Towards more accurate and efficient human iris recognition model using deep learning technology

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ABSTRACT

In this study, an end-to-end human iris recognition system is presented to automatically identify individuals for high level of security purposes. The deep learning technology based new 2D convolutional neural network (CNN) model is introduced for extracting the features and classifying the iris patterns. Firstly, the iris dataset is collected, preprocessed and augmented. The dataset are expanded and enhanced using data augmentation, histogram equalization (HE) and contrast-limited adaptive histogram equalization (CLAHE) techniques. Secondly, the features of the iris patterns were extracted and classified using CNN. The structure of CNN comprises of convolutional layers and ReLu layers for extracting the features, pooling layers for reducing the parameters, fully connected layer and Softmax layer for classifying the extracted features into N classes. For the training process and updating the weights, the backpropagation algorithm and adaptive moment estimation Adam optimizer are used. The experimental results carried out based on a graphics processing unit (GPU) and using Matlab. The overall training accuracy of the introduced system was 95.33% with a consumption time of 17.59 minutes for training set. While the testing accuracy 100% with a consumption time of 12 seconds. The introduced iris recognition system has been successfully applied.

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1. INTRODUCTION

The biometric technologies regarded as one of the most accurate, a common and reliable recognition systems in the authentication and identification in different security applications such as control of the borders [1], [2], authentication [3], forensic [4] the bank services and payments and commercial processes [5]. Recently, demand has increased for improving the daily life security in the digitalization direction in order to enhance the reliability and intelligent identification systems using biometrics. The deep convolutional neural network (CNN) is a class of artificial intelligence and has the ability to learn and extract the attributes automatically similar to a human mind, whereas the classical neural network has the inability to learn attributes automatically. There are many deep CNN architecture such as GoogleNet [6], AlexNet [7], residual neural network (ResNet) [8], and visual geometry group (VGGNet) [9]. Daugman [10] introduced the iris identification model based Gabor filter and Hamming distance using different iris dataset with high accuracy and speed. Omran and AlShemmary [11] has proposed iris recognition system called IrisNet for extracting the attributes of the Indian Institute of Technology Delhi (IITD) V1 iris dataset and classifying them automatically. The structure of the IrisNet comprised of different CNN layers and trained using backpropagation algorithm and Adam optimizer. Alaslani and Elrefaei [12] has proposed pre-trained network based AlexNet model with support vector machine algorithm for extracting the attributes and classifying the standard and segmented iris images based on four datasets: IITD, Chinese Academy of Science Institute for Automation (CASIA) ver1.0 CASIAIris-V1, CASIA-Iris-thousand and CASIA-Iris-V3 with achieving excellent performance with a very high accuracy rate. Minaee and Abdolrashidi [13] has proposed an automated deep learning framework based residual CNN for iris recognition system. This system is trained and tested on IIT Delhi iris dataset with high accuracy rate. Wang *et al*. [14] has introduced an eye recognition framework utilizing deep learning based a mixed convolutional and residual network (MiCoRe-Net) and achieved excellent accuracies on the CASIA-Iris-IntervalV4 and the University of Beira Interior Iris (UBIRIS.v2) datasets. Azam and Rana [15] has introduced iris recognition system using CNN and SVM for features extraction and classification, respectively based on CASIA database. In [16], [17] presented hybrid model utilizing deep learning technlogy based CNN, segmentation approach imag preprocessing for noisy iris dataset. In [18], [19] have suggested an autmated and efficient recognition system using CNN based histogram equalization (HE) and contrast-limited adaptive histogram equalization (CLAHE) techniques for intensive enhancement and detection of coronavirus disease of 2019 (COVID-19) chest X-ray images. Althabhawee and Alwawi [20] has sugessted an accurate new CNN model for fingerprint matching for authentication purposes. In [21]-[23] have applied real time object detection model for blind and visually impaired people utilizing you only look once (YOLO) algorithm, USB camera and Raspberry model B Pi 3. The proposed approach has been successfully achived the targeted goal and increased the efficiency of recognition system. Most of the studies mentioned above either used sophisticated approaches or dealt with fixed size and type of the images. Accordingly, in this study a new structure of deep CNN is presented as a high-level of security identification system which detects iris patterns automatically. The proposed classifier architecture for classifying iris patterns with minimum cost process and calculation time is analyzed. This paper is structured as follows. In the second section, the description of the proposed iris recognition model utilized deep learning technology based CNN is presented. The third section discusses the experimental results of the proposed model. The fourth section introduces conclusion and futures work.

2. METHODOLOGY OF IRIS RECOGNITION MODEL

In this section, the methodology for proposed iris recognition model will be discussed. Figure 1 illustrates the structure of the proposed model which consists of five steps that are:

1. Dataset collection
2. Image preprocessing and augmentation
3. Attributes extraction
4. Classification
5. Matching

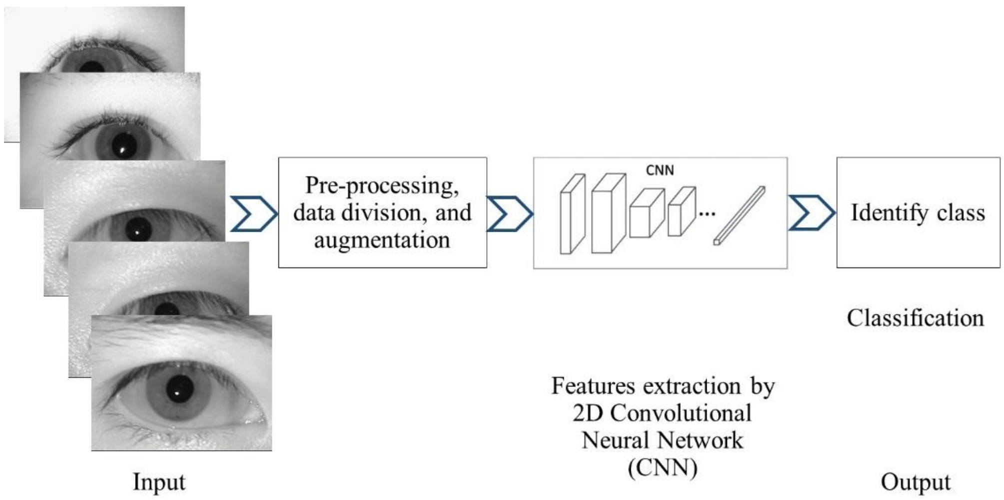


Figure 1. Proposed iris recognition model

2.1. Collected dataset

Multimedia University (MMU) database [24] is collected from a public available database which is composed of iris patterns which can be used for training process based biometric identification models. The uniqueness of the Iris images for each eye in every person is useful for individual identification. This dataset comprises of 460 images for 46 persons with 5 images for each the left and right eye [24]. The iris images are color with the size 320×240 pixel for each image and with depth as 3 dimension or channels. A samples of MMU iris database are presented in Figure 2.

Figure 2. Samples of MMU iris dataset

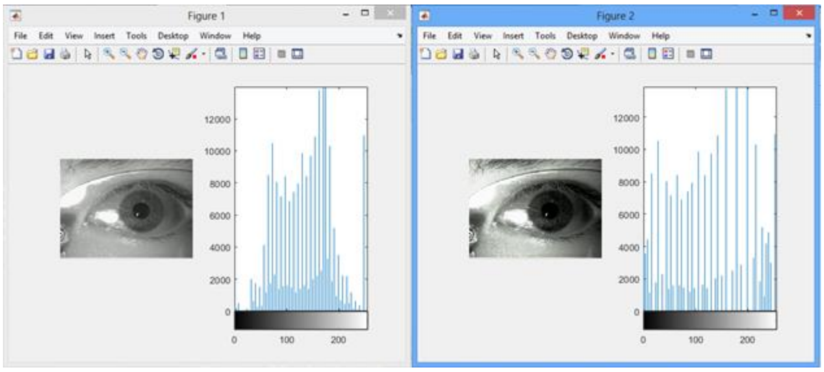
2.2. Pre-processing and data augmentation

In this step the iris dataset preparation will be done to be used in the training model. The classification accuracy of the deep learning techniques can be improved by image preprocessing and augmenting the existing data better than collecting new raw data [25]. Thus, the variety of available data can be greatly improved the performance for the training models. Data augmentation is very important technique for creating better database and enlarging its size. As well as when the dataset is imbalanced, image augmentation technique is essential to balance the dataset. In this study, the raw dataset includes 460 iris images. Therefore, it was important to augment images for increasing the size of dataset usin image data augmenter tool in Matlab deep learning toolbox [26] for generating sets of augmented images and creating modified versions of images in the dataset such as images cropping, shifting, scaling, shearing, and flipping, as demostrated in Table 1.

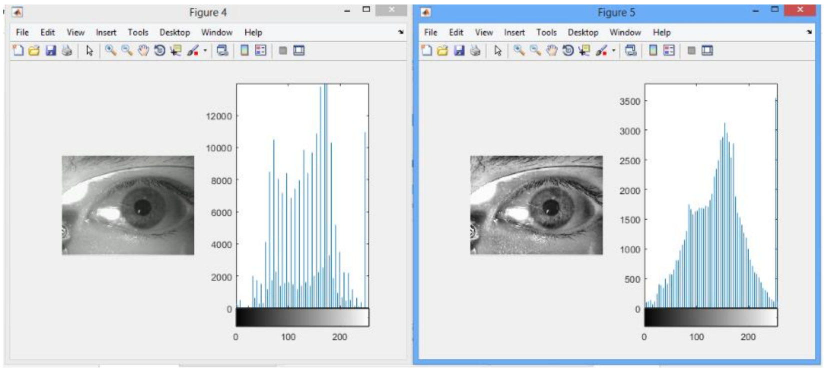
Table 1. Used parameters of the data augmentation

Name	Value
Zooming	20%
Rotation	10
Shifting	Vertical/horizontal
Brightness	[0.1, 1.5]

Followed by the visualization improvement of iris images utilizing image enhancement techniques based HE and CLAHE [26]-[28]. HE is an important image processing technique that modifies the global contrast of the entire image by adjusting the distribution of the pixel intensity of the image histogram. Then by applying CLAHE technique, the results can be further enhanced histogram. Hence, CLAHE technique works on small areas called named tiles in the image by improving the contrast of each tile in the image, so that the output area histogram roughly matches a specified histogram. In CLAHE technique the neighboring tiles will be combined using bilinear interpolation for eliminating induced boundaries artificially. The results before and after applying HE and CLAHE techniques and the cumulative distribution function (CDF) behavior are presented in Figure 3. Figure 3(a) the original on the left hand side and enhanced image based HE technique on the right hand side, and Figure 3(b) the original on the left hand side and enhanced image based CLAHE technique on the right hand side. The quality of the enhancement results has been increased as can be noticed in Figure 3. This Figure shows how to adjust the contrast in the original image using HE and CLAHE techniques. After completing the images preprocessing and augmentation, the total number of the dataset became 4600.



(a)



(b)

Figure 3. Contrast adjustment in the original image using HE and CLAHE techniques: (a) the original and enhanced image based HE technique on the left- and right-hand side, respectively and (b) the original and enhanced image based CLAHE technique on the left and right hand side, respectively

2.3. Proposed CNN model

In this step, the CNN model [29], [30] for extracting features and classifying of the iris images automatically will be designed. The proposed CNN structure has ten layers, beginning with the input layer and continuing with two convolution layers, two activation ReLu layers, two pooling layers, one fully connected layer, softmax layer, and finally the output layer, as described the proposed model's detailed structure and steps of the training algorithm in Table 2, Figure 4, and Table 3. The backpropagation algorithm [31] is used for training procedure, and Adam optimizer [32] for updating the weight. The dataset was divided into 80% for training set and 20% for testing set. The images were trained using batch size of 4, learning rate of 0.0001, for maximum of 400 epochs using Adam optimizer. The following algorithm in Table 2 illustrates the detailed steps for the proposed model.

Table 2. Detailed steps for the training algorithm

Algorithm 1. Applying tha main steps of proposed CNN model for extracting the features and classifying
Requirement: database of iris images
Taining steps:
1. Dividing the iris image into two sets (design set and testing set)
2. Dividing design set into two sets (training and validation set)
3. Training (CNN model, training set and validation set)
4. Finishing the training process when the desired performance and criteria are achieved
5. Returen: training CNN model
Testing steps:
1. Evaluating CNN model
2. Extracting the features of the testing set
3. End

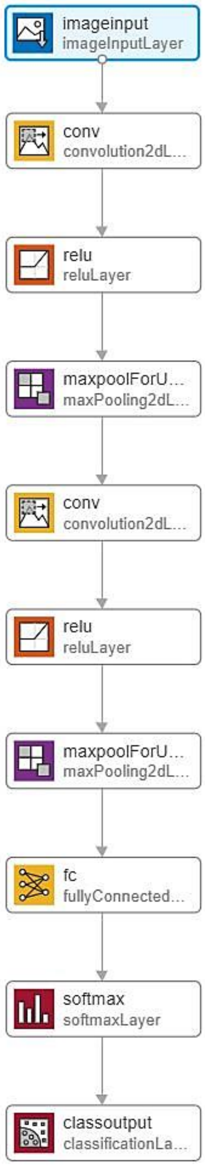


Figure 4. The structure of the CNN for iris recognition

3. EXPERMENTAL RESULTS

In order to carry out the proposed CNN model using collected and augmented iris dataset, the Matlab (2020a) is used and installed on personal computer (PC) desktop acer of the 4th generation processors, intel ® core (TM) i7-4790 CPU at 3.60 GHz and 64 operating system and windows 10 pro with 8.00 GB RAM. The graphics processing unit (GPU) type used NVIDIA GeForce GTX 1060 RAM 3GB. Verification of the performance of the proposed model and evaluation of its classification accuracy on the basis of the features extracted from the training set and the test set were carried out. Figure 5 shows the CNN performance evaluation. Whereas, increasing the number epoch will improve the training process through achieving the best results and increase the reliability but would be also increased the amount elapsed and this is clearly seen in Figure 5. The performance for the behavior of the proposed CNN model and accuracy of a training stage with constant values of a number of epochs as well as iterations, and frequency of validity and learning rate are presented in Figure 6. The percentage values of overall training accuracy was 95.33% with a consumption time of 17.59 minutes for 400 epochs. While the testing accuracy 100% with a consumption time of 12.097 seconds. Training and validation steps shown that the overall accuracy was excellent and the proposed iris recognition model has been successfully applied.

Table 3. Detailed description of the proposed CNN layers

Type of layer	Feature map size	No. of filter	Size of kernel	Padding no.	Stride no.
Input layer	240×320×1 (height×width×channel)	N/L	N/L	N/L	N/L
Second layer (1st convolution. layer)	240×320×10	10	3×3	0×0	0×0
(3rd normalization ReLu -2 layer)	N/L	N/L	N/L	N/L	N/L
(4th max pooling layer)	N/L	N/L	2×2	0×0	2×2
5th layer (2cd convolution layer)	240×320×10	10	3×3	0×0	0×0
(6th normalization ReLu-2 layer)	N/L	N/L	N/L	N/L	N/L
(7th max pooling layer)	N/L	N/L	2×2	0×0	2×2
Fully connected dropout layer layer-8 (fc8) Classification layer Softmax layer Output layer	45×1	N/L	N/L	N/L	N/L

```
Training on single GPU.
Initializing input data normalization.
|======================================================================================================================|
|  Epoch  |  Iteration  |  Time Elapsed  |  Mini-batch  |  Validation  |  Mini-batch  |  Validation  |  Base Learning  |
|         |             |   (hh:mm:ss)   |   Accuracy   |   Accuracy   |     Loss     |     Loss     |      Rate       |
|======================================================================================================================|
|       1 |           1 |       00:00:05 |        0.00% |        6.00% |      14.3420 |      13.2872 |      1.0000e-04 |
|       5 |          30 |       00:00:18 |       28.91% |       17.11% |       2.9160 |       3.2428 |      1.0000e-04 |

|     100 |         700 |       00:04:35 |      100.00% |              |       0.0020 |              |      1.0000e-04 |
|     103 |         720 |       00:04:43 |      100.00% |       94.67% |       0.0017 |       0.3259 |      1.0000e-04 |

|     200 |        1400 |       00:09:03 |      100.00% |              |       0.0008 |              |      1.0000e-04 |
|     202 |        1410 |       00:09:07 |      100.00% |       94.67% |       0.0009 |       0.3245 |      1.0000e-04 |

|     300 |        2100 |       00:13:30 |      100.00% |       95.33% |       0.0004 |       0.3243 |      1.0000e-04 |
|     305 |        2130 |       00:13:41 |      100.00% |       95.33% |       0.0006 |       0.3243 |      1.0000e-04 |

|     399 |        2790 |       00:17:54 |      100.00% |       95.33% |       0.0004 |       0.3244 |      1.0000e-04 |
|     400 |        2800 |       00:17:58 |      100.00% |       95.33% |       0.0004 |       0.3245 |      1.0000e-04 |
|======================================================================================================================|
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Figure 5. Performance evaluation of the training process.

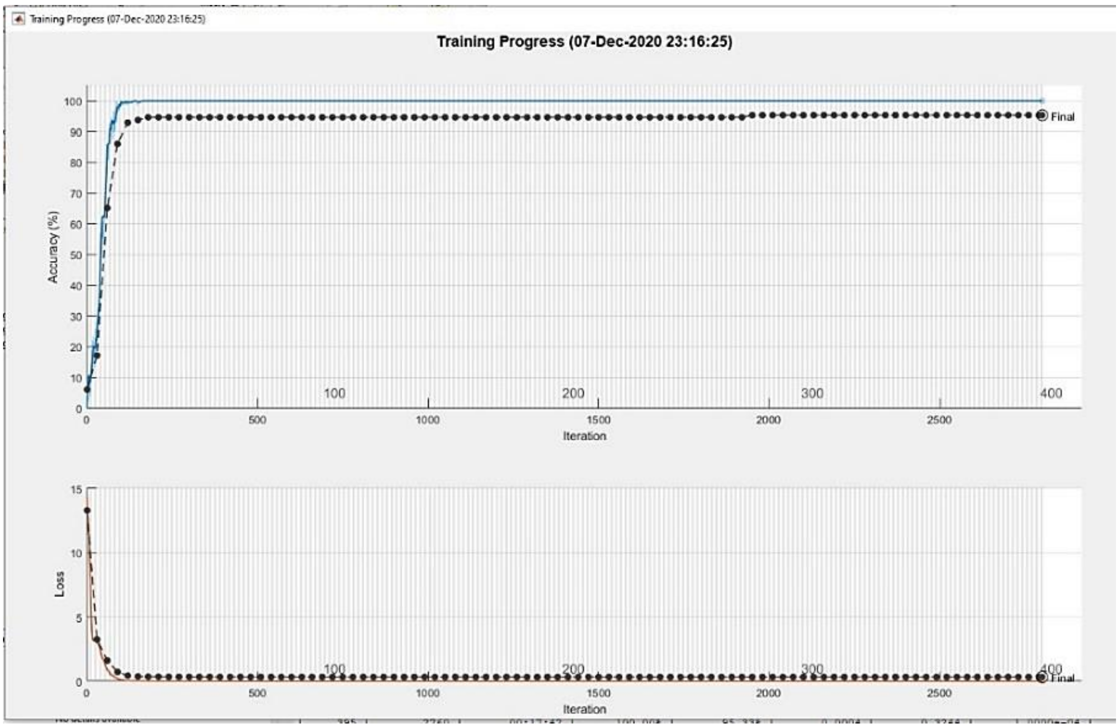

Figure 6. Accuracy and loss rate of the training process

4. CONCLUSION

In this study, an efficient and effective features extraction and classification system is presented using deep learning based CNN for human iris images. The introduced system included preprocessing and augmentation of the iris images followed by extracting the features and classification. The overall performance of the introduced system achieved high training accuracy 95.33% with consuming time 17:59 minutes for 400 epochs. While the testing accuracy was 100% with a consumption time 12 seconds. Training and validation steps shown that the overall accuracy is very good. Further extension of the introduced system can be focused on using different iris databases and different deep learning techniques as compassion study, multimodal classification system.

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