Face Detection Algorithms: A Comparison

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Abstract— With the growing technology, the human race has made surplus devices which have helped us in the development of more of that kind. Using Machine Learning was a thought few decades back. But with its exponential advancements, we are now capable to have many other facilities like automation, security, statistical analysis and many other facilities which might have been impossible without the application of Machine Learning. In this paper we have implemented Convolutional Neural Networks (CNN), Artificial Neural Networks (ANN), Independent Component Analysis (ICA), Principle Component Analysis (PCA) and others. The main aim of the paper is to identify the use of each algorithm using the parameters Accuracy, Precision, Recall, and F1 score.

Index Terms— Accuracy, Artificial Neural Networks, Comparison, Convolutional Neural Networks, Face Detection, Machine Learning, Principle Component Analysis.

1 Introduction

In this paper, we have implemented different algorithms for face detection. The dace detection algorithms are trained using a data-set. That trained data-set is then used to identify the images which are given to the program called test image. The stages for building an algorithm for face detection can be given as follows:

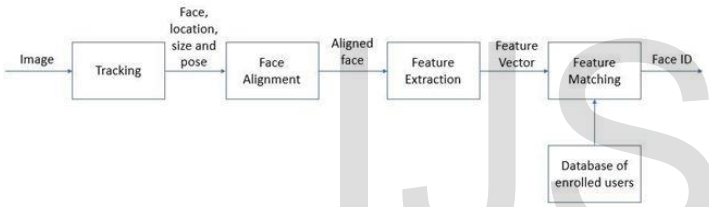

Fig 1: Stages of face detection

The input data is Image which is also called as test image. Consider an image with a lot of faces. In tracking, these different faces which are there in the image are extracted by rounding each of the face with a box. These faces extracted have different alignments i.e. the face might be 45 degrees left of right or tilted. Hence, Face Alignment is needed. The faces obtained are called Aligned faces. There are different features which can be extracted. Ad for instance, eyes, nose and lips. These features when extracted using Feature Extraction, will be called as Feature Vector. The test image is now having Feature vector which can be matched with the dataset. The whole model as described in Fig. 1 is trained using the dataset. Here, the features and faces are extracted already. Hence, the features are compared and analyzed.

1.1 Motivation

The algorithms implemented for face recognition and detection are as follows:

- CNN
- ANN
- ICA
- PCA
- LDA

There are many different algorithms for face detection. To use which algorithms depends upon the parameters like accuracy, precision, recall and F1. The other statistical parameters which can help the user to frame the data-set and input (test image) to the algorithm wisely are brightness, face pose, the exposure of the face and alike which will be mentioned further in this paper. The main concern while doing this paper was, when we implement face recognition systems in the outdoor environment, for e.g. when we use face recognition lock system on our phones, we observe that there occurs error related to pose, brightness etc. Using these analysis, one can try combining the algorithms according to their need and increase the efficiency of the program. In other words, these algorithms alone are still not ready for human perception systems. The above statement can be regarded as the future scope of the paper.

1.2 Objective

The objective of the paper is to clarify the difference between the algorithms and how one should amalgamate the programs in order to achieve the highest efficiency. By implementing the algorithms, we have found out the difference in their efficiency and what algorithms are more prone to brightness changes or face pose changes. We have also included iris detection and its efficiency which can be further used in security systems.

1.3 Approach Used

Face detection and recognition has a handful of algorithms. The ones with the most efficient are characterized by their use and other parameters. Hence, it is necessary to study each algorithm and do the statistical analysis of the same.

The approach used in this paper is implementing all the above-mentioned algorithms using the trained data-set, then training the algorithms again with randomly generated data-set by us. We used images with different brightness, blurred images and different poses in order to carry out statistical analysis. Accuracy, precision, F1 and recall were calculated then using the help of standard data-sets.

1.4 Scope of the Paper

The paper can be used in security systems but that will need real time analysis. Hence, the algorithms need to have a real time analysis and a dedicated set-up. The camera needs to access the test-image and then compare it and carry on the

process. The data-set is to be generated. The user might not know about the bright-ness and pose. Also, there can be a possibility that with a slight change in hairstyle and other styling equipment, the paper might not work. Hence, these are the limitations which are highlighted in this paper and its potential solutions like which program can be used in order to minimize the error.

Algorithm	Accuracy (%)
CNN	90
ANN	85
ICA	70
PCA	86.05
PCA with CNN	95.5

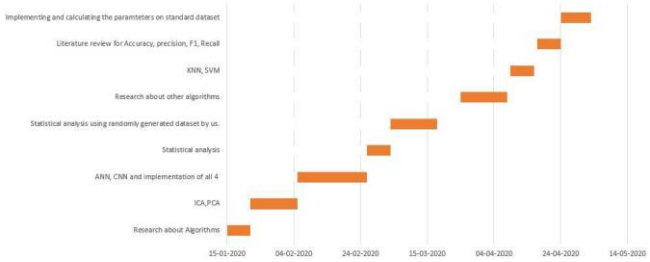

Fig2: GANTT Chart

2 Literature Review

Following are the papers referred while preparing the comparison of various algorithms:

- Baek, Kyungim, et al. "PCA vs. ICA: A Comparison on the FERET Data Set." JCIS. 2002.
  - There is no such differences in PCA and ICA algorithms' efficiency [1]
- Riaz, Zahid, Anf Gilgiti, and Sikander M. Mirza. "Face recognition: a review and comparison of HMM, PCA, ICA and neural networks." E-Tech 2004. IEEE, 2004.
  - The accuracy and efficiency of the system depend upon the situation where the system is to be used.[2]
- A Guide to Convolutional Neural Networks for Computer Vision By Salman Khan, Hossein Rahmani, Syed Afaq Ali Shah, Mohammed Bennamoun.
  - CNN is vulnerable to adversarial examples.[3]
- Kasar, Manisha M., Debnath Bhattacharyya, and T. H. Kim. "Face recognition using neural network: a review." International Journal of Security and Its Applications 10.3 (2016): 81-100.
  - PCA with ANN face recognition gives 95.45% accuracy. [4]

Depending on the accuracy of the algorithms the following chart is obtained. We can say that PCA along with CNN gives the best accuracy and hence we can use the said algorithm when accuracy is the main factor.

Fig3: Algorithms with their Accuracy.

2.1 Tools and Technologies Used

2.1.1 MATLAB

MATLAB developed by MathWorks is used for the applications of math and computations. For technical computing, it serves as a high-performance language. The main purpose is MATLAB is to provide a user-friendly environment where the problems are in the form of mathematical notation by amalgamation of computation, visualization, and programming. It allows the user to plot graphs, run functions, implementing various algorithms, also to create a user interface and much more. We have used the licensed version of MATLAB version 2019.

2.1.2 Google Colab

Google Colab is an online portal that is identical to the Jupiter notebook. Mainly, it does not require any setup to be installed and also the notebooks created in it are editable by your team. Hence, making it user friendly, easy to learn and maintain the team work. Being a user of it we can code in python and integrate with Open CV, TensorFlow, etc. Also, it allows to import database from external sources without even downloading it on your device resulting to less memory usage.

3 Face Detection Algorithms

3.1 Convolutional Neural Networks

There are two types of learning methods for training a model in Machine Learning from [5]:

- Supervised Learning
- Unsupervised Learning

In supervised learning the known variables are inputs and outputs of the system. In un-supervised learning the labels (true labels) of the image are left for the program to decide. Hence, the labels are unknown. CNN proves to be useful for both the types of learning methods. The CNN algorithm can be shown as follows:

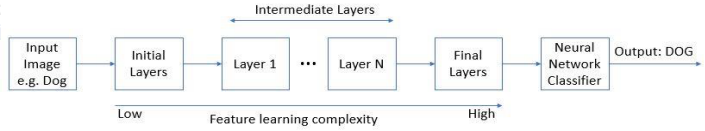

Fig4: CNN block diagram

CNN tries mapping the features which can be extracted from the given data-set. The feature extraction starts from simple ones to complex ones. These discriminative features will be used to in the network and the prediction for the true category for the test image is carried out. CNN starts learning from low level features to high level features i.e. complex ones in the intermediate layers. There are network layers which are also called CNN layers. They implement the basic functions like pooling, convolution, normalization, and complete connection between the layers. There are also complex layers like Spatial Transformer and VLAD pooling. There are convolutional layers which are also called kernel layers. They have filters and they are convoluted with the test image (input) which results into Output having feature map.

3.2 Artificial Neural Network

The block diagram of ANN can be given as follows:

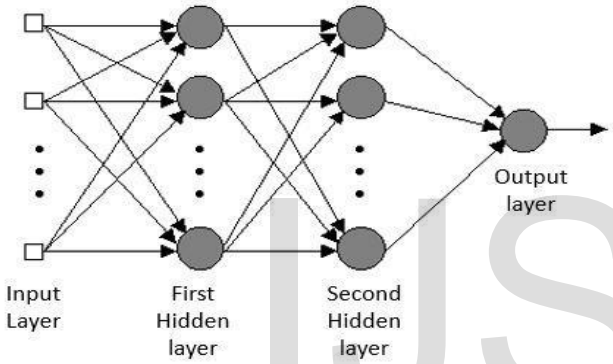

Fig5: ANN Block Diagram

ANN is a computational model [6] which impersonates the structure as well as the functions like neurons in a biological manner. With varied input, the specifications of the network also vary as it learns according to the input. All the layers as shown in fig. 3 are interconnected. The input layer passes on the neurons to the first hidden layer and those output neurons are sent to second hidden layer which in turn gives us the output.

3.3 Independent Component Analysis

The block diagram of ICA is as follows:

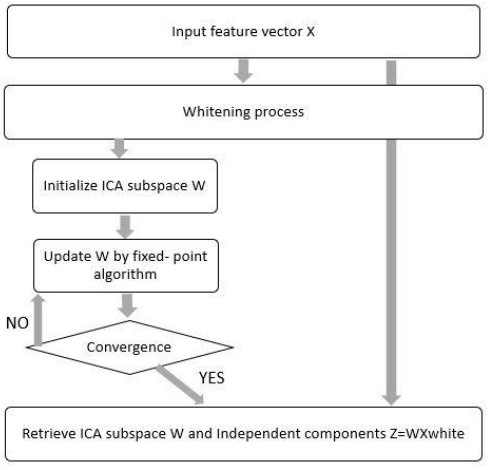

Fig6: ICA Block Diagram

Independent component analysis is mainly used as per [7] for detecting the true image by removing the noise from the image. The data in ICA is gaussian hence we need to convert the data into a non-gaussian random variables. Hence, as shown in the above figure we do the whitening process. Then, the process of extracting feature is carried on. Non-gaussian means the variables are then independent and hence the feature extraction can be carried out easily. The research for face detection using ICA is still going on. Its main application is in the field of signal processing.

3.4 Principle Component Analysis

The block diagram for PCA can be given as follows:

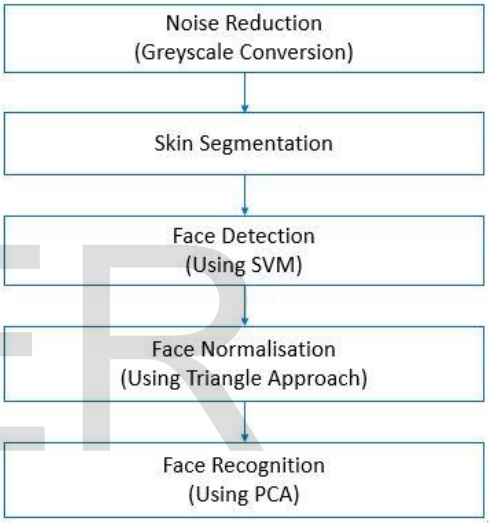

Fig 7: PCA Block Diagram

Whenever we want to compress the data, we use PCA according to [8]. In order to reduce the noise, as shown in the above figure, we have to convert the image into greyscale. Hence, the RGB vectors which are massive in number are now reduced substantially. In order to carry out the face detection process, the program is run in order to differentiate between skin colour and non-skin colour. Hence, the step of Skin segmentation is carried out. The face detection step is carried out using Support Vector Machines (SVM). It is explained in this paper further. In Triangle approach for face detection, there is differentiation of other features like mouth, eyes etc using the greyscale colour difference. Here, in the face a triangular shape is created which has three points of mouth and two eyes. However, this is not an accurate model for face detection. When PCA is implemented using CNN model, the accuracy obtained is nearly 96%.

3.5 Latent Dirichlet Allocation

LDA is the abbreviation for Latent Dirichlet Allocation. It is an unsupervised algorithm as per [9], meaning the order does not matter. It sees the content of document as a cluster of small topics. At first, it makes an assumption related to the topics

available. As we know, documents are formed with an aim of writing on a topic or topics. So, it tries to repeatedly go through the assumptions and try linking all the assumptions to get a to certain decision. It will not actually show you the topics as a result, but the words related to the topics and the frequency of the word would be the result and you have to judge the topic.

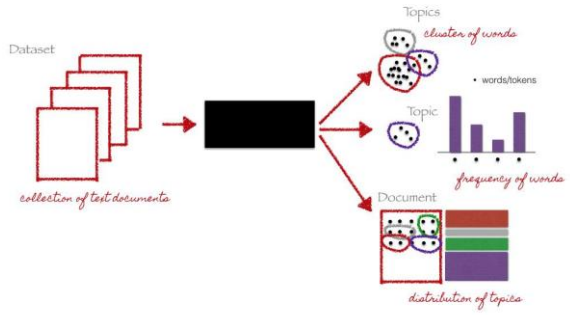

Fig 8: LDA Algorithm [10]

4 Implementation and Results

We used a custom dataset made of our own images for face detection and ran all the different algorithms. Following are the results:

	precision	recall	f1-score	support
0	0.80	1.00	0.89	8
1	1.00	1.00	1.00	8
2	1.00	1.00	1.00	8
3	1.00	1.00	1.00	8
4	1.00	0.75	0.86	8
5	1.00	1.00	1.00	8
6	1.00	1.00	1.00	8
7	0.67	1.00	0.80	8
8	1.00	1.00	1.00	8
9	1.00	0.75	0.86	8
10	1.00	1.00	1.00	8
11	1.00	1.00	1.00	8
12	0.80	1.00	0.89	8
13	1.00	1.00	1.00	8
14	1.00	1.00	1.00	8
15	1.00	0.58	0.67	8
16	1.00	1.00	1.00	8
17	0.80	1.00	0.89	8
18	1.00	0.75	0.86	8
19	1.00	1.00	1.00	8
avg / total	0.95	0.94	0.94	160

accuracy :
0.9375
Confusion matrix, without normalization
Confusion matrix, without normalization

Fig9: CNN simulation

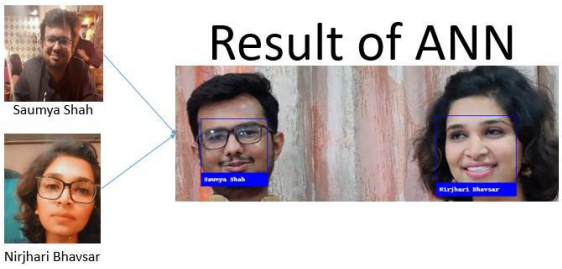

Fig10: Results of ANN

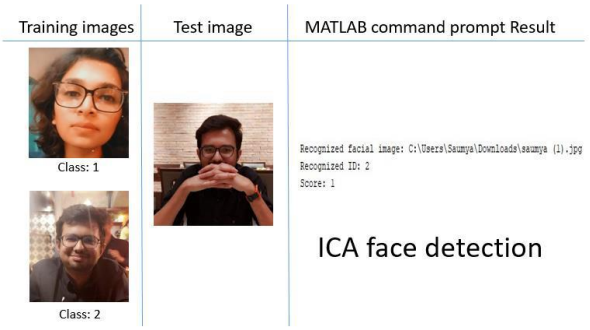

Fig11: ICA Simulation

```
Accuracy Score:  0.8478260869565217
Recall Score:  0.8478260869565217
Precision Score:  0.8478260869565217
F1 Score:  0.8478260869565218
```

Fig12: PCA Results

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Confusion matrix is
[[5 0 0 ... 0 0 0]
 [0 4 0 ... 0 0 0]
 [0 0 2 ... 0 0 0]
 ...
 [0 0 0 ... 2 0 0]
 [0 0 0 ... 0 2 0]
 [0 0 0 ... 0 0 1]]
Accuracy 0.9625
f1_score 0.9625000000000001
Recall score 0.9625
Precision 0.9625
```

Fig13: LDA Simulation Results

5 Conclusion

From the results we find the accuracies of all the different algorithms. We find that the accuracy of face detection is highest in LDA 96.25% followed by CNN at 93%. Hence, one can make the combination of various algorithms and increase the efficiency of the face recognition algorithm. This is the basic paper for the future scopes of increasing the efficiency of face unlock systems, using ML for higher security systems and increasing the tolerance capacity of the algorithms. The same results should be obtained in various other non-standard datasets.

References

[1] K. Baek, B. A. Draper, J. R. Beveridge, and K. She, "PCA vs. ICA: A comparison on the FERET data set," p. 5.

[2] Z. Riaz, A. Gilgiti, and S. M. Mirza, "Face recognition: a review and comparison of HMM, PCA, ICA and neural networks," in *E-Tech 2004*, Karachi, Pakistan, 2004, pp. 41–46, doi: 10.1109/ETECH.2004.1353842.

[3] S. Khan, H. Rahmani, S. A. A. Shah, and M. Bennamoun, "A Guide to Convolutional Neural Networks for Computer Vision," *Synth. Lect. Comput. Vis.*, vol. 8, no. 1, pp. 1–207, Feb. 2018, doi:

10.2200/S00822ED1V01Y201712COV015.
[4] M. M. Kasar, D. Bhattacharyya, and T. Kim, "Face Recognition Using Neural Network: A Review," *Int. J. Secur. Its Appl.*, vol. 10, no. 3, pp. 81–100, Mar. 2016, doi: 10.14257/ijsia.2016.10.3.08.
[5] "A Comprehensive Guide to Convolutional Neural Networks — the ELI5 way | by Sumit Saha | Towards Data Science." https://towardsdatascience.com/a-comprehensive-guide-to-convolutional-neural-networks-the-eli5-way-3bd2b1164a53 (accessed Nov. 26, 2020).
[6] "ANN Algorithm | How Artificial Neural Network Works," *Analytics Vidhya*, Oct. 20, 2014. https://www.analyticsvidhya.com/blog/2014/10/ann-work-simplified/ (accessed Nov. 26, 2020).
[7] A. Hyvärinen and E. Oja, "Independent Component Analysis: Algorithms and Applications," p. 31.
[8] J. Shlens, "A TUTORIAL ON PRINCIPAL COMPONENT ANALYSIS," p. 16.
[9] D. M. Blei, "Latent Dirichlet Allocation," p. 30.
[10] "Topic modeling using Latent Dirichlet Allocation(LDA) and Gibbs Sampling explained! | by Ankur Tomar | Analytics Vidhya | Medium." https://medium.com/analytics-vidhya/topic-modeling-using-lda-and-gibbs-sampling-explained-49d49b3d1045 (accessed Nov. 26, 2020).