



On Experimental Comparison of Color and Supervised Face Detection

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Abstract: Viola-Jones algorithm and skin detection are the two widely used approaches for face detection. This paper aims at showing, experimentally, the trade-offs associated with each of the algorithm. The parameters used in this work are the ones encountered in real images. These include the illumination, color-space representation, face orientation, image sharpness and image complexity. Experimentally, the peculiarities associated with each algorithm are shown. Based on these experimental results, the situations are commented upon where these algorithms will be efficacious. This paper moreover aims at to provide an objective comparison of the two algorithms rather than going into the subjective details of peculiarities of any individual implementation.

Keywords: Face Detection, Viola-Jones Algorithms, Skin Detection, Illumination Dependency.

1. INTRODUCTION

Face detection is a task substantial to making the computer vision applicable to real-world problems. These problems include biometric security systems, image databases and the like. The face detection is a more specific case of object detection. Many techniques have been developed to solve this problem. All of these techniques have some peculiarities, *i.e.*, they work optimally in some environments while fail to give optimum results in other environments. The different environments can be differentiated by image background, image orientation, illumination, color space used, sharpness or blurriness of the image. This paper aims at to highlight the pros and cons of two of the most used face detection techniques. One is the skin detection while the other is viola-jones framework (Viola, 2003). The underlying principle of skin detection is that it classifies each pixel as skin pixel or otherwise, based on the pixel color. The viola-jones approach, however, takes its decision based on features of an image. For this paper, we have specified parameters such as orientation of an image, illumination, multiple faces in an image, images in different color space and sharpness of an image. This paper will record the response of skin detection and viola-jones algorithms to the variance in these parameters.

There are efforts to improve the individual algorithms. (Sahbi *et al.*, 2006) have adopted a skin-color approach. This skin-color approach has combined skin-color learning and image-segmentation to have fast and accurate face detection. Using skin locus and hierarchal detectors (Haddi *et al.*, 2002) developed an algorithm which was able to detect color images in different conditions. (Viola, 2004) improved their early concept of viola-jones detection framework in their

work (Viola, 2003), where they extended it to non-frontal faces such as rotated faces. Different detectors were devised for different view of faces and then decision tree was trained to determine the class of the object being viewed. These works pertain to the goal of this paper in that, they tried to improve the implementation of their respective background theory. We aim in this paper to compare the general theories of face detection based on skin detection and viola-jones. This work is meant to be the first of its kind. While (Singh, 2006) carried out experimental study of face detection on skin-color for different color spaces. However, it still was an intra-framework comparison. There is dearth of literature comparing different face detection frameworks. This paper aims at providing an objective analysis of the two face detection algorithms by avoiding the peculiar features an individual implementation may have.

2. MATERIALS AND METHODS

Background Theory

This paper does not aim at underscoring the theoretical complexities of the two algorithms. Here, just those aspects will be highlighted which pertain to our task of comparing the two algorithms. The skin detection utilizes the concept of color space. In color space, a given class of color occupies a particular part of the color space and such region is called color cluster. So, the skin color has a specified region in the color space which is often called as skin color cluster, thus the basic principle of skin detection is that it designates a pixel of an object as skin pixel or not based on the skin color cluster (Eggamall *et al.*, 2009). The viola-jones face detection framework works on the value of simple features. Features can be used to encode ad-hoc domain knowledge which are otherwise cumbersome if it has to

be achieved through training samples (Viola, 2004). The features are characteristics of the face like distance between the two eyebrows, the distance between nose-tip to the forehead, the cheeks, the chin *etc.* These features occur in particular regions. To detect these regions two-rectangle feature, three-rectangle feature and four-rectangle features window is used.

Parameters Used in the Experiment

The parameters used here are to be perceived as variable characteristics of the image. The value of these variables affects the different aspects of the image. The face detection algorithms are sensitive to different values of these variables. The reaction of the Skin Detection and Viola-Jones is different to these parameters. The skin detection is much sensitive to illumination. Skin color occupies a particular region in color space. The lighting of the image affects the skin color cluster in a given color space. The human eye is invariant to different lighting, *i.e.*, it can recognize faces in a variety of lighting conditions. This characteristic of human eye is called color constancy. But in the color space representation, a color cluster of the same image occupies different regions depending upon the color space used. Different color spaces representation may be RGB, HIS and CIE-XYZ. So, the skin detection is heavily dependent on the choice of color space. Another challenge in skin detection algorithm is the skin-tone colors. So the second parameter is presence of skin-tone colors in an image. The third parameter is orientation of the face in an image. The Viola-Jones detects face based on distinct and clear features of face. So for, a face to be detected the features of the face needs to be visible to the rectangle window. Thus, orientation of face is a problem to Viola-Jones. The fourth parameter is sharpness of an image. As features of a face are instrumental to detection in Viola-Jones, so blurredness of the image poses a problem to it. The number of faces in an image is also a parameter of the comparison between the two frameworks. Different orientations, sharpness, presence of skin-tone colors in a multi-face image also affect the performance of the algorithms.

3. RESULTS AND DISCUSSION

This paper is concerned about commenting on the responses of the two algorithms to different input images. The images may be categorized into different categories. This section shows the results of experiments along with deep analysis of why the result has been so produced.

Skin-color-cluster-sensitivity

Skin-Detection based face detection fails to detect faces in an image as in (Fig. 1) which consists of images having color lying outside the color cluster on which the algorithm has trained. While training is also a problem to Viola-Jones, but in this particular problem of

(Fig. 2), it does well because it is not dependent on the color space representation.

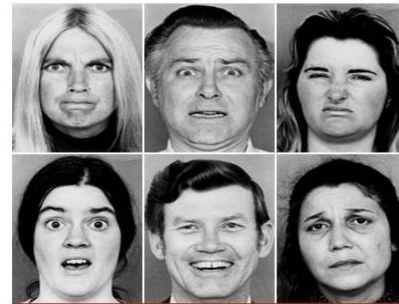


Fig. 1: Skin detection fails when color of image lie outside of cluster on which it has been trained.



Fig. 2: Viola-Jones performs well even when the color of image lies outside of the training color cluster.

Image Sharpness

As Viola-Jones works on detecting different features in an image, Blurred or otherwise damaged image poses a problem to Viola-Jones. It may fail completely when the features are not visible at all as shown in (Fig. 3). Skin detection can do better in such situations but it can also perform badly when the image contains many skin-tone colors as shown in (Fig. 4).

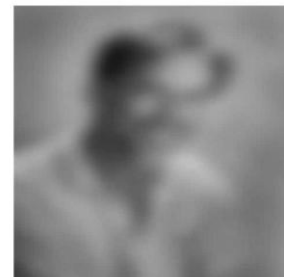


Fig. 3: Viola-Jones fails when image features are not clearly visible.

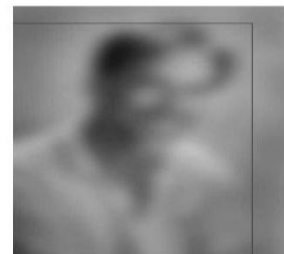


Fig. 4: Efficiency of skin detection in blurred image.

Illumination Dependency

The skin-detection faces a big problem of lighting in an image. The lighting affects the color space cluster of a given image and a given algorithm may have been designed for a specific color cluster and not for the other. The effect of this problem can be reduced by adjusting illumination in pre-processing stages. In (Fig. 5), there are no skin-tone colors but still the skin-detection failed to detect the other face because of different amount of illumination.



Fig. 5 Effects of illumination on skin detection.
False Detection

Skin detection is frequent at classifying non-face area as face area, *i.e.*, false positive. While viola-jones does not suffer from false positive at all, it maximizes true positives at the expense of false negative. (Fig. 6) substantiates the statement.

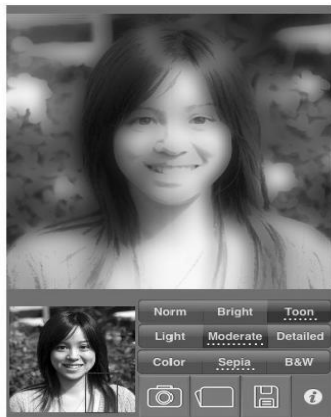


Fig. 6 Skin detection is prone to false detection

Different Orientation and Expressions

In different orientations, the face features may not be discriminate from each other. Such situations pose difficulty to viola-jones as shown in (Fig. 7). In such cases, the rectangle window cannot catch the facial features. This argument can be also extended to different expression of the face as expression also tempers with facial features. This problem is more serious than the illumination, because opposite to the illumination which can be manoeuvred, the orientation of face in an image cannot be tempered with.

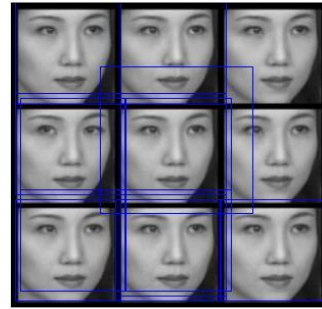


Fig. 7 Performance of Viola-Jones degrades with changes in orientation of face.

In the (Fig. 7), viola-jones failed to detect four frontal faces out of eight. This is because the orientation of the faces obscures the discriminate features. In the (Fig. 8) different expressions affect the performance of the viola-jones.



Fig. 8 Viola-Jones do not perform optimally in case of different face expressions.

Image Complexity

An experiment was carried out on a standard image used for measuring the performance of different face detection algorithms. Viola-jones was a hit with such image as can be seen in (Fig. 9). Its false negative rate was just 4/43. What lead to such great performance? The faces in the image can be characterized with having discriminate features. The features are visible so is the orientation of faces and also the range within which the faces are being captured. When the prerequisites to Viola-Jones are fulfilled, it works efficiently regardless of the complexity of the image. The multiple rectangle window and cascade architecture of Viola-Jones enable it to achieve such performance. The rectangle window help in distinguishing discrete features of one face from those of the other while the cascade architecture help it solve the multiple faces complexity.

The skin detection based algorithm failed miserably in the experiment as can be seen in (Fig. 10). It classified multiple faces as a single image. This is because the usual drawbacks with the color space representation. The algorithm designed is for specific

colors so it failed to detect at all anything outside from that cluster. The second reason is the training constraint. Viola-Jones also shares this particular constraint with skin detection. Based on the above experiment, it is proved that skin detection works badly or in some cases like this miserably, when the environment is unrestrained.

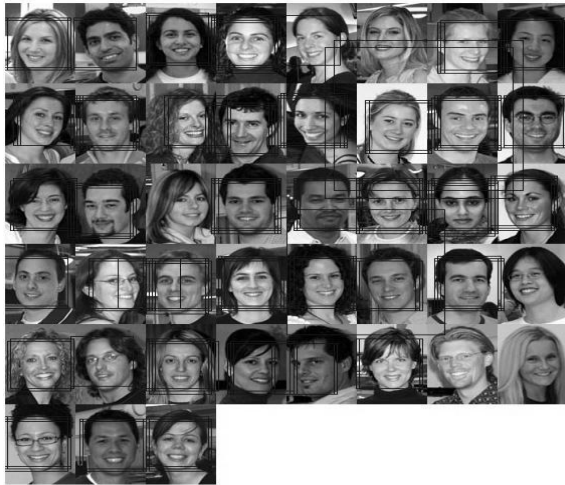


Fig. 9 Viola-Jones performs well on a standard complex testing image.



Fig. 10 Skin detection is unimpressive with a standard complex testing image.

4.

CONCLUSION

Given the specific constraints of the individual algorithm, the question which one is to be used depends on the problem in hand. When we are dealing with problems involving security then the ultimate goal is to reduce the false-positive, so the algorithm to be used is Viola-Jones. When the false positive does not affect the end result such as queries, then the algorithm of choice is skin-detection. Another problem is complexity of the algorithm. Viola-Jones is efficient in most cases but also more complex and thus time consuming. So, when a controlled environment can be provided and the false detection is not a big problem then Skin Detection

should be used. This may be the case in searching databases. The controlled environment is difficult to be provided in real-time scenarios and the focus also is on true positives so for real time applications, Viola-Jones is preferred. The need is to reduce the run-time of viola-jones and also to make it more expressive and orientation immune. The skin-detection is not complex, so it takes much less time to execute than viol-ajones. It is also more efficient when, along with face, some other objects need to be detected as in the case with nude pictures. The output of skin detection can be fed as input to the viola-jones so as to make the viola-jones much less expressive and orientation immune.

REFERENCES:

Eggamal A., C. Muaang and D. Hu (2009) Skin Detection-A Short tutorial. Encyclopedia of Biometrics by Springer-Verlag Berlin Huddleberg.

Hadid A., M. Pietikainen and B. Martinkauppi (2002) Color based Face skin detection Using Skin Locus and Hierarchal Filtering, Proceedings of the 16th International Conference on Pattern Recognition. 196-200.

Shabi H. and N. Boujemma (2006) Coarse to Fine Face Detection based on Skin Colour adoption. Biometric Authentication Lecture Notes in Computer Science, Vol. (2359). 321-326.

Singh S. K., D. S. Chauhan, M. Vasta and R. Singh (2003) A Robust Color Based Face Detection Algorithm. Tamkang Journal of Science and Engineering. Vol. (6): No 4, 227-234.

Viola P. and M. Jones (2004) Robust Real-Time Object Detection International Journal of Computer Vision Vol. (57): No 2, 137-154.

Viola M., M. Viola, J. Jones, P. Viola (2003) Fast Multi View Face Detection, Mitsubishi Electric Research Laboratories, TR2003-96.