Eng. & Tech. Journal, Vol. 28, No.18, 2010

Face Occlusion Detection and Recovery using Fuzzy C-Means

Dr. Emad K. Jabbar * & Wildan J. Hadi**

Received on: 14 /4/2010
Accepted on: 2 /9/2010

Abstract

This paper presents a framework to detect and recover the occluded facial region. We based on fact that any face has symmetric and not symmetric facial features and all these symmetric facial features are consistent with the shape of the face. So that, if there is an occlusion in one half of the input face image, then the second half is used to recover the occlusion. Using symmetry feature of the face makes the recovered face very close to the original face image in terms of pixel values and in general appearance. In other side when features do not symmetric, the occlusion can not be recovered using the symmetry feature of the face as the case the mouth region is occluded, so the images database is used to select from it the most similar face images to the occluded face image to use it to select similar face to recover occlusion. In current work, we first detect the occluded face image by using pixel based skin color segmentation and eye template matching. Then, using fuzzy c-means to detect occlusion. Finally, the procedure for recovery is implemented. The results shows that the proposed algorithm provides an effective solution to solve the problem of face occlusion. This work can used in many applications as in repair the important persons historic image and archive image which we get results reaches to 73% of identical to original image which has 40% occluded.

Keywords: face, occlusion, fuzzy c-means, template matching, skin color segmentation.

اكتشاف واصلاح المناطق التالفة في صورة الوجه باستخدام المنطق المضبب

الخلاصة

هذا البحث يقدم إطار عمل لاكتشاف وإصلاح المنطقة المحجوبة او التالفة في الوجه. تم الاستناد إلى حقيقة أن أي صورة وجه فيها خصائص وجه متماثلة ومتناضرة مثل العينيين والحاجبين ..., واخرى غير متماثلة مثل الانف والفم وان الخصائص المتماثلة والمتناضرة لصورة الوجه متناسقة مع شكل الوجه وحجمه, وهذا يعني ان حجب او تلف اي جزء في الوجه من الاجزاء المتماثلة يمكن التعويض عنه من الجزء المناضر له في الجهة الثانية من الوجه. اما اذا كان الحجب في المناطق الغير المتماثلة يتم التعويض عنه من قاعدة بيانات تم استعمالها لايجاد صورة وجه مشابه لتعويض التلف. ان العمل الحالي يكشف منطقة الوجه باستخدام عملية التقطيع بالاعتماد على لون الجلد البشري وقناع العينيين للمطابقة, ثم يتم تحديد منطقة الحجب باستخدام خوارزميات المنطق المضبضب ومن ثم يتم اصلاح الحجب باستخدام الخوارزمية المقترحة. ومن خلال النتائج التي تم الحصول عليها نجد ان الخوارزمية قدمت حل فعال لمشكلة المناطق التالفة من صورة الوجه, حيث حصلنا على نتائج 73% من التطابق مع الصورة الاصلية التي بها نسبة التلف 40% . يمكن استخدام الخوارزمية المقترحة في تصليح الصورة التاريخية للشخصيات المهمة وصور الارشيف وغيرها من الصور المهمة .

* Computer Science Department, University of Technology/ Baghdad
** Computer Science College, University of Baghdad/Baghdad

https://doi.org/10.30684/etj.28.18.11
2412-0758/University of Technology-Iraq, Baghdad, Iraq

1. Introduction

In recent years, face images has attracted much attention and its research has rapidly expanded, since it has many potential applications in computer vision, communication, and automatic access control system. Especially, face detection is an important part of face recognition and many applications. However, face detection is effected by many factors that modify face image appearance such as, viewing angle (front, non front), occlusion, image orientation, illumination, facial expression and individual factors [1].

Face occlusion represents big problem in many applications like face recognition, image archive system, history image …etc. So a technique that can automatically recover the deterioration in the face images is needed.

Recently, some algorithms are proposed to recover partially deteriorated face images. Hwang and Lee presented a method to recover occluded faces by linear combination of faces. Initially, a face image is represented with two eigen bases, one for the shape correspondence between the particular face and reference face, and a second for the shape-normalized face texture. Given a face with occluded region, the shape and texture of known regions are fit with a linear combination of their respective eigen vectors and the same combination is then used to recover the unknown (occluded) region [2]. Mo et al presented a method to recover occluded face image using a positive only-mixture of training faces .Negative least sequares algorithm is used for the positive mixture representation of a given face .Given a target face with occluded region, a subset of the training faces that are relatively similar to the target face are determined firstly .Then, positive representation weights are chosen to evaluate the match in the occluded region [3]. Dahua and Xiaoo presented a framework to automatically detect and recover the occluded facial region. Initially, a Bayesian framework unifies the occlusion and recovery stages .Then a quality assessment model is developed to drive both the detection and recovery process, which captures the face priorities in both global and local patterns [4].

2. Face Image and Occlusion Types

Human face represents one of the most common biometric patterns that our visual system encounters daily. Faces to be useful biometric, facial features should remain invariant to factors unrelated to person identity that modify face image appearance [1]. Deterioration has large effect on face image since it may be damage the face image , lose part of the face image , or cause high noise .the face deterioration has many shape and many affection , so we can take the following types of deterioration like ,

1- Face deterioration by text.
2- Face deterioration by stain

3. Skin Color Segmentation and Eye Template Matching

To detect face region, a combination of skin color segmentation and template matching is used here. Skin color segmentation has proven to be useful and robust cue for face detection and tracking. There are many feature-based face detection methods, the most important once using skin color as detection cue. Skin color allows fast processing and is highly robust to geometric variations of the face pattern. There are many color spaces; one of these color spaces is the (red, green, blue) RGB color space that is used by our algorithm for skin segmentation purpose. It is one of the most widely used color spaces for processing and storing of digital image data [5].

Face image can be separated into skin and non skin regions based on the knowledge that in RGB space the skin has a higher red content than other component. So (R, G, and B) is classified as skin if [6]:

$$R > 95 \text{ and } G > 40 \text{ and } B > 20 \text{ and } Max(R, G, B)-min(R, G, B) > 15 \text{ and } R-G > 20 \text{ and } R-B > 20, \quad \ldots\ldots.(1)$$

Figure (1) shows an example of applying pixel based skin color segmentation.

When the results of RGB based skin color segmentation produce more than one skin color regions, then eye template is used as verification process to further distinguishes face from other non-face regions that have the same skin color. Eye template shown in Figure (2), is generic and captures the general properties of the eye and its surrounding area.

The basic method to perform template matching is to loop through all pixels in the search image and capture them using the following steps:

Step -1 Resize the width of the skin regions to the width of the eye template which is equal to 45 pixels.

Step -2 Convert the skin region to binary levels.

Step -3 Perform tracking vertically on the search region (skin region) and then compute the similarity measure for each block.

Step -4 Select the block with maximum value and set the corresponding skin region as the face is detected.

Figure (3) shows the results of applying eye template matching on the skin regions. At this point, the occluded face region is detected.

4. Occlusion Detection and Fuzzy c-means

In many image processing applications, we employ prior knowledge to interpret an input scene. Examples are pattern recognition, region segmentation, scene description, and so on. Fuzzy logic offer us powerful tool to represent process of human knowledge in the form of fuzzy if-then-else rule[7].

The most popular fuzzy clustering algorithm, known as fuzzy c-means algorithm (FCM). FCM algorithm partition an input image of size M×N specified by m-dimensional vector of K data points u_k(k = 1, 2, . . . ,K) into C fuzzy clusters, in which each point have a membership associated with it. This membership value m_{ik} represents the extentent to which a pixel belongs to a class, having a specific attributes. It finds a cluster centre in each, minimizing an objective function. Fuzzy c-means is different from hard c-means, mainly because it employs a *fuzzy partitioning*, that is, a point can belong to several clusters with degrees of membership. To accommodate the fuzzy partitioning, the membership matrix **M** has elements in the interval [0, 1]. A point's total membership of all clusters, however, must always be equal to unity to maintain the properties of the **M** matrix. The objective function is:

$$J(M, c_1, c_2, \ldots, c_c) = \sum_{i=1}^{c} J_i = \sum_{i=1}^{c} \sum_{k=1}^{K} m_{ik}^{q}\, d_{ik}^{2} \quad \ldots\ldots(2)$$

Where item m_{ik} is the membership value in the interval [0, 1] of data point k of cluster i, vector c_i is the centre of fuzzy cluster i, scalar

d_{ik} = $||u_k - c_i||$ is the Euclidean distance between the ith cluster centre and the kth data point, and scalar q is the *fuzziness exponent*. The commercial tools usually recommend a value q = 2. There are two necessary conditions for J to reach a minimum,

$$c_i = \frac{\sum_{k=1}^{K} m_{ik}^{q} u_k}{\sum_{k=1}^{K} m_{ik}^{q}} \quad .....(3)$$

and

$$m_{ik} = \frac{1}{\sum_{j=1}^{c} \left(\frac{d_{ik}}{d_{jk}}\right)^{2/(q-1)}} \quad ...... (4)$$

The algorithm is, in essence, iteration through the preceding two conditions[7].

The algorithm for occlusion detection is based on the fact that the detected face share similar properties in Y$C_r C_b$ color and RGB component. So that; occlusion can be extracted from the detected face region as a different region. This different region should be determined firstly by one of the segmentation algorithm to recover it in the next processing . FCM clustering algorithm is one of the most successful image segmentation algorithm, is used here for segment the detected face into two regions occluded and non-occluded regions. The proposed algorithm for occlusion detection is performed using the following steps:

1- Convert the occluded face image from RGB to Y$C_r C_b$ components using the following eq.[8]

$$Y = 0.299R + 0.589G + 0.114B$$
$$C_r = R - Y$$
$$C_b = B - Y \quad .... (5)$$

2- Segment the occluded face image into two regions using Cr Information as the main feature For classification.
   - 2.1 Initialize the cluster centers C To 2.
   - 2.2 **Set** the convergence error £=0.001%.
   - 2.3 **Set** fuzziness exponent q to 2 .
   - 2.4 **Initialize** randomly the Membership matrix, M=M^0. Set j=0.
   - 2.5 If $\max\left(m_{ik}^{j} - m_{ik}^{j-1}\right)_{i=1,\dots,C,\,k=1,\dots,n} > £$, go to step 2.6 Otherwise , go to step 2.7 .
   - 2.6 Compute the class centers and update the membership matrix
     - 2.6.1 j=j+1 .
     - 2.6.2 Compute the class centers using eq. (3).
     - 2.6.3 Update the membership matrix by (4).
     - 2.6.4 Go to step 2.5 .
   - 2.7 Set the final membership matrix M=M^j and the final class center C=C^j .

3- Repeat step 2 to perform the second segmentation on the occluded region using gray value and coordinate information as features for classification .

4- End.

The results of occlusion detection are shown in figure(4).

5. Proposed System

The main component of our system is shown in figure (5):

The proposed system does not work with face image that have 2 on the fact that any face has symmetric facial features and all these symmetric facial features are consistent with the shape of the face, so that, if the occluded region of the face is the left eye, then right eye can be used to recover left eye. But, when the occluded region is not one of the symmetric facial features, such as nose and mouth, then the recovery process is not based on the face itself, but based on another similar face that is built from face data base according to specific similarity measures.

5.1 Face Database

The face data base used here contains about 100 face images with frontal view. Figure (6) shows a sample set of face images stored in the data base. All face images in the face data base are of size 96×96 px with mask shape. The face images are stored in the data base with several information related to it such as : person sex(male, female), person age (young , old), Standard deviation value for the main parts of the face which include left eye, right eye, nose, and mouth using the division in Figure (7). Table(1) shows the fields of the face database.

5.2 Steps of Proposed System

Step-1 input occluded face image, with any size.

Step-2 Detect face region using skin color segmentation and template matching.

Step-3 segments the occluded region inside face mask using fuzzy c-means algorithm.

Step-4 compute percentage of the occlusion inside the face mask using the following eq.,

$$occlusion\ Percentage = \frac{no.of\ deteriorated\ points\ inside\ face\ mask}{no.of\ all\ points\ inside\ face\ mask} \quad ....(6)$$

,

So, if the percentage is less than specific threshold, then goto step 5, else goto step8.

Step-5 test the location of the occlusion region , if the location is one of the symmetric region then replace the occlusion region with its symmetric region in the occlusion face image , else select from the face data base the set of faces which are most similar to the occluded face and then built mean face. These faces which are used to built mean face are selected using the following parameters ,

- Skin standard deviation.
- Person age.
- Person sex (male, female).

Skin standard deviation is computed over visible regions of the occluded face.

Step-6 performs occlusion recovery by using mean face to recover occluded region.

Step-7 performs an enhancement filter on the resulted image to smooth the variation in the colors. We apply enhancement filter on the surrounding area of the deterioration region only to obtain not blurred face image.

Step-8 exit**.**

Figure (8) shows the results of face occlusion recover.

6 Results

In order to test the efficiency of the proposed system that is implemented using Programming language Visual Basic, a series of experiments was performed using many different sets of images. Initially, three face data bases are used for testing the accuracy of the proposed face detection algorithm as follows :

1- The first face data base DB_1[9] is a collection of 100 frontal face images with clean background. Figure (9) shows a sample set of face images from DB_1.
2- The second face database DB_2[10] is a collection of 100 face images of 100 persons with frontal views and different illumination conditions and partial occlusion. Figure(10) shows a sample set of face images from DB_2.
3- The third face database DB_3[11] is a collection of 100 face images with frontal views and generic background. Figure (11) shows a sample set of face images from DB_3.

6.1 Experiment-1

The results of applying Experiment-1 to the proposed face detection algorithm using three types of face database with different properties are shown in Table (2). The face detection ratio is computed using the following eq.[12]

$$Accuracy = \frac{Number\ of\ correctly\ detected\ faces}{Total\ number\ of\ faces} \times 100\% \quad ....(8)$$

This experiment is performed using three standard face data base . The results are displayed in Figure (12). It can be seen that the proposed face detection algorithm achieves 84% detection ratio for DB_2 face database which make it robust to partial occlusion and pure illumination , and also achieves 80% detection ratio for DB_3 face database which make it is flexible to detect face images with complex background.

At a result, it can be noted from Figure(11) that the face detection ratio increases when the face images are considered with clean background.

6.2 Experiment-2

The results of applying Experiment-2 to the proposed face recovery algorithm using 100 occluded face images are shown in figure (13) using the following eq.[13]

$$Distance\ (A, B) = \frac{1}{W*H}\sum_{i=1}^{W}\sum_{j=1}^{H}|A(i,j) - B(i,j)| \quad ....(9)$$

Figure (12),a shows the comparison between recovered images against the ground truth in the case that occluded face is recovered using symmetry feature of the face only, while Figure (12),b shows the recovered occluded face using mean face.

At a result, it can be noted from figure (13) that the difference between recovered face image and the original face image using symmetry feature of the face is very low in compression with recovery quality using mean face only. So that, it is very easy to obtain very similar face image to original face image by using symmetry feature of the face.

6.3 Evaluation

To evaluate the whole system performance ,some measures are used like:

1- The distance between the original face image A and the occluded face image B using eq.(9).

2- The distance between the original face image A and the recovered face image C using the following eq.

Distance2 (A, C) =

$$\frac{1}{W*H}\sum_{i=1}^{W}\sum_{j=1}^{H}|A(i,j)-C(i,j)| \quad \dots (10)$$

All previous works apply their algorithms on gray occluded face images, while the proposed algorithm is applied on color occluded face images. Hwang's method[2] achieves 50% recovery quality , whereas Mo et al's[3] method achieves 53% recovery quality , Xiaoou's[1] method achieves 64% recovery quality, while the proposed algorithm achieves 73% recovery quality for color face images. Notes in Table(3) the difference ratio between the original face image and occluded face image is 0.6% , but after recover the occlusion the difference ratio between the original face image and recovered face image become 0.03%,
which means that the similarity between the recovered face image and the original face image is very high.

7- conclusions

This study has resulted in an overall success, being able to detect occluded face and recover it.

From previous simulation and discussion some conclusions related to the behavior and performance of the suggested face occlusion detection and recovery algorithm could be drawn .They are as follows:

1- There is no threshold is need during the processing of the occluded face imagebecause FCM algorithm have the ability to detect the real area without using threshold..

2- The proposed algorithm gives a good result as shown in Table (2).

3- The proposed algorithm for detecting and recovering occluded face image achieves high recovery quality equal to 73% see Table (3).

4- The proposed algorithm proves that it is possible to recover color occluded face image.

References

[1]G.Ralph ,B.Jian , and C.Jeff ." Quo vadis face recognition ". CMU-RI-TR-01-17,june 2001.

[2].Hwang and S.Lee ." Reconstruction of partially damaged face images on a morphable face model ".IEEE Trans.PAMI,25(3):365-372,2003 .

[3]Mo,J.P.Lewis , and U.Neumann. " Face inpainting with local linear representations ". In Proc.of BMVC'04,2004.

[4]. Lin and X. Tang, "Quality-driven Face Occlusion Detection and Recovery", Web address : http://mmlab.ie.cuhk.edu.hk/2007/CVPR07_face01.pdffaceocclusion

[5]V.Vladimir , S.Vassili , and A.Alla ." A survey on pixel-based skin color detection techniques ". http://graphics.cs.msu.ru/en/publications/text/gc2003vsa.pdf

[6]R.Nikhil ." The avatar :3-d face reconstruction from two orthogonal pictures with application to facial makeover". http://www.svcl.ucsd.edu/~nikux/3d/images/report_nikhil.pdf.

[7]J.Jan." A physical analogy to fuzzy clustering" . http://fuzzy.iau.dtu.dk/chios2004/Day3/P_%20jantzen04.pdf .

[8]V. Manian and A. Ross, "Face Detection using Statistical and Multi Resolution Texture Features",

University of Puerto Rico, Mayaguez,PR00681-9042.
[9]CVL face data base.Web address : http://www.lrv.fri.uni-lj.si/.
[10]GATV face data base . Web address : http://gps-tsc.upc.es/GTAV/ResearchAreas/UPCFaceDatabase/
[121]The GEORGIA face data base. Web address : http://www.ee.surrey.ac.uk/Research/VSSP/georgia/.

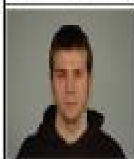
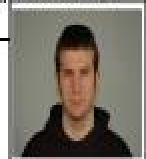
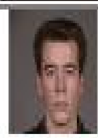
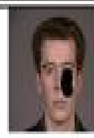
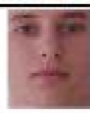
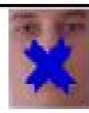
Table (1) The fields of face data base.

Number	Picture	Age	LeftEye	RightEye	Nose	Mouth	Sex
79	Package	young	4518.04444855	9710.69472749	9587.27645362	7483.39044334	male
80	Package	young	2381.71791945	4723.08641294	8586.97056264	5817.00480273	male
81	Package	young	4646.50822409	8050.02671411	1648.79837734	7956.86870976	male
82	Package	young	0723.83935129	0157.94587617	5151.04413237	5849.60499374	male
83	Package	young	4139.13356216	1077.48989131	4141.22246836	89206.3346268	male
84	Package	young	6314.91713429	9990.86009178	4855.28886901	9570.19416248	male
85	Package	young	9844.95945459	5186.37532577	8555.59891039	0572.56100731	male
86	Package	young	7452.21880291	5014.13806398	5061.30256871	9305.52411733	male
87	Package	young	3700.74805398	2818.08914455	9131.41110483	4040.29462799	male
88	Package	old	34465.4556492	2829.28775518	1668.21778362	6636.56166567	male

Table (2) The results of applying Experiment-1 to the proposed face detection algorithm

Data Base Type	Number of Test Images	Number-of Misclassified Images	Detection ratio %
DB_1	100	7	93%
DB_2	100	16	84%
DB_3	100	20	80 %

Table (3)Shows the results of the system evaluation using the above easures

Original Image	Occluded Image	Distance1	Difference Ratio btw. Original and Occluded Face Images	Recovered Image	Distance 2	Difference Ratio btw. Original and Recovered Face Images
		47.561	0.6%		2.420	0.03%
		24.009	1.9%		6.061	0.4%
		304.057	22%		33.251	6.1%

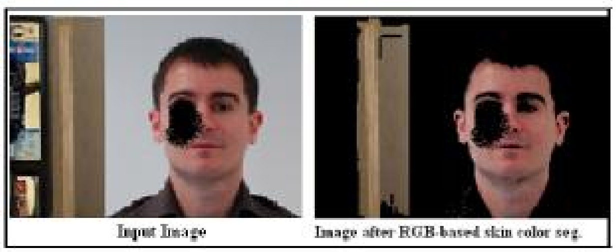


Figure (1) The results of skin color segmentation.

Figure (2) Eye Template.

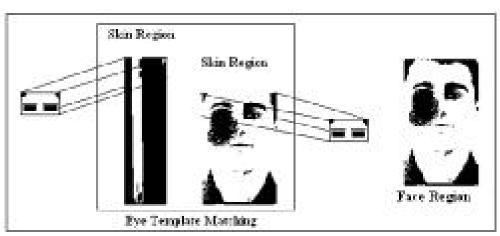


Figure (3) The results of eye template matching.

Figure (4) The results of Occlusion detection algorithm.

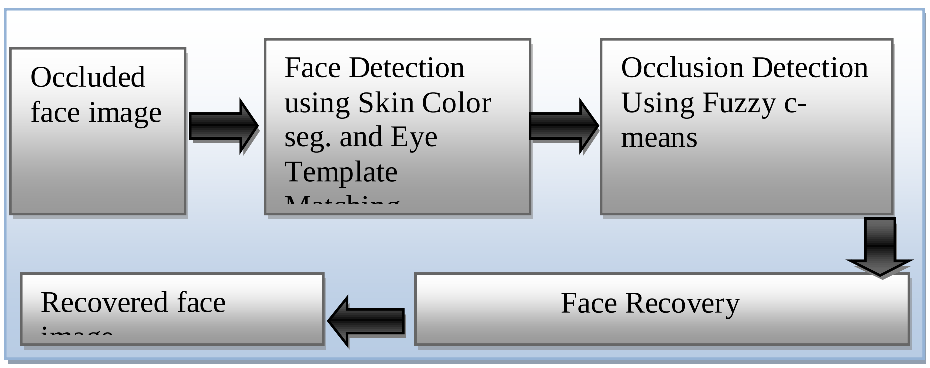


Figure (5) Outline of the proposed face occlusion detection and recoverysystem.

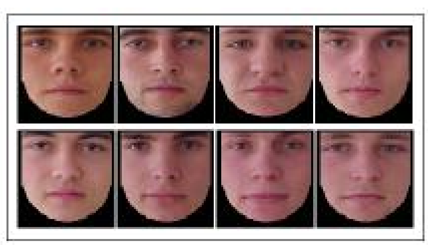


Figure (6) Sample set of face images in data base.

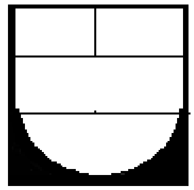


Figure (7) Division of the face area.

Figure (8) The results of face occlusion recovery.

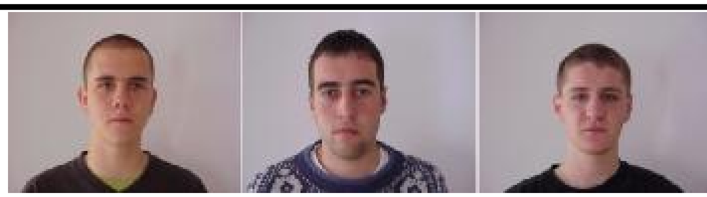


Figure (9)sample face images from DB_1.

Figure (10) sample face images from DB_2.

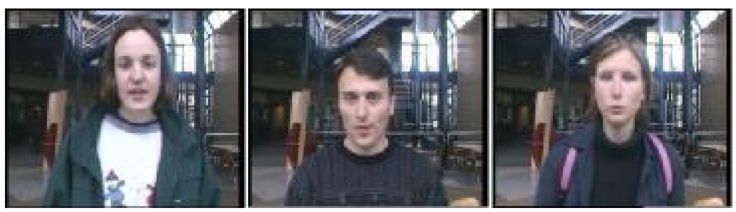


Figure (11) sample face images from DB_3.

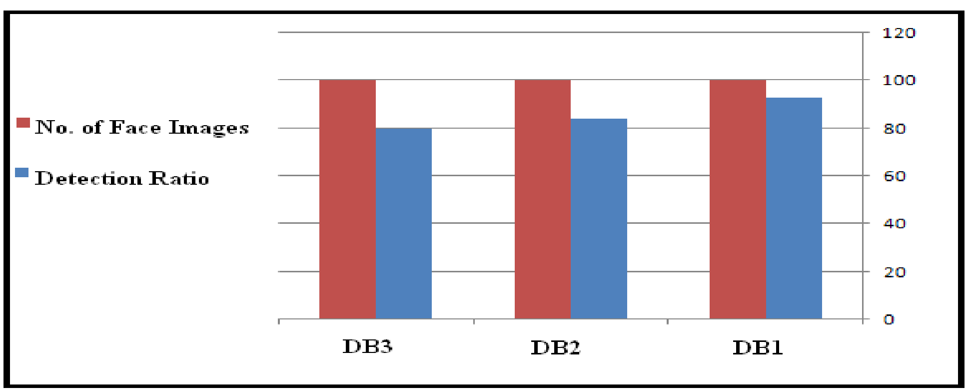


Figure (12) The results of face detection algorithm .

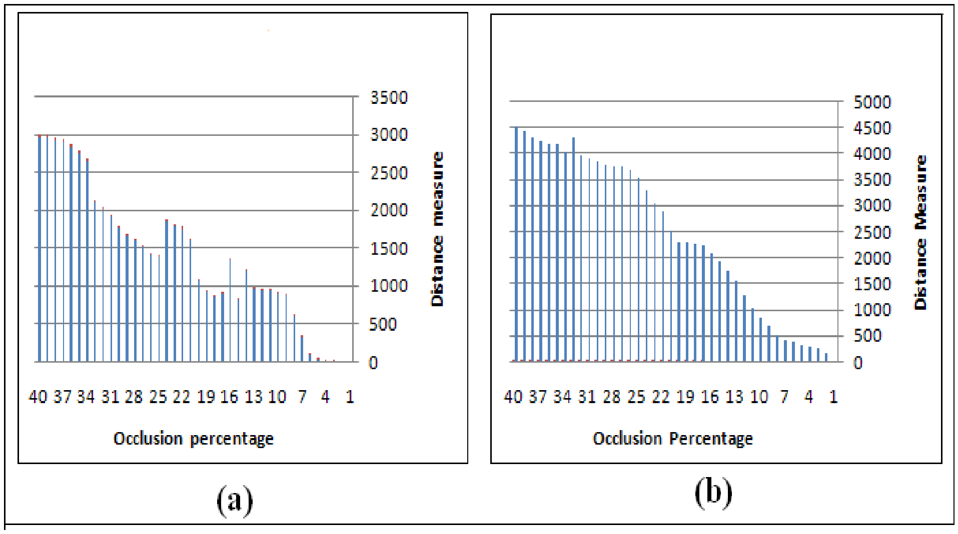


Figure (13) :a)The results of face recovery using symmetry only .
b)The results of face recovery using mean face only.