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Improvements in OpenCV's Viola Jones Algorithm in Face Detection - Tilted Face Detection

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***Abstract*— This paper proposes a new improved approach for tilted face detection on OpenCV's Viola Jones Algorithm. In this approach, eyes and skin detection are used to detect the tilted faces. Skin Detection can be done by using two colour spaces i.e. HSV (Hue, Saturation and Value) and YCrCb (Y is luma component and Cr- red difference, Cb- Blue difference) and eyes are used to identify the tilted faces. As a result, it is found that skin and eyes are able to detect the tilted faces. Our proposed method has accuracy is about 88.89% for tilted faces.**

***Index Terms*— Face Detection, Viola Jones, Eye Detection, OpenCV, Tilted faces**

I. INTRODUCTION

Face Detection in Images and Video Sequences has become an important part of the recognition. For face recognition, detection is must when multiple faces are present in an image. The Correct suited Face Detection is still in demand since false detection leads to wrong face detection and wastage of computational power as well as time. Several Face Detection Techniques are available like Hidden Markov Models, Neural Networks, Optical Flow to Haar Cascade Classifiers. Most of the authors used the Viola Jones Algorithm based on Haar Cascade Classifiers [1]. OpenCV is the Open Source Computer Vision Library by Intel. It has several Implemented and Optimized algorithms of Image Processing usage. One of the most popular algorithm is Viola Jones algorithm which is capable of Detecting Face and objects. The Viola Jones Method was given by Viola and Jones in the year 2001 and has been improved several times. The paper proposes detection of tilted faces by Viola Jones. For coloured image, faces can be detected by using skin colour of face HSV and YCrCb colour models [2] [3] [4] [5] [6] [7].The Viola Jones Algorithm is not able to detect the tilted faces. Thus, for tilted faces, the eyes are used for detecting the faces [8].

This paper is organized as follows. Section II summarizes some related work in the field of face detection. And brief about Viola Jones methods. Section III provides our proposed method. Experimental results & analysis are in section IV, followed by Conclusions & future scope in Section V and VI.

II. RELATED WORK

Many authors have worked on various methods for face detection. One of them is the Eigenfaces method which is used by several authors. Neural Networks and artificial neural networks are also extensively used. Improvements in Viola Jones have also been done [3]. For False Positives Filtering, Dayem et.al gives an insight about various colour spaces that can be used for filtering the wrong face detections and specify the

skin colour ranges as well [7] .For detection of the faces through eyes, Wong et.al. [8] gives information to evaluate the face length and breadth on the basis of various parameters and relationship between different parameters of the face.

A. Viola Jones Algorithm

Viola Jones Object Detection framework Proposed by Paul Viola and Michael Jones in 2001 was one of the first methods to provide object detection at very fast rates [1]. It is the method for rapid and correct object detection through Adaboost machine learning. The major features of Viola Jones Algorithm are:

1. Integral Image Representation : Rapid Detection of Objects requires computation of haar features and in order to compute them, integral image is required. Integral image is obtained using few operations per pixel. After this computation, Haar features of any type can be computed in constant time.
2. The Adaboost Learning algorithm, which created efficient classifiers from set extracting important visual features. For fast classification, learning must exclude a majority of features available in the image. This algorithm extracts critical features while discarding all other unimportant features.
3. The "cascade" classifier which focuses on Object like parts and discards the background (shown in Fig 1). Cascade is a type of mechanism that knows its region of attention and discarded region are not likely to contain any object. This is very fast in Real Time detection.

III. PROPOSED METHODOLOGIES

Problem Statement: "Detection of tilted faces in Viola Jones face detection algorithm". While detection of faces in using OpenCV's implementation of Viola Jones algorithm, the tilted faces usually go undetected.
Our proposed methodology is focused on detection of tilted faces by using skin detection and eye detection. First, the normal faces are detected using the basic Viola Jones face detector and false positives are removed using the skin detection method. Through these correctly detected faces, the average face size and normal distance between eyes is calculated. For detection of tilted faces, the eye detection over the image is performed. Pair of eyes is chosen in accordance to the data calculated before and face areas are constructed. All these face areas are then checked for skin percentage threshold, and then marked as tilted faces. The flow chart of proposed algorithm is shown in Fig. 2.

A. Skin Detection

The detected face region of interest is converted from RGB colour space to HSV and YCrCb colour space for detecting the skin percentage. An explicit skin colour detection mechanism defined as follows:

For YCrCb colour range
In this color space, the *Y* component stores the luminance information, while the *Cb* and the *Cr* components represent the chrominance of the blue and the red colors, respectively [3]. Dayem et.al proposed the following colour range is used for skin detection: [7]

$$80 \leq Cb \leq 120, 133 \leq Cr \leq 173.$$

For HSV colour Range [2]
In the HSV color model, where H, S and V stand for Hue Saturation and Value respectively. The HSV colour domain for skin colour lies in the following range: [7]

$$0 \leq H \leq 50 \text{ and } 0.23 \leq S \leq 0.68,$$

Where $H \in [0°, 360°]$, $S \in [0, 1]$ in the input image.
Oliviera et. al. [6] proposed $6<H<38$ for skin detection, however the above specified range covers a broader skin range. The detected region of interest is taken from the image and converted into YCrCb and HSV colour range.
For each of the colour range, the pixels that fall in the domain of skin are converted to white and the pixels that are not in the domain are converted to black as shown in Fig.3. The skin ratio of region of interest is total number of white pixels is to total number of pixels in the face. If the ratio is above 70% (threshold value), then the detected part is considered a face. Otherwise, it is a falsely detected region. As per observations, it is found that 70% is a good threshold value for face detection (since the face detection detects face including background, hair, eyes, etc, which do not fall in the skin colour range) as shown in Fig.4 and Fig.5.
Also, whenever there is 100% skin in images in both colour ranges, then the image is discarded because this

condition is possible only when complete detection has no other colour than of skin colour range which is not possible for faces.

B. For Tilted Face Detection

Viola Jones Face Detector basically detects only frontal and non-tilted faces through the classifier. The classifier cannot be trained for every tilt faces. It is observed that eyes are always present whether the face is frontal or tilted. Viola Jones is capable of detecting the eyes through "haarcascade_mcs_lefteye.xml" cascade classifier.

Firstly, the average eye width and average eye distance is calculated with the help of already detected correct faces. After detection of eyes, the following parameters are used for detecting the tilted faces and forming the region of interest for tilted faces (shown in Fig. 6). For these distances the following equations are used: [8]

$$h_{face} = 1.8\, d_{eye} \quad (1)$$

$$h_{eye} = 0.2\, h_{face} \quad (2)$$

$$w_{eye} = 0.225 h_{face} \quad (3)$$

Where,

h_{face} = height of the face

d_{eye} = distance between eyes

h_{eye} = height of eyes

w_{eye} = width of eyes [8]

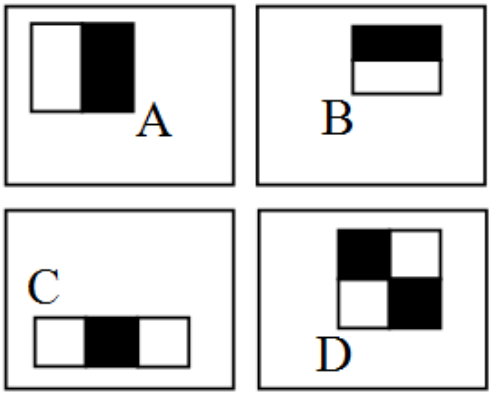

Figure 1. Haar Cascade Classifier

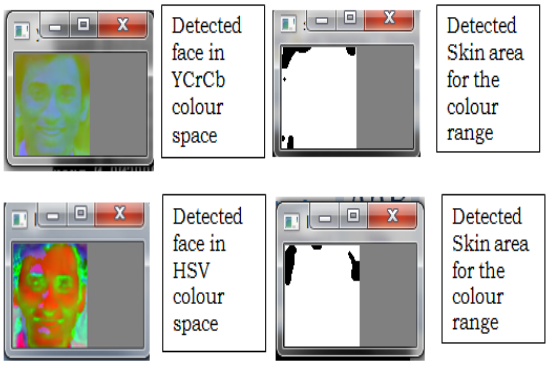

Figure 3. Face in YCrCb and HSV colour ranges and corresponding skin

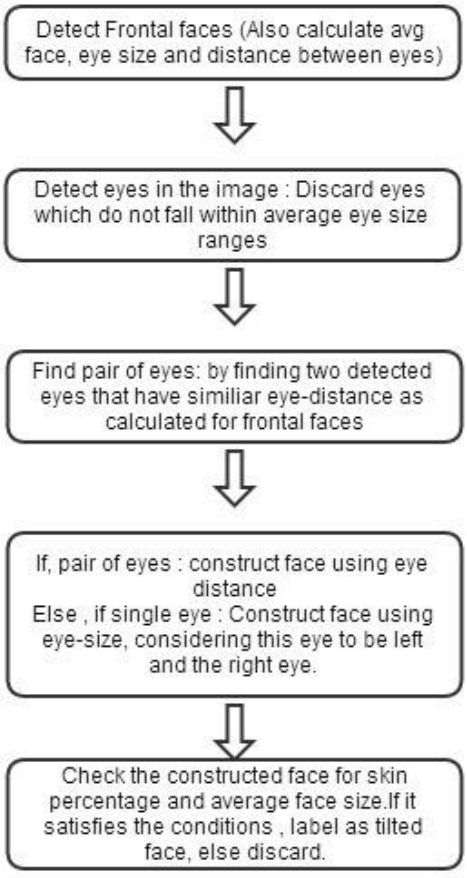

Figure 2 . Flow Chart for proposed algorithm

All the correctly detected faces have almost similar length and breadth of eyes. Thus, to take the average value for both the width of eyes as w_{avg} and distance between eyes as d_{avg} are calculated by using (4).

$$Average = \frac{(\sum_{i=1}^{n} xi)}{n} \quad (4)$$

Let the distance between eyes are d_{eye}, average distance between eyes are d_{avg} and width of the eyes is w_{eye}. For all the eyes in the image, if the respective value of d_{eye} and w_{avg} are such that:
For single eye face detection:

$$w_{avg}/2 < w_{eye} < 2*w_{avg} \quad (5)$$

For double eye face detection:

$$d_{avg}/2 < d_{eye} < 2 * d_{avg} \quad (6)$$

In the images, it is seen that the eyes in the image are of almost same sizes. Thus, for each eye (1),(2) and (3) are used to calculate values of w_{eye} and d_{eye}. All those eyes whose parameters do not satisfy (5) or (6) are considered outliers which either have very large size or are very small. Therefore, all the eyes which were less than twice these averages and greater than half of these averages were only selected**.** It removes falsely detected eyes if their value does not lie between.
Thus, the Euclidean distance between (x1, y1) and (x2, y2) is calculated as:

$$Dist = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2} \quad (7)$$

Now through the eye detection following are the further steps:
Step 1: Eyes detected in already detected faces.
Step 2: Detection of eyes.
Case (1): Both eyes detected (make a pair of eyes).
Case (2): Any one eye detected (for single eye).

Step 1: Eyes detected in already detected faces.
The coordinates for all the faces previously detected were stored. When these eyes were detected, they were first checked for their presence inside the coordinates of the face (see (8) & (9)). All the eyes of existing detected faces are not considered for the algorithm.
For Eg: if (p1, q1) and (p2, q2) are coordinates of the face and (r1, s1) and (r2, s2) are coordinates of the eyes, if (eyes are present inside the face)

If, p1< (r1 and r2 both) < p2 (8)
If, q1< (s1 and s2 both) < q2 (9)

Otherwise, Eyes are Discarded (lie outside the face).
Step 2: Detection of eyes.
For the remaining eyes, compute the distance between the eyes by using (7) and if that distance satisfies (7) then distance signifies that eyes are paired eyes of face or not.
When one eye is detected then it is checked with other eyes for being a pair of eyes by their intermediate distance and near about same sizes. If the two detected eyes are rectangles such that their topmost leftmost points are (x1, y1) and (x2, y2), Compute the distance between these two points using (7).
For all eyes left
If (there is an eye with Euclidean distance between the eyes less than 2 * d_{avg})
Then,
Make these a pair.
Remove all nearby eyes.
Then, two conditions are formed:
Condition-1 :Pair of eyes is found.
Condition-2 :Pair of eyes is not found.

Condition-1:
For each pair found, find region of interest of face i.e. make the square which represents the face.
If more than one pair of eyes are formed like.

1. (x1,y1),(x2,y2)
2. (x1,y1),(x3,y3) … and so on

For all the pair of eyes:
The Region of interest (ROI) is constructed for all the pair of eyes, shown in Fig.7 as R1 and R2.
The ROI is formed with taken min of x_1 , x_2 & y_1 , y_2 .

The min(x) and min(y) is the starting point of the ROI, This rectangle is extended on both sides with the (1). If more than one ROI are formed shown in Fig.8 then, evaluate the skin percentage (should be >90%). It is observed by the Fig.4 and Fig. 5. If skin percentage is more than the threshold and maximum out of taken ROI's, accept that region of interest for those pair of eyes as a face.

Condition-2:

Pair of yes is not found(for single eyes).When the pair of eyes is not found [Distance between the eyes does not satisfied the (5)], then, w_{eye} is used to construct the Region of Interest using (3) as shown in Fig 8.

In a similar way evaluating the skin percentage for ROI R3, R4 and R5, which represent the face on left, the right and upper side respectively .Whichever has the maximum skin percentage value then consider that ROI as a face.

In tilted face method, the skin threshold is taken as 90% because in this case most of the face is taken in account rather than hair and background shown in Fig. 10 and Fig. 11.

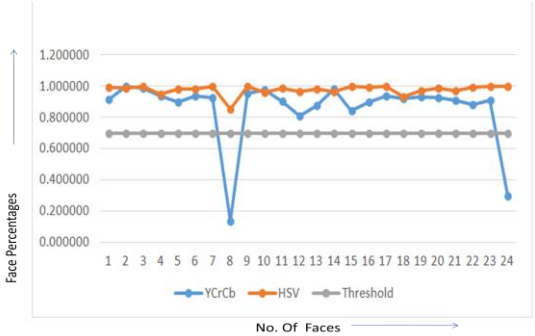

Figure 4. Skin percentage values for Sample Image 1

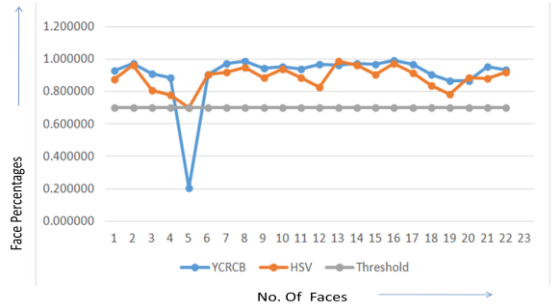

Figure 5. Skin percentage values for Sample Image

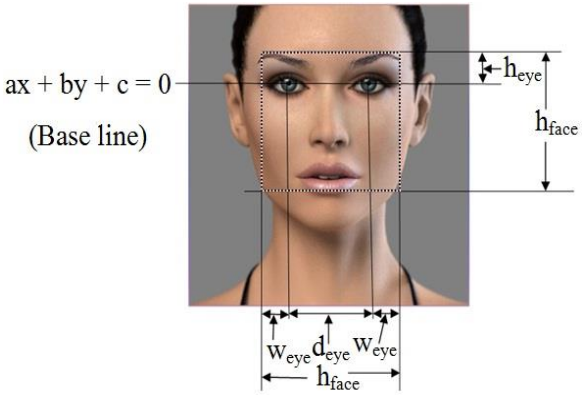

Figure 6. Variable Description [8]

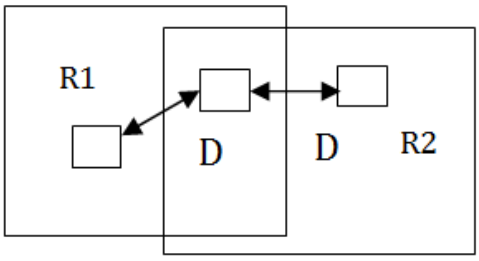

Figure 7. Make a pair of eyes for face detection

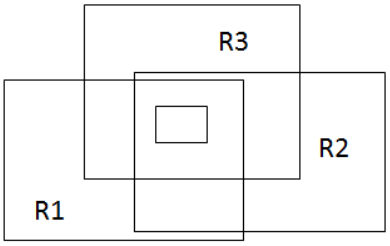

Figure 8. ROI (Region of interest) for single ey

IV. Experiments and Results

In OpenCV's, implemented Viola Jones Algorithm are used for face detection, by enhancing the code which removes the falsely detected faces by using skin percentage and eyes which detect the tilted face both. The code was written in Visual C++ in C++ language. The images of groups were taken from the internet. All the images are coloured. For testing, 10 images are taken which contain frontal as well as tilted faces as shown in Fig. 9.

Our algorithm works for front and the tilted face detection as well. As a result, Black-boxed faces show the frontal faces and dotted black-boxed faces show the tilted faces shown in Fig. 10 and Fig. 11.Fig.10 shows the frontal faces detected by Viola Jones . Fig.11 shows the tilted faces with the help of skin detection and eye detection.

The percentage is calculated by Total tilted Faces Detected by Our Algorithm/ Total tilted Faces Present.

The algorithm achieved 88.89 % accuracy in tilted face detection, detecting 24 out of 27 tilted faces in 10 images from various sources along with 40 frontal faces out of a total of 57 faces. Here, the correct percentage becomes 100% if the images are clear and eyes are properly detected. In images 5, 7 and 9(as shown in Table 1) specify that if any kind of noise like watermark present in the image, it reduces the efficiency of the algorithm.

It is analyzed that our method detects the faces correctly and efficiently as compared to Viola Jones as shown in Fig. 12. Skin Percentage and Eyes play an important role for detecting front and tilted faces because it reduces the false positive detected faces.

Figure 9. Original Picture (Tilted Faces) [10]

Figure 10. Viola Jones original detections [10]

Figure 11. Tilted Face Detection [10]

TABLE 1.TILTED FACES DETECTION PERCENTAGE TABLE

Sr.No.	1	2	3	4[13]	5[14]	6[15]	7[16]	8[17]	9[18]	10[19]	Total
Total Faces present in the image	5	20	8	5	5	3	5	5	4	7	57
Total Frontal Faces	4	19	3	3	0	1	2	2	2	4	30
Total Tilted Faces	1	1	5	2	5	2	3	3	2	3	27
Total Tilted Faces detected by our Algorithm	1	1	5	2	3	2	2	3	1	3	24
Correctness Percentage (%)	100	100	100	100	60	100	66.66	100	50	100	88.89

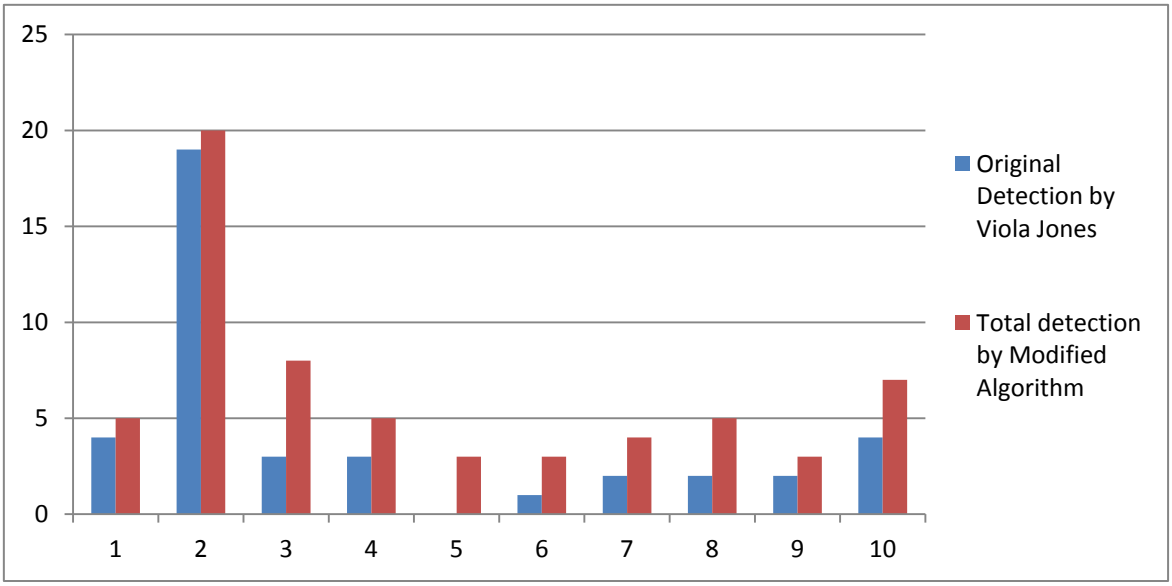

Figure 12. Graph depicting Tilted Faces detection

V. Conclusion

It is concluded from the experimental result & analysis that the improvements were applied as skin detection, skin percentage and the eye detection. The skin and eyes play an important role for enhancing the efficiency of Viola Jones Algorithm. As a result, tilted as well as frontal faces are detected. The efficiency of the algorithm becomes 88.89% when noise is present in an image otherwise the detection is almost 100%, which is not done in Viola Jones Face Detection.

VI. Future Work

As per experimental results, it is found out that there is more scope of future work on coloured images. To remove the hair part when the hair tone is similar to the skin tone colour and detect the extremely tilted faces even if noise is present are the future aspects of this method.

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