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Exploration of Face Detection methods in Digital Images

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***Abstract:** Face detection is a challenging computer vision task that identifies and localizes the faces of human beings from digital images or video streams. It is predominantly the first phase in the process of developing a wide range of face applications such as face recognition, emotion recognition, authentication, surveillance systems etc. The process of face detection is easy from the human perspective but, a complex task for computers that involves searching of the face in variable circumstances of pose, colour, size, occlusion, illumination etc. If the outcome of face detection is intended to be input for another algorithm, an accurate, well informed selection of an appropriate face detection technique is essential because the overall performance of face application is dependent on face detection algorithm's precision. The survey paper presents a review of three commonly used face detection algorithms available in literature namely Viola Jones, Neural networks (NN) and Local Binary Pattern (LBP) for the purpose of ascertaining the most suitable face detection algorithm to implement for our future work in developing an 'Online student concentration level recognition system'.*

***Keywords:** Computer vision, Face detection, Local Binary Pattern (LBP), Neural Networks (NN), Viola and Jones.*

I. INTRODUCTION

The term "face detection" and "face recognition" are usually used interchangeably but they have different meaning. Face detection and face recognition are both complex computer vision tasks [2]; but face detection is normally the first step in many face related applications [5] that identifies existence, site and dimension of human faces in digital images [10], while face recognition consists of mainly two phases, initially face detection followed by face recognition i.e. matching the detected face with an existing face image in a database [22], [23]. The paper will major on the analysis of face detection feature extraction algorithms.

The process of identifying and localising the face is also perceived as a classification task, which when given an input as a digital image from various sources that include video, scanner, internet, and camera, the face detection technic should correctly classify (small False Positive rate) if a human face is present or absent in the digital image. The following *i. Pre-processing, ii.Feature extraction iii. Classification*

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Pre-processing comprises of several operations such as scaling, resizing, normalization, while feature extraction is achieved by transformation approaches such as LBP, Gabor wavelets, PCA [23] and lastly classification using SVM, NN, Distance classifiers, HMM model etc. [5],[11], [12] ,[37] and[23].

This paper is structured as follows: Section 2 and 3 focuses on presenting a short description of face detection algorithms categories and drawbacks of existing algorithms. A detailed review of related work on each of the three common face detection algorithms is provided in section 4. A comparative analysis of the feature extraction algorithms used for detecting the face is established in section 5 and section 6 concludes the paper.

II. CATEGORIES OF FACE DETECTION FEATURE EXTRACTION ALGORITHMS

Feature extraction algorithms used in detecting the face are implemented in a wide range of real time, non-real time and android face applications [14]. The realization of various face detection algorithms has paved way to the exponential rise in the development of numerous face related applications such as authentication system [2], surveillance system [3], emotion recognition[7], [8], iris detection system [38]], speech production application[6], automated attendance system[1] driver fatigue detection [14] etc. Some of the common face detection algorithms used in these applications include; Support Vector Machine (SVM), local Binary Pattern (LPB), Ada boost, Eigen faces, template matching, neural networks, Viola Jones, Principle Component Analysis (PCA) [5],[11] and [12]. These face detection algorithms are generally classified into four key categories [10], [15], [19], [37] and [38]:

- *Knowledge based methods- Top down approach*

Knowledge based methods use rules of thumb (heuristic rules) to detect the face region. There are two main challenges to this mechanism; if the rules are too strict the algorithm may fail to detect the faces which do not satisfy the rules otherwise if the rules are too general many false positives will occur. The solution is to use a multiresolution hierarchy and rules to guide searches.

- *Feature based methods–Bottom Up approach*

Feature based methods are based on initially extracting invariant features using edge detection techniques, followed by constructing a statistical model to articulate the relationships and validate the existence of a face. The invariant features include facial features (eye, nose, mouth, and eyebrows), texture, skin color and other multiple features. The major drawback in this method is that shadows can contribute to strong edges in comparison to feature boundaries which make the algorithm inefficient.

- *Template matching method*

Template matching uses predefined or deformable templates. The method is easy to implement, it uses correlation values to determine the existence of a face. However it is inadequate for face detection since it cannot deal with variation in shape, pose or scale.

- *Appearance based method /Learning based methods*

Appearance based methods use machine learning and statistical analysis these have proved to have a higher degree of accuracy in face detection in comparison to traditional methods. Some of the algorithms used are neural networks, LPB, Viola Jones, Hidden Markov Model (HMM), SVM, Naïve Bayesian, Eigen faces. The limitation of some of these methods is that they are time and memory intensive.

III. DRAWBACKS OF EXISTING FEATURE EXTRACTION ALGORITHMS

Numerous feature extraction algorithms in detecting the face detection have been suggested; however inadequate consideration has been given to the detection precision [15]. Detection rate is the key success factor in face detection. Therefore there is a need for enhancing the precision [18]. Below is a list of some of the factors that affect precision or accuracy [4], [12], [19].

- Pose
- Presence or absence of structural component
- Facial expression
- Occlusion
- Image orientation
- Imaging conditions

IV. RELATED WORK

This section provides detailed review of the three face detection algorithms used for feature extractions are neural networks, LBP and Viola Jones.

A. Neural Networks

The neural networks method for detecting the face overcomes the constraint of non-frontal face detection [30] and results in high detection accuracy in comparison to other existing methods such as Viola Jones, LBP etc. [23] and [31]. There are two main variations of neural networks used for face detection namely classical and convolutional neural networks. Convolutional neural networks also known as deep convolutional neural network [26] are an advancement of classical or traditional neural networks. The main limitation of classical NN is the curse of dimensionality in high resolution images which led to the development of CNN. Convolutional neural networks provide better accuracy with much fewer connections and parameters compared to classical NN. In addition CNN can automatically extract features, work well with huge data sets and are easy to train [26], [23], [30], [20] and [21]. However, their main drawback in CNN is that they require huge training datasets and training time. The draw backs are overcome since huge amounts of data are being generated due to advancement in computer technology and the use of pre trained model such as VGG, RESNET, ALEXNET [18],[26], greatly reduces training time.

B. Method

The method comprises of two stages training and testing. The training stage involves exposing the neural network model to labelled face and non-face images for learning features that distinguish face image from other images. The larger the training dataset the more the model learns which results in good generalization. The model is validated to identify whether there was under fitting or overfitting during training. Finally the model is tested using images not used for training. If the model correctly classifies face and non-face it implies the model is performing well.

C. Neural network model

Classical neural networks models differ from convolutional neural network models in that CNN have more layers compare to classic NN and CNN have better accuracy with much fewer connections and parameters compared to classical NN[26][23][30 . The CNN model consists of a series of convolution and pooling layers followed by fully connected layers as shown in Fig 1.

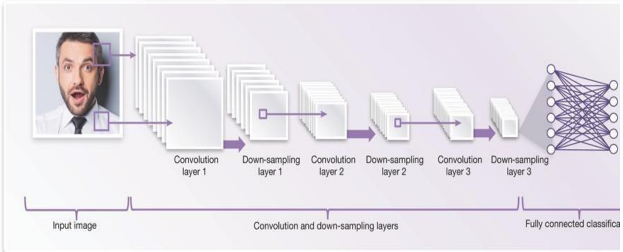

Fig 1. Convolutional Neural Network model

The convolutional layer is for automatic extraction of features from input image. Convolution is performed using a filter or kernel. Different types of kernels are available such as Sobel, Prewitt, and Roberts but each filter type has a specific purpose such detecting lines, edges, corners etc. The series of convolution layers in the CNN can use different or same kernels. Pooling reduces size of the feature map and removes redundant information by downsizing based on distinct features. There are also different kinds of pooling, we have average and max pooling but max-pooling but max pooling frequently used. The fully connected layer is also referred to as the dense layer and is used to provide classification output.

(i) Classical neural networks

H. A. Rowley et al. in [29] designed "Neural network-based face detection," on upright frontal faces. The model has two phases; the first phase used a collection of kernels based on neural network on an image and the second phase used a mediator to aggregate the output. The training and testing data sets used were CMU and FERET face datasets respectively. The designed application was able to detect between 77.9% and 90.3% of the faces.

C. Chen and S. P. Chiang in [28] focused on "Detection of human faces in colour images" using a three-stage method for face detection based on neural networks. In the initial stage candidate face area of interest was subdivided from the colour image with respect to skin colour using neural networks, followed by extracting the facial features and lastly candidate lip area was extracted from the prior stage and validated using shape descriptors. A collection of 450 colour images were used for testing. The images were divided into three groups according to source; digital camera, colour scanner and video signals. The experiment achieved 96%, 90% and 76% detection rate for colour, scanner and video image groups respectively. The observation revealed poor face detection in too much highlight or too dark.

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R. Feraund et al. in [27] describes "A fast and accurate face detector based on neural networks"; the Constrained Generative Model (CGM). The face detector is composed by four stages. Motion filter, colour filter, Multi-layer perceptron and CGM. The model was tested on Sussex Face Database and CMU data sets. The face detector detected side view and front view faces with a detection rate of above 80%.

(ii) Convolution Neural Network

M. Z. Khan et al. in [26] proposed a "Deep Unified Model for face recognition based on Convolution Neural Network and Edge computing". The model had two stages the first was region proposal for detected face and secondly recognizing detected face. The model was trained and tested on LFW data set and achieved an accuracy of 97.9 %. W. Wu et al. in [30] presented a "Face detection with different scales based on Faster R-CNN", The model included two steps the region proposal network (RPN) for detection of ROI on human face using a face detector (boosting cascade) .The Fast R-CNN was used for different scale of proposal. The AFW, PASCAL faces, and WIDER FACE data sets were used for testing and the FDDB for training. The proposed method achieved a recall rate of 96.69%.G. Storey et al. in [18] designed an "Integrated Deep Model (IDM) for Face Detection and Landmark Localization from In the Wild Images", to resolve the challenges of increasing precision of face detection. The IDM model merged two convolutional neural network architectures Faster R-CNN and stacked hourglass to leverage the inter-connectivity of the learnt features, which resulted in enhanced detection rate and landmark localization accuracy. The major advantage of CNN is that it produces good results with non-frontal face. C. Garcia and M. Delakis in [31] established a "Convolutional face finder (CFF): a neural architecture for fast and robust face detection," designed to locate multiple faces. It has the capability of deducing explicit feature extractors automatically, from huge face datasets. It consists of a series of convolutions for automatic feature extraction and feature classification as a single system. A huge collection of Internet images and scanned newspaper images was used to train the model. The CMU, web, cinema test data sets achieved 93.3%, 98% and 95.3% accuracy respectively. The proposed CFF method is good for numerous computer vision tasks, where the patterns to be detected experience distortions that are challenging to empirically model.

D. VIOLA JONES

Viola Jones algorithm uses weak classifiers [10] that provides a good real time detection [13]. According to [10], [13] and

[35] the Viola Jones method has four components;

1. Generate Haar like features
2. Integral image
3. Ada boost classifier
4. Combining classifiers in a cascade

Haar like features are rectangular features for identifying edges, lines, centre surrounded and diagonal features shown in Fig 2.

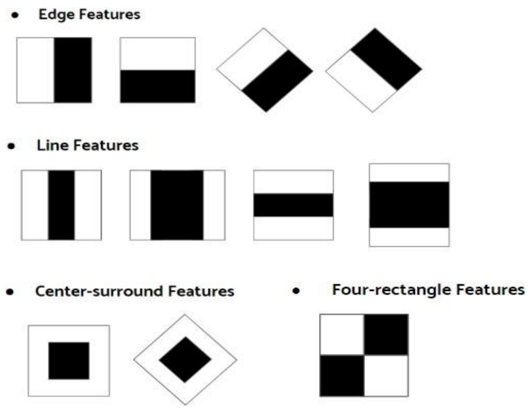

Fig 2. Haar like features

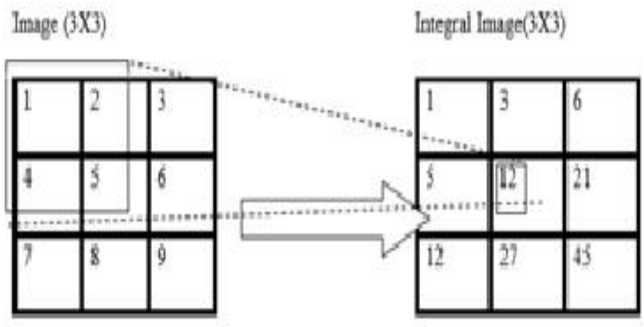

Fig 3. Integral Image

The integral image makes computation of image feature values faster. The feature value (**V**) is calculated by finding the difference between average light and the average dark pixel subdivision values (Equation1) followed by comparing it with the threshold (Equation 2). If the calculated difference value is below threshold it implies feature is absent; else it is present [10].

$$V = Sum_{white} - Sum_{black} \quad (1)$$

$$Detection = \begin{cases} Face & V \geq Threshold \\ Non-Face & V < Threshold \end{cases} \quad (2)$$

Ada boost is a machine learning based approach for detecting faces, by identifying strong classifiers; a linear composition of weak classifiers [13]. Fig 4 illustrates the process that an image goes through for face detection. If an image passes through classifiers C_1 to C_N successfully (T) it implies a face is detected, otherwise if it fails (F) to meet the threshold values of any classifier it exits the detection .Combining several cascades achieves greater accuracy and is computationally efficient compared to using a fixed cascade [36].

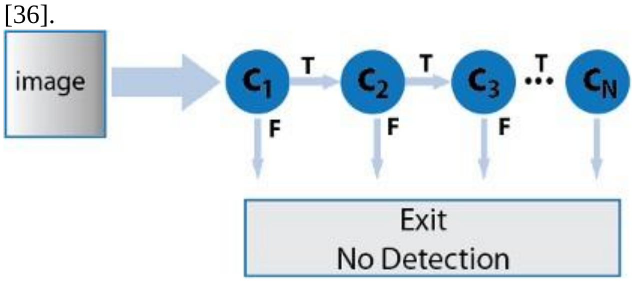

Fig 4. Ada Boost classifier

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According to [3], [16], [15] and [13] advantages of the Viola Jones algorithm are less computation time; High accuracy (low false positive detection rate) and widely used in real time applications. Disadvantage is that non frontal faces can hardly be detected**.** D. Shamia and D. A. Chandy in [25] presented on "Analyzing the performance of Viola Jones Face Detector on the LDHF database". Only near infrared (NIR) shot atdifferent distances at night were considered from the LDHF database for testing. The Viola Jones algorithm had detection rate of 95% in 1m NIR and 56% in 150m NIR. The results reveal a continuous reduction in detection rate as the NIR distance increases .The algorithm must strive to enhance distant NIR image detection rate and address the shortcomings of reflectance effect.W. Lu and M. Yang in [24] focused on "Face Detection Based on Viola-Jones Algorithm Applying Composite Features". Although the original Viola Jones realizes real time detection the false detection rate is not low. In the presence of objects in the face the original Viola Jones is likely to generate false detection. The proposed model was compared with the original Viola Jones on FBBB dataset. The proposed model had a lower missed detection rate and false detection rate in comparison to the original Viola-Jones algorithm. K. Vikram et al. in [13] discussed on "Facial parts detection using Viola-Jones Cascade Object Detector" using a combination of filters and methods to detect face, eyes, nose and mouth of a human faces. The Bao database with varying pose and light was used to test the classifier compared to AR and Yale face datasets which comprises less complex invariant frontal face images. The experiment was done using MATLAB and achieved 92% accuracy.M. Da" san et al. in [16] established a "Face detection using Viola and Jones method and neural networks". In the preliminary stage of face detection Viola and Jones method was employed. The second stage consisted of three sub-stages; feature extraction using Gabor filters, feature vector reduction using PCA and lastly classification of the candidate images as face or non-face using neural network. The proposed model reflected an improvement in face detection rate. M.N Chaudhari [17] suggested an "Improvised Viola Jones model for Face Detection using Viola Jones Algorithm and Neural Networks". Viola-Jones algorithm was used for eye detection and Neural Network (NN) for detection of glasses. This algorithm boosted the face detection accuracy to 90%. The major advantage of the improvised method is better face detection accuracy with reduced computation time.

E. LOCAL BINARY PATTERN

The LBP texture descriptor is based on appearance with high discriminative power [10]. The descriptor is used a plethora of applications that include; face recognition, age estimation, gender classification, real time face detection[34],[32],[10]. It identifies important texture patterns like spots, ends edges and corners. Different type of operators can be used such shown in Fig 5.

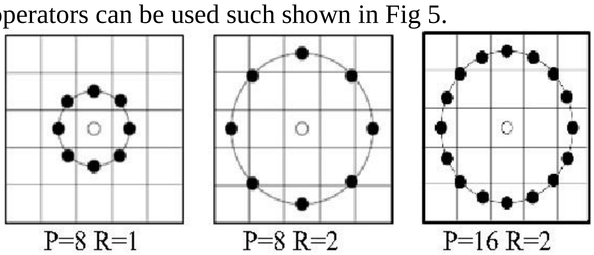

Fig 5. LBP operators

The value of P indicates the number of neighbourhood pixels and R is the radius. Each pixel value (P) is compared with the centre pixel value. If the pixel value(P) is greater than or equal to the centre pixel value a label binary digit of one (1) is placed in pixel value else a zero (0). The comparison process is iterated for the entire neighbourhood pixels. An 8-bit or 16 bit encoding is generated based on type of operator used and respective integer value calculated. For each pixel in the subdivision the process is repeated. The method can generally be described as follows:

i. The face is divided into subdivisions.
ii. LBP is used to compute description for each subdivision.
iii. The histogram for each subdivision is derived.
iv. All histograms are combined to get a global face vector
i.e. the whole face.

Advantages of LBP according to [32] and [34] are;

- Computational simplicity and efficiency.
- No gray scale normalisation required before applying the LBP operator to the face image.
- It can survive pose and illumination changes.

Disadvantages of LBP

- Good at small scale encoding but limited with broad encoding scales
- It is a hand crafted feature falls short when modelling the huge extent of diversity existing in uncontrolled environments [33]

O"Connor et al. in [9] discussed on "Face recognition using modified LBP (MLBP) and random forest" since the basic LBP operator may fail to detect the illumination variation and facial expressions accurately. MLPB fuses sign and magnitude components to preserve most of the information of local difference and provide additional discriminant information; this enhances the overall recognition accuracy. Random forest was used for feature selection and Manhattan distance for matching. The Craniofacial longitudinal morphological face data set with facial images of males and females of various ethnicities in different non ideal factors, was used for testing. For the (N:1) setup, 6×5 patch configuration, with 7680 features, MLBP operator exhibited the best accuracy of 32.96% while LBP operator had 30.97% . Similarly for (1: N) setup, 6×5 patch configuration MLBP operator had a higher accuracy of 40.71% while LBP operator achieved 38.46%.

K. Kadir e t al. [10] conducted a "Comparative study between LBP and Haar like features for face detection using OpenCV". The model was tested on three data sets that focus on a single face frontal image, with occlusion of 30 degree to right and left; Taarlab, MIT and Color FERET datasets. The Haar achieved an average detection rate of 84.7% and LBP 89%. The detection speed was 241 and 101 respectively. The LBP proved to be an efficient texture analysis operator with high discriminative power, computational simplicity, good for real time application and robust to monotonic gray scale. M. A. Abuzneid and A. Mahmood in [23] proposed an "Enhanced Human Face Recognition using LBPH Descriptor, Multi-KNN, and Back-Propagation Neural Network". LBPH was used for feature selection and dimensionality reduction, Multi KNN used a combination of five distance measures Mahalanobis, Euclidean, Manhattan, Canberra and Correlation to generate T-Dataset for classification using BPNN. ORL and Yale data sets were used for testing and achieved 98% and 97.7% accuracy respectively. Evaluation was performed on LFW data set which achieved a high accuracy of 95.7%. The strength of the model is on the generation of the T- data set for faster convergence.

V. ANALYSIS OF FACE DETECTION ALGORITHMS

Table I exhibits a summary of the three commonly used algorithms in literature, the datasets, detection accuracy and limitations in respective reference papers [Ref].

Table I. Detection rate and limitation of various methods

Ref.	Method	Dataset/ Detection Rate	Limitation
[29]	Neural Networks	FERET / Between 77.9% and 90.3%	Based on upright frontal face detection.
[28]	Neural Networks	FTP / Colour image: 96% Scanner image: 90% Video image: 76%	Too much highlight or are too dark results poor face detection.
[27]	Neural Networks	CMU Sussex / CMU: CGM5: 85% Sussex: CGM5 :87.5%	As orientation increases detection rate reduces. Use of colour filters reduces detection rate
[26]	CNN	LFW / 97.9%	As distance increases, the picture becomes blurry which results in poor detection of blurry faces.
[30]	CNN	AFW PASCAL Wider face FDDB / 96.69%	Requires more computation time.
[10]	LBP and Haar	Taarlab, MIT Color FERET / Haar: 84.7% LBP: 89%.	Tested on single face frontal images only.
[9]	LBP and MLBP	Craniofacial longitudinal morphological face data set / MLBP: 32.96% LBP: 30.97% MLBP: 40.71% LBP: 38.46%	Test dataset, had noise factor or non-ideal factors,
[13]	Viola Jones	Bao database / 92%	Requires long training time
[25]	Viola jones	LDHF (NIR images only) / 95% in 1m NIR 56% in 150m NIR.	Reduced detection in NIR as distance increased
[17]	Improvis ed Viola Jones	SoF „SpecsOnFace"/ 90%	Requires long training time

Table II. Algorithms Detection Accuracy

Algorithm	Detection Accuracy% and [REF]	Average Detection Accuracy %
NN	90.3% [29] 96.0% [28] 87.5% [27]	91%
CNN	97.9% [26] 96.7% [30] 99.6% [18]	99%
LBP	89.0% [10] 38.5% [9] 95.7% [23]	74%
Viola Jones	95% [25] 92% [13] 90% [17]	92%

A. ALGORITHM DETECTION ACCURACY

The algorithm detection rate refers to how well the proposed model is capable of detecting faces correctly. Table II provides a summary of some of the detection rates achieved in referenced papers [Ref] relating to each algorithm. An average detection rate was calculated for each algorithm based on number of referenced papers and a graphical plot was generated in Fig 6.

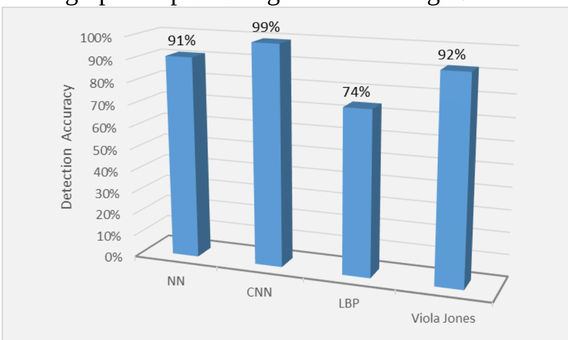

Fig 6. Algorithms Detection Accuracy

VI. CONCLUSION

The literature review on the three face detection algorithms indicates that CNN have the highest detection rate followed by Viola Jones, neural networks and lastly LBP (fig 6). The CNN provides higher accuracy with automatic feature extraction; they also work well with huge data sets and are easy to train. The major merit is their ability to overcome the limitation of non-frontal face detection. In light of these advantages Convolutional neural networks will be selected as the most appropriate face detection algorithm for the future work in developing an "Online student concertation recognition system" compared to other commonly used algorithms Viola Jones and LBP.

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