Facial Features' Localization using a Morphological Operation

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Abstract. Facial features' localization is an important part of various applications such as face recognition, facial expression detection and human computer interaction. It plays an essential role in human face analysis especially in searching for facial features (mouth, nose and eyes) when the face region is included within the image. Most of these applications require the face and facial feature detection algorithms. In this paper, a new method is proposed to locate facial features. A morphological operation is used to locate the pupils of the eyes and estimate the mouth position according to them. The boundaries of the allocated features are computed as a result when the features are allocated. The results obtained from this work indicate that the algorithm has been very successful in recognising different types of facial expressions.

1 Introduction

Developments in digital image processing have grown with different algorithms for various applications of Computer vision techniques. Such applications have been reported by Lekshmi *et al.* [7] for face detection, Hannuksela *et al.* [3] for facial feature extraction and Mohamed *et al.* [10] for face recognition.

Face detection is one the active research applications in these areas. Face detection is defined by Yang *et al.* [13] to find the location and the size of the face in the input image. Some of face detection approaches do not have any assumptions regarding the number of faces in the image but they assume that a face exists in the image in order to classify as face and non-face regions [1], [4]. In the facial localization, it is normally assumed that the input image has at least one face. Generally, facial recognition problems are based on the features in the face. Salient features can be recognized easily by human eyes but it is challenging to locate and extract these features using a machine. The challenges of these applications are associated with pose, structural components, facial expressions, illumination, occlusion, and image quality of the subjects [11], [13]. Previous research has been concerned with the applications of face detection and recognition [9]. Many methods have been developed to locate and extract facial features. These methods classify into two categories: Feature based and Holistic. In the feature-based method, face recognition relies on the detection and localization of facial features and their geometrical relationships [1]. In a holistic method, a full face image is transformed to a point on a high dimensional space such as Active Appearance Model (AAM) [8], neural nets [5].

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The morphological operation is a well-known technique used in image processing and computer vision for manipulating image features based on their shapes [2]. However, some methods need a considerable amount of computational or intensive memory to implement, and improve the speed and accuracy [7]. Our research aims to develop a simple and an accurate method that can be used in facial systems such as emotional detection.

In facial detection systems, eyes detection is a significant feature in the human face, where the detected eyes are easier to locate than other features. Also, the localization of the eyes is a necessary stage to help in the detection of other facial features which can be used for facial expression analysis as they convey the human expressions.

Although research have been done in this area, the process of solving the problem of facial features' detection is still incomplete due to its complexity [6], [7]. For example face posture, occlusions and illumination have effects on the performance of the features' detection.

In this paper, a facial localization algorithm for salient feature extraction is presented. The algorithm consists of three steps: (1) a morphological process is applied to search the darkest parallel features in the upper face as a result of eyes localizations; (2) the distance between the estimated pupils is used to locate the mouth. (3) Localization of the salient features is used to compute their boundaries.

2 Facial Feature Localization

Features that are commonly used to characterise the human face are the eyes and mouth. It is normally assumed that the facial region is present in the input image and the features are searched within this region. The algorithm is based on the observation that some features such as the pupils of the eyes are darker than other facial features. Therefore, morphological operations can be used to detect the location of the eyes. The morphological operations are compatible with rough feature extraction for their fast and robust nature [3], [12].

The method proposed in this paper involves the morphological technique to detect the pupil of the eyes, and then the distance between them is used to detect the position of the mouth. The method is also simple and less computationally intensive. It has the advantage of using three facial features points instead of using the holistic face such as Active Shape Model with 58 facial feature points to locate the features [14].

The morphological erosion operation is applied on a grayscale face, using this operation to remove any pixel that is not completely surrounded by other pixels. The operation is applied when assuming 8-pixels are connected in order to reduce the unnecessary pixels in the boundaries of the face. Fig. 1 shows the some faces after applying the erosion operation. The eyes localization is determined based on the darkest pixels that are close to each other. The positions of the eyes allow the distance between them to be computed and also to locate the mouth.

Fig. 1. Face after apply the erosion.

2.1 Eyes Detection

The upper face is scanned individually to search for the pupils of eyes. However, when the darkest pixel is obtained for every eye, the algorithm is searched again for all the pixels that have the same value as the darkest one. Fig. 2 shows correct eyes detection where the search algorithm of the darkest pixel is satisfied. Also, Fig. 3 shows the final eyes detection where the pupil of the eyes estimated the darkest pixels of each eye.

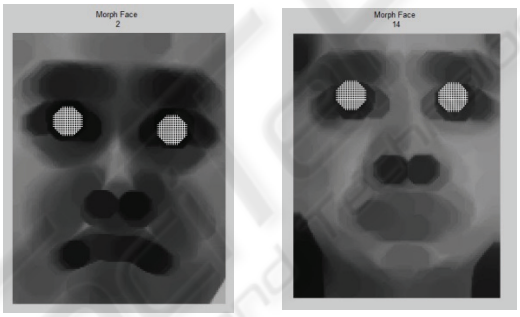


Fig. 2. The eyes region detection.

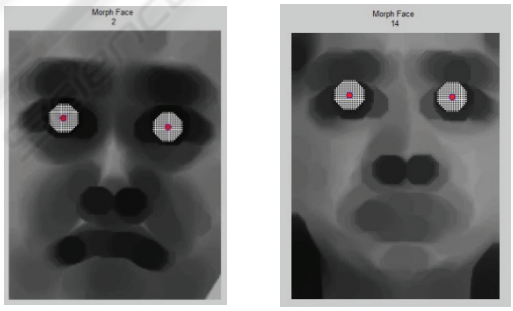
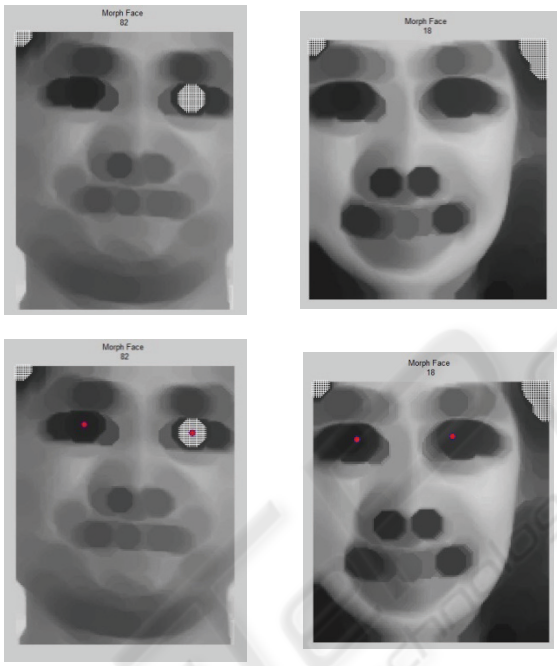


Fig. 3. The final eyes detection

The location of the pupils is calculated based on the average of the darkest pixel of each eye. Some experiments gave unsuccessful eyes location detection. These were corrected by adjusting the distance between them in the order of 15 to 20 pixels. Fig. 4 shows some unsuccessful eyes detection, and correcting this fault detection based on the distance between the averaged dark pixels.



(a) **(b)**

(a) Unsuccessful detection is left eye.
(b) Unsuccessful detection is left and right eye.
Upper image is false detection and lower is right re-detection.

Fig. 4. Re-correct eyes detection.

2.2 Mouth Detection

The mouth detection algorithm is presented when the localization of the eyes is known. Otherwise, the algorithm ignores this face. The mouth position is calculated according to the distance D_{Eyes} between the estimated pupils of both eyes.

The L_{Eye} represents the computed centroid point (X_{Leye}, Y_{Leye}) of the left eye (i.e. pupil of the left eye), and the R_{Eye} represents the computed centroid point (X_{Reye}, Y_{Reye}) of the right eye (i.e. pupil of the right eye).

The distance between the eyes D_{Eyes} is computed as follows:

$$D_{Eyes} = (X_{Reye}, Y_{Reye}) - (X_{Leye}, Y_{Leye}) \quad (1)$$

The average of the pupils $D_{Eyesμ}$ is used to estimate the mouth position that represents the middle of distance between the eyes illustrated in equation (4). Therefore, it is computed by averaging the L_{Eye} and R_{Eye} as shown in equations (2) and (3).

$$X_{Eyesμ} = μ(X_{Leye}, X_{Reye}) \tag{2}$$

$$Y_{Eyesμ} = μ(Y_{Leye}, Y_{Reye}) \tag{3}$$

$$D_{Eyesμ} = (X_{Eyesμ}, Y_{Eyesμ}) \tag{4}$$

The centroid point of the mouth (X_m, Y_m) is computed based on equations (1), (2) and (3) as follows:

$$X_m = X_{Eyesμ} + D_{Eyes} \tag{5}$$

$$Y_m = Y_{Eyesμ} \tag{6}$$

In this work, the facial features are segmented from the face image based on the D_{Eyes}.

Fig. 5 illustrates the centroid point of the left eye (X_{Leye}, Y_{Leye}), the centroid point of the right eye (X_{Reye}, Y_{Reye}), the distance between the eyes D_{Eyes}, and the centroid point of the mouth (X_m, Y_m).

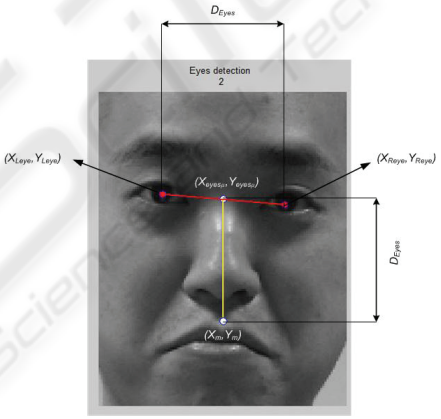


Fig. 5. Final eyes detection with eyes distance and mouth position estimated.

3 Facial Feature Boundaries

After the possible facial features are detected, the distances D_{Eyes}, (X_{Leye}, Y_{leye}), (X_{Reye}, Y_{Reye}) and (X_m, Y_m) are applied to evaluate the features' boundaries.

The boundaries are determined according to the D_{Eyes} based on the experimental evaluation. The width and height of the facial features are calculated, where W_e and H_e are the width and height of the rectangles of each eye illustrated in equations (7) and (8) respectively. Also, equations (9) and (10) show W_m and H_m represent the width and height of the rectangles of the mouth.

$$W_e = \frac{2}{3} D_{Eyes} \tag{7}$$

$$H_e = \frac{2}{3} D_{Eyes} \tag{8}$$

$$W_m = D_{Eyes} \tag{9}$$

$$H_m = \frac{2}{3} D_{Eyes} \tag{10}$$

The left eye coordinate can be calculated as:

$$X_L = X_{Leye} - \frac{D_{Eyes}}{3} \tag{11}$$

$$Y_L = Y_{Leye} - \frac{D_{Eyes}}{3} \tag{12}$$

where (X_L, Y_L) is the upper left corner coordinate of the left eye. In the same way, the right eye coordinate can be calculated as:

$$X_R = X_{Reye} - \frac{D_{Eyes}}{3} \tag{13}$$

$$Y_R = Y_{Reye} - \frac{D_{Eyes}}{3} \tag{14}$$

where (X_R, Y_R) is the upper left corner coordinate of the left eye.

Furthermore, the upper corner of the mouth coordinate (X_M, Y_M) can be calculated as:

$$X_M - X_{Leye} - X_m \tag{15}$$

$$Y_M = Y_{Leye} + \frac{3}{4} D_{Eyes} \tag{16}$$

The boundaries and the centroid points are illustrated in Fig. 6.

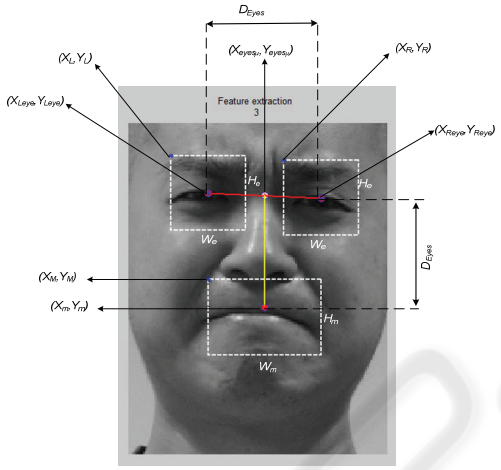


Fig. 6. The relationships and positions of facial detection.

Briefly, once the eyes are identified correctly, the mouth is detected from the distance between the eyes. Then, the boundaries are computed as the following Fig. shows.

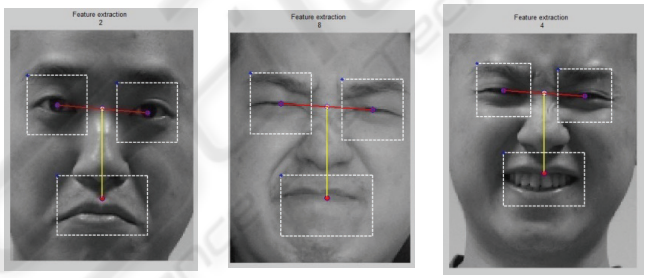


Fig. 7. Some facial features boundaries.

4 Experimental Results

The efficiency of this algorithm was tested on individuals' images captured as frontal faces using a digital camera from the same distance and with normal room lighting conditions. It is well known that the difficulties to locate the features exactly on each face due to the face structure and the difference of face features. The proposed algorithm located the face features based on the erosion operation on the greyscale facial

cropped image and distance between the pupils of the eyes were computed and ignored any image that did not satisfy the location of the eyes correctly. The eyes detection based on darkest pixels of each eye. As the localization of the eyes is identified, the mouth location is computed based on the distance between the estimated pupils of both eyes. The boundaries of facial salient features are computes according to position based on calculated distance.

This algorithm needs adjusting due to the presence of some incorrect detection of the location of the eyes as a result of lighting and some occlusions such as glasses. A success rate of over 91% has been achieved based on a sample rate of 318 images. The following table shows the ratio detection for every facial feature.

Features	Ratio of Feature detected
Left Eye	96.3%
Right Eye	95.6%
Mouth	91.9%

The experiments' results show that locating the eyes is more accurate compared to the mouth. Therefore, further work is needed to increase the accuracy of features location.

5 Summary and Future Work

This work presents a new algorithm based on morphological process to detect the eyes localization and use the distance between them to locate the mouth position. The method defines a morphological operation to extract the important contrast regions of the face. These features are robust to lighting changes.

Future work will concentrate on improving the mouth detection to reduce the false rate detection. The false eyes detection can be enhanced as well, which will increase the ratio of features detected. The outcome of this algorithm can be used in other facial detection systems such as the analysis of facial expressions.

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