

# A Survey on Different Face Detection Algorithms in Image Processing

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**ABSTRACT:** Face detection of digital images has acquired much importance and interest in the last two decades. Face detection is a very specific object detection approach in image analysis with the objective of localizing the face region from the background. Face detection has several applications in various fields like face recognition, video surveillance, intelligent human computer interfaces and so on. A wide variety of techniques have been proposed for face detection. This paper presents a survey on various face detection methods proposed. We also give a presentation of a fusion model for face detection and the algorithms used in the model.

**KEYWORDS:** Face detection, fusion model, hybrid detector, NPD, Haar classifier, Exemplar.

## I. INTRODUCTION

Face detection is a computer technology being used in a variety of applications that identifies human faces in digital images. Face detection has been studied extensively for improving human computer interaction (HCI). Face detection is the first step to all facial analysis algorithms, like face alignment, face modelling, face relighting, face recognition, face verification and authentication[1]. However, not all face detectors perform well in unconstrained scenes due to variations in image appearance such as pose variations, illumination, expression variations, occlusions and facial expression. Due to the increasing importance of various applications of face detection like video surveillance and personal authentication, detectors should be highly accurate to locate faces in digital images and videos as opposed to the challenges faced. In this paper, a detailed study is performed on the various face detection algorithms, analysing their advantages and disadvantages. Finally, a fusion algorithm is presented that aims to reduce the disadvantages caused by the well known algorithms.

### A. WHY FACE RECOGNITION?

Security is of major concern in the present era. However it should not interfere with the lives of the individuals. Passwords, PINs, smart cards etc could be compromised easily because of their simple inherent complexity. Using other forms of authentication like biometrics offers better security because of their uniqueness. However the major concern is to use some form of authentication without compromising the Quality of Experience (QoE). Face recognition offers distant authentication technique in the event a user brushes pasts the camera and also improves QoE as the user may be engaged in other activities which require them to use the body parts which are part of biometric authentication. It also improves the amount of positive detection because generally, in case of other biometrics, the damaged tissue (reasons like wear and tear, cut, bruises etc.) will fail to authenticate correctly. Using other forms of authentication like voice recognition is not possible practically because of external interferences like noise in recording. However facial images can easily be obtained since it is nonobtrusive and hence doesn't hinder the working of the individual.

### B. APPLICATIONS OF FACE DETECTION

Face detection is being used in a variety of applications that identifies human faces in digital images nowadays. Certain major applications include:

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**Facial Recognition:** Face detection is used in biometrics, usually as a part of or along with a facial recognition system. It is also used in video surveillance, human computer interface and image database management.

**Photography:** Nowadays, digital cameras use face detection for autofocus especially for selecting regions of interest in photo slideshows. Modern digital cameras and smart phone cameras also use smile detection to take a photograph at an appropriate time[1].

**Marketing:** Face detection is widely used for marketing. A webcam is integrated into a television and detects any face that passes by. Once the face is detected, the system then calculates the race, gender, and age range of the face. Based on the information collected, a series of advertisements can be played that is specific toward the detected features.

**Identification:** An individual's image can be used to determine his/her identity by comparing the image with an image database containing images of known individuals. An individual's access to various facilities can be controlled by this means[5].

## C. CHALLENGES IN FACE DETECTION

**Illumination Problems** - Illumination can change the appearance of an object drastically. This effect is mostly affects the performance of face detection systems in outdoor platforms. Illumination changes can result in changes in highlights on an image, which in turn can result in changes in the face appearance.

**Pose Variations** - In video surveillance systems, the face images captured by the camera is likely to have some degree of rotation. The dataset used for training a face detector will have frontal view face images than pose angle images. As pose variation is an unconstrained factor, it becomes difficult to train a face detector to detect profile faces.

**Occlusions** - Occlusion is a major challenge to face detection when it comes to detecting multiple faces in a crowd. Occlusion can either be due to another object on its way or by the object itself. In some cases, the angle of the camera determines the extend of occlusion.

**Low Image Resolution** - In video surveillance systems, the distance between the camera and the object class to be detected is large resulting in low resolution images for detection. Most of the face detectors can detect face images only in high resolution images.

**Out-of-focus blur** - Out-of-focus blur is a significant factor for reducing the image quality. The performance of a face detector depends upon the image quality. Illumination changes and low resolution of the image also adds up to the blurred effect on an image.

## II. RELATED WORK

### A. RAPID OBJECT DETECTION USING A BOOSTED CASCADE OF SIMPLE FEATURES:

The Viola-Jones object detection framework is an approach that improves the accuracy of object detection in addition to reduced computation time. This approach mainly focuses on solving the problem of face detection. The Viola-Jones face detector combines three key ideas that enabled rapid face detection even in real time applications. The first idea being a new image representation known as "Integral Image", helps reduce the computations involved in feature extraction. The second contribution is the AdaBoost learning algorithm that can build efficient classifiers by selecting critical features from a larger set of features. The third is a method of combining these efficient classifiers in a cascade which allows to discard those regions of the image that are unlikely to contain the object of interest. However, the approach proves to be time consuming when working with large and complex face detection datasets.

### B. EFFICIENT BOOTSTRAP EXEMPLAR BASED FACE DETECTION:

This method sheds light on the fact that despite years of research on face detection the problem is yet not completely solved. When traditional methods face challenges such as extreme pose, lighting, and occlusion, exemplar based face detection required large exemplar database to resolve the challenges, even though Exemplars are themselves "high level features" that are more discriminative for face detection. Moreover the issue of redundancy and false alarm in highly cluttered environments was a big concern. Proving that it was practically difficult to implement. The new method introduces a more efficient Boosted exemplar based face detector which overcomes the defect of the previous work by being faster, more memory efficient, and more accurate. This approach uses the RealAdaboost framework to

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select the most discriminative exemplar. Additionally concepts of negative exemplar is added which helps suppress false alarms.

### **C. A FAST AND ACCURATE UNCONSTRAINED FACE DETECTOR:**

Shortcomings such as failure to detect unconstrained scenes like pose variations, occlusion, expression variation and out of focus blur can be addressed by 2 methods proposed here[2]: Normalized Pixel Difference (NPD) and Deep Quadratic Learning tree. NPD feature is computed as the ratio of the difference between any two pixel intensity values to the sum of their values. This feature is scale invariant, bounded, anti symmetric and has the ability to reconstruct the original image. Deep Quadratic Learning tree feature is used to learn the optimal subset of NPD features and their combinations. Thus different types of faces can be automatically divided into different leaves of a tree classifier. AdaBoost Algorithm is used to learn the NPD feature based deep quadratic trees. Only a single cascade classifier is learned for unconstrained face detection, hence there is no need to label the pose of each face image manually or cluster the poses before training the detector. Also NPD feature evaluation being extremely fast, only single memory access is required using a lookup table, making the face detector very fast.

### **D. PEOPLE COUNT ESTIMATION USING HYBRID FACE DETECTION:**

This method brings out the constraints found in simple face detection algorithms like HAAR classifier and NPD. These algorithms even though used widely are slow and fails to deliver results in unconstrained situations[1]. NPD fails to detect large pose variation and has higher false rate. However it remains constant and doesnt change with respect to the scale change of intensity pixels. Because of this NPD is much better than other algorithms against illumination changes.

HAAR classifier on the other hand requires lots of training based on inputs and templates. Therefore accuracy of training is very important. Hence a combination of HAAR classifier along with HAAR classifier for profile faces and NPD is used to deliver the best result. A combination of Haar classifier algorithm, Normalised Pixel Difference and Haar Classifier for profile faces, known as a hybrid face detection algorithm can be used so as to detect faces with high accuracy and to reduce false positives. It can detect faces in complex backgrounds and profile faces. NPD is used to detect faces in the image and Haar classifiers are used as a secondary detector so as to reduce false detections. Now for profile and rotated face images, Haar classifiers for profile faces is used.

### **E. TWO-STAGE CASCADE MODEL FOR UNCONSTRAINED FACE DETECTION:**

Detection of faces is a challenging task even in modern world[6]. The major challenges are variability and diversity of the face pose, the presence of occlusions, expression variability, different illumination conditions, scale variations, and colour and texture richness. The method focuses on using NPD first and then followed by using DPM (Deformable part model) which reduces the number of false reports obtained from NPD.

A mixture of multiscale DPMs, represented by HOG features, is used for joint face detection, pose estimation and landmark localization methods. The histogram of oriented gradients (HOG) is a feature descriptor used in computer vision and image processing for the purpose of object detection. From analysis, we can see that by using the two phase model we can reduce the number of false negative detections.

### **F. REALTIME DETECTION OF MULTIPLE FACES AT DIFFERENT RESOLUTIONS IN VIDEO STREAMS:**

Multiview face detection plays an important role in many applications[5]. In this sense, if Human Computer Interaction (HCI) could be more similar to human communication, HCI would be non-intrusive, more natural and comfortable for humans. In this paper, we describe a real time vision system which goes beyond traditional still image face detectors, adding to a state of the art object centered face detector elements in order to get a better, more robust, more flexible and realtime multiresolution face detector. The additions are related to: The integration of knowledge about features, particularly eye location is also provided, present in faces the integration of the temporal coherence, and the advantages evidenced by the local context in head detection for low resolution and difficult head poses. Histograms of extracted features are learned to represent class distributions and to construct probabilistic classifiers. The method is applied to both multiview face and eye detection, and experimental results demonstrate improved performance over existing methods.

### III. ALGORITHMS USED FOR FACE DETECTION

The various algorithms used for face detection in different methods are stated below:

NPD face detection is a fast and accurate method for face detection in cluttered scenes. The NPD feature measures the relative difference between the intensity values of two pixels in an image. NPD feature is scale invariant, which is expected to be robust against illumination changes. Then NPD features are optimally combined together in a deep quadratic tree to represent the intrinsic face structure. Haar Cascade Classifier face detection is based on the concept of simple Haar-like features. Haar-like features of any size can be calculated in constant time by the concept of integral image. Integral image simplifies calculation of sum of pixels, how large may be the number of pixels, to an operation involving just four pixels. The approach then uses the boosting algorithm AdaBoost to select the critical features to build classifiers. Then a Cascade of these classifiers is used to detect the frontal face region. Haar classifier for profile faces is also taken which is fine to detect profiled faces.

AdaBoost algorithm for classifier learning is a popular boosting technique which helps you combine multiple weak classifiers into a single strong classifier. Initially, the algorithm needs a lot of positive images (images of faces) and negative images (images without faces) to train the classifier. AdaBoost assigns a weight to each training image, which determines the probability that each image should appear in the training set. After training a classifier, AdaBoost increases the weight on the misclassified images so that these images will make up a larger part of the next classifiers training set. The final output is just a linear combination of all of the weak classifiers.

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#### Algorithm 1: NPD face detection

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Input: Video Frame

Output: Face Region

1: NPD feature is defined as

$$f(x; y) = \frac{xy}{x+y}$$

where  $x; y \geq 0$  are intensity values of the two pixels in an image.

2: Initialise  $f(0; 0)$  as 0 when  $x = y = 0$ .

3: For pixel pairs  $1 \leq i < j \leq p$ , compute NPD feature  $f(x_i, x_j)$  for the image resulting in  $d = \frac{p(p-1)}{2}$

4: For  $i = 1$  to  $d$ , perform quadratic splitting to learn the object structures in each feature.

- For feature  $x_i$ , evaluate tree node splitting as  $(ax^2 + bx + c) < t$  where  $a; b; c$  are constants w.r.t.  $x_i$ , and  $t$  is the splitting threshold.
- If  $x$  is in a range  $[\Theta_1; \Theta_2]$ , where  $\Theta_1$  and  $\Theta_2$  are two learned thresholds, then add  $x_i$  to the optimal subset.

5: Combine the features in the optimal subset in a deep quadratic tree.

6: Adopt AdaBoost algorithm to learn the NPD feature based deep quadratic tree.

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#### Algorithm 2: Haar Cascade Classifier face detection

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Input: Video Frame

Output: Face Region

1: Compute the integral image  $ii(x; y)$  at location  $x; y$  from the original image  $i(x; y)$  using the following pair of recurrences:

$$s(x, y) = s(x, y-1) + i(x, y)$$

$$ii(x; y) = ii(x-1, y) + s(x, y)$$

2: Compute the rectangular features from the integral image.

3: Use AdaBoost algorithm to select a set of features and train the classifier.

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4: Pass each subwindow of the image through a cascade of classifiers. If a negative outcome generates then, reject the sub window.

### Algorithm 3: AdaBoost algorithm for classifier learning

Input: Rectangular features and training images

Output: Strong classifier

1: Given training images  $(x_1, y_1), \dots, (x_m, y_m)$ ;  $x_i \in X$  is the object or instance,  $y_i \in \{-1, 1\}$  is the classification.

2: Initialize weights  $D_1(i) = 1/m$ , where  $m$  is the number of training images.

3: For  $t = 1, \dots, T$

- Normalize the weights to generate probability distribution.
- Select a weak classifier  $h_t : X \rightarrow \{-1, 1\}$  with minimum error w.r.t. distribution  $D_t$ .

4: Choose  $\alpha_t \in \mathbb{R}$

5: Update the weights

6: Output the strong classifier:

Below table shows the results of comparison between different face detection methods with their advantages and disadvantages.

Methods	Advantages	Disadvantages
People count estimation using Hybrid Face Detection	NPD - good in low illumination and difficult backgrounds. Faces missed by individual algorithms wo'nt be missed. Higher speed. Reduces false positives. Efficiency 90.20%	Did not achieve 100% efficiency.
Real-time Detection of multiple Faces at Different Resolutions in Video Streams	Faster and better detection rates. 99.9% faces and 97% eye pairs detected on 26338 images. 45.6ms FPS process rate.	Error rates upto 8%. Colors not given much importance at present.
Efficient Boosted Exemplar Based Face Detection	Faster. More memory efficient. More accurate. Size of database largely reduced. Suppress false alarms.	Requires large Exemplar data base
Two-stage Cascade Model for Unconstrained Face Detection	Reduces number of false negative detections. DPM detector has higher precision than NPD detector.	Additional false negative face detections may be introduced in the second stage.
A Fast and Accurate Unconstrained Face Detector	Can replace OpenCV in terms of speed. Faster feature evaluation using look up table. Pose labelling not required. Handles illumination changes, occlusions, blurs. Scalable.	NPD alone has weak discriminative ability (Requires deep quadratic).
Rapid Object Detection using a Boosted Cascade of Simple Features	Calculations involved with each feature is reduced. Cascade function minimizes computation time. Faster than previous approaches.	Experiments on large and complex datasets are difficult and time consuming.

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Vol. 6, Issue 1, January 2017

## IV. CONCLUSION

In this paper, we presented an extensive survey on various face detection techniques and also perform a brief study on the fusion model to help improve the accuracy and speed of face detection. Viola and Jones approach to face detection used simple Haar features that could detect only frontal faces. The hybrid face detector based on the fusion model can overcome this disadvantage of Viola-Jones face detector. In addition to detecting frontal and non-frontal faces, hybrid detector also guaranties high detection accuracy in unconstrained scenes. Fully automated accurate human face detection systems can be build based on this hybrid face detection algorithm.

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