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Face Selection for Digital Image Watermarking

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Abstract

Discriminative facial features vary from one image segment to another. A few researchers have studied most of the discrimination features for face recognition. According to them, face recognition concentrates on human face information without considering the specific subject, whereas biometric face recognition focuses on face-specific information by ignoring age and emotional information. However, previous works were concentrated on security aspect of face recognition by applying watermarking technology. As a consequence, the performance of face recognition technique was degraded due to side effect of watermarking on facial image. To solve this problem, a novel way is proposed to embed the watermark into less important parts of image by applying face selection technique. This paper used different state-of-the-art face selection to propose a new way to preserve most of the discriminative features of face image and to secure face image by applying image watermarking scheme. This proposed face selection scheme not only can enhance the performance of face recognition system, but also can save memory and computation time of the process of feature extraction. In this paper, face partition detection was done for each face image to extract person's face. Also, watermark information is not embedded into the green channel of the RGB image due to human visual system (HVS). MOBIO Corpus was used for evaluation. The experimental outcomes showed an overall (21%) effectiveness of face selection scheme for face recognition and digital image watermarking. Hence, performance, memory and computation time can be improved by applying face selection for digital image watermarking.

Keywords: digital image watermarking, face recognition, MOBIO, face selection, RGB.

INTRODUCTION

Face recognition is one of the most outstanding abilities of human vision, and is probably the biometric method easier to understand. This is the reason that the features of individual face are considered in security and access control systems. However, many vulnerability slots available in network systems must be protected. For the eight vulnerability slots that have been investigated in a biometric system [1], The most important slots to be secured are located at transmission and recording steps. Furthermore, the originality of real face must be checked. For example, the results of face recognition may not automatically be accepted as evidence in law [2-4]. Hence, these days a combination of biometric systems and security schemes is unavoidable. Digital image watermarking is a suitable scheme to improve the security of biometric face recognition systems through network channels [5]. Digital image watermarking also is used for video conference [6], forensic applications [7], access control [8] and authentication purpose [9]. There is further interest to add authentication of digital image recording on face recognition as evidence for the court. Due to nature of watermarking which embeds induce other information into the original image, the facial information is affected. Thus, different studies have been investigated to reveal that how facial information is distributed across the face image under various conditions [10]. For example, discrimination of face features is found in eyes, noses, lips, and background in a descending order. In each image channel, identical facial features are not equally distributed in frequency bands. For example, the red and blue channels for face discrimination in face recognition are within the range of low and mid Human Visual System (HVS) bands [11]. For HVS, discriminative facial features for green channel are most important [4, 12].

Although the facial has to be modelled in feature domain, not all features have discriminative power equally. Some features can degrade the face models due to a lack of training features (underestimate) for short training or redundant features (overestimate) for large number of training. Using face selection scheme as a solution not only can decrease the number of face partitions before the process of feature extraction, but also can produce coherent face models. Therefore, the scheme can save processing, memory and computation time while improving recognition rate [12]. Some researchers have studied face selection for face recognition purpose [7, 10]. Their idea is that low target score segments and high variance impostor scores cannot show clear discrimination ability. However, the main idea in [13] is that high order moments (>2) can be dominated by larger pixels of values which are likely the causes of environmental disturbances and mismatches. A mismatch influences facial distribution in asymmetry and abnormal flatness. Other face selection schemes are based on distance measurements among partitions. In Euclidean distance, more values are assigned to more dissimilar partitions. In weighted Euclidean distance, low variable partitions are assigned more weights. However, in Fisher ratio (F-ratio), partitions with more ratio, meaning more partitions distance from each other, are selected using Equation (1):

$$F-ratio = \frac{among\ face\ images\ variability}{within\ face\ componnents\ variability} \quad (1)$$

In contrast to age and emotional recognitions that groups different faces of different persons the same person, face recognition groups face partitions of same person with different images. Furthermore, no intelligent face selection scheme considers the following: decimation which selects a specific number of face from the total image, averages with means of partition and random selection of partitions from the total number of partitions.

Unfortunately, none of the face selection schemes are optimum. In face selection schemes, the means and covariance matrix of impostor and target user should be known as requirements to model them. In [13], Rayleigh distribution is applied to the modelling of each partitions; but not all transmission channels can be modelled by Rayleigh distribution. Furthermore, not all face image mismatches are detected by high order moments. Although there are many facial discriminative features available green channel, suitable partition selection scheme must be developed based on HVS.

The rest of this paper is organized as follows: section 2 discusses system and source face image' features; partition selection is proposed; in section 3 discussion and experimental results are presented in section 4; finally section 5 concludes this paper and presents future trends.

PROPOSED FACE SELECTION SCHEME

The proposed face selection scheme applied face discrimination information in eyes, noise and lips features to weigh the partitions of the face image. For this reason, eigenface was done for each partitions to extract fundamental features. Eigenface can separate among the facial features of the face image. Therefore, eigenface models the parameters of the face image as background and face images.

The partitions were weighed in such a way that a higher value for the partition's weight could show better face discrimination. The face's selection scheme must be fast to ensure feasibility. The first face image was segmented into partitions. Then some pre-processing scheme such as histogram equalization and filtering were applied on face image. Eigenface was then computed to detect eyes, nose, and lip. As mentioned earlier, Eigenface were converted to eigeneyes, eigennose, and eigenlip.

In contrast to human recognition of the groups with faces of different user recording the same face, the face recognition groups with the faces of the same user recording different face. Equation (1) finds the most important partition. It means whenever the F-ratio is increased, more ability to discriminant the user is achieved. Furthermore, it seems that green channel has more important on face recognition performance which is prevented from the watermarking. The rest colour image channels such as blue and red have been watermarked. The procedure is showed in Fig 1:

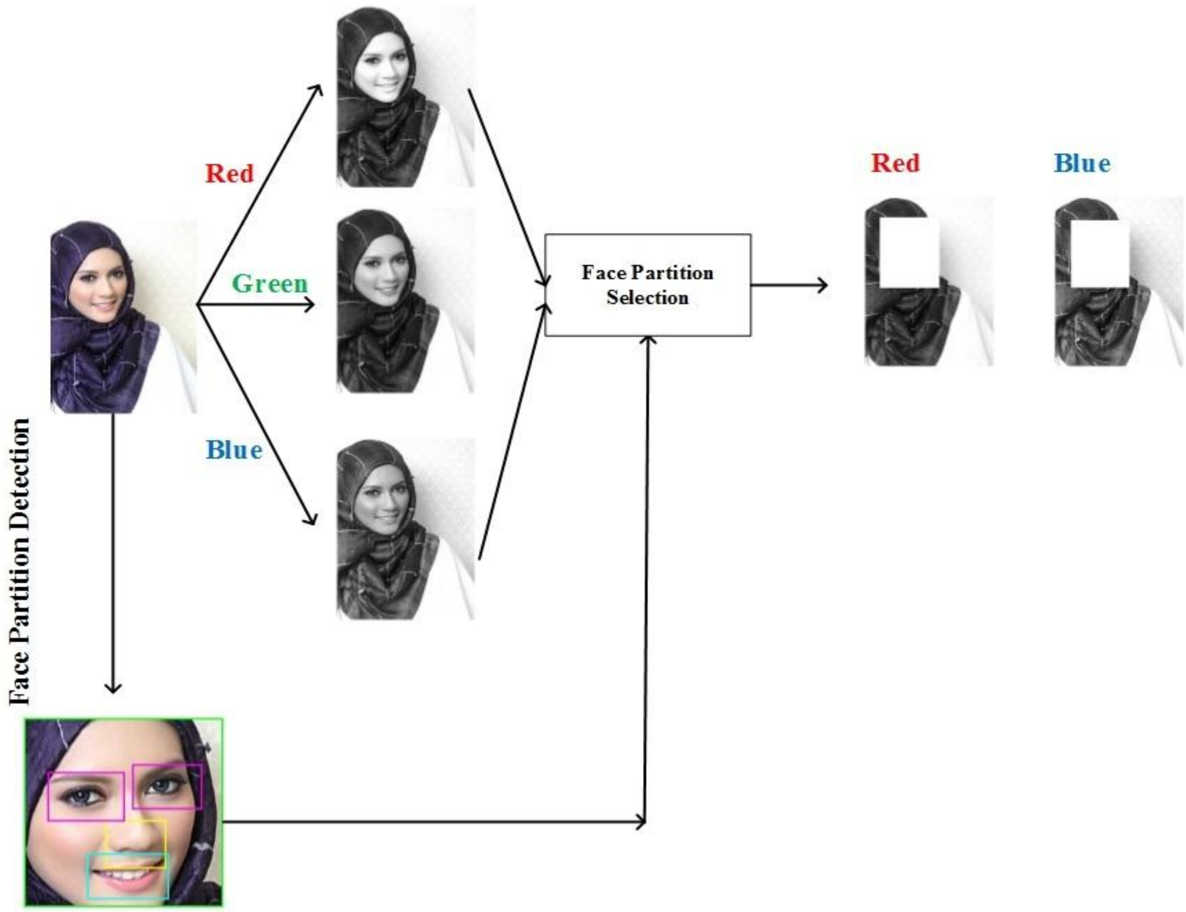

Figure 1. Proposed face selection scheme.

After the proposed face selection scheme is applied to input image, face and background images were produced. The eyes, nose, and lip for i_{th} face image shows more face discrimination ability of i_{th} user. Depending on the memory, computation time, cost, performance and accuracy, the lower face partitions' weight can be ignored for face recognition or applied for digital image watermarking. As a result, watermarking of the partitions having lower weights can result in minimum degradation on the performance of the face recognition. The proposed face selection algorithm is briefly described in Table 1 by pseudo code.

Table 1. The proposed face selection algorithm.

Basic pseudo code for the proposed face selection algorithm

1. Variables definition.

   IMG: Original face image

   NF: Size of original face image

   F: index of the detected face component parts in image.

   Path: Input path of the image

   R: red channel of the image

   G: green channel of the image

   B: blue channel of the image

   W1, … W5: Weights for each partitions.

   Thresh: Threshold level for energy.

2. Read original image.

   $IMG \leftarrow Read(\text{path})$

3. Find red, green, and blue channels.

   $R, G, B \leftarrow IMG2RGB(\text{IMG})$

4. Detect the face component from the original Face image IMG

   $[\text{F}] \leftarrow DET(\text{IMG})$

   F={Fi, i=1,…, N} where N is number of component

5. Find the energy of the channels

$$Enr\_R_i \leftarrow \sum_{n=1}^{\text{Nf}} R(n)^2$$

$$Enr\_B_i \leftarrow \sum_{n=1}^{\text{Nf}} B(n)^2$$

$$Enr\_G_i \leftarrow \sum_{n=1}^{\text{Nf}} G(n)^2$$

1. Compute amount of weight for each partition

   $Sum_i = 0$

   FOR i←1 … N

   IF (Enr_B_i>Thresh) AND ($Enr\_R_i > Thresh$)

   $\{Sum_i\} \leftarrow W_i \times R(\text{Fi}) + W_i \times G(\text{Fi}) + Sum_i$

   END

   END

2. Normalize and weight each face image for each subject

$$M1 \leftarrow \mathrm{MAX}|Sum_{i=1,\ldots,N}|$$

$$Weight_i \leftarrow \frac{Sum_i}{M1}$$

Note:

DET(.) Detects the face partitions such as left eye, right eye, noise, and lip.

IMG2RGB (·) convert the color image into red, green, and blue channels.

Read (.) Read the face image from input.

MAX(.) computes the maximum value.

To achieve weighting for the most discriminative partitions, uniform blocks filter with uniform size, were used for MOBIO corpuses. The purpose was to quantify the partition's discrimination power for each face component. In this experiment, the size of a face was 512. The histogram equalization was applied to before face' component detection.

Combination of Face Recognition and Digital image watermarking

The face recognition system is secured by applying digital image watermarking. The proposed system is shown in Fig 2. This combination system is to maximized recognition performance and security over an unknown channel.

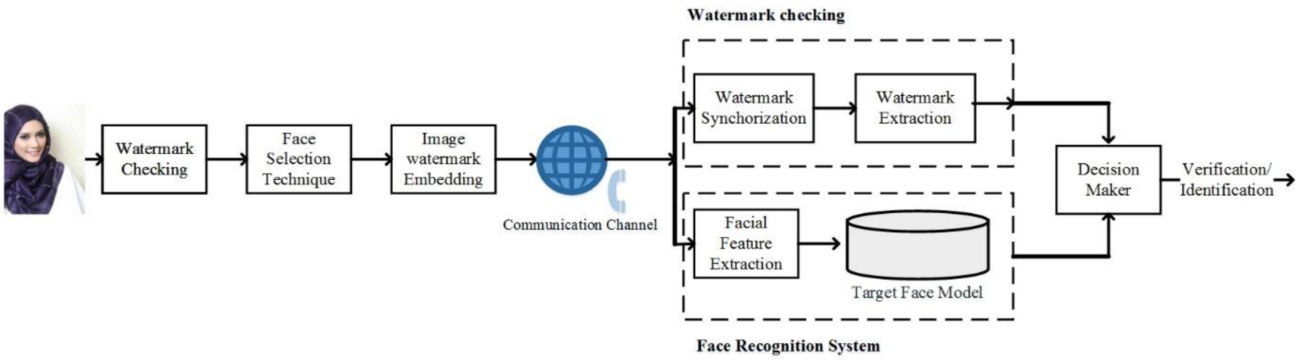

Figure 2: Proposed combination of face recognition and digital image watermarking over unknown channel.

When the face image is captured, it's checked for watermark. If the watermark exists within the image, it means some attacks (replay attacks) have happened. Once the image is clear of any watermark, the proposed face selection scheme is applied to choose lesser facial-specific partitions for embedding watermark. This step not only can preserve more biometric and forensic features of the user but also can have large improvements over resources, computation time, performance and security. Lastly, the watermarked face image is sent to the receiver by integrating all non-watermarked and watermarked partitions of the image. This can improve the watermarking and face recognition system at receiver side.

Face discriminative information is mostly investigated in the facial features of the face images. For this reason, firstly, the most discriminative frequency sub-bands were investigated for face recognition system. Then the right eye, left eye, nose, and lip of the face image (which was investigated in face recognition performance) were studied. Lastly, the recognition performance of the developed part selection was investigated for the face verification system and face identification system.

Table 2. The effect of each facial feature on the performance of face identification for different face databases.

Feature	Face Database	Recognition rate (%)	EER (%)
Left eye	ORL MOBIO	31 25	15.33 15.30
Right eye	ORL MOBIO	30.20 26.14	15.81 15.61
Nose	ORL MOBIO	15.11 17.98	15.01 14.45
Lib	ORL MOBIO	14.57 18.02	18.82 15.61
Face part	ORL MOBIO	74.20 63.50	1.50 5.45
Background part	ORL MOBIO	74.25 63.58	1.31 5.22

As presented in Table 2, there were significant differences between the amount of recognition rate, computation time, and memory of the different parts of the face image. Furthermore, there was a difference among the recognition rate of various part. The left eye and right eye of the face image seem to be similar. However, these amounts were much lower for background of the face image. Furthermore, it seems that face part can discriminate better between the impostor and authorized user as well as the eyes parts compared to nose or lip. Furthermore, it seems that whenever the size of the face increases, the difference increases. As presented, there were significant differences between the amounts of recognition performance for different parts of the face image, when 15dB AWGN was added to the clean face image. However, serious noise (5 dB AWGN) could degrade the differences between various parts of the image as well as the critical parts of the face image. It was predictable because the noise affected the shape of the PDF of the face image which was changed to Gaussian PDF.

Performance of the Developed Part Selection

The performance of the developed face selection was studied in face verification system and face identification system. For better investigation, the performance of the face part and the background part were evaluated separately. Furthermore, two scenarios were done to study the effects of the face size on the performance of face recognition. In the first scenario, separate facial features were considered as different face tests. However, in the second scenario, whole part of face image was combined as one face test. It is shown that whenever the size of the face image increases, more features can be removed by assuming higher weighting threshold. These results confirm the results in these studies which explain the condition as “The key factor seems to be the facial variety of the feature vectors scored, not the absolute number of feature vector”.

EXPERIMENTAL OUTCOMES

In this study the corpus of MOBIO are used to obtain the experimental outcomes to evaluate the performance, efficiently and accuracy of the proposed face selection scheme. MOBIO corpus is designed for speaker verification under noisy environment with limited enrolment data and is publicly available [14]. MOBIO speech corpus was designed as bio-modal (audio and video) with 152 subjects (100 males and 52 females) and is publicly available.

Digital image watermarking focuses on robustness whereas steganography focuses on imperceptibility and invisibility as their top priority. However, both of them still employ stenographic approach for embedding information inside the face image. A new image data hiding method is developed based on Quantization Index Modulation (QIM) and contourlet transform [15]. This data hiding scheme applies the original angle of contourlet for embedding the watermark. The goal is for optimizing perceptual imperceptibility to have the least degradation on image face and quality when using QIM for embedding step. This scheme is considered as a basic data hiding scheme. Although it has lesser degradation over facial-specific features, it is not an efficient and robust way to embed the data in face image.

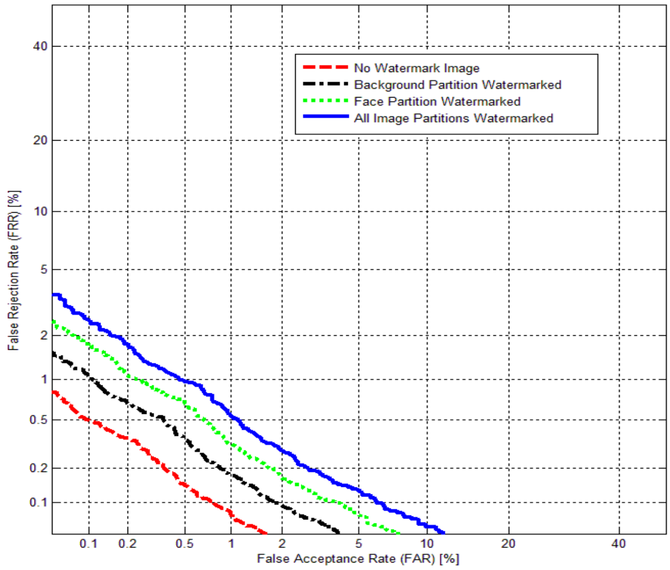

Figure 3. DET curves for four condition.

Figure 3 elucidates various results for different assumed systems. Although there was no enhancement when the developed system was applied for the limited enrolment data, it can show that less memory and time were consumed as seen in Table 3. It can be seen that the watermark data can be applied with facial features without any significant degradation over face recognition performance (black curve). The green curve shows how the developed system can improve the recognition performance. While all parts of the image were watermarked (blue curve), a serious noise was added which was degraded the face recognition performance. The experimental results on Figure 3 can be computed to reveal 21% improvement were achieved.

In some conditions like real time systems, computation time is considered as an important requirement. Table 3 presents the run time for the developed system and normal face modelling schemes. It should be mentioned that “cputime” function was used to measure time and memory for Table 3.

Table 3. Average CPU computation time comparison for training, impostor modelling and testing.

	User modelling	**Test modelling**
With face selection	4768	1734
Without face selection	5464	2045

DISCUSSIONS

As discussed, the devolved face selection scheme can select partitions with lesser facial-specific features to minimizing the degradation effect of image watermarking scheme, computation time and cost. It also can assign high weights to red and blue channels for HVS purpose as well as face recognition. In respect to computation time and memory overhead, many image watermarking scheme have applied watermark embedding and extraction methods. Therefore, it should be awarded that the devolved face selection scheme can run simultaneously, parallel to real time with digital image watermarking.

CONCLUSIONS AND FUTURE WORK

Although watermarking can solve security problems, it may affect the facial-specific features. However, the performance of face recognition can be enhanced by considering the discriminative ability of facial-specific features which do not uniformly exist in image. This paper study the scenario for availability of watermark with face recognition at the same time. Although the recognition rate was not improving via the developed face recognition system, memory and time were improved. In addition, coexistence of watermark and facial feature is proved.

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