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Research Paper

Frontal and Non-Frontal Face Detection Using Deep Neural Networks (DNN)

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A B S T R A C T

Face recognition has always been one of the most searched and popular applications of object detection, starting from the early seventies. Facial recognition is used for access control, authentication, fraud detection, surveillance, and by individuals to unlock their devices. The less intrusive and robustness of the face detection systems, make it better than the fingerprint scanner and iris scanner. The frontal face can be easily detected, but multi-view face detection remains a difficult task, due to various factors like illumination, various poses, occlusions, and facial expressions. In this paper, we propose a Deep Neural Network (DNN) based approach to improve the accuracy of detection of the face. We show that Deep Neural Networks algorithms have better accuracy than traditional face detection algorithms for multi-view face detection. The DNN gives more precise and accurate results, as the DNN model is trained with large datasets and the model learns the best features from the dataset.

Keywords: Face recognition, Deep Neural Networks (DNN), OpenCV, NumPy, PyCharm, Python, machine learning.

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1. Introduction

The enhancement of science and technologies has made life more comfortable than in older days. The emerging technologies like neutrosophic shortest path [1]-[5], transportation problem[6]-[8], uncertainty problem [9]-[14], fuzzy shortest path [15] and [19], Powershell [20], wireless sensor network [21]-[28], computer language [29] and [30], neural network [31], routing [32], machine learning [33] have made the products more intelligent and self-healing based. Smart city applications like smart image processing [34] and [35], smart grid, smart parking, smart resource

management, etc. are based on IoT and IoE [36]-[39] technologies. In this manuscript, the frontal and non-frontal face detection system is proposed. Facial recognition is one of the most popular topics in the machine learning field for object detection. There are hundreds of facial recognition algorithms today, but the first facial recognition algorithms were developed in the early seventies [40] and [41]. Since then, the accuracy of the algorithms has improved so much, that nowadays face recognition is often used over the other biometric authentication systems, that were considered more secure, such as fingerprint or iris recognition [42]. Facial recognition is preferred over other biometric authentication systems is because of its non-intrusive nature.

Facial recognition has various real-life applications, covering from public to personal security. Moreover, users in their devices use facial recognition as a method to unlock the devices. Even though these face detection algorithms are popular, the problem of face recognition is yet to be solved.

In recent years, the accuracy of face detection techniques has significantly improved. Traditional algorithms focused on merging techniques such as SVMs, or LDA with features like texture descriptors, edges, etc.

2. Problem Definition

The face detection algorithms are not completely reliable. While frontal face detection has been solved to a great extent, thanks to the influential work by Viola and Jones [43]**,** multi-view face detection remains a difficult task due to substantial appearance changes under various pose, lighting, and expression conditions. The Viola and Jones [43] detector perform well for front faces, but due to the limitations of the haar features, the detector becomes ineffective for non-frontal faces. The cascade classifier of Viola and Jones [43] was used for non-frontal face detection with large pose variations. We divide the face images based on various factors like frontal, profile, half profile, etc. Several classifiers can then be trained for various subcategories. Few works [44]-[46] proposed to merge the results of the cascade classifier that was trained for each view of the face. Few other works [47]-[49] suggested first gauge the posture of the face and then run the cascade of the corresponding face pose for detecting the faces.

The complexity of the previous approach increases with the increase in the number of pose categories, while the precision of the earlier is susceptible to the mistakes of the face pose estimation. Large datasets can be trained with the deep learning methods, and that benefits face detection, as it learns the best features from the available datasets.

Facial recognition in the real-world environment possesses a lot of challenging factors like the high variability in the face images. These variations consist of aging [50] and [51], poses [52], lighting conditions [53] and [54], and expressions of the face [55] in ***Figure 1***.

(a) Aging [56] and [57].

(b) Pose [58] and [59].

(c) Lighting conditions [60].

(d) Facial expressions [60] and [62].

Figure 1. Variations of different style.

3. Literature Review

The research work on automatic face recognition was written in the early seventies in Kelly's and Kanade's [40] and [41] Ph.D. theses. The research work proposed that the use of contour and edge detectors for calculating the relative position and distances between the set of facial landmarks. These research works were done on a very small dataset of facial images. In [63], the authors proposed a method to transform the facial images to gradient images for preferable precision over the calculation based strategies.

Faces are represented using the entire face region in Holistic methods. The face images are projected on to a low dimensional space that removes useless features and details that are not useful for face recognition. PCA is one of the most popular Holistic methods. The idea [64] and [65] is to train the face image datasets using the PCA method. The variance in the data was found by the eigenvectors.

Later, the probabilistic approach [66] to find the differences between images using Bayesian analysis was proposed. The author proposed to train the model based on intrapersonal and interpersonal variations using two sets of eigenfaces.

3.1. Different Researcher's Contributions

Some of the major contributions in Geometry and holistic based facial image recognition are discussed in ***Table 1***.

Table 1. A literature review of Geometry and holistic based image processing.

Authors	Years	Different Approaches to Solve Image Processing
Schölkopf et al. [67]	1997	The authors proposed the non-linear extension of PCA based on kernel methods.
Bartlett et al. [68]	2002	The author proposed a PCA that can catch high-arrange conditions between pixels.
Yang et al. [69]	2004	The authors proposed a 2D PCA dependent on 2D picture lattices.
Shi et al. [70]	2006	The authors studied the feasibility of face recognition using geometry and facial landmarks.
Daniyal et al. [71]	2009	The authors proposed 3D face recognition using compact face signatures based on automatically detected 3D landmarks.
Gupta et al.[72]	2010	The authors proposed a 3D face recognition technique using 10 anthropometric facial fiducial points.
Dryden and Mardia [73]	2016	The authors proposed to measure the Procrustes distance and proportions of Procrustes separation between two arrangements of the facial tourist spots.

Table 2 discusses the contributions in Geometry and holistic based face detection.

Table 2. A literature review of Geometry and holistic based face detection.

Authors	Years	Different Approaches to Solve Image Processing
Huttenlocher et al. [74]	1993	The authors proposed using Hausdorff distance to compare binary images.
Wiskott et al. [75]	1997	The authors proposed an elastic bunch graph matching (EBGM) feature-based method.
Takacs [76]	1998	The author proposed a feature-based method that uses binary edge features.
Liu and Wechsler [77]	2000	The author proposed two new coding schemes, probabilistic Reasoning models, and enhanced FLD (Fisher linear discriminant) models.
Gao and Leung [78]	2002	The authors proposed LEMs for face portrayal.
Albiol et al. [79]	2008	The authors proposed a new face recognition algorithm based on the well-known EBGM which replaces Gabor features with HOG descriptors.
Chen et al. [80]	2013	The authors proposed a high-dimensional face portrayal by thickly removing multi-scale LBP (MLBP) descriptors around facial milestones.

Table 3 discusses the contributions of deep learning methods for face detection.

Table 3. A literature review of deep learning methods for face detection.

Authors	Years	Different Approaches to Solve Image Processing
Bromley et al. [81]	1993	The author proposes an algorithm for the verification of signatures written on a pen input tablet.
Lin et al. [82]	1997	The author proposes probabilistic decision-based neural networks (PDBNN).
Taigman et al. [83]	2014	The author proposes to derive a face representation from a nine-layer deep neural network.
Schroff et al. [84]	2015	The author proposes a system named FaceNet.
Krizhevsky et al. [85]	2017	The author classifies the 1.3 million images into 1000 classes.

One undertaking from the above discussions is that face recognition techniques have evolved over the past. Additionally, the higher literature review reveals that there are gaps in the study of facial image recognition. As such, the subsequent gaps are studied:

- Models like haar cascade can detect objects only if they have clear edges and lines.
- Multi-view face detection is always hard to detect.
- Various factors like head pose, lighting conditions, facial expressions affected the accuracy of the algorithms.

Therefore, this motivates us to provide a new model for society.

- Improve the accuracy of detection by training models with large datasets.
- Using DNN, as it takes the best features from the face image dataset, which improves the face detection.
- The main attraction of this paper is to detect both frontal and non-frontal faces with different variations like aging, poses, lighting conditions, and facial expression.

4. Description of the Research Work

There were many problems in face detection algorithms that already existed before few years. However, with the use of DNN, there is an improvement in the accuracy of the detection of the faces. One of the main issues was the detection of the non-frontal faces. While frontal face detection was easy to detect with the haar features, the non-frontal face has many factors like various poses, lighting, and expression conditions, which affect the accuracy of the algorithm. We have used DNN to solve the issue of detecting the non-frontal faces. In this method used, the input that will be given to the system will be an image/video, and the output will be a rectangular box corresponding to all the faces present in the image/video.

Figure 2. Non-frontal face image [86].

Figure 3. Non-frontal face image with variation in lighting condition.

Figure 4. Face image of people of different age groups [87].

4.1. Proposed Deep Neural Network (DNN) Method

Table 4. Proposed deep neural method.

Steps	Overview
Step 1	Considering our method, we will need an image/video, later we need to train a model based on the features, shape of the face. The model will also be trained for various lighting conditions, head poses, and aging factors.
Step 2	Here, we will create the face detection python files for both images and videos.
Step 3	Here we will make use of OpenCV which will check all the image/video with the trained face detector model.
Step 4	This last step includes displaying the faces in the images/video within the rectangular box.

5. Result and Discussions

The face recognition algorithms have significantly improved as compared to the early seventies. Deep learning methods have replaced traditional methods. The Deep learning-based methods are the new standards due to their improvement in accuracy in recent times. Also, the Deep learning methods are scalable, as their accuracy can be improved by expanding the dataset. Deep learning methods require labeled datasets, which are expensive and are slower to train and test.

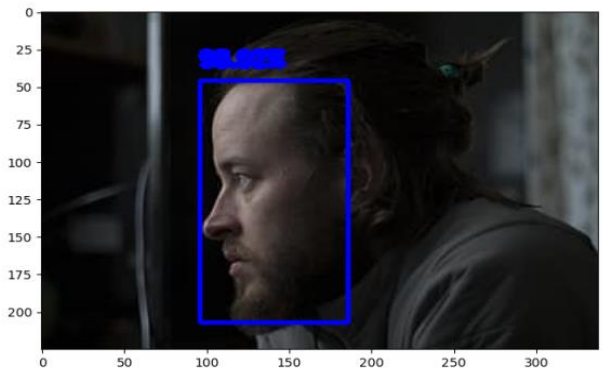

Figure 5. Result showing face detection in image using our proposed model [86].

Figure 6. Result showing face detection in image in low lighting conditions using our proposed model [86].

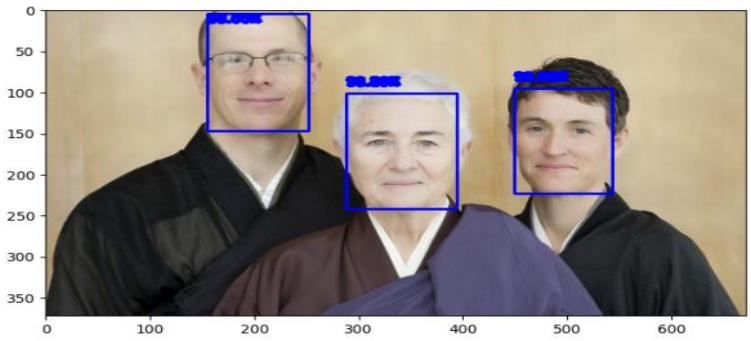

Figure 7. Result showing multiple face detection in image using our proposed model [87].

Here we can see the results that are obtained by using our method and we can detect the frontal and non-frontal faces using only the DNN method. After executing the model using the DNN method, we obtain the following result in the below ***Figures (5)-(7).***

Our proposed model can detect both frontal and non-frontal faces, and has better accuracy than the existing models. The proposed model detects the non-frontal face as shown in ***Figure (5)***, and it can detect faces of different ages as shown in ***Figure (7). Figures (8)-(9)*** have the images of the face that have been detected from the video.

Figure 8. Result showing face detection in video using our proposed model [88].

Figure 9. Result showing face detection in video using our proposed model [88].

6. Conclusion

In the view of the present study on the non-frontal side face detection problem of uncertain conditions, the conclusions are drawn and it is recommended for future use also. The major objective of this thesis was to develop and modify an efficient algorithm for solving non-frontal face detection. All of the problems of face detection have been solved by using the Pycharm tool. The thesis aims to solve the face detection in the first usage using the DNN from images/video. It is one of the best detectors in terms of accuracy, reliability, and speed. The main attraction of the paper is to solve the different types of face images having one face, two faces, and multiple faces, which is difficult to detect by the haar cascade classifiers.

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