution time, recognitions' efficiency and accuracy. The smallest obtained mean squared error is 9.9991e-04 for the training data set and 0.1764 for the testing data set when they are recorded for a modified neural network which makes the developed system more reliable. Finally, the artificial neural network demonstrates the ability to detect the unseen relationship between features belong to the same face.

Keywords*: Face Recognition, Artificial Neural Network, Laser Triggering Circuit, Arduino uno, Arduino - MATLAB Communication.*

1. INTRODUCTION

For many years, face recognition received great attention from the research community due to its wide range of application in identification (credit card ID recognition password), and security (security monitoring systems in buildings and banks or even in some government departments, etc) [1, 2, 3]. The development of biometrics detection has tended to the issues that influence the traditional verification techniques. Biometric usually used a dynamics signature for human features extraction like a fingerprint, iris, face, and speech in order to be used for confirming a person's identity. Biometric recognition is based on unique human features this makes it a very effective method because this information cannot be shared or stolen [3]. Face recognition has a high attraction because it can be integrated into multimodal biometric and surveillance systems [4].

In real-world applications, it is required to have an independent system for face recognition because it gives more protection,

equipment improvement and simplicity of joining. To satisfy this aim, field-programmable gate array (FPGA) is utilized to implement real face recognition [5].

Face recognition system could be developed as a three-phase process [6]. In the first phase, the face was detected and localized which is the fundamental part of recognition face. The procedure of face recognition in pictures is very complex due to the changeability that presents across human faces such as the facial expressions, orientation, skin color, pose, facial hair and the presence of glass, different camera gains, image resolution, and lighting conditions. Face detection ought to be performed before recognition. This is done to differentiate significant data from the face and facial expression analysis which is considered as the second phase of processing [7]. Finally, the face is distinguished by comparing the results with the database. This phase did comparison method using accuracy measures and classification algorithms [6]. Different studies of face recognition algorithm-ms and applications were proposed such as the work presented in 2011 [8]. Face recognition technique was developed using high-intensity feature vectors which were obtained from Gabor wavelet transformation of the personal images. This method was combined with Independent Component Analysis (ICA). Another approach was proposed to extract the features in [8] to increase the strength to varieties in facial and geometry. This was achieved by using the capabilities of the discrete cosine transform (DCT) combine together with an illumination normalization approach in the logarithm domain. whilst in 2018, the work presented in [9] used Convolution Neural Network to recognize the face. The results of the aforementioned work showed that high recognition accuracy and high robustness in the complex environment were obtained because an open source of deep learning processes was used.

Ways for face recognition can be separated into two groups, First ways based on information extracted from face images and second, ways based on appearance which use the raw pixel data such as intensity histogram [10]. In this paper, a real dataset is used as the project's raw data. This dataset is characterized by high variation in the position of the face from the tacking picture which is one of the most important challenges in face recognition applications. Using real dataset in the real world has some difficulties such as the face may be appeared in different locations in the image, different image size (pixels dimensions), and various backgrounds. The other contribution is the use of system rejoinder in MATLAB-Arduino communication program as a response to the result of the recognition phases from the developed face recognition system that is based on artificial neural network and error backpropagation algorithm. The proposed approach in this paper initializes from the identification process which starts by localization and segmentation of the input image and then tries to locate and extract the face part from the input image for subsequent processing.

2. RELATED WORK

The researchers introduced a facial recognition paradigm based on principal component analysis, genetic algorithms, and support vector machines, in which principal component analysis is used to minimize unrelative information, genetic algorithms have been utilized to refine research design, and support vector machines are used to achieve classification [11]. The work in [12] applied shallow CNN, Alex-Net, and enhanced VGG-19 deep CNN to recognize the facial expression data on the Extended Cohn–Kanade expression database. The finds show that the improved VGG-19 network model can recognize facial expressions with 96 percent accuracy, which is clearly superior to the performance of other network models. Another research implements a face recognition algorithm on a field-programmable gate array (FPGA) chip. The accuracy of the data is 79%, and the benefit of the presented method is the ability to deal with images in real-time in [5]. The development of a machine learning algorithm

for real-time facial expression recognition is the subject of this article. Two of the most common approaches for facial recognition are explored, simulated, and introduced using the Raspberry Pi in [13]. In [14], designing a face recognition approach is introduced utilizing a machine learning algorithm and principal component analysis (PCA) to automatically detect the face of the person from an image. Furthermore, using PCA and linear discriminant regression, the obtained identification precision of 97 percent and 100 percent respectively. An automated door access method based on face recognition and detection is proposed in this study. The Viola-Jones approach is used to detect the face, and Principal Component Analysis is used to apply face recognition (PCA) [15]. The purpose of this work is to create a Convolutional Neural Network-based face recognition application for a biometric device. It introduces a Deep Learning model structure that can improve current state-of-the-art precision and processing time [16]. A light-CNN based on an updated VGG16 model is employed in this to identify faces with a small dataset. The proposed light-CNN is small, but it performs well, with a 94.4 percent accuracy [17]. This paper introduces the idea of Face Recognition-based Smart Glasses, which would serve as a new method for implementing security initiatives. Authentication mechanisms can now be performed efficiently using this technology by classifying individuals using a convolutional neural network [18]. In [15] involved essentially of three sub-phases: face detection, face recognition, and automatic door access control. The Viola-Jones method is used for detecting the face and the Principal Component Analysis (PCA) is used to implement the face recognition.

3. METHODOLOGY

S Smart Airport Security System (SASS) is designed to maintain and improve safety and security in a cost-efficient way of saving manpower. In this paper, the system is designed and implemented in two stages: hardware and software.

3.1 Hardware Structure Specifications

In this project, the face recognition pattern was used for recognizing the unwanted people before boarding to the airplane, as a security process. The system was designed and implemented for the smart airport is shown in Figure 1. Any passenger should be passed through the checkpoint before boarding to the airplane. At the checkpoint,passenger's information will be checked up by the following steps using the security setup shown in Figure 2:

Figure 1. The Smart Airport Security System (SASS) experimental setup diorama.

1. When the passenger cut off the laser line at the checkpoint, a picture will be taken automatically using a laser triggering circuit. The laser trigger circuit is used for triggering camera capturing remotely. This type of triggering has many benefits such as avoiding camera shakes or taking a picture without a timer. Laser trigger circuit composed of a webcam, LED-laser, relay and an LDR sensor with Arduino UNO as depicted in Figure 3.
2. A real image will be captured and saved in the airport-security computers for analysis and recognition processes using the MATLAB software (explained in details in Sec. 2.2)
3. The result of the recognition from Step 2 will be sent from MATLAB to Arduino using communications software tools. If the passenger will be recognized from the unwanted people, then the passenger's information will be sent to the security center and the buzzer will be released.

4. On the other hand, if nothing is recognized, then the gate-door will be opened automatically using Arduino servo motor and the passenger passed through and boarding to the airplane.

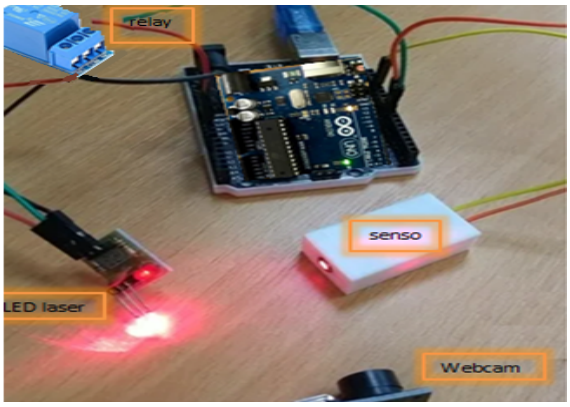
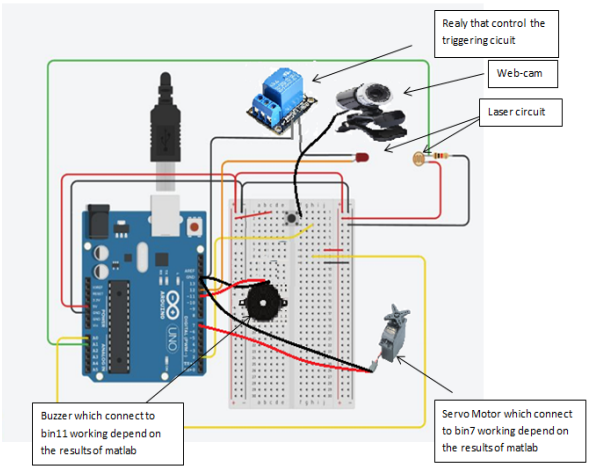
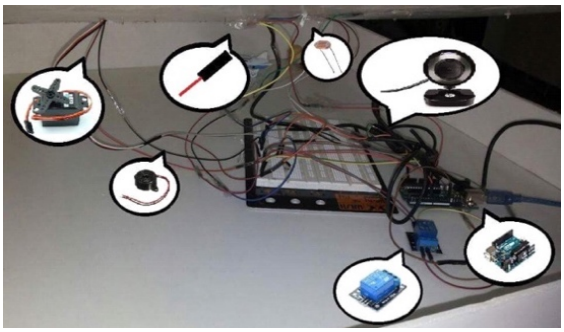


Figure 2. The laser trigger circuit.



(a) The interconnection of the suggested system components



(b) The tested of the suggested SASS

Figure 3 b the security system setup with the laser trigger circuit

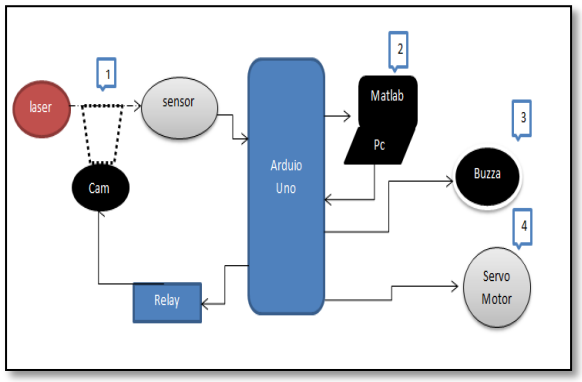


Figure 4. Security system steps.

3.2 Software Specifications

The design of the system is demonstrated in five phases. The first phase starts when the image of the passenger is acquired by a web camera. Then the second phase is followed by extracting the face from the captured image. During the third phase, a number of preprocessing operations are applied to the image from the second phase. While in the fourth phase, the relevant information is extracted using a discrete wavelet transform (DWT). Finally, the neural network is applied to recognize the input image in the fifth phase. The general model of the proposed system is illustrated in Figure 4.

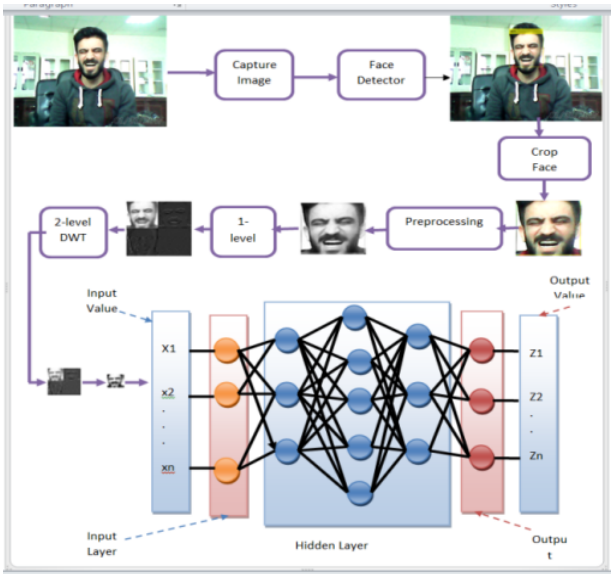


Figure 5. The block diagram of the developed face recognition system.

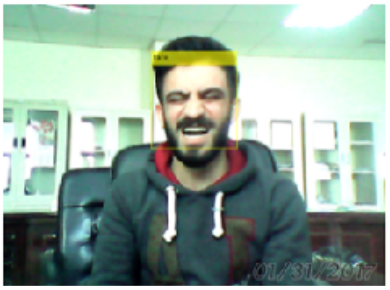
1) Phase 1: Image Preparation

The first stage consists of the image captured using a web camera with the laser trigger

circuit. The image was captured by cutting the laser line by the passenger while the size of the captured image is 480×640×3 as shown in Figure 5.

2) Phase 2: Face Detection

Locating faces in an image and extracting the face parts only is depicted in Figure 6. This phase is done using MATLAB.



(a) Image after Face detector

(b) Face components

Figure 6. Captured Image

3) Phase 3: Preprocessing

Preprocessing is the group of operations that are applied to the image for enhancing its quality. It is a necessary part in any computer vision system. A standard color format of the image is RGB (Red, Green, and Blue). The captured image is converted to grayscale and then normalized in order to reduce the effect of lightning source amplitude's variations. Figure 7, shows the image after preprocessing stage.

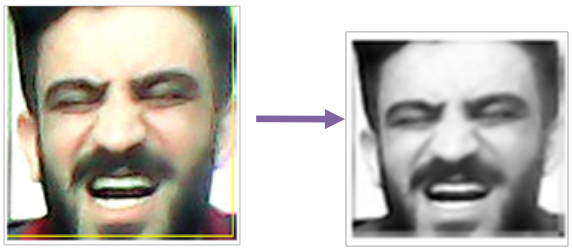
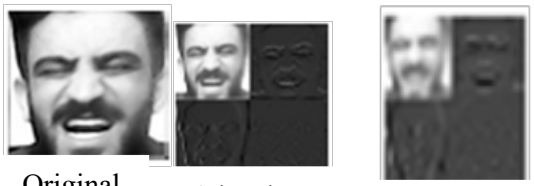


Figure 7. Image after the preprocessing stage.

4) Phase 4: Feature Reduction

Discrete wavelet transform (DWT) is used for features reduction. DWT can decompose images into various multi-resolution subbands. The aim of this operation is to extract relevant information from the image [19]. The size of input image (70×70) pixel is decomposed up to (1 and 2) level using Haar wavelet transform. From Figure 8, the most energy focused in the first quarter and the other bands represent its reflections.



Original Image 1-level 2-level

Figure 8. The DWT of the original image for level-1, level-2.

5) Phase 5: Artificial Neural Network Classifier

The artificial neural network (ANN) is a collection of units that are connected by the weights with the ability to learn from their environment. It is provided reliable predictions because it is inferred essential information from hidden data [20]. The artificial neural network is used to assign the new input to one of the categories of the training data.

The ANN architecture that is utilized in this work has two differences from the standard one. Firstly, each input in the training set is assigned to output when needed. Secondly, an additional layer is added after the output layer which is called the competitive layer. This layer recognizes winner output with the highest value among all other outputs and gives the final classification result. The proposed model of the artificial neural network classifier is shown in Figure 9. For ANN classifier, the network structure is $n_i - n_h - n_o$. It has an input layer with n_i input nodes, a hidden layer with n_h hidden nodes and n_o output nodes in the output layer. The number of output nodes is equal to the number of the person in our dataset. Suppose $X_{ni} = \{x_1^k, x_2^k, x_3^k, \dots, x_{ni}^k\}$ $\forall\, k = 1,2,\dots,m$ be the m is total number of vector in the training set and n_i is the number of elements of each input vector. a_{lj} weight connection between input nodes and hidden nodes and b_{ji} weight connection between hidden nodes and output nodes. The $z_1^k, z_2^k, z_3^k, \dots, z_{no}^k$ is the actual

output and the output of competitive layer in equation (1).

$$W = \text{maximum}(z_{no}) \quad \text{Eq. 1}$$

A sigmoid function (sig) is used in hidden nodes. The desired output of the matrix is the number of people multiplied by the number of images. If the number of images is 3 for each person then the desired output matrix is 9×3.

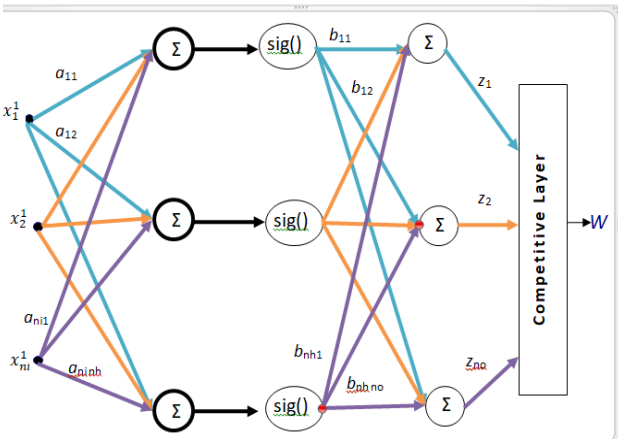


Figure 9. The proposed model of the artificial neural network classifier.

The face part is extracted in the training set, then normalized and converted into grayscale. After the feature reduction, the image size is 18×18. Finally, the resulting image is flattened into a single vector and fed into the neural network. The parameters of the proposed model as shown in Table I. The classifier is then trained until the error between the real output and the target output is less than the threshold value (ε) or the maximum number of epochs is reached. At this point, a neural network can be able to recognize which image belongs to a pre-defined class.

Table 1. The parameters of the proposed artificial neural network model

Parameters	Values
Image Input layer	18×18=324
Hidden layer nodes	2×input nodes=648
Hidden layer	One hidden layer
Learning rate	0.1
Output nodes	3
Desired output	3

3. TESTING RESULTS AND EVALUATION

The performance of the introduced system is demonstrated based on face recognition for the airport security system as a case study. Classification accuracy, mean squared error, classification time and recognition efficiency are used to measure the performance of the developed system. The classification accuracy is given in equation (2) [19]. While the classification time is time taken for all processing in the face recognition phase. When the classification time is small, the model of the system is simple. The system efficiency is defined in equation (3) [11].

$$\text{Accuracy} = \frac{\text{Total number of correct reconition}}{\text{Total Number of sample}} \quad \text{Eq. 2}$$

Table 2. The Obtained results of the developed system.

Iteration	MSE for Training Set	MSE for Testing Set	Accuracy for Testing Set	Classification time (sec)
50	0.0745	0.3832	73.333333	0.156682
100	0.0268	0.2049	86.666667	0.175138
1000	9.9991e-04	0.1764	93.333333	0.696530

$$\text{Efficency} = \log \frac{E_n}{I_n} \quad [11] \quad \text{Eq. 3}$$

Among them En is the wrong sample number, in is the number of iterations.

4. DATASET

The face database is a facial dataset for Iraqi students collected at Al-Iraqia University/ College of Engineering. In January 2017. There are 14 students participated in the image collection stage, these include 13 males and one female with a total number of 140 captured images. The dataset is this work can better reflect the changes in facial expression

under various conditions. There are seven kinds of changes include illumination change, posture change, expression change, occlusion and decoration change, background change, distance change, and time span change. Each person has 10 images with a resolution of 480×6403. The first five images from each individual in the database are selected for the training set and the rest of the captured images are included in the test set. The training images take 50% (70 images) from the total image and the rest of the image are used for the testing system. A sample of the face images is shown in Figure 10.

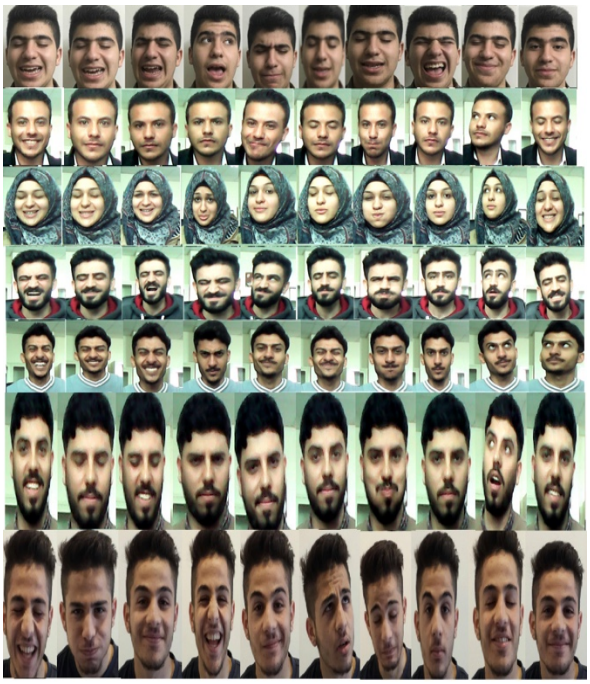


Figure 10. Sample images from the dataset of the developed system.

5. RESULTS

Several experiments have been conducted on the collected face dataset with a different number of iterations. The obtained image (18×18) is flattened into a one-dimensional vector and feed it into an input layer of the artificial neural network. All the parameters (number of hidden nodes, number of iterations, learning rate (α)) were chosen for all experimental scenarios by trial-and-error. The obtained results are summarized in Table II. The accuracy was obtained 93.3333, mean squared error 0.1764 and time of classification 0.69653 over 1000 iterations. Figure 12 shows the performance of the proposed method.

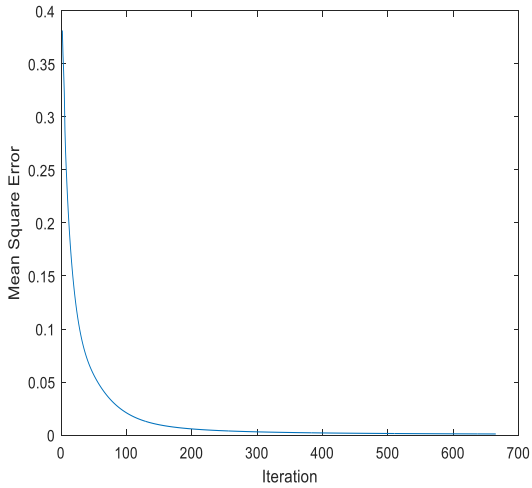


Figure 11. The mean squared error versus iterations.

The structure of the proposed system is 324-648-14, 324 is the number of input nodes in the input layer, a double number of input nodes in the hidden layer, the output classes is 14. The number of iterations was selected to be 1000. The input and output weights were learned at each iteration with learning rate 0.1.

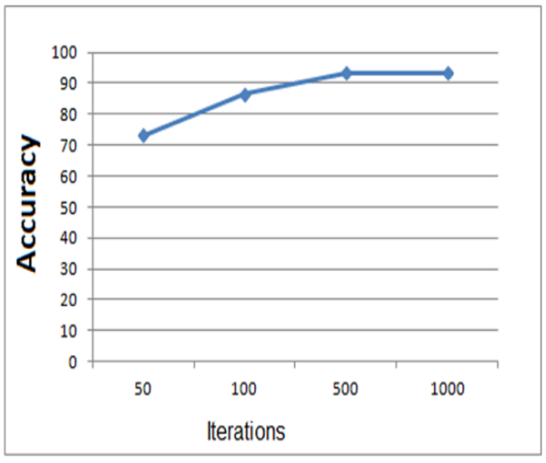
6. DISCUSSION

This paper introduced a new model for human face recognition in an advanced security system. The performance of the artificial neural networks (accuracy of recognition and efficiency of recognition) depends on the number of iterations. It is very necessary to find the optimal number of iterations that will improve accuracy and efficiency recognition. Therefore, a comparative evaluation was carried out on the different experiments, including the measure of various parameters as shown in Table 3.

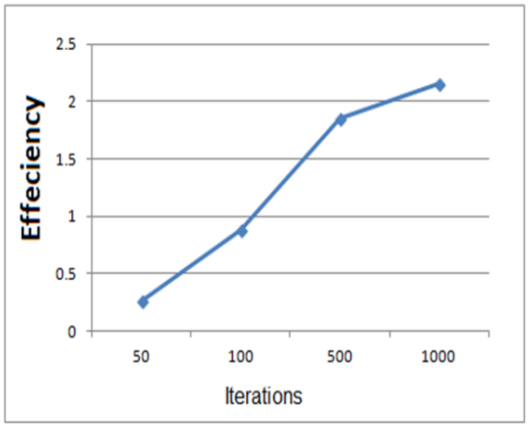
Table 3. Comparison of face recognition results.

Iteration	Number of the Wrong Samples	Accuracy for Testing Set	Absolute Efficiency of Classification
50	27	73.333333	2.154
100	13	86.666667	0.886
1000	7	93.333333	0.267

The number of iterations in artificial neural networks is directly affected by the recognition rate (efficiency and accuracy recognition). In order to improve the recognition rate, it is very important to find the optimal number of iterations. Figure 12 shows the relationship between the recognition rate and the number of iterations. It can be seen that the recognition rate increases with the increase in the number of iterations. This means that the artificial neural networks learned more and more the system behavior. In other words, the artificial neural network can be able to capture relevant information from the face than another region in the image and map the detected face to the right class. The result shows the efficiency and accuracy recognition can be balanced at 1000 iteration.



(a)



(b)

Figure 12 (a,b): the relationship between the recognition rate (efficiency and accuracy recognition) and training iterations.

7. CONCLUSIONS

In this paper, the design and implementation of a smart face recognition system are developed and presented as a new approach for security systems in the airport. The developed system introduces secure identity management systems for police and governments. It will be helpful to arrest the wanted people. The framework depends on the laser trigger circuit, image processing in addition to artificial neural network techniques. Thus, the main accomplishment of this work is to enhance the performance (accuracy and efficiency recognition) for face recognition. This paper is not only illustrated the distinct ability of the proposed approach to detect and recognize faces in an image but rather demonstrates the robustness of the developed model in terms of mean squared error, execution time, efficiency and recognition accuracy. After the artificial neural networks learned from the input, initial parameters, and their relations, it can predict the unseen relationship between features belong to the same face. The result shows that the artificial neural network modelling can be used as a good approach in face recognition applications because of its ability to learn

hidden relationships in the data without imposing any fixed relationships in the data.

The future work of this paper is to use the Quantum Recurrent Neural Network for face recognition in order to improve the execution time.

REFERENCES

[1] L. Hui and S. Yu-jie, "Research on face recognition algorithm based on improved convolution neural network," *2018 13th IEEE Conf. Ind. Electron. Appl.*, pp. 2802–2805, 2018.

[2] E. Kussul, "Face Recognition Using Special Neural Networks," *2015 Int. Jt. Conf. Neural Networks (IJCNN). IEEE*, 2015.

[3] S. A. Nazeer, N. Omar, and M. Khalid, "Face Recognition System using Artificial Neural Networks Approach," *IEEE - ICSCN 2007*, pp. 420–425, 2007.

[4] E. J. Leavline, H. X. P. Rajan, D. A. Antony, and G. Singh, "Feature Extraction and Classification Framework for Face Recognition System," *Int. J. Appl. Eng. Res. ISSN 0973-4562*, vol. 10, no. 55, 2015.

[5] P. Gate and A. Fpga, "Implementation of Face Recognition Algorithm on Field," *J. Circuits, Syst. Comput.*, vol. 28, no. 8, pp. 1–25, 2019.

[6] M. Roomi, "A Review Of Face Recognition Methods," no. April, 2013.

[7] O. N. A. Al-allaf, "R EVIEW O F F ACE D ETECTION S YSTEMS B ASED A RTIFICIAL N EURAL N ETWORKS A LGORITHMS," vol. 6, no. 1, pp. 1–16, 2014.

[8] A. Kar, D. Bhattacharjee, D. K. Basu, M. Nasipuri, and M. Kundu, "High Performance Human Face Recognition using Independent High Intensity Gabor Wavelet Responses : A Statistical Approach," vol. 2, no. 1, 2011.

[9] L. Yuan, Z. Qu, Y. Zhao, H. Zhang, and Q. Nian, "A Convolutional Neural Network based on TensorFlow for Face Recognition," *YUAN, Liping, al. A convolutional neural Netw. based TensorFlow face recognition. 2017 IEEE 2nd Adv. Inf. Technol. Electron. Autom. Control Conf. (IAEAC). IEEE*, pp. 525–529, 2017.

[10] Z. Wu, R. Xiamixiding, A. Sajjanhar, J. Chen, and Q. Wen, "Image Appearance-Based Facial Expression Recognition," *Int. J. Image Graph.*, vol. 18, no. 2, pp. 1–12, 2018.

[11] H. Zhi and S. Liu, "Face recognition based on genetic algorithm," *J. Vis. Commun. Image Represent.*, vol. 1, no. 58, pp. 495–502, 2018.

[12] S. Cheng and G. Zhou, "Facial Expression Recognition Method Based on Improved VGG Convolutional Neural Network," *Int. J. Pattern Recognit. Artif. Intell.*, vol. 34, no. 7, pp. 1–16, 2020.

[13] S. Singh, R. Ramya, V. Sushma, S. Roshini, and R. Pavithra, "Facial Recognition using Machine Learning Algorithms on Raspberry Pi," *4th Int. Conf. Electr. Electron. Commun. Comput. Technol. Optim. Tech. ICEECCOT 2019*, pp. 197–202, 2019.

[14] A. Bhadauriya, "Face Recognition System using Machine Learning in GUI," *Int. J. Res. Appl. Sci. Eng. Technol.*, vol. 8, no. 7, pp. 218–221, 2020.

[15] I. O. P. C. Series and M. Science, "Automated door with face recognition : using artificial neural network approach Automated door with face recognition : using artificial neural network approach," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 1052, no. 1, p. 012060, 2021.

[16] K. Tao, Y. He, and C. Chen, "Design of Face Recognition System Based on Convolutional Neural Network," *Proc. - 2019 Chinese Autom. Congr. CAC 2019*, vol. 10, no. 3, pp. 5403–5406, 2019.

[17] A. B. Perdana and A. Prahara, "Face Recognition Using Light-Convolutional Neural Networks Based on Modified Vgg16 Model," *2019 Int. Conf. Comput. Sci. Inf. Technol. ICoSNIKOM 2019*, pp. 14–17, 2019.

[18] S. Khan, M. H. Javed, E. Ahmed, S. A. A. Shah, and S. U. Ali, "Facial recognition using convolutional neural networks and implementation on smart glasses," *2019 Int. Conf. Inf. Sci. Commun. Technol. ICISCT 2019*, pp. 1–6, 2019.

[19] S. M. R. Taha and D. Ph, "Analysis and Classification of EEG Signals based on a New Quantum Inspired Wavelet Neural Network Model," *Int. J. Comput. Appl. (0975 – 8887)*, vol. 92, no. 5, pp. 23–30, 2014.

[20] S. M. R. Taha and Z. K. Taha, "EEG signals classification based on autoregressive and inherently quantum recurrent neural network," *Int. J. Comput. Appl. Technol.*, vol. 58, no. 4, pp. 340–351, 2018.