Improved Performance of CNN Classifier-Based Face Recognition Using HOG Features Extractor Against Variant Conditions

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Face recognition is a critical task in various applications, such as surveillance, security, and human-computer interaction. Recently, Convolutional Neural Networks (CNNs) have emerged as a powerful tool for face recognition, outperforming traditional methods in many scenarios. However, the performance of CNN-based face recognition systems can be affected by various conditions, such as pose, illumination, images quality and occlusion. This paper aims to investigate the performance of CNN-based face recognition classifier under different challenging conditions such as low resolution, face poses, low light condition, ages and various facial expressions. This research focuses on the evaluation of the effectiveness of CNN-based face recognition systems and evaluates their performance as a classifier on a combination of the Celebrities face dataset and the Indian Movie Faces Dataset (IMFS) have been trained in order to obtain varying levels of illumination conditions, images quality, face poses and facial expressions. For face detection, the Haar Cascade face detection technique is utilized for this purpose. The facial features extraction is a vital process in this system. Therefore, Histogram of Oriented Gradients (HOG) is employed as facial features extractor method. The findings suggest that by carefully designing the CNN architecture and incorporating techniques to improve information propagation, the performance of the face recognition system can be enhanced, even under adverse conditions. The obtained results show an improved level of accuracy in which the proposed system achieved 96%.

Povzetek: Predstavljen je CNN klasifikator za prepoznavanje obrazov, okrepljen z izluščanjem HOG značilk. Znanstveni prispevek je robustna kombinacija Haar Cascade, HOG in CNN za zanesljivo prepoznavanje v zahtevnih pogojih.

1 Introduction

Rapid advances in Artificial Intelligence (AI) and its emerged subfields such as Machine Learning (ML) Artificial Neural Network (ANN) and Deep Learning (DL) have made them the most dominant research fields nowadays. Biometrics refers to the automatic recognition of individuals based on their physiological attributes such as fingerprint, face, or iris characteristics and behavioral traits like gait, signature, or voice. The use of biometric technology has emerged as a modern method of identifying and verifying people quickly and accurately. Various sectors depend on the automatic recognition of human faces in order to provide better identification mechanism in various sectors such as industries, healthcare, self-driving technology, surveillance applications and private data protection. Face recognition system has been widely deployed as one of the most reliable biometrics recognition techniques. This technique achieved a high rate of accuracy in comparison to other biometrics authentication techniques such as finger recognition, iris recognition, voice and gate recognition [1,2]. Due to the rising concerns of security, the importance of conducting an intelligent technology like face recognition system in the current era and a set of advantages have progressively raised the need to use face recognition among other authentication technologies. For example, the less interaction or human efforts that are required by the system. Also, the low cost of implementation and deployment [1,3,4].

In general, recognizing an individual can be automatically performed either by using his/her physiological characteristics such as face, ear, hand geometry, finger print and iris. On other hand, lots of authentication systems depend on the behavioral attributes of an individual such as signature, keystroke dynamics, gait and lips movements [5]. For many years, human facial features have received vital attention by various industries due to several advances. For example, people can easily communicate with others by capturing the facial characteristics.

However, the widespread use of surveillance applications such as criminal detection has led many researchers to develop some machine learning algorithms such as Principal Component Analysis (PCA), Independent Component Analysis (ICA) and Linear Discriminant Analysis (LDA) improvement. On the other hands, the outperformance of neural network and deep learning methods such as Convolutional Neural Network (CNN) and its excellent achievements in various surveillance applications for the automatic recognition purpose. This has led to the continuous improvements of such algorithms by images processing and computer vision researchers. CNN has received a lot of attention due to the incredible results in providing reliable authentication process with less mathematical calculations [2,3,4].

The main purpose of this research is to evaluate the efficiency of CNN algorithm in terms of successfully recognize an input face images when the input dataset includes set of images with complex background. However, the more complexity in the input dataset the more difficulty to accurately classify the human faces. One of the main challenges in this work is to deal with the various conditions in the used dataset are face alignment, low resolution, bad illumination, poor quality, facial expressions and head poses. Therefore, this research conducted a powerful mechanism to perform all the steps of the face recognition system starting with images normalization, low light images enhancement, face detection and finally features classification.

CNN is defined as one of the various categories of ANN architectures that is typically build on the machine learning basis. It is one of the most popular algorithms of deep learning [6,7]. It was firstly introduced by Hubel and Wiesel when they proposed the effective structure of CNN in 1960[2]. The general derivation of CNN comes from the same idea of human nervous system which led to the implementation of neural network. More details about CNN and its architecture are comprehensively explained in section 3. Figure 1 illustrates the AI and its subfields.

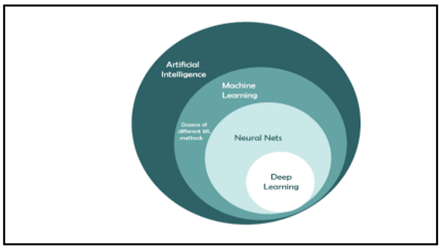


Figure 1: Artificial intelligence and its subfields.

Few years ago, many websites have been emerged which publicly provide the utilization of several processes like running code, statistics and virtualization. Kaggle, is the public library that allows users to freely access hundreds of datasets in addition to users' notebooks and scientific collaborations. Also, a variety of free face images datasets are available through the internet which can be freely accessed for research purposes [8].

The general organization of this paper is made as follows: Section 2 provides a brief presentation of the related work. In Section 3, a comprehensive discussion about the proposed methodology to improve the effectiveness of the CNN classification algorithm-based face recognition. The experiments have been well explained in section 4. A comprehensive analysis of the obtained results is provided in section 5. Finally, the future recommendation and the plan of forthcoming update of this research are discussed in section 6.

2 Related work

The primary issues that are related to a typical automated face identification are: images resolution, images quality, illumination, light conditions and other factors that can significantly affect the overall system performance. Numerous papers introduce advanced methods to overcome the challenge of the severe low illustration of the face images datasets. This work focuses on the deployment of powerful methodology to tackle the dark images and achieve excellent recognition accuracy.

The researchers in [9], proposed a joint High-Low Adaptation (HLA) framework to overcome the low light challenge for the face detection. Their obtained results showed an interesting level of accuracy.

The conducted methodology in [10], focused on the development of automated Facial Expression Recognition (FER) using CNN where a mix of face images datasets have been trained. The developed FER system was examined under various number of conditions but not limited to the low-resolution issue. The researchers then achieved 93.7% system accuracy.

The authors of the paper [11], introduced an efficient method for face detection and recognition as they manipulated the issue of blurring in the low light captured images. The researches achieved an impressive level of accuracy.

In the work [12], the researchers evaluated an improved facial recognition technology that is mainly deploy on the use of the Gabor-low order restoration as the main classification technique. The obtained results of their work achieved 98.56 % accuracy under different illumination conditions.

The proposed system in [13], analyzed the issue of low-quality face images along with noise, blur and brightness. The work of the authors has employed the Viola-Jones algorithm to perform the detection process while the FLD, LBP and PCA algorithms are used for recognition operation.

3 Proposed methodology

The proposed face recognition system in this paper is described in Figure 2 below.

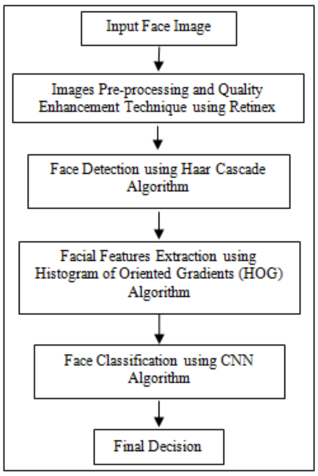


Figure 2: Workflow of the proposed system

3.1 Input data

Face recognition system is based on a dataset of face images as per this work. The face images of celebs are used as a dataset to evaluate the efficacy of the proposed system. The face dataset is listed below and its complete analysis.

3.2 Face images dataset

Recently, hundreds of face images datasets which are freely available through the internet are being used for research purposes. The Celebrity Face Images Dataset is a public face images dataset that is freely available through the online library Kaggle. This library provides many free machine learning tools and datasets for research purposes. This face images dataset consists of face images of 18 celebrities which have been collected by the internet. Each celebrity has 100 face images that is collected under different conditions such as ages, facial expressions, light conditions and face poses. The Indian Movie Faces Dataset (IMFDB) has 100 unique celebrities with total number of 34512 face images that have been taken from 100 movies. A combination is made between these two face datasets to test the accuracy of the utilized CNN algorithm [7].

In this work, the data sets are obtained by collecting a modified face images dataset of several celebrities that are publicly available through the internet. In order to examine the efficiency of the conducted algorithms of face recognition system. The final dataset consists of 100 individual samples in which each individual has 365 face images that are collected through a combination of both the Celebrities Face Dataset and the Indian Movie Faces Dataset (IMFDB) under different conditions such as illumination, facial expressions, face pose and age. Therefore, the total number of the dataset is 36500 face images. All the images are transformed into grayscale with one size is 48 x 48 pixels. The database is divided into two subsets; the first subset is 70% which is used for training the proposed model while the rest 30% is used to test the face recognition system. Below in Figure 3, examples of the proposed face images dataset.

Figure 3: Samples of the modified face images dataset

The FEI face database is a popular Brazilian database collected in 2005 and 2006 by the FEI Artificial Intelligence Laboratory in Sao Bernardo do Campo, Sao Paulo, Brazil. The FEI face database consists of 200 individuals (100 males and 100 females) with 14 images per individual. Therefore, the total number of images is 2800. Most of the faces refer to the academic staff and the students of the FEI lab. All images were captured with a high tip position on an isotropic background and colored. In addition, the images have the size of 640 x 480 pixels and different conditions were used such as various appearance, hairstyle and adorns with a profile rotation of up to 180 degrees [6]. Figure 4, shows examples of the FEI face images dataset.

Figure 4: Sample of FEI face images dataset.

3.3 Images pre-processing

The initial step in the proposed system is the pre-processing step. In this step, the input data is a set of face images which have been treated and manipulated by applying several tasks to achieve best face images in terms of image resize, grayscale transformation, light enhancement and remove all unnecessary data. Figure 5, illustrates the followed steps of the preprocessing task.

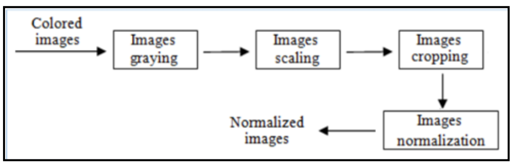
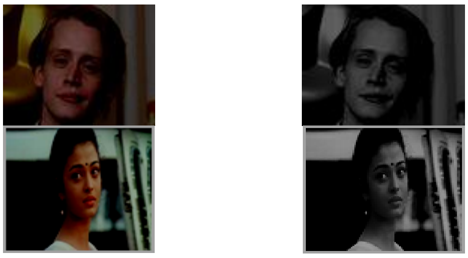


Figure 5: Preprocessing steps

Converting colored images into grayscale is an important step in various images processing systems. Although, a grayscale image contains a less information than the colored one, but it is very essential to minimize the computational complexity as less as possible. Since, a face recognition system deals with huge amount of data, the time consuming needs to be degreed by converting each input face image in the data set into a small size of 48x84 pixels.



A B

Figure 6: Samples of original face images (A) and samples of grayscale face images (B)

Figure 7: Samples of normalized face images

In figure 6, samples of the modified face images from the dataset and their grayscale converting samples. While, the figure 7, the results of the normalization process on the input images are obvious.

3.4 Low-light images enhancement techniques

In the images processing field, Low Light Images Enhancement (LLIE) methods have received a considerable attention by the researchers over the last years [14,15]. Before 2017, conventional mastering-primarily based (TL) techniques are the ad-hoc solution for LLIE. As proven in figure 8, mainstream conventional getting to know methods in LLIE utilize histogram equalization, Retinex, dehazing or Statistical techniques. Since 2017, deep mastering-based (DL) techniques have started out to dominate this field. Supervised gaining knowledge of is thus far the most popular strategy.

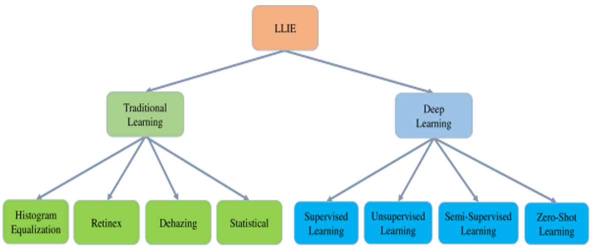


Figure 8: Classification of low-light images enhancement methods

A before B after

Figure 9: Samples of before and after applying images enhancement technique

Retinex-based techniques are primarily based on the Retinex idea of coloration vision which assumes that a picture can be decomposed into a reflectance map and an illumination map. The enhanced photograph can be obtained via fusing the enhanced illumination map and the reflectance map.

3.5 Face detection techniques

In any automatic recognition system of human faces, face detection plays a significant role in allocating the most important facial features such as eyes, nose and mouth. Obtaining such facial characteristics in an efficient way leads to an effective and accurate face recognition system [16,17]. There are many state-of-the-art methods of face detection, but most of them still have not reach sufficient level of accuracy. Examples of face detection techniques are AdaBoost, HAAR classifier, Support Vector Machine (SVM), Local Binary Pattern (LBP) and Histogram of Oriented Gradients (HOG) [17]. In order to overcome the computational complexity and obtaining better system performance, Haar Cascade algorithm is used to accomplish the facial attributes detection.

The general framework of Haar Cascade algorithm was firstly introduced by both of the researchers Paul Viola and Michael Jones in 2001[17]. The main idea of this method is to extract the facial features (eyes, nose and mouth) based on rectangular boxes. This algorithm works on grayscale images and so all the face images have been converted to grayscale before applying face detection process in order to increase the system efficiency and decrease the time consumption. Due to the high achievements of this face detection mechanism which is proposed by Viola-Jones method in which many researchers adopted this method to increase the level of accuracy [18]. A general speech, Haar Cascade uses two to three rectangles. The implementation of this face detection algorithm is performed using OpenCV (Open-Source Computer Vision Library) is one of the most computer vision and machine learning library ovides excellent implementation of more than gorithms for many intelligent applications. Figure s examples of detected faces.

Figure 10: Samples of detected faces

In order to obtain better results of face detection process in terms of speed of detecting faces and increasing the detection accuracy. The size of face images has been set to 48x48 pixels. Haar Cascade works better with small size of images but it may lead to time consuming. A successful combination can be made between Haar Cascade as a features detector and CNN as a features classifier. Since the Haar Cascade depends on the regions of interest (ROIs) technique, this is used as an input to the CNN for more refined classification purpose. The conduction of this approach leads to successful integration between the computational efficiency of the Haar Cascade and the advanced feature learning of the CNN.

3.6 Facial features extraction method

The detection of facial features constitutes an essential step in most of advanced face recognition systems. To realize good face analysis and recognition, being able to correctly determine and localize major facial features such as the eyes, nose, mouth and jawline is necessary.

The extracted facial features are the basal work for a pool of face-based applications: face detection, facial expression analysis, emotion recognition, age and gender estimation and person identification. By precisely encoding the spatial relations and the geometric properties of those facial attributes, face recognition algorithms discriminate different people, and also show a robustness against changes in illumination, pose, occlusion, and resolution of the image [19].

Histogram of Oriented Gradients (HOG) is one of the most effective face detection and features extraction techniques. In order to obtain the most distinguished facial features of the input face images from the proposed database, HOG can be used for this purpose. The main idea of HOG is to convert the input face image (RGB) with heightH x widthW x 3 into one feature vector with length *I*. However, the challenge of variation in light conditions, illumination, poses and image quality put a significant need to apply powerful features extraction like HOG [28]. It measures the occurrence of gradient orientation in localized areas of an image. Then, each face image which is entered into the system is divided by the HOG into small areas called cells, after that a histogram of gradient directions is generated within each cell, followed by normalization of local contrast in overlapping blocks. More details about the mathematical implementation of HOG method are well described in [20,21,22].

3.7 Classification method

In general, CNN or ConNet has derived its popular name from the use of two or more computational or mathematical operations in a rolling way (roll together) such as Sigmoid, Tanh, ReLU and Leaky ReLU [23]. The biological connectivity of neurons in the visual cortex of the animals has led to the inspiration of CNN [24]. In the recent years, huge improvements have been made on the complex construction of its structure. Basically, CNN has four layers which are sequentially arranges to figure out the main structure of the CNN [2]. These layers are Convolutional Layer, Pooling Layer, Fully Connected Layer and Loss Layer [23,24].

The first and essential layer is known as Convolutional Layer. This layer contains most of the computational processes. The input parameters that are required by this layer are set of learnable filters or kernels [23,24]. In order to create a separate 2-dimensional activation map, these filters are convolved with the feature maps. This map is then layered along the depth dimension to create the output volume [23,24].

The feature map is made up of the output of a string of dot products of the input and filter, and the kernel is of 3X3 size, is variable, and is applied to the area of the picture. Convolutional layers enable learning of low-level information by converting images into numerical values. When deeper layers of a model learn higher order or more abstract information, it works very well [25].

The second layer in CNN is called Pooling layer. Down sampling is the other name of the pooling layer. In this stage, the received output from the convolutional layer will be treated by this layer and it reduces the number of parameters in the network and the spatial dimension of the activation maps, hence lowering the total computational complexity. Convolution's stride can be used to perform down sampling. The pooling operation's size is less extensive than the feature maps. This manages the overfitting issue [23,25]. Different numbers of pooling operations are involved in this layer. The following pooling operations are some of the more popular ones: maximum, average, stochastic, spectral, spatial pyramid, and multiscale orderless. The average pooling operation selects the average value inside the receptive field as the pooling layer progresses across the input, whereas the max pooling operation chooses the maximum value to deliver to the output array. Max pooling is the most popular of these two pooling techniques [23].

Fully connected layer, in a typical neural network, all of the neurons in this layer are completely connected to all of the neurons in the layer above. Here, sophisticated reasoning is used. The neurons are not grouped spatially (one dimensional); hence a convolutional layer cannot come after a layer that is fully connected. The last layer is Loss layer. Figure 11, illustrates the construction of CNN algorithm.

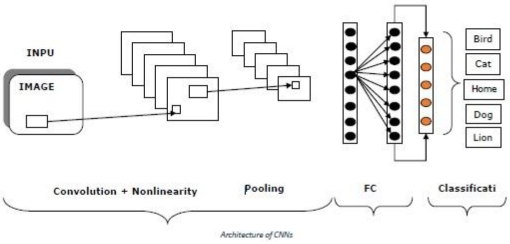


Figure 11: General mechanism of CNN algorithm

Many research efforts have been made over a long period of time for developing various models of the CNN algorithm architecture, starting with the first model presented in 1990, the LeNet and its developed version model LeNet5. Other models include, AlexNet, VGGNet, NiN architecture, Google Net, ResNet, Dense Net, RCNN, and YOLO. Below, a brief description of the most common CNN models these days [25,26].

3.7.1 LeNet

In 1990, LeCun et al were the first researchers who introduced LeNet model [23]. They performed the task of Handwritten Digit Recognition (HDR) using ConvNets which finds application in reading zip codes, digits and etc. This was one of the pioneering works in using convolutional neural networks. At the time, there was a break in the use of CNN due to the lack of powerful computers which led to the development on the use of CNN in 1998 [24].

3.7.2 AlexNet

The researchers who worked on the birth of AlexNet model are, Alex Krizhevsky, Geoffrey Hinton and Ilya Sutskever [23,24]. They made a comprehensive development on the previous version ConvNet, and to provide a better performance by increasing the size of the datasets in which the model can deal with effectively. Basically, AlexNet consists of eight layers. The first five layers are built to make the convolution layer, while the last three layers are used as fully connected layers. In comparison to the previous model LeNet, AlexNet is greater and deeper [23,24].

3.7.3 VGG

VGG stands for Visual Geometry Group, which led to develop a deep Convolutional Neural Network (CNN) structure. VGG models are recognised for their simplicity and effectiveness, achieving strong overall performance on diverse pc imaginative and prescient obligations, mainly image class and object recognition. A defining characteristic of VGG is its intensity [27]. The maximum popular versions, VGG-16 and VGG-19, have 16 and 19 convolutional layers, respectively, making them very deep CNNs for his or her time. This depth permits the community to extract complex features from images. VGG uses a uniform architecture at some stage in the network. This way convolutional layers are stacked together in repeating blocks, with every block normally containing: Multiple (commonly 2 or three) convolutional layers with small filters (normally 3x3). A max-pooling layer for down sampling the photograph and lowering its dimensionality.

4 Experiments

In order to verify the efficiency of the conducted face recognition method, the modified celebrities face database is the main face images dataset that is utilized to carry out the experiments of this research. The number of classes is 100 for each sample 365 face images have been collected under various conditions. The total number of the entered data into the main system is 36,500 images which is divided into two main datasets, the training dataset (70%) which consists of 25,550 images while the testing dataset (30%) contains 10,950 images. The learning rate = 1e-6, batch-size = 32, number of epochs = 50. The size of the images in both of the testing and training datasets has been set to 48x48 grayscale images. The full implementation of the proposed method is made using the OpenCV library. The system specifications of the employed hardware device to complete the experiments of this work is HP Laptop, Intel Core i7-1165G7 Processor (up to 4.7 GHz with Intel® Turbo Boost Technology, 12 MB L3 cache, 4 cores), RAM: 16 GB DDR4-2666 SDRAM. A comparison is made between different proposed systems by several researchers along with their conducted face datasets such as the modified face dataset, Kaggle FER, FER 2013 and LFW face dataset. Detailed information about the comparison that is performed in this work is provided in Table 1 below. The level of accuracy that has been reached for training the proposed system is 96%.

Table 1: Comparison of different face recognition systems

Seq.	Reference No.	Face Dataset	Face Detection Technique	Facial Features Extraction Method	Classification Method	System Accuracy
1	[9]	WIDER FACE and DARK FACE dataset	DSDF framework	-	-	44.4
2	[10]	FER-2013		CNN	CNN	93.70
3	[11]	Personal dataset (Student Dataset)	-	Face-locations, Python built-in library	KNN	81%
4	Proposed system	A modified face images dataset	HCC	HOG	CNN	96%

5 Results discussion

The effectiveness of the conducted methodology of this work has been examined while performing the experiments of the face recognition system using modified face images dataset. The main input data is facing images that have been normalized and preprocessed in order to reduce the computational time. All details of the modified face images dataset in this research are discussed in section 3. The main challenge in this research is the examination of the efficiency of the proposed methodology in recognizing a given set of face images under variant conditions such as light conditions, low resolution, different face expressions face poses and aging. However, utilizing a single face images dataset with several conditions that can directly degrade the utilized methodology performance is still a challengeable task. This work focuses on the various conditions of the conducted face images dataset to test the efficiency of the proposed system. In the experiments, both of the training and testing datasets have different complexity levels in terms of the illumination, different facial expressions such as smiling, angry, face pose and other accessories like sun glasses. In the training dataset, each sample has 7 different conditions such as low light condition, three different facial expressions, aging condition, pose, gender and makeup condition. In the test process, the face dataset images have three different conditions such as gender, illumination and facial expression. The obtained results from the experiments ensure the efficiency of the conducted method of the CNN as a face images classifier based on the achieved results of the accuracy, loss and validation of accuracy and validation loss as shown below in Figures 12,13,14 and 15 subsequentially.

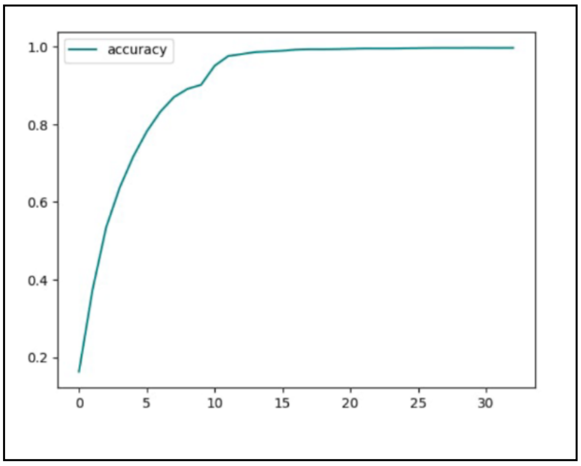


Figure 12: Results of accuracy of CNN Classifier

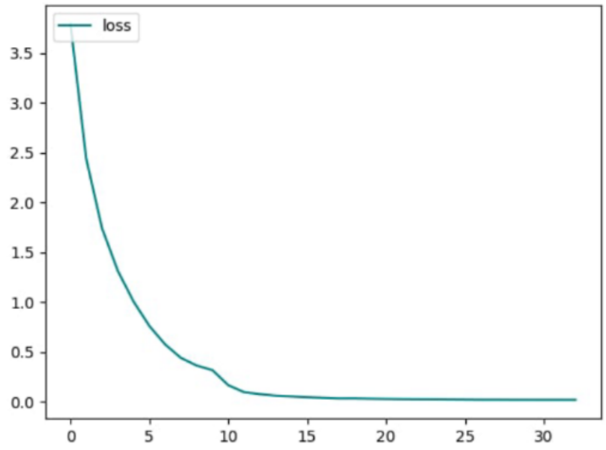


Figure 13: Results of Loss function

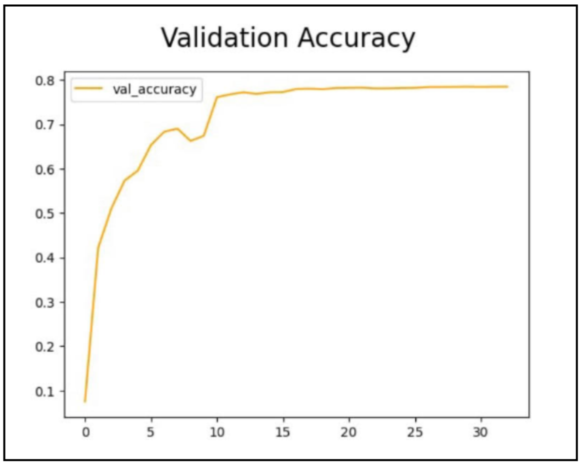


Figure 14: Results of validation accuracy

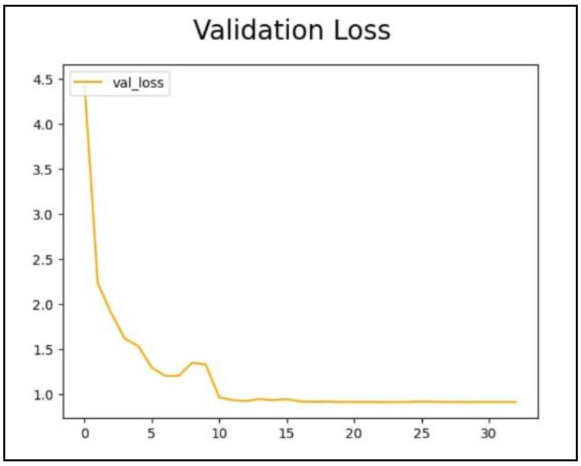


Figure 15: Results of validation loss function

6 Conclusion and future work

In this work, an improved level of accuracy has been achieved in recognizing human faces with low resolution by deploying the intelligence of deep learning algorithms which is CNN. The proposed methodology of this system is particularly focused on the classification process in which CNN based classifier which has been utilized for this task. The AlexNet model of CNN algorithm is employed to effectively deal with large face images dataset. The Celebrity Face Image Dataset and The Indian Face Movie Dataset are both used to test and train the CNN algorithm in recognizing faces under various conditions. The achievements of the proposed system have shown an improved level of accuracy when the CNN algorithm reached 96% for training process. In the future, a modification will be followed in utilizing the deep learning techniques such as Deep Convolutional Neural Network (DCNN) algorithm with real-time face recognition system.

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