

Implementation of combined Viola-Jones and NPD Based Face Detection Algorithm

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Abstract—Now a days video information is growing more and more widespread, their intelligent or automatic examining is becoming exceptionally important. People, i.e. human faces, are one of most common and very specific objects in video, which are tried to trace with help face detection tools. Face detection is a difficult task in image analysis which has each day more and more applications. In this paper we presented comparison of two face detection methods, which are commonly used. The Viola-Jones face detector is first reviewed and different techniques used in this algorithm to extract features are discussed. Secondly color based face detection approach is reviewed. In this paper, we implement Viola-Jons and Normalized pixel difference (NPD) detection methods. These algorithms are explained in brief. These face detection methods that are universally used are elaborated with their capabilities, advantages and disadvantages.

Index Terms— Face detection, Viola-Jones face detector, Color Space, NPD, Adaboost, Feature Extraction

I. INTRODUCTION

Many aspects of human physiology are used to authenticate a person's identity. The characteristics trait can be broadly classified in to two categories i.e. physiological and behavioral. Measurement of physical features for personal identification is an age old practice. With the advancement in technology, biometric authentication has been widely used for access management, law enforcement, security system. A person can be identified on the basis of different physiological and behavioral traits like faces, iris, hand geometry, ear pattern, voice recognition, and thermal signature.

Face detection is the step stone to the entire facial analysis algorithms, including face alignment, face relighting, face modeling, face recognition, head pose tracking, face verification /authentication, facial expression tracking/recognition, gender/age recognition, and lots of more.

The difficulty associated with face detection can be attributed to many variations in scale, location, orientation (in-plane rotation), facial expression, occlusions, and lighting conditions.

This paper presents implementation details of Viola-Jones, and NPD face detection approaches. Advantages and disadvantages of both the algorithms are discussed and compared with help of various features.

II. FACE DETECTION

Face detection determines the presence and location of a face in an image, by distinguishing the face from all other patterns present in the scene. This requires appropriate face modeling and segmentation. The approach should also take into account the sources of variation of facial appearance like viewing geometry (pose), illumination (color, shadowing, and self-shadowing), the imaging process (resolution, focus, imaging noise, perspective effects), and other factors like Occlusion [4]. Alternatively, face detection can be carried out by using the entire face [5], [6], making occlusion difficult to handle. Face detection methodologies classified on the basis of the image information used to aid in detection—color [7], geometric shape [8], or motion information [9], [10].

Face detection is also a part of object detection [16]. Face detection can be classified into two classes (face and non-face). Most applications are based on face recognition and tracking. These applications needs to locate the position of the face in the image or video. Moreover, face detection has added a much needed aspect of security in the recent years. Biometric systems, a front sided camera (Selfie) of a smart phone, human presence detection are some of the key implementations of face detection. Basically face detection senses the presence of the face in a 2D frame. Several methods and approaches are developed for face detection.

III. VIOLA-JONES FACE DETECTION ALGORITHM

A very fast and accurate approach to detect a face is using by viola and Jones in the year 2001. The breakthrough in face detection occurred with Viola & Jones idea to combine many

weak classifiers to create one strong classifier. In their paper, Viola & Jones introduce four main concepts which are: the Haar-like features, the integral image, the use of AdaBoost in machine training, and a cascade of classifiers [1].

The basic principle of the Viola-Jones algorithm [1] is to scan a sub-window capable of detecting faces across a given input image. The image processing approach would be to rescale the input image to different sizes and then run the fixed size detector through these images. This approach turns out to be rather time consuming due to the calculation of the different size images. The first step of the Viola-Jones face detection algorithm is to turn the input image into an integral image. This is done by making each pixel equal to the entire sum of all pixels above and to the left of the concerned pixel. This is demonstrated in figure 1.

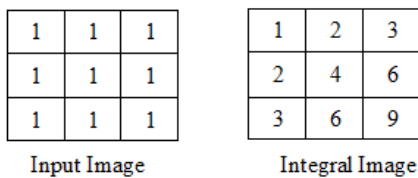


Figure 1: The integral image.

This allows for the calculation of the sum of all pixels inside any given rectangle using only four values. These values are the pixels in the integral image that coincide with the corners of the rectangle in the input image. This is demonstrated in figure 2.

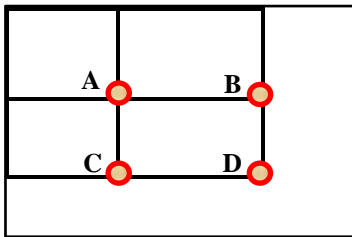


Figure 2: Sum calculation.

Sum of grey rectangle = $D - (B + C) + A$
 Since both rectangle B and C include rectangle A the sum of A has to be added to the calculation.

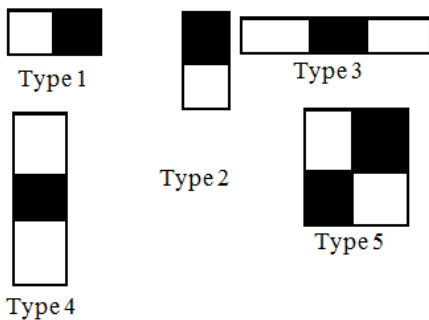


Figure 3: The integral image.

The Viola-Jones face detector analyzes a given sub-window using features consisting of two or more rectangles. The different types of features are shown in figure 3. Each feature results in a single value which is calculated by subtracting the sum of the white rectangle(s) from the sum of the black rectangle(s). In order to find these features Viola-Jones use a modified version of the AdaBoost algorithm developed by Freund and Schapire in 1996 [11]. AdaBoost is a machine learning boosting algorithm capable of constructing a strong classifier through a weighted combination of weak classifiers.

The main advantages of Viola-Jones algorithm is uncompetitive detection speed while relatively high detection accuracy, comparable to much slower algorithms. Constructing a cascade of classifiers totally reduces computation time while improving detection accuracy. Viola Jones gives accurate face detection.

Drawback of Viola-Jones algorithm is it takes long training time and detector is most effective only on frontal images of faces. Another major drawback is that it can hardly cope with 45° face rotation both around the vertical and horizontal axis.

IV. FACE DETECTION BY SKIN COLOR

Face detection by skin color is one of the more simple methods [4]. First it relies on extracting the regions, within a colored image, as shown in figure 4, which are likely to contain human skin. These regions are found by applying filters that rely on color and texture. Then after finding areas which contain human skin, a gray scale image is used, along with the information about skin locations to detect the face location. YCbCr skin color classification algorithm is used for further process.



Figure 4: RGB



Figure 5: YCbCr



Figure 6: Binary image which represents skin Region



Figure 7: Detected face

YCbCr skin color classification algorithm [12] uses color statistics gathered from YCbCr color space shown figures 5. Pixels belonging to skin region exhibit similar Cb and Cr

values. Skin color model based on the Cb and Cr values can provide good coverage of different human races. The thresholds be chosen as [Cr1, Cr2] and [Cb1, Cb2], a pixel is classified to have skin tone if the values [Cr, Cb] fall within the thresholds. The skin color distribution gives the face portion in the color image. This algorithm is also having the constraint that the image should be having only face as the skin region.

After getting the skin region, facial features like Eyes and Mouth are extracted. The image obtained after applying skin color statistics is subjected to binarization i.e., it is transformed to gray-scale image and then to a binary image by applying suitable threshold which is shown figures 6. This is done to eliminate the saturation values and consider only the luminance part. This luminance part is then transformed to binary image with some threshold because the features to consider further for face extraction are darker than the background colors. After thresholding, opening and closing operations are performed to remove noise. Now to extract the eyes, ears and mouth from the binary image by considering the threshold for areas which are darker in the mouth than a given threshold.

A triangle drawn with the two eyes and a mouth as the three points in case of a frontal face to get an isosceles triangle (i j k) [14] in which the Euclidean distance between two eyes is about 90-110% of the Euclidean distance between the center of the right/left eye and the mouth. Then face region is identified which is shown in figure 7.

The main advantage of color based face detection is very simple to implement. Irrespective of face angles it detects face. A disadvantage of the color based face detection is its sensitivity to illumination color changes and, especially in the case of RGB, sensitivity to illumination intensity.

Color based face detection is affected by complex background. Due to which it is difficult to locate facial features because of several corruption (illumination, noise, occlusion) and detects non face regions in addition to face.

V. NPD BASED FACE DETECTION

A very A new type of feature, called Normalized Pixel Difference (NPD) is proposed by [32], which is efficient to compute and has several desirable properties, including scale invariance, boundedness, and enabling reconstruction of the original image. Deep quadratic tree learner is used to learn and combine an optimal subset of NPD features to boost their discriminability.

The Normalized Pixel Difference feature between two pixels in an image is defined as

$$f(x,y)= \frac{x-y}{x+y}$$

where $x, y \geq 0$ are intensity values of the two pixels, and

$f(0,0)$ is defined as 0 when $x= y=0$. NPD feature measures the relative difference between two pixel values. The sign of $f(x,y)$ indicates the ordinal relationship between the two pixels x and y , and the magnitude of $f(x,y)$ measures the relative difference (as a percentage of the joint intensity $x + y$) between x and y . Note that the definition $f(0,0)=0$ is reasonable because, in this case, there is no difference between the two pixels x and y . Compared to the absolute difference $|x-y|$, NPD is invariant to scale change of the pixel intensities.

NPD uses the AdaBoost algorithm to select the most discriminative features and construct single strong classifiers [1]. AdaBoost algorithm is used [38] to learn the NPD feature based deep quadratic trees. Further cascade classifier is used for rapid face detection. NPD learn only one single cascade classifier for unconstrained face detection robust to occlusions and pose variations.

Advantages in NPD are that there is no need to label the pose of each face image manually or cluster the poses before training the detector. In the learning process, the algorithm automatically divides the whole face manifold into several sub-manifolds by the deep quadratic trees. NPD detector is also efficient and faster when it is compared with Viola-Jones face detector.

NPD works very slow on very low image resolutions. Because the NPD features involve only two pixel values, they do not extract rich texture information on the face.

VI. EXPERIMENTAL COMPARISON OF ALGORITHMS

The graph in figure 7 shows the time taken for each method to process an image. The images used to establish those benchmarks were approximately 348x450 pixels and were processed on relatively similar processor.

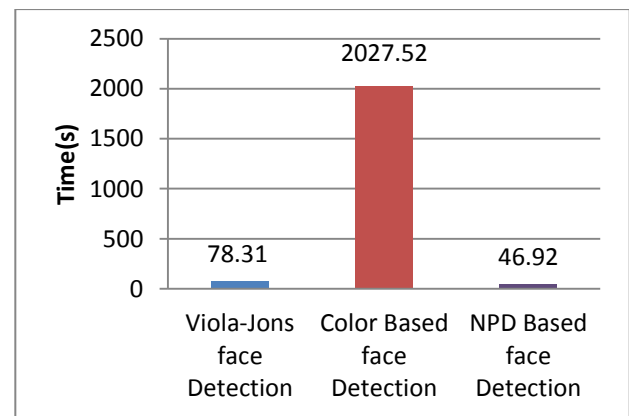


Figure 7: Graph showing time taken by each method

In color based face detection algorithm the speed of detection wasn't taken into account as such. Crowley and Coutaz [15] said one of the simplest algorithms for detecting skin pixels is to use skin color algorithm. The perceived human color varies as a function of the relative direction to

the illumination. The pixels for skin region can be detected using a normalized color histogram, and can be further normalized for changes in intensity on dividing by luminance. And thus converted an [R, G, B] vector is converted into an [r, g] vector of normalized color which provides a fast means of skin detection. This gives the skin color region which localizes face. As in [15], the output is a face detected image which is from the skin region. This algorithm fails when there are some more skin region like legs, arms, etc. Viola-Jones algorithm work very slow on tilted faces. Hence, it can be clearly concluded that NPD method work significantly faster when compared with color based and Viola-Jones face detection algorithm. It is also considered as one of the breakthroughs in the face detection industry.

Table 1: Comparison of detection rate (%) of three face detection algorithm

Algorithm	False positives (FP)	False negatives (FN)
Color Based	63.33	54.21
Viola-Jones	18.18	42.1
NPD	36.36	27.36

Table 2: Performance Comparison Chart of the Algorithms on Fddb database

Algorithm	Viola-Jons (% of detection)	Color Based (% of detection)	NPD Based (% of detection)
Clear Frontal Face	100	70	100
Tilted Face	1	40	92
Profile Face	60	44	74
Complex Background Frontal Image	70	30	81

Performance of both the algorithms is compared considering different angled images. This comparison shows that the NPD based algorithm gives good results in complex background images and also execution time is faster than the Color Based face detection algorithm and Viola-Jons algorithm. Table 1 and Table 2 shows performance comparison chart of the algorithms based on different types of images.

VII. CONCLUSION

In this paper implementation of two algorithms has been made. Viola-Jons face detection algorithm is used for detecting faces in the controlled background. Results show

that Viola-Jons algorithm is more efficient in comparison to NPD when frontal face images are used as input. For tilted and curved face images NPD algorithms shows good performance. But still these two algorithms are not able to give very good results in different environmental conditions. Based on the results of the two algorithms, it can be concluded that both algorithms have their own advantages and disadvantages in different environments.

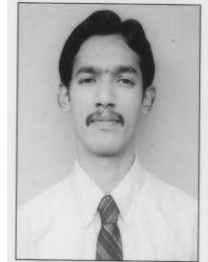
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