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Applying Gamma and Histogram Equalization Algorithms for Improving System-performance of Face Recognition-based CNN

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Abstract— *In the last few years, many applications have viewed great development, such as smart city applications, social media, smartphones, security systems, etc. In most of these applications, facial recognition played a major role. The work of these applications begins by locating the face within the image and then recognizing the face. The circumstances surrounding the person at the moment of taking the picture greatly affect the accuracy of these applications, especially the inappropriate lighting. Therefore, the stage of preparing the images is very important in the work. To solve this problem, we proposed a system that combines the use of gamma and Histogram Equalization algorithm (HE) to improve the images before starting to detect the face using the Viola-Jones. Then extract the facial features and identify the person using convolutional neural networks. The proposed system achieved a very small error rate and an accuracy during training that reached 100%.*

Index Terms— *Viola-Jones, HE, AHE, Gamma, CNN.*

I. INTRODUCTION

The process of detecting faces and recognizing faces is of great importance in most modern applications and systems [1], [2]. Detecting the face and determining its location in the image is a very important step that precedes the face recognition step, as it reduces the excess information during the face recognition process, thus increasing the speed and accuracy of the system [3], [4]. One of the machine learning algorithms known for its power in detecting faces is Viola-Jones [5]-[7]. It consists of four main stages which are: Integral Image, Haar Features, Haar Feature Classifier, and Cascade [8]-[10]. One of the most important problems that strongly affect the accuracy of the results of the viola algorithm is a low-quality image, especially in terms of lighting, if the image is very bright or dark [11], [12]. It has been used by many researchers in their studies, for example: In [13], Viola-Jones used it as the first stage of research in detecting the face and then recognizing faces using eigenface with an accuracy of 90%, the researcher also mentioned that the results are greatly affected by the conditions in which the image was taken, especially if the images were dark. In [14], The number of faces in one image was calculated using the Viola-Jones and achieved an accuracy of 93%. In [15], The proposed system determines the age of the person using the J48 algorithm after detecting the face using the Viola-Jones.

CNN is characterized by its ability to detect and recognize faces with high accuracy, better than many algorithms such as PCA and Local Binary Patterns Histograms (LBPH)...etc. but it suffers from complexity in its calculations in addition to its need for a large dataset during training, so it needs a large memory space compared to other machine learning algorithms [12], [16], [17]. So that, to reduce the impact of these problems on the accuracy of CNN results, many researchers have used the Viola-Jones to locate the face and segment as a first stage, then CNN is used in the next stage. In [18], The

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Viola-Jones used to locate the face and then used the CNN to classify the face's emotions in real-time. The researcher did not mention the impact of the accuracy of the training image if the images were of low quality.

In [19], the Adaptive Histogram Equalization algorithm (AHE) was used to improve the images after detection of the faces in the image using the Viola-Jones, then two different types of CNN architectures were used, namely VGG16, ResNet50 to recognize the faces, and it achieved an accuracy of 97, 23% and 98, 38% correspondingly.

In [20], the Modified Contrast Limited Adaptive Histogram Equalization algorithm (M-CLAHE) was used to improve the images after detection of the faces in the image using the Viola-Jones, then three different types of CNN architectures were used, namely VGG16, ResNet50, and Inception-v3 to recognize the faces, and it achieved an accuracy of 99, 44% and 99, 89%. The problem of the last two researchers is that they did not address the problem of low-quality images in the first stage before detecting the face using the Viola-Jones, as the accuracy of the viola-Jones results is greatly affected by the quality of the images [21], [11], thus affects the accuracy of CNN's results in recognizing faces. Therefore, we proposed a system that addresses the problems of low-quality images in the first stage of the system using both gamma, and HE. The reason for choosing gamma is that it is a method that treats both very dark and bright images at the same time, according to the value of the gamma coefficient, which is determined after studying the characteristics of the image. It is characterized by speed and simplicity in implementation when compared with the logarithm function, which is one of the non-linear methods also that treats dark images only, and the gamma has proven its efficiency in working with Viola-Jones in extracting faces. As for linear methods, such as contrast stretching, they are also fast and easy, but they cause some image details to be lost when they are improved sometimes due to the irregular improvement of the image [22].

II. THE PROPOSED MODEL

Most of the systems that use neural networks trained on high-quality images did not take into account the effect of low-quality images during training, Also, did not take into account the possibility of decreasing image quality during testing [23].

The proposed system tried to process low-quality images during the preprocessing stage, in which the Viola-Jones cannot detect faces. It has been trained on a faces94 data set, which contains 3060 images divided into 124 classes, according to the number of people in the database, to take images, they used artificial lights [1]. In some images, the Viola-Jones was unable to detect faces, either because of poor lighting or because of the tough reflection of light on the faces. To improve the results of face detection, we use different processing methods to treat different problems in the images, as there is no perfect way to treat all problems in the same way. One of the non-linear optimization methods that we used in our proposed system is gamma correction, which is based on the principle of transforming the gray level of the image [22]. The gamma parameter is a constant value determined according to the image information. If the image is dark, the parameter value is set less than zero, which leads to compression of low gray pixels values and stretch of high gray pixels values. But if the image is bright, the parameter value is set to a value greater than one, which leads to compression of high gray pixels values and stretches high gray pixels values, As shown in the following equation [22].

$$f(x,y) = J(x,y)^k \qquad (1)$$

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Where k is a constant value represented gamma correction parameter. Gamma is an inexpensive way to solve most of the problems of images that are completely dark or in part of the image in the dataset under study. The following example, shown in *Fig. 1*, shows how gamma works in improving, where the gamma parameter was determined by the value 0.6:

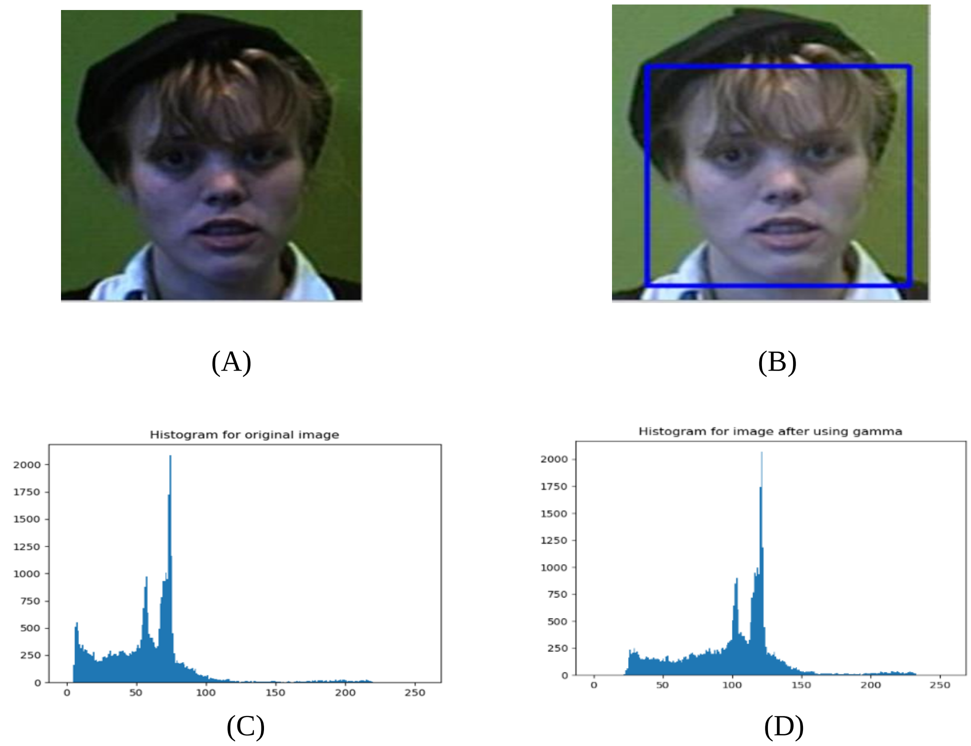

FIG. 1. (A) THE ORIGINAL IMAGE, (B) IMAGE AFTER GAMMA IMPROVEMENT, (C) THE HISTOGRAM OF THE ORIGINAL IMAGE, (D) THE HISTOGRAM OF THE IMAGE AFTER USING GAMMA.

As for the images that suffer from the reflection of light on parts of them, the gamma alone could not improve them so that the Viola-Jones could detect the face in them. Therefore, we suggested the use of double optimization using HE after using gamma. HE tries to uniform the distribution of pixels' gray level overall of the image by changing the spatial histogram of all the pixels in the image [24], [25]. The problem with HE is that it cannot process images in which the change in illumination is not uniform in all parts of the images, so it causes problems like dense saturation, noise, and over-enhancement [26]. Therefore, other types of HE have appeared, such as the adaptive histogram equalization (AHE), contrast limited adaptive histogram equalization (CLAHE), and iterative brightness bi-histogram equalization (IBBHE), and so on. That treats each part of the image separately. The problem with these methods is that they suffer from complexity in the calculations, in addition to that they do not fully address all the problems [22], [24].

In order to reduce the problem of complexity in solving the problem of non-uniform lighting in images. We proposed a system that uses gamma first to reduce the effect of changing the lighting and then using HE as a double improvement on the mage, as shown in *Fig. 2*, which is a diagram that explains the proposed system steps.

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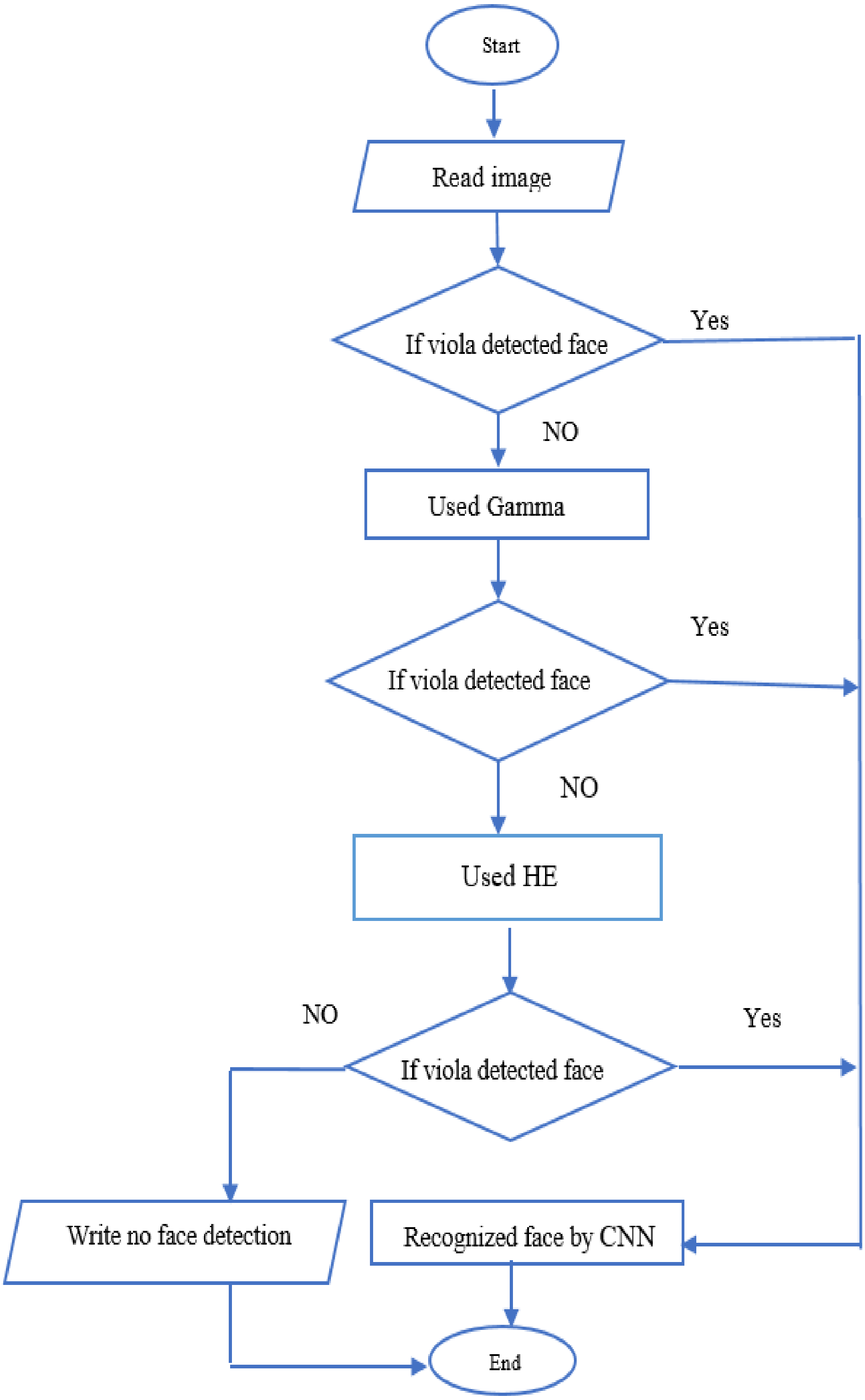

FIG. 2. A FLOWCHART EXPLAINS THE PROPOSED SYSTEM STEPS.

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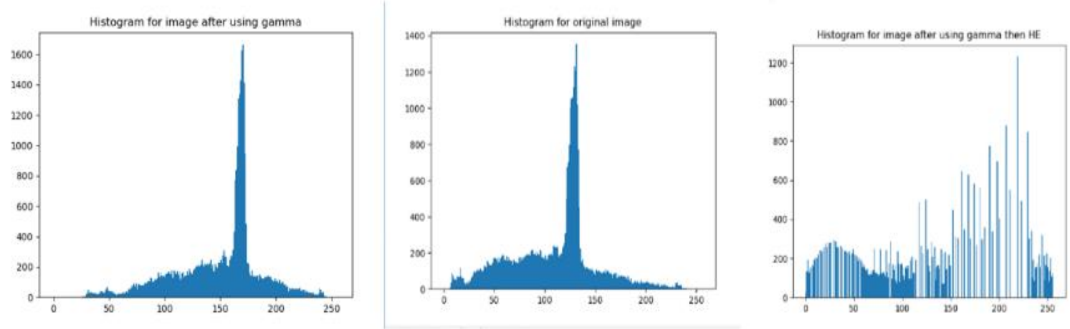
The use of gamma and HE in improving the images gave good results in helping the Viola-Jones to detect faces. As shown in *Fig. 3*:

(A) (B) (C)



(D) (E) (F)

FIG. 3. (A) ORIGINAL IMAGE, (B) IMAGE AFTER GAMMA IMPROVEMENT, (C) IMAGE AFTER GAMMA, AND HE IMPROVEMENT, (D) THE HISTOGRAM FOR THE ORIGINAL IMAGE, (E) THE HISTOGRAM FOR THE IMAGE AFTER GAMMA IMPROVEMENT, (F) THE HISTOGRAM FOR THE IMAGE AFTER GAMMA, AND HE IMPROVEMENT.

After optimizing the images in the data set under study, and cutting the detected faces using the viola-jones, CNN is training on these images of faces after cutting them and removing the unimportant parts of the image. The CNN architecture used in this study consists of four convolution layers, four MAXPooling 2D layers, and one fully connected layer. In the hidden layers, the ReLU activation function is used and in the output layer, a SoftMax function is used. Table I, contains the training parameters, while *Fig. 4* describes the architecture of the CNN used in this study.

TABLE I. CONTAINS THE TRAINING PARAMETERS

Training parameters	Value of parameters
Optimizer	Adam
Initial Learn Rate	0.0001
Epochs	150
Batch Size	32

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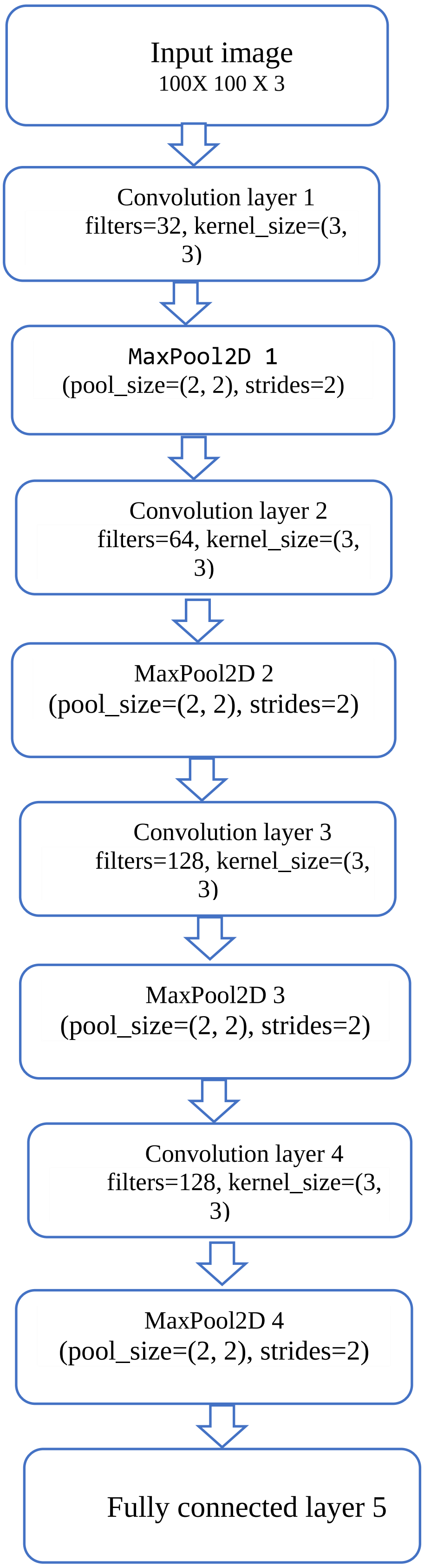

FIG. 4. ILLUSTRATES THE CNN ARCHITECTURE

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The data set used for training CNN is (faces94), which was divided into three parts (train, validation, test) with percentages (80%, 10%, 10%) respectively.

III. RESULTS AND DISCUSSION

The final results of face recognition after applying the proposed system proved a significant improvement in the accuracy of the results for each of the train data, and validation data, as shown in Table II.

TABLE II. THE FINAL ACCURACY RESULTS

Data type	Before	After
Training data	0.9895	1.000
Validation data	0.9802	0.9958
Testing data	0.9765	0.9924

Table III contains other metrics for evaluating the performance of the CNN model on the test data after using gamma, and HE to enhance photos, such as precision, recall, and f1-score.

TABLE III. CNN MODEL PERFORMANCE METRICS AFTER APPLYING OPTIMIZATION TO IMAGES

Class_NO	precision	recall	f1-score	support	Class_NO	precision	recall	f1-score	support
1	1	1	1	2	63	1	1	1	2
2	1	1	1	2	64	1	1	1	2
3	0.67	1	0.8	2	65	1	1	1	2
4	1	1	1	2	66	1	1	1	2
5	1	1	1	2	67	1	1	1	2
6	1	1	1	2	68	1	1	1	2
7	1	1	1	2	69	1	1	1	2
8	1	1	1	2	70	1	1	1	3
9	1	1	1	2	71	1	1	1	3
10	1	1	1	2	72	1	1	1	2
11	1	1	1	3	73	1	1	1	2
12	1	1	1	2	74	1	1	1	2
13	1	1	1	2	75	1	1	1	2
14	1	1	1	2	76	1	1	1	3
15	1	1	1	2	77	1	1	1	2
16	1	1	1	2	78	1	1	1	2
17	1	1	1	2	79	1	1	1	2
18	1	1	1	2	80	1	1	1	2
19	1	1	1	3	81	1	1	1	2
20	1	1	1	2	82	1	1	1	2
21	1	1	1	2	83	1	1	1	2
22	1	1	1	2	84	1	1	1	2
23	1	1	1	2	85	1	1	1	2
24	1	1	1	2	86	1	1	1	2
25	1	1	1	2	87	1	1	1	2
26	1	1	1	2	88	1	1	1	2
27	1	1	1	2	89	1	1	1	2
28	1	1	1	2	90	1	1	1	2
29	1	1	1	2	91	1	1	1	2
30	1	1	1	2	92	1	1	1	2
31	1	1	1	2	93	1	1	1	2
32	1	1	1	2	94	1	1	1	2
33	1	1	1	2	95	1	1	1	2
34	1	1	1	2	96	1	0.5	0.67	2
35	1	1	1	2	97	1	1	1	2
36	1	1	1	2	98	1	1	1	2
37	1	1	1	2	99	1	1	1	2

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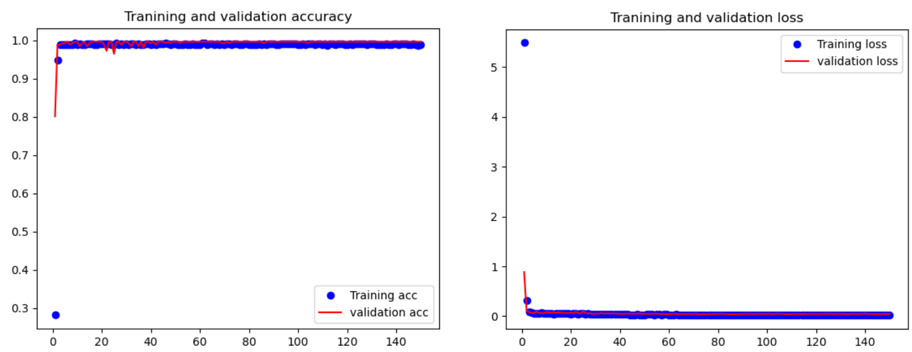
38	1	1	1	2	100	1	1	1	2
39	1	1	1	2	101	1	1	1	2
40	1	1	1	2	102	1	1	1	2
41	1	1	1	2	103	1	1	1	2
42	1	1	1	2	104	1	1	1	3
43	1	1	1	2	105	1	1	1	2
44	1	1	1	2	106	1	1	1	2
45	1	1	1	2	107	1	1	1	2
46	1	1	1	2	108	1	1	1	2
47	1	1	1	2	109	1	1	1	2
48	1	1	1	2	110	1	1	1	2
49	1	1	1	2	111	1	1	1	2
50	1	1	1	1	112	1	1	1	2
51	1	1	1	2	113	1	1	1	2
52	1	1	1	2	114	1	1	1	2
53	1	1	1	2	115	1	1	1	2
54	1	1	1	2	116	1	1	1	2
55	1	1	1	2	117	1	1	1	2
56	1	1	1	2	118	1	1	1	2
57	1	1	1	2	119	1	1	1	2
58	1	1	1	2	120	1	1	1	2
59	1	1	1	2	121	1	1	1	2
60	1	1	1	2	122	1	1	1	2
61	1	1	1	2	123	1	1	1	2
62	1	1	1	2	124	1	1	1	3
					Average	**0.997**	**0.995**	**0.997**	

The results also showed a decrease in the loss function after applying the proposed system for each of the training data and validation data as shown in Table IV.

TABLE IV. THE LOSS FUNCTION RESULTS

Data type	Before	After
Training data	0.0191	4.3852e-07
Validation data	0.0455	0.0197

Fig. 5, discusses graphically the results of accuracy and the loss function before and after using viola, gamma, and HE to improve CNN.



(A) (B)

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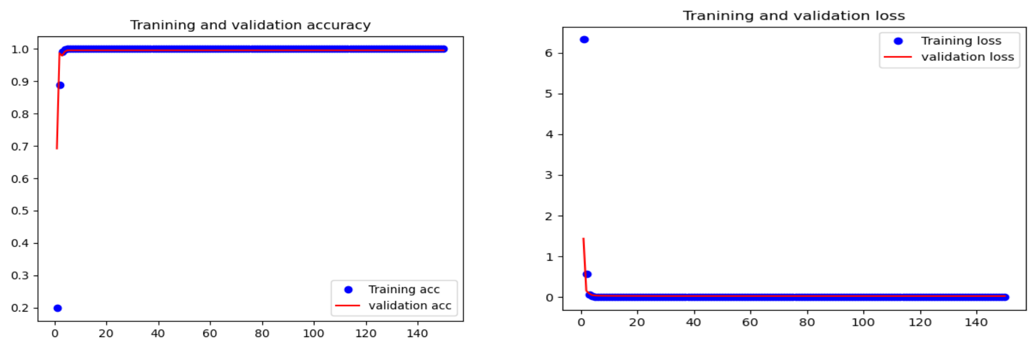

(C) (D)

FIG. 5. (A) ACCURACY RESULTS BEFORE IMPROVEMENT, (B) LOSS FUNCTION RESULTS BEFORE IMPROVEMENT, (C) ACCURACY RESULTS AFTER IMPROVEMENT, AND (D) LOSS FUNCTION RESULTS AFTER IMPROVEMENT.

IV. CONCLUSIONS

The proposed system improved only the images of a preserved quality that need improvement using a simple method, which is the gamma, which solved most of the problems of the images. As for the images that suffer from a strong light reflection on part of them, they were improved by using HE in addition to the gamma. This improvement improved the results of the Viola face detection and thus significantly improved the final results of face recognition using CNN.

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