MULTI INVARIANT FACE DETECTION VIA VIOLA JONES ALGORITHM

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Abstract

Face Detection also called Facial Detection is computer-based technologies which find or identify human faces in any digital Image. The detection of face in any image is a method to detects the person face and ignores whatever thing else unlike plants, bodies and buildings and so on. There are various complexities associated with face detection like scale, location, view point, illumination, occlusions, etc. Various face detection algorithms are also available; one of the widely used algorithms is the Viola Jones algorithm for object detection. The purpose of our research paper is to find out face and non-face from any random image by using Viola-Jones algorithm. We use Viola Jones algorithm to identifying and locating the person face irrespective of its dimension, situation and background.

Keywords: Viola-Jones, Face Detection, Haar feature, Adaboost. Cascade Classifier, Matlab.

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1. INTRODUCTION

Face detection is a sort of object detection. Face detection technique separates face and non-face area in images. All face recognition system requires confirming object subject to it is a face. Challenges to face detection are:

Face detection helps in many ways and it is useful to prevent crime, face lock system in smart phones, help vision impaired persons, forensic works, and helps to spot person inside images in social media [1].

1.1 Head Pose: - The head movement and viewing angle of the person make facial features partially or wholly hidden like showed in Figure 1.1.

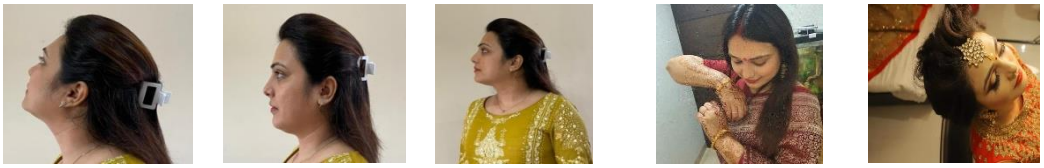


Fig. 1.1 Different Head Poses

1.2 Occlusion: - It is caused due to natural face features (beard and moustache patterns), scar due to major or minor accidents, accessories worn by men or women as a result major area of their face is not available in an input image as shown in fig 1.2.

Fig. 1.2 Occlusion in Face Images

1.3 Facial expression: - It is result of willfully contracting facial muscles so as to make it attractive or appealing someway as shown in Figure 1.3.

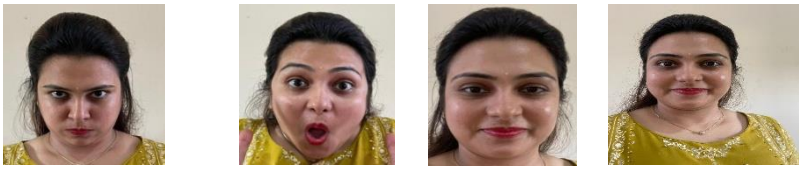


Fig. 1.3 Different Facial Expression

1.4 Imaging conditions: - When an image is taken from a camera lighting conditions, exposure, shutter speed, movement of object etc affect the quality of the image as shown in Figure 1.4. [2]

Fig. 1.4 Different Imaging Condition

Paper is organized in the following section: Section II describes the researches work in face detection. Section III describes methods of face detection. Section IV describes at length viola-jones algorithm. Sections V describe methodology and results and the last section VI describes the conclusion.

2. LITERATURE REVIEW

Throughout years numerous researches has been completed in the area of face detection and recognition.

Sinha & Barde, 2022 presented that viola Jones algorithm method is best for face detection. It is also useful in case of illumination invariant face image [3].

Sinha & Barde, n.d. offered evidence that the viola Jones algorithm is effective in detecting faces.[4]

(Sinha & Barde, 2022a)Found that face detection using viola jones is best method for face detection.[5]

Shukla et al. (2021) compiled the various techniques and models which are helpful to solve the problems related to faces. They prominent that when we combine machine learning approach among various image-based dataset then effectiveness of the classifier to guess information linked with face detection and recognition will increase. [6]

Kumar et al. (2018) presented a comprehensive survey on Face detection various techniques, different challenges and different standard databases with their features. [7]

Bhosale et al. (2018) explained, analyzed & compared several methods for face detection and concluded that among all the face detection method haar like feature extraction technique is superior for detecting face from any image. [8]

Goyal et al. (2017) explained numerous methods that we can utilize for face detection and compared the whole methods with keeping time and space as major term. They concluded that Haar cascades are more proficient to be utilize as face detection and in case of numerous facial expression it outputs the enhanced accuracy.[9]

Cen (2016) found face detection via using Viola Jones results not only very quickly processing of images but also accomplish far above the ground face detection rates. He conducted experiment to improve the performance. [10]

Barnouti et al. (2016) concluded that face detection by using Viola-Jones techniques process the face images at a very high speed and also detects the face area from face which results high detection rates. Viola Jones is also recognized as the first object detection framework so as to can execute in actual time. [11]

Jang et al. (2014) projected a new face detection algorithm. This algorithm is divided into two steps first one is face location and the second one is face verification. Generalized Hough transform is used for identifying face location and quantum-inspired evolutionary algorithm (QEA) was employed for face verification. The performance of was improved and false alarm rate was reduced. [12]

Wang (2014) proposed Viola-Jones algorithm be primary face detection in actual time. Some times when we use Viola-Jones algorithm for face detection it returns multiple detections in any image so we have to utilize a post-processing step that will overcome detection duplicity which utilize a robustness parameter. [13]

Ghimire et al. (2013) proposed a strong face detection technique that is purely dependent on the color of the skin and edges. Robust real time face detection was also done using a set of Haar like features with cascaded classifier. But, they were prone to false positives. [14]

3. Various Approaches for Face Detection

There are various algorithms for face detection. Yan, Kriegman, and Ahuja have classified face detection into four parts [15]:

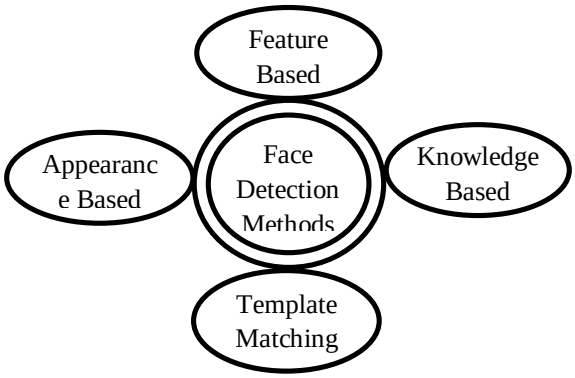


Fig. 3.1 Types of Face Detection

3.1 **Feature Based Methods**:

This approach is also called bottom-up approach. It looks for unique elements, such as eyes, nose and mouth etc, of face to extract features. The statistical model is developed to

establish relationship of extracted features. Objective of this method is to find features that are invariant. Invariant features can be intensity, texture, shape, edge, color, etc. Results are more reliable because these elements are always present human subjects. Some approach face detection, using skin texture and color. The classifier in this method is trained to differentiate between face and non-face region of image. This method of face detection makes model pose invariant. However, this approach is still susceptible to illumination, occlusion, etc. [16]

3.2 Knowledge-Based Method:

This method is also known as top-down approach. Knowledge that nose, eyes, and mouth within certain distances and positions with each other forms the basis of Knowledge based methods. A set of rules based on above knowledge. Challenge with this method is to build effective set of rules. The system falsely detects face when it should not, when rules are very detailed or general. This approach alone is insufficient and unable to find many faces in multiple images. [17]

3.3 Appearance Based Method:

This method comes under machine learning and statistical study. A classifier is built in this method. Effectiveness of classifier depends on how well classifier learns the face features from training images. Techniques applied in these methods are neural networks, Haar-like features, support vector machine, principal component analysis, hidden Markov model, Gaussian mixture models [e]. Models built in these methods are generally fast but it requires lot of training images to train the model. [18]

3.4 Template Matching Methods:

Face template means data corresponding to a person's image that is unique to that face. This is used for face detection. This data may be landmarks points (face, nose, mouth, etc) and curves in images. It detects face by computing correlation between the face templates and input image. Advantage with method is that model does not require training and works with fewer amounts of data. Disadvantage with this method is that frontal images are required. It takes extra time to identify face from any image. [19]

IV VIOLA JONES ALGORITHM

The Viola-Jones algorithm is an objection detection framework. It can be trained to detect not only faces but many objects, if it is trained to do so. To be effective on face detection, frontal face grayscale image is required by Viola–Jones algorithm. [20]

The Viola-Jones Object Detection Framework consists of four stages:

4.1 Calculation of Haar-like Features

4.2 Integral Image Creation

4.3 Using Adaboost Algorithm

4.4 Cascade classifier implementation

4.1 Haar like Feature:

Viola-Jones techniques at first changes face image to grayscale and moves a search frame across the array of an image from left to right and moves down and starts again from left to right in search of Haar-like pattern among cell values. The size of search frame within which Haar-like feature is searched may be 24 x 24, or even bigger.

Haar-Like features are rectangular frames. These frames have white side which represent light portion of image and the black side which represents darker part of the image. Viola-Jones applied following basic Haar-like features are: 1. Edge Features 2. Line Features 3. Four rectangle feature.

Two Rectangle Features also known as Edge Features 		Detect edges of an object. It identifies forehead and eyebrows.
Three Rectangle Features also known as Line Features 		Detect lines and highlights within an object. It identifies eyes and nose.
Four Rectangle Features also known as Diagonal Line Features 		Detect diagonal edges and lines. It identifies jaw, chin, wrinkles, etc.

Fig. 4.1 Commonly Haar Features with example

Many Haar-like features have been developed after development of algorithm by viola jones. These are often referred to as extended Haar-like features. [21]

The average of pixel intensities of darker region is lower than average of lighter region. This is how algorithm detects dark and light region. Viola-Jones algorithm finds average of intensities of pixels in both the black and the light portion within the search frame in the image, finds the difference in the average of both areas and compares it with threshold value. When diversity is extra as compare to threshold value, then our method moves search frame ahead. If diversity is fewer than threshold value, method determines that there is Haar-like feature in the search frame. This computation keeps on repeating so long as relevant face features (forehead, eyebrows, nose, eyes, mouth, chins, etc) have been found inside the frame.

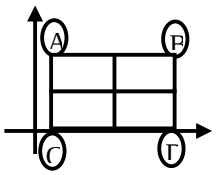
$$\text{FV (Haar Features)} = \sum FW - \sum \text{FB}$$

FV (Haar Features) is the total Haar-like Feature $\sum FW$ is the feature value of light area and $\sum$ FB is the feature value of dark light area.

4.2 Integral Images:

As discussed in previous section, it takes lot of computing resources to compute worth for all face features. Algorithm requires to do calculations on all the pixels within given search frame to detect whether values of pixel is forming pattern of Haar-like feature. The integral image enables to speed up calculations. The worth at some point (x, y) inside face integral image can be displayed by follow formula:

$$ii(x,y) = \sum_{\substack{x' \le x \\ y' \le y}} i(x',y')$$

i stand for original image whereas ii stands for integral image. 

The sum of ii (x, y) over the rectangle with corner A, B, C and D is:

$$\sum_{\substack{x0 < x \le x1 \\ y0 < y \le y1}} ii(x,y) = I(D) + I(A) - I(B) - I(C)$$

84	101	14	138	254	35
102	128	153	77	51	26
153	153	153	77	51	26
153	153	179	102	77	51
128	153	204	128	102	77
128	128	179	102	77	51

Original Image

84	185	199	337	591	626
186	415	582	797	1102	1163
339	721	1041	1333	1689	1776
492	1027	1526	1920	2353	2491
620	1308	2011	2533	3086	3283
748	1564	2446	3070	3682	3948

Integral Image

Fig.4.2 Conversion of Original Image into Integral Image

An integral image two-dimensional reference array. It contains values of sums of cells above it along y axis and x' axis including that cell itself. We can also call it as summed area tables. Instead of performing calculation on pixel,

algorithm creates sub-rectangle and array references for each of sub-rectangles.

4.3 Adaboost Classifier:

The AdaBoost can be also recognized as Adaptive Boosting which is based on machine learning algorithm. This algorithm selects relevant features from available non-useful features in sub-region. This results a classifier.

As per viola-jones, number of features present in the 24 x 24 search frame is nearly 180000, but to identify face in an image only a few of these features are required. Therefore, AdaBoost algorithm is required to identify a face the best features out of 180000 features, if 24 x 24 search frames is used.

Each Haar-like feature that is used in viola-Jones algorithm can be weak classifier or learner. When we have to chose tat which type and size of a face feature will be our final classifier, then all supplied classifiers performance are checked by AdaBoost. [22]

All supplied classifiers performance is calculated which is based on whole sub-areas of our training images that we used while training. The Sub areas which have person face return a high reply to the classifier. These replies can be categorized as strong positives. In case when sub area don't have person face provide weak reply to classifier will known as negatives or weak classifier.

The classifier which returns strong positives is given upper weight age or priority in simple term. The final outcome of all the training process is strong classifier also called as boosted classifier. This classifier includes weak classifiers which are best performing.

A Strong Classifier is made up of a linear combination of "Weak Classifiers" (best features).

$$H(x) = w_1h_1(x) + w_2h_2(x) + w_3h_3(x) + \ldots.w_nh_n(x)$$

Where, H(x) represents a strong classifier and $w_nh_n(x)$ represents a weak classifier. Value of feature ($h_n(x)$) can either be 1 or 0.

4.4 Cascade Classifier

The AdaBoost algorithm just narrows down the number of features but they could even be time consuming and resource exhaustive to calculate features as the 24 x 24 search frame moves over sub-region of image. The cascade helps in quick identification of face in image thus it quickly rejects non-face regions of image.

Cascade Classifier works as multi-step classifier. Every step of this classifier includes a strong classifier which is created with the help of AdaBoost Algorithm. In every step, many weak classifiers are added to strong classifier so strong classifier increases.

When face image sub-region is passed through cascade, it is evaluated by all stages. It has to result positive in all stages. If it is able to pass through all the stages, it is classified as containing human face. In any step if a classifier results false result then face image is discarded without delay and defined as non-face image. This multi-stage approach allows computing resources to focus more on positive input (probable face regions) and discard negative outputs as shown in below figure 4.2

The cascade classifier is created by adaboost training and complexity of cascade increases with number of stages. [23]

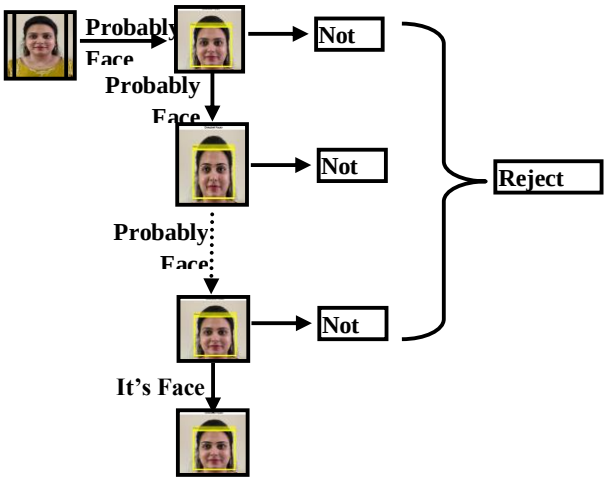


Fig. 4.3 Cascade Classifier illustration

5 METHODOLOGIES AND RESULT

The purpose of our research paper is to identify face area from any image. The computer vision (CV) tool box provided necessary algorithms and functions to perform face detection. Proposed algorithm was implemented in MATLAB (R2019) on a Pentium i5 processor 8GB RAM Windows 10. To display the feasibility of the projected method, we conducted a number of experiments on following types of images; the faces detected have accordingly been shown in figure 5.1.

- Simple frontal images and group of people image.
- Changing occlusion and changing illumination conditions
- With different facial expression.
- Group Photo with Different Poses.

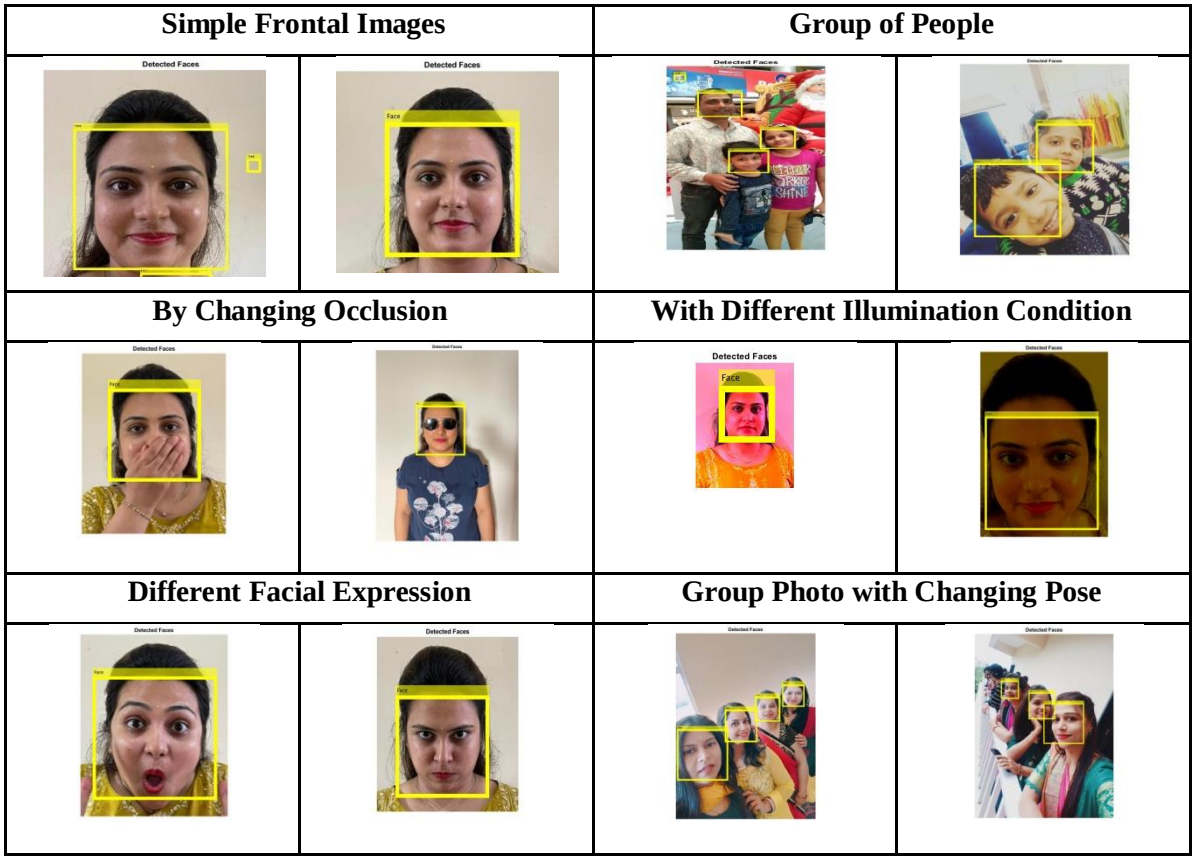


Fig. 5.1 Results of Various Experiments

Viola-Jones algorithm performed well with all image challenges at threshold value more than 5. We put algorithm to test at lower threshold value. Conclusions worth mentioning are as follows: When group of people first image were checked for face detection Viola-Jones algorithm could easily found face with high threshold values, above 5. But when threshold were reduced to 3 it could identify face in the banner in the back ground but could not locate face of Santa even with threshold value of 1.

Second image of that category also did well up to threshold of 5 but to get boy's face detected threshold value were to be reduced to 3 probably because two rectangle features that detects eyes did not work well with tilted face.

An observation worth mentioning is that when face is posed such that only one side of image is exposed in the image Viola-Jones algorithm detects false positive the reason could be that only line feature works with that pose four-rectangle feature is not extracted. With group of photo with changing pose category, it has been found that Viola-Jones algorithm does not detects face of persons deeper into image.

6 CONCLUSIONS

In this paper, several existing face detection methods have been studied. As a conclusion, appearance based method has been used for face detection. Out of various algorithm, we have chosen Haar-like feature extraction because it is simple and yet robust. This method has been tried over many images which contains subject i.e. face in such that they are thought to be challenging for face detection.

Experiment results were quite motivating. Viola-Jones algorithms were effective in detecting faces. The only things that required were to change threshold values. We found that using Viola-Jones algorithm makes model

illumination and expression invariant. This work will be expanded by building database of challenges to face detection and experiment Viola Jones algorithm there on.

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