

A New Approach of Facial Features' Localization using a Morphological Operation in still and sequence images

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ABSTRACT

Facial features' localization is a crucial step for many systems of face detection and facial expression recognition. 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. The fundamental technique used in facial analysis is to detect the face and subsequently the associated salient features. In this paper, a new Algorithm is based on morphological properties of the face region for the extraction of salient features is proposed. 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. This algorithm is applied to individual images subsequently application to video sequences. The experimental results achieved from this work indicate that the algorithm has been very successful in recognizing different types of facial expressions.

Keywords: Face detection, Facial features localization, Morphological operations, Facial recognition, and geometric distance.

1. INTRODUCTION

The facial detection and facial feature localization are important processes in order to perform certain relevant tasks in computer vision. These tasks include efficient feature extraction methods for face recognition, facial modeling and facial expression systems analysis. Developments in Facial analysis and detection have grown with different algorithms for various applications of Computer vision techniques. Such applications have been reported by Lekshmi *et al.* [1] for face detection, [2, 3, 4] for facial feature extraction and Mohamed *et al.* [5] for face recognition.

Face detection is one the active research applications in these areas. Face detection is defined by Yang *et al.* [6] 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 [7, 8]. In the facial localization, it is normally assumed that the input image has at least one face [8]. Generally, facial features are represented by salient points in face region such as eyes, nose and mouth. Similarly, the eyebrows, nostrils and chin tip can be used as facial landmarks [9,10]. Facial features detection bears the same challenging problems as face detection. 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 prone to personal changes such as gender, race, occlusions, illumination, expression, and pose [9,11,12]. They are also susceptible to variation in illumination due to lighting conditions [6,13].

With respect to facial feature segmentation for expression analysis, numerous facial features detection techniques have been proposed to address the challenging issues associated with this problem in the literature [3,14]. These techniques generally fall under two main categories of approach: feature-based and holistic approaches. The facial feature-based method locates the shape of facial parts such as the mouth, eyes, and nose in a face region. Features are then extracted from the region [2, 15]. In a holistic method, a full face image is transformed to a point on a high dimensional space such as Active Appearance Model (AAM) [4,16] and neural nets [17]. A new method computes facial

features based on template matching proposed by Yuen *et al.* [18] that aimed to reduce the effect of beard and moustache for facial features detection.

Despite the success of these methods, it is sensitive to variation of poses and illumination changes, especially if there is significant difference between the contrast of the test set and that of the training set. Facial-based methods, on other hand, have some advantages over the holistic methods. In that, they are more flexible against of noise and illumination, robust and require less computational cost to detect features [12, 19].

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 [1,10,12, 20]. For example, face posture, occlusions and illumination have effects on the performance of the features' detection.

In this paper, a new algorithm known as Facial Features Distance Algorithm (FFDA), based on morphological properties of the detected face region for the extraction of salient features is proposed. The algorithm consists of three steps: (1) Apply a morphological process to search the darkest parallel features in the upper face as a result of eyes localizations; (2) Use the distance between the pupils to estimate and locate the mouth; (3) Use the estimated distance to compute the boundaries of the salient features.

2. FACIAL FEATURES DISTANCE ALGORITHM (FFDA)

The morphological operations are a well-known technique used in image processing and computer vision for manipulating image features based on their shapes [21]. This is much simpler than the methods by Lekshmi *et al.* [1] and Asbach *et al.* [22] which relied on a considerable of computation and intensive memory requirement to compute features. This work aims to develop a simple and an accurate method for features detection that can be used in facial expressions detection system.

In a facial detection system, eyes detection is a significant task, where the detected eyes are easier to locate than other features. Also, the localisation of the eyes is a necessary stage to help in the detection of other facial features which can be used for facial expression analysis. 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 proposed algorithm (FDDA) is relied 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 [2, 23,24,25].

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 [26].

2.1 Facial feature localization

The morphological erosion operation is applied on a greyscale 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 hence estimate the mouth position.



Figure 1. Faces after apply the erosion

2.1.1 Eyes Detection

The upper face is scanned individually to search for the pupils of eyes. Consequently, the darkest pixels of the eyes are located by the algorithm. Fig. 2 shows the correct eyes detection after using the search algorithm. The darkest pixels show where the pupil located. Also, Fig. 3 shows the final eyes detection where the pupil of the eyes are estimated using the darkest pixels of each eye.

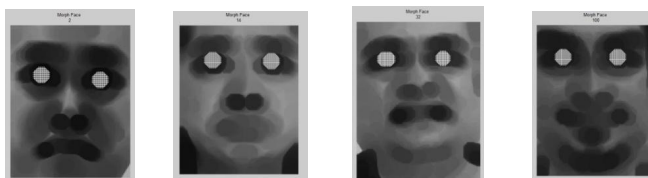


Figure 2. The eyes region detection.

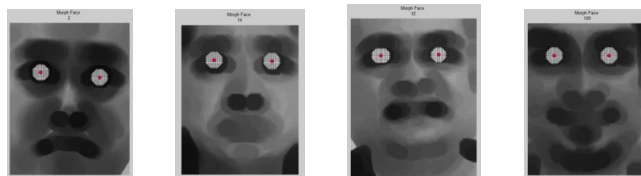
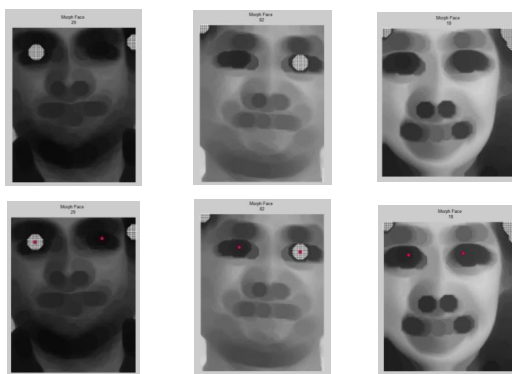


Figure 3. The final eyes detection.

The location of the pupils is calculated based on the average of the darkest pixel of each eye. These were corrected by adjusting the distance between them in the order of 15 to 20 pixels. Fig. 4 shows some instances of successful and unsuccessful eyes detection. The correction of these faulty detections is based on the distance between the averaged dark pixels.



(a) (b) (c)

(a) Unsuccessful detection of the right eye, (b) Unsuccessful detection of the left eye,
(c) Unsuccessful detection of both eyes

Figure 4. Instances of eyes detection showing the upper row of images producing false detection with the lower row having the re-correct eyes detection.

2.1.2 Mouth Detection

The mouth detection algorithm is presented when the location of the eyes is known. Otherwise, the algorithm ignores the image as a face. The mouth position is calculated according to the distance $DEyes$ between the estimated pupils of both eyes.

Let $LEye$ represents the computed centroid point $(XLEye, YLEye)$ of the left eye (i.e. pupil of the left eye), and the $REye$ presents the computed centroid point $(XREye, YREye)$ of the right eye (i.e. pupil of the right eye). Then the distance between the eyes $DEyes$ is computed as follows:

$$DEyes = (XReye, YReye) - (XLeve, YLeve) \quad (1)$$

The average position of the pupils $DEyes_{\mu}$ 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 $LEye$ and $REye$ as shown in equations (2) and (3).

$$XEyes_{\mu} = \mu(XLeve, XReve) \quad (2)$$

$$YEyes_{\mu} = \mu(YLeve, YReve) \quad (3)$$

$$DEyes_{\mu} = (XEyes_{\mu}, YEyes_{\mu}) \quad (4)$$

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

$$Xm = XEyes_{\mu} + DEyes \quad (5)$$

$$Ym = YEyes_{\mu} \quad (6)$$

In this work, the facial features are segmented from the face image based on the $DEyes$.

Fig. 5 illustrates the centroid point of the left eye $(XLeve, YLeve)$, the centroid point of the right eye $(XReve, YReve)$, the distance between the eyes $DEyes$, and the centroid point of the mouth (Xm, Ym) .

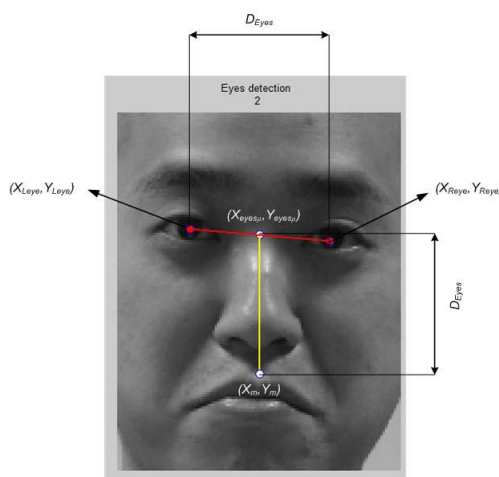


Figure 5. Final eyes detection with eyes distance $DEyes$ and mouth position estimated.

2.2 Facial feature boundaries

After the possible facial features are detected, the distances $DEyes$, $(XLeve, YLeve)$, $(XReve, YReve)$ and (Xm, Ym) are applied to evaluate the features' boundaries.

The boundaries are determined according to the $DEyes$ based on experimental evaluations. The width and height of the facial features are calculated, where We and He are the width and height of the rectangles of each eye as illustrated in equations (7) and (8) respectively. Equations (9) and (10) represent Wm and Hm as the width and height of the boundary rectangles of the mouth respectively.

$$We = \frac{2}{3}DEyes \quad (7)$$

$$He = \frac{2}{3}DEyes \quad (8)$$

$$Wm = DEyes \quad (9)$$

$$Hm = \frac{2}{3}DEyes \quad (10)$$

The left eye coordinate can be calculated as:

$$X_L = X_{Leye} - \frac{DEyes}{3} \quad (11)$$

$$Y_L = Y_{Leye} - \frac{DEyes}{3} \quad (12)$$

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:

$$X_R = X_{Reye} - \frac{DEyes}{3} \quad (13)$$

$$Y_R = Y_{Reye} - \frac{DEyes}{3} \quad (14)$$

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

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

$$X_M = X_{Leye} - X_m \quad (15)$$

$$Y_M = Y_{Leye} - \frac{3}{4}DEyes \quad (16)$$

Note that, all constants in equations (7) to (16) are derived from experiments. Fig. 6 illustrates the boundaries and the centroid points of the eyes and mouth.

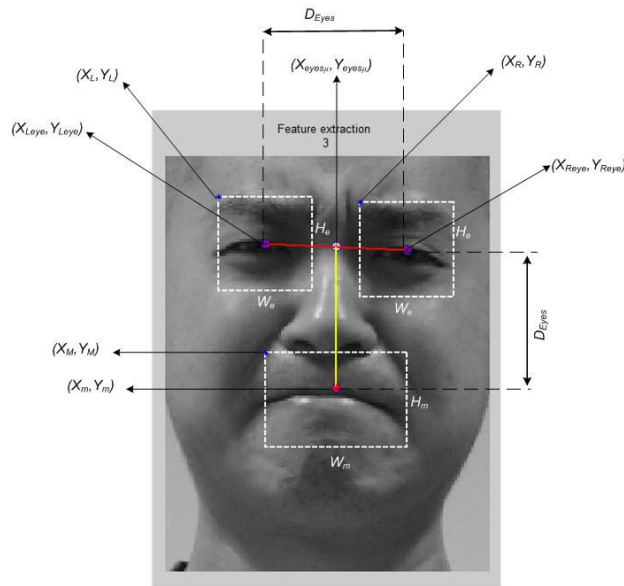


Figure 6. The relationships and positions of facial detection

Briefly, once the eyes are identified correctly, the mouth is detected from the distance between the eyes and then the boundaries are computed as shown in Fig. 7.



Figure 7. Some facial features boundaries

3. EXPERIMENTAL RESULTS AND ANALYSIS

The central processor for facial features detection in this paper is the Facial Features Distance algorithm (FFDA). This algorithm is tested on individual images captured as frontal faces obtaining from a video 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. Fig. 8 shows the processing steps of facial feature localisation as discussed in section 2.

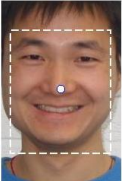
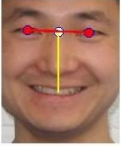

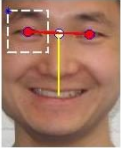

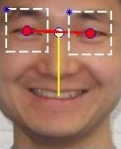

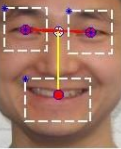




| | | | | | |
|-----|---|---|------|--|--|
| (1) |  | Face detection with eliminating facial region | (7) |  | Estimate the mouth position using of centroid point & distance between the eyes, formula (1,5,6) |
| (2) |  | Cropped face | (8) |  | Computed the boundary of the left eye, formula (11,12) |
| (3) |  | Grey cropped face | (9) |  | Computed the boundary of the right eye, formula (13,14) |
| (4) |  | Morphological face | (10) |  | Compute the boundary of the mouth, formula (15,16) |
| (5) |  | Eyes localization | (11) |  | Crop the detected features, |
| (6) |  | compute the centroid point between the eyes | (12) |  | Grey cropped features |

Figure 8. Some facial features boundaries

Using the FFDA, a successful detection rate of over 95.7% was achieved based on a sample of 329 still images. Table 1 shows the detection rate of facial features (i.e. left eye, right eye, and mouth) in single images. The experimental outcome showed that locating the eyes features were more accurate as compared to that of the mouth. The difference in the detection rate achieved was attributed to experimental glitch in the data.

Table 1: Feature detection rate for FFDA

| Features | Ratio of features detected |
|-----------|----------------------------|
| Left Eye | 96.1% |
| Right Eye | 95.2% |
| Mouth | 93.0% |

A successful detection rate of 93.5% minimum was measured for 200 video clips. Fig. 9 shows a sequence of face images that experimented by the proposed algorithm. Consequently, Facial Features extracted from these sequences are shown in Fig. 10.

TestVideo30.AVI , Frames (55 :66)



Figure 9. Sequence of facial images

TestVideo30.AVI , RGBLeftEyes , Frames (55 :66) TestVideo30.AVI , RGBRightEyes , Frames (55 :66)



TestVideo30.AVI , RGBMouths , Frames (55 :66)



Figure 10. Sequence of segmented facial features images

3.1 Comparative results of Facial feature localization

A comparison between the proposed algorithm developed in this paper and other methods is shown in the following table.

Table 2:: Segmentation rate for different facial feature detection method

| Method | Authors | No of images or frames | facial feature detection rate |
|---|---------------------------|-----------------------------|-----------------------------------|
| The proposed algorithm | This paper | 329 images and 14848 frames | 95.7% and 93.5% |
| K-means clustering algorithm | Lekshmi <i>et al.</i> [1] | 100 images and 200 frames | 92% |
| AAM with Gabor wavelet 17 facial points | Weiwei and Nannan [4] | 400 images | 94% |
| Liner Hough transform | Arof <i>et al.</i> [11] | 300 images | 85% |
| ASM 75 feature point | Mahoor <i>et al.</i> [16] | 70 images | 70% |
| Template Matching | Yuen <i>et al.</i> [18] | 72 images | 93% and 95.8% for mouth detection |
| AdaBoost classifiers | Jiao <i>et al.</i> [20] | 1846 images | 88.4% |

The proposed algorithm (FDDA) uses two points for the eyes pupils to locate and detect the facial features and compute the distance between those points to estimate the mouth location. The algorithm is simple, computationally inexpensive and easy to implement as compared to all the methods identified in previous table.

4. CONCLUSION

The task of quick and accurate facial feature localization has been presented as a novel algorithm named Facial Features Distance Algorithm (FFDA). It applies morphological operation (i.e. an erosion) to detect the eyes within the facial image and searches the darkest features in the upper face. As a result the eyes positions are estimated. The mouth position is then estimated by using of the distance between the detected eyes. Morphological operations are simple and efficient to implement and are not computationally expensive to implement. This algorithm has the advantage that the whole face image is not needed in order to establish the positions of mouth and eyes in an image. Therefore, it reduces the cost of the computations in the proposed system. Experimental results show that the algorithm is accurate regardless of different face shape due to ethnicity and gender. The outcome of this algorithm can be used in other facial detection systems such as the analysis of facial expressions.

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