Detection of Facial Expressions based on Morphological Face Features and Minimum Distance Classifier

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***Abstract*—A facial expression is one of the non-verbal information that plays an important role in understanding face-to-face communications. Therefore, facial expressions are the most important means of detecting emotions and behavioral analysis science. Although human being have ability recognize the face practically without any effort, but facial recognition system is still challenging by machine. This paper addresses the problem of detecting facial expressions of the human face through the analysis of images and subsequent application to video sequences. This work concentrates on the design of a facial expression detection system used to recognize facial emotions by focusing on the analysis of still images based on Morphological features and Minimum Distance Classifier (MDC) for classification.**

Keywords*— facial detection; ; Morphological operations ; Properties of regions; K-mean, Minimum Distance Classifier; facial expressions detection.

I. INTRODUCTION

Facial expression detection/recognition from images and video sequences is an active research area. Analysis of facial expressions by the machine is a challenging task with many applications. Computer vision techniques have been applied for the understanding of facial expression detection. Such applications have been reported in Lekshmi *et al.* [1] for face detection, [2] for facial feature extraction and [3] for face recognition.

Facial imaging is a popular research area committed to the extraction and analysis of human facial information. It gives rise to face detection and tracking, facial feature detection, face recognition, facial expression and emotion recognition.

A plethora of applications include facial detection and recognition systems for security [4], criminal identification [5], surveillance [6], human-computer interaction [7], and biometric authentication [8]. Facial detection plays an important role in detecting emotions. Its importance has been reported in many disciplines such as computer science [9] and medicine [10].

There are many problems associated with face detection and it is one of the challenging problems in image processing due to building systems that perform facial recognition. It is essential in applications such as video surveillance, human computer interface and face recognition. Facial detection depends on the characteristic of the acquired image and can be very sensitive to noise and poor lighting conditions. Yang *et al*. [11] and Arof *et al*. [12] stated that the challenging factors related to face detection include the pose, structural components, facial expression, illumination, occlusion, and image quality of the subjects. For example, with respect to the pose of the subject, the position of the face can cause some parts of the face such as eyes and nose to be occluded in the captured image. In terms of the structure components, features such as beard, moustache and glasses, may not result in correct face detection as these are subject to change. Similarly, individual affective nature changes with time could cause some difficulties in the machine's correct identification. The other problem concerns occlusion where faces may be partially occluded by other objects such as a scarf, hat or some faces by other faces in an image consisting of a group of people.

According to Espinosa *et al.* [13] the classical face detection system can be decomposed into several stages: image acquisition, image pre-processing, feature extraction and classification.

In the image acquisition stage, the captured images are obtained from a video camera. This is followed by image pre-processing stage where the captured images are enhanced by eliminating noise and to reduce the complexity for later processing. The feature extraction stage detects and extracts the salient features from the face. Finally, the classification stage classifies the features into various categories of emotions.

This paper presents the techniques and algorithms that are used to accomplish facial expression detection. Therefore , the research methods identified in this work are as follows: (1) Review facial detection systems: Study and review existing techniques of face detection and recognition and adapt them for use in behavioral analysis;(2) Implement features of detection system: Apply computer vision techniques to recognize facial expressions; (3) Experimentations: The images of individuals and videos sequences captured as frontal images using a digital camera from the same distance and with normal room lighting conditions to test the functionality of the proposed system.

II. REVIEW FACIAL DETECTION SYSTEMS

A. Face detection

Many methods have been proposed to address the problem of face detection. The idea of face detection is to identify the face regardless of changes in lighting conditions, poses and facial expressions. Although existing techniques are not appropriate for images that have a combination of occlusions, most of the face detection techniques initially identify the face skin region before the face is finally classified. Furthermore, most of face detection and recognition algorithms assume that a face exists in the image in order to classify as the face and non-face regions [14, 15].

As cited in Nallaperumal *et al.* [16], face detection techniques can be categorised into four categories: knowledge-based, facial feature-based, appearance-based and template matching methods. The details of these methods are description in [17].

The face detection and location are the first important steps in facial expression detection system to determine facial regions and features from background images. In this work, face regions are detected in three steps. Firstly, the skin-like regions are verified by analysing the skin colour tones. Secondly, the skin regions are verified to identify whether they show a face or not based on the region properties such as ellipse and box elements. Finally, the face region is refined if the height to width ratio of this region satisfy the golden ratio ((1+√5)/2).

The skin color model developed for this work is built based on ,the Gaussian and Likelihood models that are computed using the normalized RGB color space according to [10, 18]. The skin-training mode is constructed from a range of 200 images is selected to cover different human skin colors. The color histogram is the distribution of the skin color in the chromatic color space of various ethnicities. The skin color distribution can be represented by a Gaussian model $X\sim(\mu, \sigma^2)$ [19]. The mean and covariance of the skin training model are substituted into Gaussian and Likelihood models to obtain the segment skin. For each input image the normalised colour space is achieved and the skin-like region is computed using the Gaussian and Likelihood model. Then, the optimal threshold is selected experimentally when the number of skin segments is set to minimum in the Likelihood image. Although, noise can corrupt the output image, this noise may appear as a small hole in the skin region. The face detection algorithm involves the morphological operations to refine the skin regions extracted from the skin segmentation process. The facial region can contain some small holes as a result of certain features such as eyes and mouth. The sub-regions can be grouped together by using the simple dilation and erosion operations on the regions. The dilation is to fill any small hole in the region and erosion to remove any small object from the background. This work assumes that only one face is shown in an image and, as a result, using these operations will lead the skin detection to be more accurate.

In this stage, the identified regions determine the existence or absence of a face. The algorithm discards any skin region other than a face. Therefore, it is required to identify the face where every pixel in the image is classified as a skin pixel. Subsequently, it categorises the skin pixels in different groups. This will signify some meaningful group such as face and hands. Face region detection is accomplished by using skin region properties which are ellipse and box regions, and the centroid point of a region.

Every region is labelled based on the binary skin region from the previous stage. Each pixel in the region is examined with 8 of its neighbour's pixels and marks them if they are similar to this pixel. If any neighbouring pixel is marked, then it will be labelled with the current label. When the regions are labelled, each one is examined separately to identify if it is a face region or not based on its properties.

Most of the face detection algorithms are based on skin region segmentation and classify the region as a face if it has at least one hole. However, the face detection can fail when the morphological operations are applied [20].

The proposed method scans the skin segmentations in the image for the possibility of a face based on the ellipse region properties. Properties of the regions are derived experimentally and used to detect and filter the face regions. The face region is detected when the ellipse ratio ranges from 1.0 to 2.2. Also, the major and minor of the ellipse are scaled at least 150 and 100 pixels, respectively.

Finally, the face skin region is refined to reduce the negative facial detection that considers the neck or forehead as sub-regions of the face. This helps in obtaining a more accurate result and to reduce the computational cost of future stages such as facial features extraction and facial expression detection.

The final face region is cropped based on the following process:

- Initially determining the centroid point of the face region. Then the box ratio of the face region is calculated.
- If the box ratio is more than the golden face ratio as approximated in $(1+\sqrt{5})/2 \approx 1.618$ and the ellipse ratio is ranged between 1.8 and 2.2, then the region box is adjusted by shifting up the high box and the centroid region. As a result, the unnecessary skin, such as forehead and neck, is reduced.

Fig.1 shows the processing steps of face detection as explained in this section.

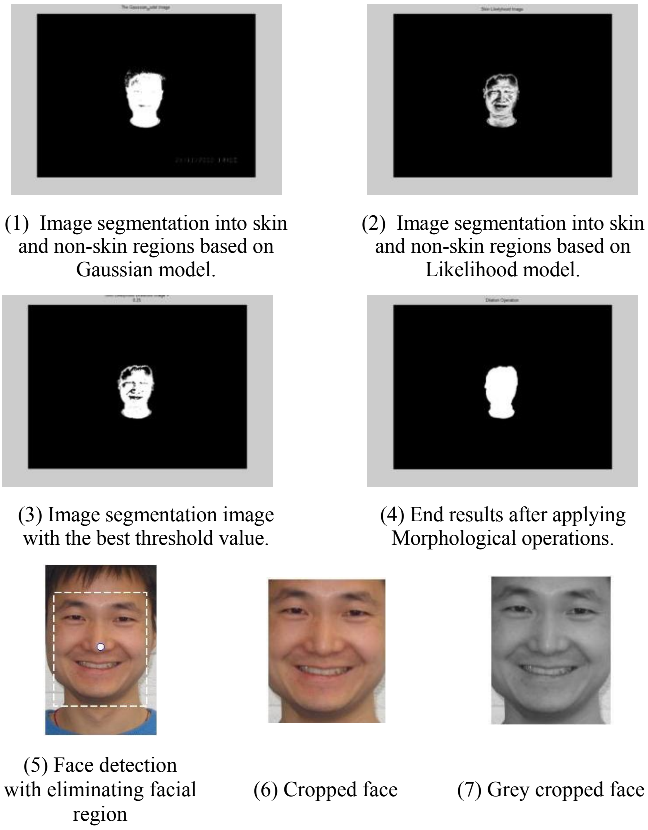

Fig. 1. The processing steps of face detection in this section.

B. *Facial feature localization*

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.

Generally, Facial features' techniques 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, 20].

The morphological operation is a well-known technique used in image processing and computer vision for manipulating image features based on their shapes [22]. However, some methods need a considerable amount of computational or intensive memory to implement, and improve the speed and accuracy [1]. Our method in this section 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 [1,23]. For example face posture, occlusions and illumination have effects on the performance of the features' detection.

In this work, a facial localization algorithm for salient feature extraction is presented by Bozed *et al.* [24]. The algorithm consists of three steps: (1) a morphological process is applied to search the darkest parallel features in the upper gray 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.

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.

The efficiency of this method was tested on individuals' images and sequence 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. Fig 2 shows the processing steps of facial feature localization.

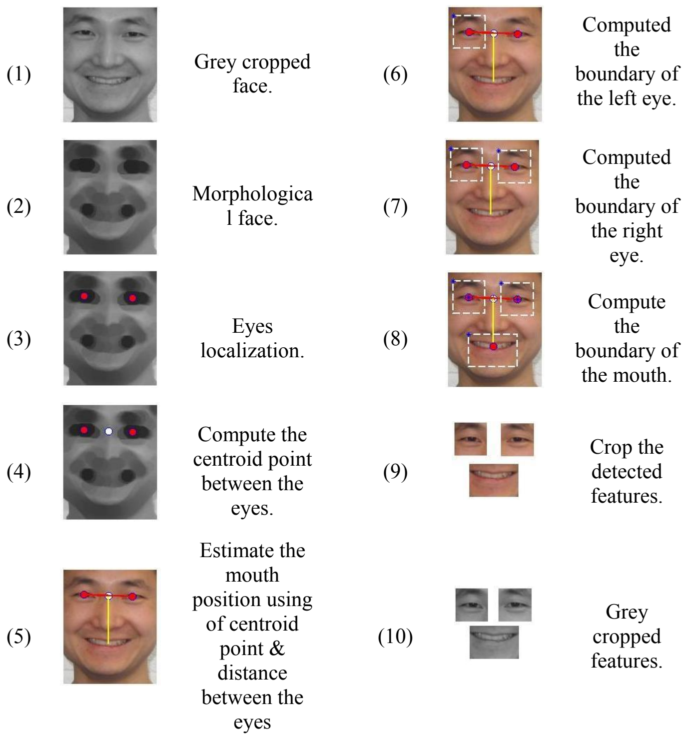

Fig. 2. The processing steps of facial feature localization

C. Facial feature extraction

Having identified the boundaries, the next step is to extract the salient features from them. Feature extraction is a key to finding significant data in order to reduce the dimensionality problem. The features should be informative, invariant to noise or a given set of transformations and quickly calculated [25].

In this work, the mean and the standard deviation are used as the facial features. This reduces the bulk of data and hence the complexity of the calculation.

The classes of joy, anger, surprise and disgust are built to detect facial emotions .For every image in the class, the facial features are computed. The features' regions of each image within each class are obtained. The mean and standard deviation are computed to extract these features and reduce data quantity. The fig 3 shows the computation of facial features extraction.

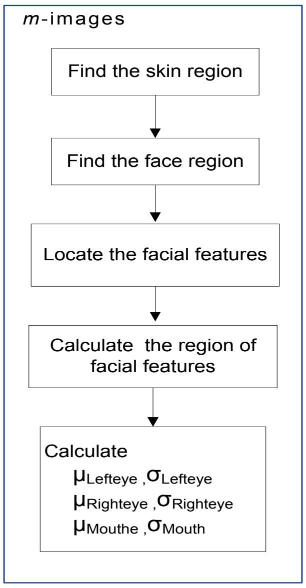

Fig. 3. The processing steps of facial feature extraction

When this algorithm is computed, the features of each class are extracted. Each image in the class can be represented as a point in a 6-dimensional space. As a result, each image has $(\mu_{LeftEye}, \sigma_{LeftEye}, \mu_{RightEye}, \sigma_{RightEye}, \mu_{Mouth}, \sigma_{Mouth})$ used in the classification algorithm.

D. Facial feature classification

The fundamental issue about the facial expression classification is to define a set of categories to deal with. The classification of facial expressions can be computationally intensive and complex due to the large data involved [26, 27]. Therefore, feature extraction is employed to resolve the above problems by reducing the dimensionality of the data. Facial expressions can be classified by using some face parts such as eyes and mouth [28, 29]. Different classification methods are used to classify facial expressions in still images or videos [30].

Image classification analyses the characteristic properties of different image features and classifies the data into classes. The classification algorithm is divided into two phases of processing: training and testing. In the training phase, the characteristic properties of the image features are extracted. Therefore, each class has a unique description based on these features. In the testing phase, these features are used to classify unknown image features.

1) Training phase: The training of classes is an important step of the classification process. In this work, unsupervised classification that relies on K-mean clustering algorithm is used to cluster the training data into sub-clustering based on the cluster centroids and Euclidean distance. The K-mean algorithm is computationally faster, and produces tighter clusters [31]. Features are clustered using a clustering algorithm. K-mean clusters the set of feature vectors into three clusters with three centroids for each class. The number of clusters is defined in advance and each cluster is defined by its centroid. The clustering proceeded by assigning each data point to the proper cluster with shortest distance to the centroid based on the Euclidean distance. The cluster centroid is re-computed as the centroid of the data points is assigned to this cluster. The three clusters are estimated experimentally as the best number of clusters. The computation of K-mean features clustering is illustrated in the fig 4.

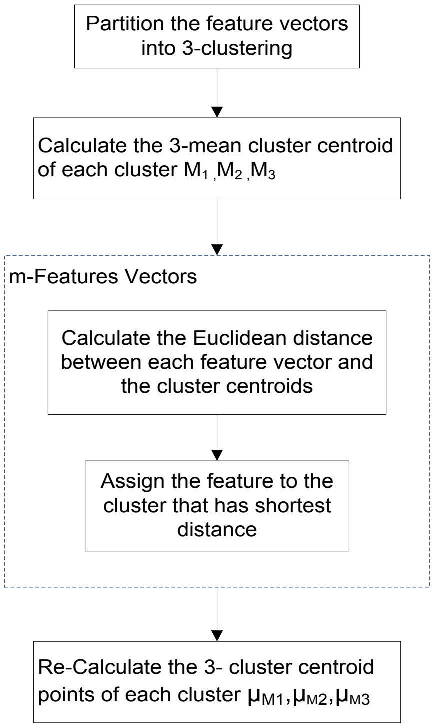

Fig. 4. Training the data classes using the K-mean Algorithm [31]

2) Testing phase : In this phase, the classifier uses the trained classes to test the unknown faces under the same consideration of feature extraction. The classifier can determine the tested face, to which class it belongs to. In this work, only four categories are used in the classification stage: joy, anger, surprise and disgust.

The Minimum Distance Classifier (MDC) is used to analyze and calculate the distance between the unknown image and the data of classes based on the mean of the cluster centroids. The MDC determines the Euclidean distance from an unknown object to the centroid of each class and assigns this object to the closest class. The shortest distance measured between the unknown image and all of the classes. The unknown image is classified to belong to a correct class according to the shortest distance.

The Class Boundary (CB) is used when the discrimination is difficult as it can be used to recalculate the shortest distance between the CB and unknown image. The CB represents an imaginary border surrounding each class. Using the CB ensures that the feature vector belongs to the proper class when the discrimination between the feature vector and mean centroids are difficult to compute.

The mean of K-mean clustering is used to calculate the variance feature vectors of the class. The variance of the class is calculated by the sum of the squares of feature vectors deviations from their centroid point. The mean and variance are used as statistical measurements of the data set to compute the boundary of the class to determine the reject boundary of the class [32, 33, 34]. In this work, the mean of K-mean clustering and variance are used to compute the class boundary surround the cluster centroids. The largest variance determines the rejection of the class boundary to classify or reject the unknown image. The classification algorithm is illustrated in fig 5.

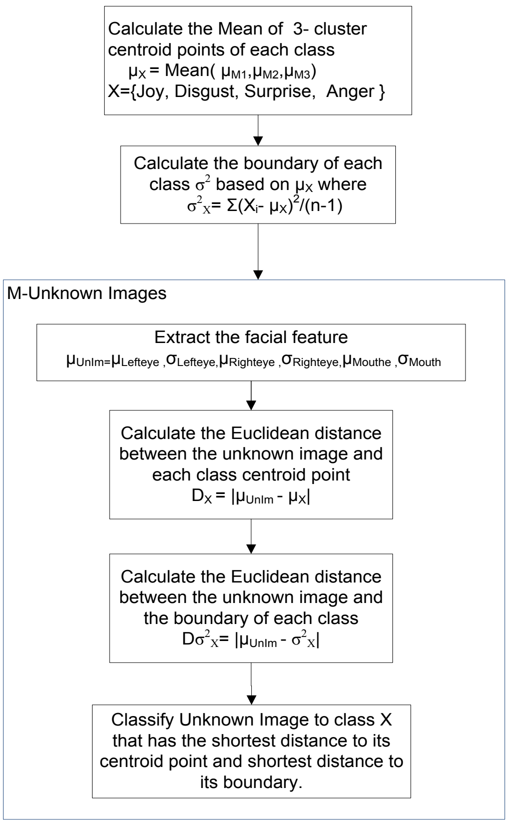

Fig. 5. The Feature Classification Algorithm

III. EXPERIMENTATION AND RESULTS

The efficiency of this work was tested on individuals' images captured as frontal faces using a digital camera from the same distance and with normal room lighting conditions. A large number of images are applied with different races, ages and gender. No constraints have been imposed on the face such as glasses, beard or moustache in the first two stages. Experiments were performed in relation to skin detection, face detection, facial feature localization, facial feature extraction and facial feature classification.

Experimental outcomes of the skin detection showed that the Likelihood model was more accurate and less computationally intensive as compared to the Gaussian model. It was also observed that the Likelihood model was more robust against black skin with a detection rate of 96.67% whilst the Gaussian model resulted in 93.3%.

The face detection proposed method was able to detect face regions even when the face has some occlusion such as glasses and facial hair. The proposed method was firstly applied to a sample of 335 still images. Following this, it was applied to 240 video clips where each has between 45 to 157 frames. The successful face detection rate achieved was 98.2% for still images. Further experiments were conducted on 240 video clips. These contained a total of 14848 individual frames that were subsequently applied to the proposed method. Out of this, the number detected successfully was 14446 frames that gave 97.3% rate of detection.

In the facial features localization stage, frontal face images without glasses were used. 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 method located the face features based on the erosion operation on the grey facial cropped image and distance between the pupils of the eyes 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. A successful detection rate of over 95.7% was achieved based on a sample of 329 still images and detection rate of 93.5% minimum was measured for 200 video clips. The following table shows the detection rate of facial features (i.e. left eye, right eye, and mouth) in the single images.

TABLE I. *FEATURE DETECTION RATE FOR FFDA*

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

The experiments' results show that locating of the eyes is more accurate compared to mouth location. Therefore, it needs more refinement to increase the accuracy of features location.

In the stage of feature extraction, the classes of facial expressions were built. The mean and standard deviation of features were computed for each image in the same class. The features of each image are extracted to represent feature vectors of each sample in the classes to eliminate the dimensionality of data.

At stage of facial feature classification, the work has developed a prototype for testing the proposed algorithm for recognizing four basic expressions: joy, anger, surprise and disgust.

The classification of classes built in two stages: training and testing. In the training stage, the features of each class clustered using K-mean with three centroids point that derived experimentally.

Each class is divided into 3-clustering. The number of training images in each category should be the same because of using the variance in the classification process. The different number of images led to misclassify the unknown image. Moreover, no image can be classified to the zone of this category. The Euclidean distance is used to achieve testing and classifying unknown image. Also, the class boundary is used as essential measure where the discrimination of unknown image is difficult.

The classification algorithm needs further development and the results can be improved by increasing the number of images in the training and testing stages. The first result was very low and as the images were increased, the result was improved. The ratio of facial expression detection of the first experiment to this stage was 60 % and improved up to 90%. In the first experiment, the number images of training classes were different and joy class was almost misclassified.

Further experiments have been done with the number of images in the training stage was similar. In each experiment, as the number of images in the training and testing stages has increased, the ratio of facial expressions detection has increased exponentially. The following table shows the facial expressions ratio.

TABLE II. FACIAL EXPRESSIONS RATIO

Class	Joy	Anger	Surprise	Disgust
Ratio	83.3%	91.4%	80%	88.6%

Experimental results show that the facial expression cannot always be achieved correctly because of the appearance of these expressions may be different between people, even humans still cannot recognize different expressions. For example, humans cannot recognize expressions of someone they do not know before, because of the similarity of expressions such as joy and surprise or disgust and anger.

IV. CONCLUSION

This paper summarizes the progress of this work that undertake in relation to the theoretical analysis and design of the prototype facial expression detection system. In general, facial expression detection is a difficult task due to inherent difficulties in pattern recognition and computer vision. In this work, an investigation of facial detection, feature extraction and facial expression have been reviewed.

Also, a simple and efficient detection method to detect the faces in color images is presented based on the skin region properties. The ellipse ratio, box ratio and the centroid point are used compute the optimal face region that reduce redundant region such as neck and forehead. This further reduces the time and complexity in the later stages. This method detected the frontal face with moustache, beard or glasses. The advantage of this method overcomes some of the occlusion problems associated with faces.

Moreover, a proposed method to detect and locate the facial features for feature extraction is presented. A morphological process applied to locate the eyes position. The mouth position is computed based on the distance between the eyes' pupils.

The features of each class are computed to represent feature vectors of each sample in the classes to eliminate the dimensionality of data. For all the classes of facial expressions (joy, anger, disgust and surprise), the class model was built and features extracted. Finally, the minimum shortest distance classifier was applied to detect the facial expressions.

Future work will concentrate on improving the the feature localization method to increase the accuracy of features detection. The false eyes detection can be enhanced to reduce the false rate of mouth detection in order to increase the ratio of features detected.

Also, further work is ongoing to complete the rest of the expressions model (fear, sadness) to group the natural six facial expressions and extend capability of the existing facial feature extraction methods to recognize expressions. Moreover the proposed facial detection techniques can be developed in order to apply in analyzing facial expressions at different instances of time based on video sequences.

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