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A New Robust Face Detection Method Based on Corner Points

Samir El Kaddouhi[1], Abderrahim Saaidi[1, 2] and Mustapha Abarkan[1]

[1]*LIMAO, Department of Mathematics, Physics and Computer Science*
Polydisciplinary Faculty of Taza, SidiMohamed Ben Abdellah University
B.P. 1223, Taza, MOROCCO
[2] *LIIAN, Department of Mathematics and computer science,*
Faculty of Sciences, Dhar-Mahraz, Sidi Mohamed Ben Abdellah University, B.P 1796
Atlas- Fez, MOROCCO
samir.kaddouhi@gmail.com, saaidi.abde@yahoo.fr,
mustapha.abarkan@usmba.ac.ma

Abstract

This paper describes a method of faces detection based on skin color, face shape and corner points. The skin regions are detected by the segmentation of image with a threshold calculated by a combination of rules proposed on elements of the three color spaces RGB, HSV and YCbCr. Next, the geometric constraints (surface, ratio, eccentricity) are applied to eliminate the skin regions detected that do not have a shape similar to a human face. Then the corner points of Harris are used to verify the existence of eyes in the regions detected. The results obtained are satisfactory in terms of the quality of detection and rapidity.

Key-Words: *Face detection, skin color, excentricity, corner points, template matching*

1. Introduction

Face detection is a very interesting field of research that verifies the presence of faces and locates their positionsin an image. Similarly, it is the basis of many applications such as face recognition; vision based robot, human computer interaction (HCI), video surveillance, the selective encryption, emotion recognition and video telephony [1].

However, face detection is a challenging task due to several factors such as: the expression and orientation of the face, the computation time, lighting conditions and the presence or absence of structural components such as glasses, beard or mustache [1]. To overcome these problems, various techniques have been developed in recent years: Template matching methods [2, 3], skin color [3-9], neural networks [9-14], the principal component analysis [14, 15], the support vector machine [16], AdaBoost algorithm [17-21], and genetic algorithms [11, 19].

In this paper, a new method of face detection is proposed. It is based on the skin color, face shape and the eye detection by feature points in the image. Our method is composed of three steps: In the first one, we determine the rules for defining regions of the skin by using a set of training images in three different colors spaces. Next we segment the skin regions with these rules, and then we apply a combination of morphological operations on skin regions extracted to fill the holes and remove small segments. In the second one, we remove regions of the skin that does not have the shape of the face by the operations of the form (ratio, eccentricity ...) and the skin regions characterized by a similar color are also removed by the principle of color variation. In the third step, the eyes are detected by matching the eye template and small regions determined by the grouping characteristic points (corner points detected by Harris

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detector) neighbors. This eliminates the regions which have the face shape that does not contain eyes.

The different steps of our method of face detection are presented in Figure 1.

The verification of the existence of eyes in the regions with the color of the skin is made by applying a template eye. This reduces the very high number of false faces obtained by methods based on skin color. Moreover, this model is applied only on small regions defined by grouping corner points detected by Harris, but not on the entire region. This reduces the computation time compared to the application of the model eye on the entire region of the skin.

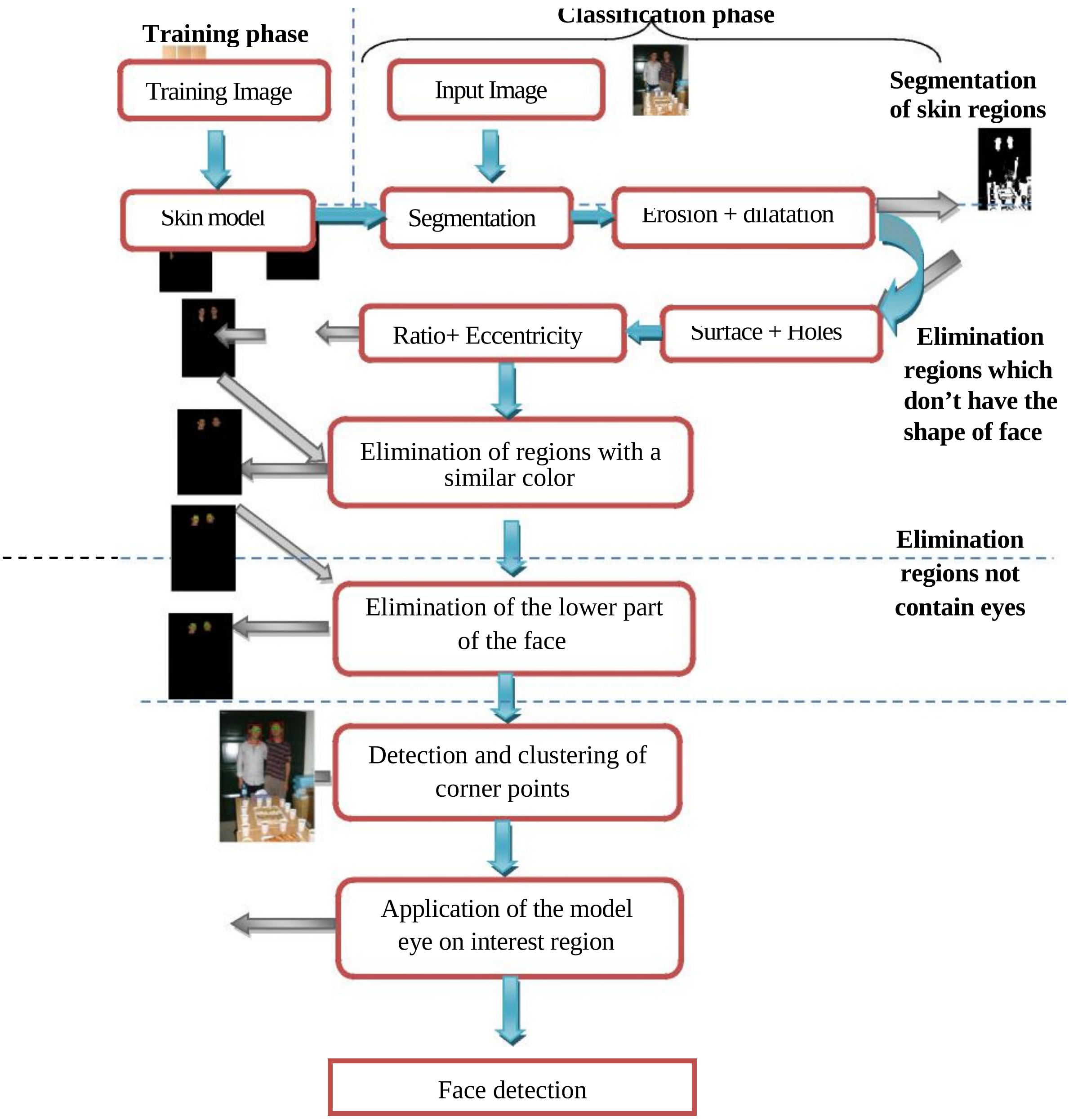


Figure 1. Diagram of Face Detection by our Method

The rest of this paper is organized as follows: the second part presents the related work of the face detection. In the third and the fourth part we dwell on our approach and its experimental results. And the fifth part is devoted to the conclusion.

2. Related Work

Face detection is a current subject that has been studied by many researchers in recent years. Several methods of face detection are proposed and can be classified into five categories:

- Template matching methods which consist of creating templates of entire face or different facial features, then calculating the correlation between the full set of sub-images of the processed image and the template. Two factors are essential to these approaches: the way of creating templates which may be manual (the mean of images which contain only faces) or by a parametric function and the correlation method used (Euclidian distance, cross-correlation function normalized cross-correlation) [1-3]. These approaches are characterized by a simple and rapid treatment, but their major disadvantages are related to variation in light, scale and pose and to estimate a template representing all faces.
- Knowledge-based methods that use rules defined from the relations between the different facial features. Generally, a face appears in an image with a mouth, a nose, two eyes and two symmetrical eyebrows. The relationship between these features can be represented by their relative positions and distances [1, 22]. The shortcomings of these approaches are the difficulty of translating human knowledge into well-defined rules, and it is difficult to extend this approach to detect faces in different poses
- Appearance-based methods treat face detection as a classification problem (face / non-face). To decide if an image belongs to the class of faces or the non-faces, a set of training images are used to determine the rule of separation between the two classes. Many approaches are proposed for classification. There are, for example, neural networks [9-14], genetic algorithms [11, 19], the principal component analysis [14-15], the support vector machine [16] and AdaBoost algorithm [17-21]. The major problem with these methods is that they require a very long computation time in the training phase.
- Feature invariant approaches can be classified into two categories: Methods based on the skin colors which are to determine the pixels corresponding in this color to an image, and methods based on face features which locate the four characteristics (two eyes, two nostrils, nose and mouth) to detect face [3-9]. These techniques are limited because the skin regions are not necessarily faces and facial features can be covered by some components (glasses, hair).
- Hybrid approaches that combine between several techniques to improve the quality of face detection. More articles are cited: Zhen-Xue Chen, *et al.,* [6] propose a method of face detection based on a model of skin color which uses an improved "reference white" method to remove the interference of non-skin-color region. Then they apply a Gaussian model in YCbCr space to segment skin regions. After that they verify certain conditions the hair and the face surface to remove regions of the skin that are not faces. This method is not influenced by the variation of illumination, but it is limited when the color of the background and the man's clothes are similar to the skin color. Another method of face detection by skin color is proposed by Deepak Ghimire, *et al.,* [7]. It enhances the input image, segments the skin regions in color spaces RGB and YCbCr, and combines the edge image with the skin color image to separate between the skin regions and the background. It also uses features of face shape (area, bounding box proportions, centroid, extent) to check whether a skin region detected is a face or non-face. The advantage of this method is the detection of faces in

different illumination conditions, different sizes, different poses, and different expressions, but its disadvantage is the detection of a very high number of false faces when the image has a complex background with a color close to that of the skin, and it is unable to detect faces when there are structural elements (glasses, beards, ..). The face detection method proposed by Shady, *et al.,* [8] allows to segment regions of the skin, to apply a set of filtering operations (width and height of a region, solidity property, and shoulders removal), and using a set of face features as nose point, chin point, nose bottom point, nose above point, neck point, and angle between (nose, nose above and nose bottom) points. This technique gives good results particularly in profile faces. However, it is limited when people wear clothes or have hair with color similar to the skin color or when changes lighting. Viola and Jones [17] present a method of face detection based on the concept of integral image, using a simple and efficient classifier built from the Haar features using AdaBoost algorithm and a combination of cascaded classifiers which allows background regions of the image to be quickly discarded. This approach gives good results for the detection of frontal faces in real time, but it did not treat the images under different lighting conditions in the presence of occultation, faces in profile, and facial features. To improve the experimental results, several authors combined with the previous method with others such as Katsimero, *et al.,* [18] who suggest a technique that begins by first creating a solid mask to the skin using the skin segmentation (histogram equalization, color correction, color space transformation and skin pixel classification). Then they apply the method of Viola & Jones on skin regions detected. However, this method does not resolve all the problems of Viola & Jones detector especially to detect profile faces and detection of facial features.

3. Our Method

In this section, the different steps of our face detection method will be presented. We begin with segmenting skin regions by thresholds defined from a set of training image. Then we apply the geometrical constraints (surface, ratio, Eccentricity and similarity) to eliminate the regions of the skin that don't have the shape of face. Then we use feature points (corner points) and the template eye to conserve only the regions containing eye.

3.1. Detection of Skin Regions

This step is to determine a set of rules that define the regions of the skin, then use these rules to segment images into regions skin and non-skin. Then the morphological operations are applied to the regions of the skin detected to close the small holes and eliminate small segments

3.1.1. Rules defining the skin regions

The following Table (Table 1) shows the rules that determine skin regions in the three color space normalized RGB (r=R/(R+G+B), g=G/(R+G+B), r+g+b=1), HSV and YCbCr. These rules are defined from a set of images of the database Brazilian FEI [25] containing 2800 images of 200 individuals taken under different conditions (lighting, pose...).

Table 1. Rules Defining the Skin Regions

Space	Rules	
Normalized rgb	**A**	
	B	
YCbCr	**C**	
	D	
HSV	**E**	
	F	

3.1.2. Segmentation

Thresholding segmentation is done according to the rules listed in the Table 1. The use of three color spaces (normalized rgb, YCbCr and HSV) gives better results than a single color space [23]. These three spaces are combined using the logical AND and OR follows:

$$((\ ) \quad (\ )) \quad ((\ ) \quad (\ )) \quad ((\ ) \quad (\ )) \qquad (1)$$

This rule allows to segment images into two regions (skin and non-skin) then the images are converted to binary images in which the white represents regions with the skin color and the black represents regions not having the skin color, as shown in Figure 2.

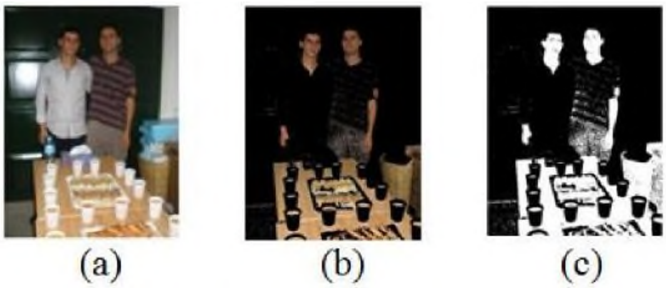


Figure 2. Segmentation Skin Regions: Input Image (a), Image Segmented in Two Regions Skin and non Skin (b), Binary Image (c)

3.1.3. Morphological Operations

The role of morphological operations is to modify the pixel value according to its neighbors using a structuring element (ensemble of known geometry, composed of a central pixel and its neighbors) and consequently to modify the structure and the shape of the region.

The morphological operations used are: erosion that removes undesirable small segments, and dilation which closes the small holes to recover regions of the face removed by erosionas shown in Figure 3.

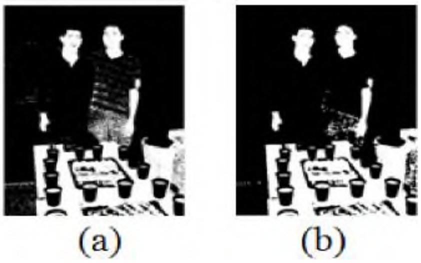


Figure 3. Effect of Erosion and Dilatation: (a) Original Binary Image, (b) Binary Image Obtained after Erosion and Dilation

3.2. Removal of Regions having no Shape of Face

This step involves removing regions of the skin detected that do not have the form of face, by the use of certain constraints related to the shape of faces as surface, ratio, eccentricity and the variation of the color.

3.2.1. Constraint Surface and Holes

After labeling of all regions of the skin detected in the image, regions of small surface are removed, and then the holes located inside all the remaining regions are also eliminated. The result after application of the constraint region and holes is shown in Figure 4.

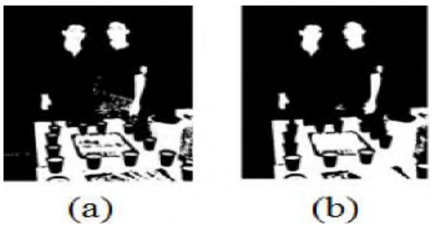


Figure 4. Effect of Region and Holes: (a) Original Image, (b) Image Obtained after Application Region and Holes

3.2.2. Constraint Ratio

We studied different faces of the database FEI. We determined the ratios of all images meaning, the ratio between the width and the height. Thus, only the regions that have a ratio between 0.5 and 2 are kept as shown in Figure 5.

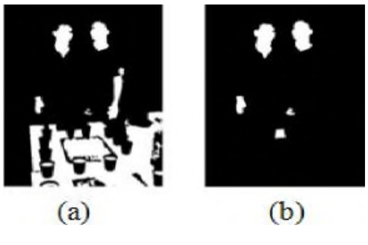


Figure 5. Effect Ratio: (a) Original Image, (b) Image Obtained after Application of Ratio

3.2.3. Elliptical Constraint

The face is generally in the form of an ellipse, so to find the regions close to an ellipse; we used the function of eccentricity defined by the following relationship.

(2)

( ) √

Where x and y are respectively the small and large axis of a region detected. The function of eccentricity can be expressed by:

( ) ( )

{ In practice, the regions that have an eccentricity value close to 1 may be considered faces (Figure 6).

Figure 6. Elimination Regions not having the Shape of an Ellipse: Original Image (a), Image Contains Only the Regions having the Shape of an Ellipse (b)

3.2.4. Constraint Color Variation

We conducted a statistical study on all the images of the database studied. We observed that different regions of the face (hair, skin regions and eyes) undergo a sharp variation of color. Thus, a region that has more than 2/3 of the pixels having values near the average value of the concerned region is eliminated as shown in Figure 7.

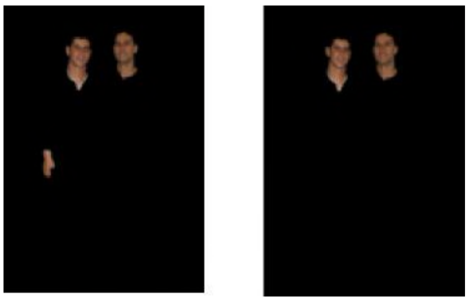


Figure 7. Elimination Regions with Similar Color: (a) Original Image, (b) Image Obtained after the Removal of Regions with Similar Color

3.3. Eye Detection Through Harris Detector

The objective of this step is to verify the presence of one or two eyes in each region detected based on corner points which are the points characterized by a strong change in the signal of the image. In general, the eyes are located at the upper face and are also characterized with a strong variation of color. Thus after the removal of the lower part of the face region, Harris detector is applied to the upper part. Then a step of grouping neighboring corner points is made and each group obtained compared with a template eye to verify the presence of an eye.

3.3.1. Detection of Corner Points through Harris Detector

To determine the corner points with Harris detector [24], the factor R is calculated by the formula given by [42]:

( ) (3)

With:0<K<0.25 (in general k=0.04)

( ) (4)

( ) (5)

( ) (6)

wis a Gaussian window.

is the convolution product.

Rx, Ry, Gx, Gy, Bx, and Byare the gradients of the three RGB channels according to x and y. They are calculated from the convolution of the three components R, G and B by the following derivative filters:

[ ] (7)

[ ] (8)

Figure 8 illustrates the result obtained after applying the Harris detector on the upper portions.

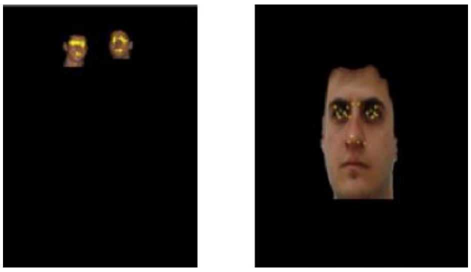


Figure 8. Two Images Obtained after the Detection of Corner Points with Harris Applied to the Upper Regions. (a) Real Image and (b) Image of the Database FEI

3.3.2. Grouping of corner points

Grouping corner points is to collect all the neighboring points of a region. We say that two points are neighbors if the Euclidean distance between them is less than a determined threshold S as shown in Figure 9.

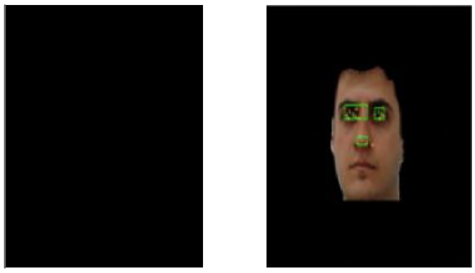


Figure 9. Two Images Obtained after Grouping Corner Points Neighbors: (a) Real Image and (b) Image of the Database FEI

3.3.3. Matching of the Template Eye with Interest Regions

The main idea of this step is to create a template eye (T), with the average of eyes images for many people taken from database FEI, then calculate the correlation between this template and the different interest regions (IR) by using the normalized cross-correlation (NCC) [2] defined by the formula (9).

Σ (9)
{Σ ( ) Σ ( ) }
(
(}
( )

,

with:
{ } ,
{ }
{ }
{ }
( ) ( )
( ) ( )
Σ ( )
Σ ( )

I is the input image
T the template
is the average of the template.
is the average of the image in the template region.
m and n are the image sizes.
p and q are the sizes of the template.
The matching of the template eye with an interest region is shown in Figure 10:

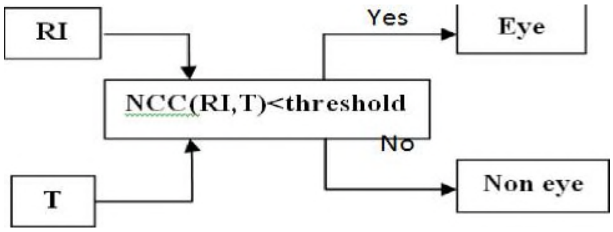


Figure 10. Matching of the Template Eye with Interest

Regions Figure 11 shows the result of Eye detection obtained by our method.

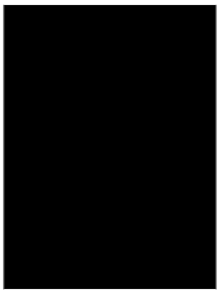


Figure 11. Two Images Represent the Eye Detections: (a) Real Image and (b) Image of the Database

4. Experimental Results

To evaluate the performance of our algorithm, we have established three following indicator parameters: the correct detection rate (**CDR**), the non-detection rate (**NDR**), and the false detection rate (**FDR**) defined:

( )

( )

( )

4.1. Simulation (Dataset): Performance, Evaluation and Discussion

We tested our method on the database FEI [25] available Online. It contains 2800 face images taken in different lighting conditions with various poses, expressions and occultation (beard, glasses).

Under standard lighting conditions, our method has a correct detection rate almost total. The obscurity makes the discernment among the regions of the skin more difficult, which explains the lack of detection 14.44%. The position of the face in an image (profile, front), its expression and the presence or absence of occultation (beard, glasses) has no impact on the quality of face detection (see Table 2).

Table 2. Face Detection Results Obtained using our Technical

Characteristics of the database FEI [25]			Face Detection with our method					
Images	Number of images	Number of face	Number of faces detected		Number of faces not detected		Number of false faces	
Frontal	1400	1400	1400	100%	0	0%	21	1,48%
Profile	800	800	800	100%	0	0%	12	1,48%
somber lighting	400	381	326	85,56%	55	14,44%	0	0%
Occultation (glasses)	66	66	66	100%	0	0%	0	0%
Occultation (beard)	266	266	265	99,62%	1	0,38%	0	0%
facial expression	200	200	200	100%	0	0%	3	1,48%
Total	**2800**	**2781**	**2726**	**98,02%**	**55**	**1,98%**	**40**	**1,45%**

The Figure 12 shows an example of results illustrates the face detection in the presence of these factors.

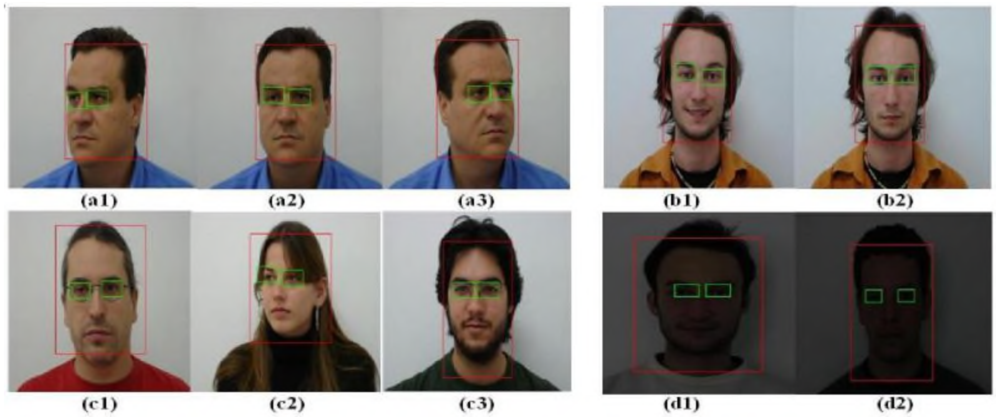


Figure 12. Face Detection Obtained using our Algorithm in the Presence of Different Preceding Constraintes: a1, a2 and a3: Correspond to Different Poses. b1 and b2 Different Facial Expressions. c1, c2, and c3: In the Presence of Occultation, Glasses, Hair and Beard. d1 and d2 in the Case of Sombre Images

We compared the results of our method with and without the step of eye detection on the one hand and the results of this method with other methods based on the skin color [6, 7 and 18] on the other hand (Table 3).

Table 3. Improved Face Detection with our method

	Correct detection rate	non-detection rate	false detection rate
Our methodwithout eye detection	98,02%	1,98%	14,97%
Our method	**98.02%**	**1.98%**	**1.45%**
Zhen-Xue, *et al.*, [6]	96,04%	3,94%	10%
Deepak, *et al.*, [7]	92,78%	7,22%	12,84%
Katsimerou, *et al.*, [18]	98%	2%	8,14%

Our new detection method can discriminate faces with the highest rate of literature and the lowest rate of error detection. So, up to now, according to these criteria, our method can be considered the best technique for face detection.

For greater visibility, Figure 13 also illustrates that the various detection methods of the literature have correct detection rate higher than 92%.

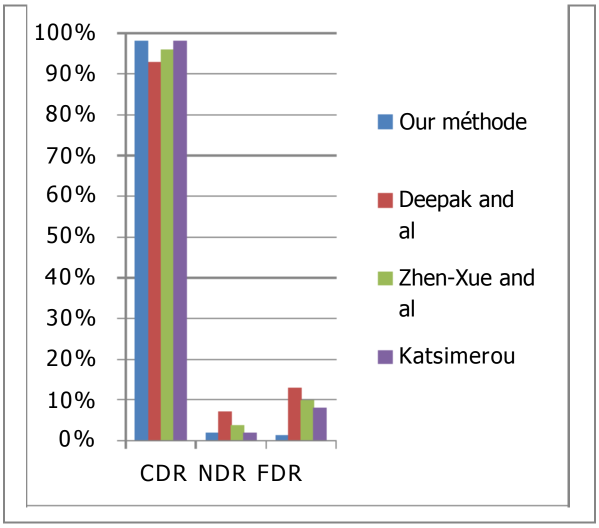


Figure 13. Comparison Results Detection of our Method with other Methods

Commonalities in these techniques explain these high rates, since each use algorithms based on the segmentation of regions of the skin and the application of certain geometric properties (region ratio, eccentricity and similarity).Further, the false detection rate of our method is the lowest compared to other methods. The quality of the detection of our new method is due to the part of our technique that checks the existence of the eye by corner points detected by the method of Harris. This additional step performed on just the upper part of the face allows saving time calculation.

4.2. Real Data

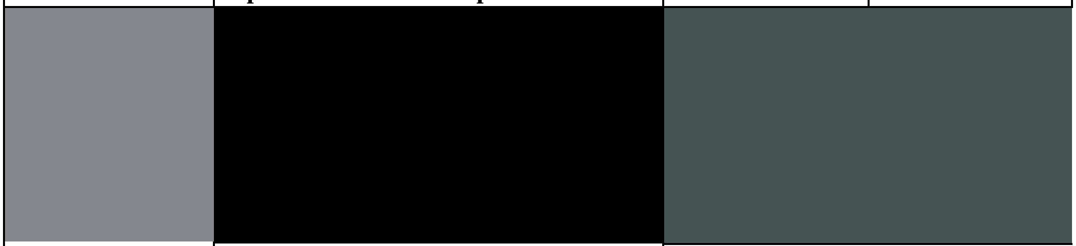
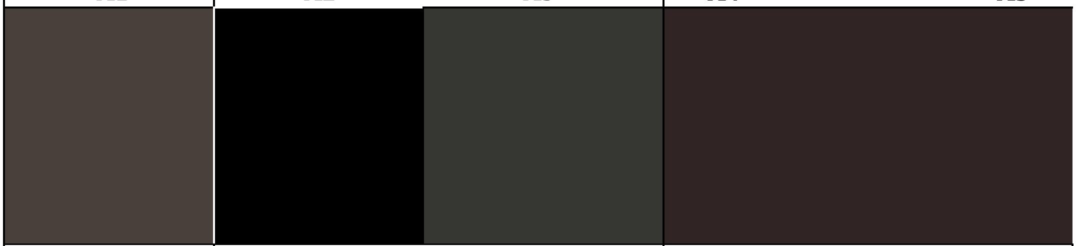
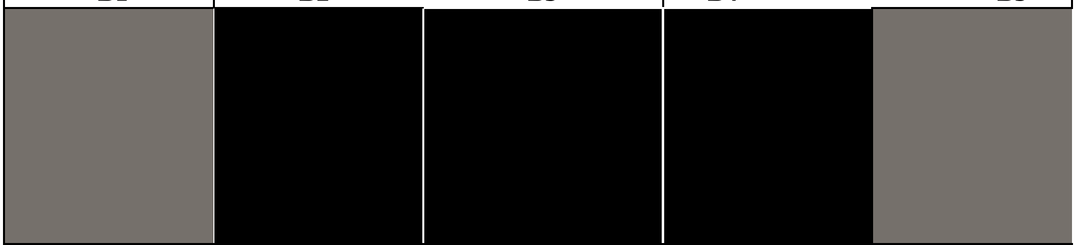
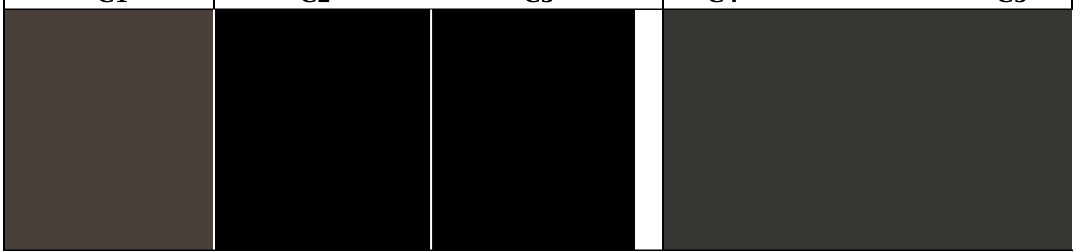
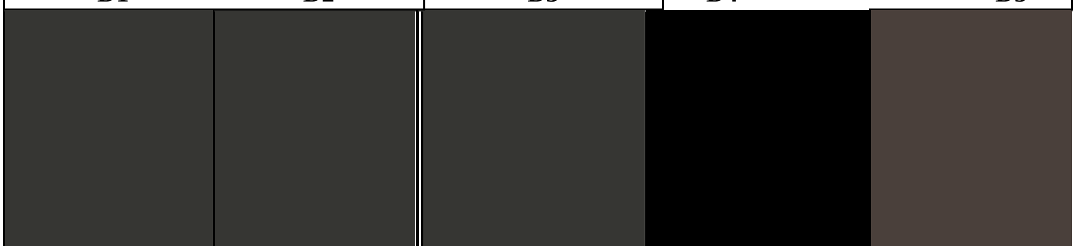
We compared our method on the data base FEI characterized by the presence only of bodily form, bust and back Monochrome Plans. It is interesting now to study the effectiveness of our detection technique on real images. We thus applied on a basis of 50 images containing 141 faces. These images are complex with body parts, several people and backgrounds can disrupt the process of detection. The results obtained (Table 4) again show the performance and robustness of our technical facing the various previous constraints; since we got a correct detection rate higher than 95% and a false detection rate about 6%.

Table 4. Face Detection Results Obtained

Total number of faces	Number of detected faces		Number of not detected faces		Number of false faces	
141	135	95.74%	6	4.26%	9	6.25%

To illustrate the different stages of our method, we have presented in the following Table (Table 5) the results of six selected images from the previous base.

Table 5. Steps of Detection on Images Characterized by Complex Background

Input imagesRGB	Images after segmentation of skin regions and morphological operations	Images after the elimination of regions which don't have face shape	Images obtained after the detection of eyes	final Result
				
A1	A2	A3	A4	A5
				
B1	B2	B3	B4	B5
				
C1	C2	C3	C4	C5
				
D1	D2	D3	D4	D5
				
E1	E2	E3	E4	E5

5. Conclusion

Our new method of face detection is based on the detection of skin regions, the application of the geometric constraints (surface, ratio, eccentricity and similarity) and clustering corner points detected by Harris, which are paired with an eye template that creates a set of eye database FEI. The results show that this technique has many advantages in the quality of the detection. Under all conditions of pose, expression or the presence of occultation, our method provides perfect face detection. It is also, up to now, the technique allows overcoming effectively false detections.

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Authors

Samir El Kaddouhi, he received the master’s degrees from Faculty of Sciences, Tetouan in 2010. He is currently working toward the PhD degree in the Laboratory Informatic, Mathematics, Automatic and Optoelectronic (LIMAO) at the Faculty Polydisciplinaire of Taza. His current research interests include computer vision, artificial intelligence, optimization, face recognition, face detection.

Abderrahim Saaidi, he received the PhD degree from SMBA-Fez University in 2010. He is currently a professor of computer science at SMBA-Taza University. He is member of the LIIAN and LIMAO Laboratories. His research interests include camera self calibration, 3D reconstruction and real-time rendering.

Mustapha Abarkan, he received the DEA and PhD degrees in optoelectronic from the University of Metz, in France, in 1998 and 2002, respectively. His research was devoted to the study of nonlinear optical crystals for electro-optic Q-switching of laser resonators. He then performed thesis works at LMOPS (laboratory Optical Materials, Photonic and Systems, Metz, France). He became Assistant Professor at the University of Fès, in Morocco in 2003 where he received the HDR professor in 2007. Since 2012, he leads researches and works in computer vision. He is member of the Laboratory Informatic, Mathematics, Automatic and Optoelectronic (LIMAO) at the Faculty Polydisciplinaire of Taza, in Marocco.