

Facial Expression Recognition Using 2D Images: a Survey

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ABSTRACT: Facial expression is a one of the way of conveying the emotional state of a person to the observer. Recognizing the facial expression has been one of the challenging tasks in the field of computer vision. Recognizing the expressions has its applications in the field of education, study of human behaviour, human computer interaction, and many more. Over the last two decades a lot of research has been done and many methods are developed to recognize the facial expressions. The current paper presents a survey of various challenges, facial databases available and the different techniques used in the area of facial expression recognition.

KEYWORDS: Facial expression recognition, Computer Vision, survey

I. INTRODUCTION

Computer vision is a field of science that deals with acquiring, processing and interpreting the visual input. Facial expression recognition is one of the challenging tasks in the field of computer vision. A person's emotion is rendered through their facial expression. Facial expressions can be classified into six basic emotions, namely happy, fear, surprise, sad, disgust and anger [1]. Recognizing the facial expressions has many applications such as lie detection, human computer interaction, study of human behaviour, robotics and many more.

Research is being done in the area of facial expression recognition over last two decade. The current paper presents a survey of various challenges, various facial databases available and the different techniques used in the area of facial expression recognition. The objective of this paper is to provide the new researcher in the area of face expression recognition, the information of the various challenges and the different techniques used in the area of facial expression recognition.

The rest of the paper is organized as follows; section 2 introduces the different challenges to be addressed in the area of facial expression recognition. Section 3 introduces to the study done on the behaviour of the facial muscles and the standardization of the facial expression parameters. Section 4 describes the steps and some of the techniques used for facial expression recognition. Section 5 introduced to the various publicly available facial expressions databases. The section 5 is followed by the conclusion section and the references section. The reference section contains the details of the various articles referenced in building this article.

II. CHALLENGES IN RECOGNIZING FACIAL EXPRESSIONS

Facial expression recognition is a complex task because faces vary from one person to another due to colour, size, age, shape etc. The challenges associated with facial expression recognition can be listed as the following factors:

- **Pose:** The images of a face vary due to the relative camera position such as frontal or non-frontal. Face pose may be at different angles like frontal, profile, 45 degree, upwards or downwards.
- **Presence or absence of structural components:** Facial features such as moustaches or beards may make the process of recognizing the facial expression with high accuracy an important challenge. Also these components vary in size, colour, and shape.
- **Illumination:** Illumination is the one of the highly important factor that affects appearance of a face. Lights changes a lot among indoor and outdoor environments. Light source can have very bad effect on certain facial features.
- **Occlusion:** faces that are occluded can be very challenging to perform expression recognition.

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- **Image orientation:** Face images directly vary for different rotations about the camera’s optical axis i.e. In-plane rotation.
- **Imaging conditions:** When the image is formed, factors such as lighting, distortion, compression, noise and camera characteristics etc. may affect the appearance of a face.

III. PARAMETERIZATION OF FACIAL EXPRESSIONS

A facial expression is the result of the behaviour of different muscles under the facial skin. In the late 19th century attempts were made to create the set of standard parameters which could encode various facial muscle behaviours. The two important such parameter sets are the facial action coding system (FACS) by Ekman et al. [2] and the facial animation parameters by Moving Pictures Experts Group (MPEG).

Facial action coding system consists of a set of action units (AU) and combination of these action units forms the different facial expressions. Each action unit is nothing but behaviour of the facial muscle. There are 64 action units defined in the facial action coding system. The table 1 shows some of the action units and its descriptions such as rising of inner eye brow, jaw dropping, etc. The combination of several action units forms the facial expression. For example the surprise facial expression is the result of the combination of the AU1, AU2, AU5, AU25 or AU26. More detailed information on FACS AU can be found in the FACS manual [3].

Table 1: Details of Various FACS Aus

Action Unit	Description
Action Unit 1	Raise inner eye brow
Action Unit 2	Raise outer eye brow
Action Unit 26	Jaw dropping
Action Unit 19	Put the tongue out
Action Unit 6	Raise the cheeks

In the field of animation, the facial animation parameters (FAP) were used as a standard set of parameter for creating different facial expressions. The facial animation parameter standard defines a face model in the neutral expression and a set of 84 geometrical feature points over the model. Similar to the action units, the variations of the feature points (FPs) were used to create different facial expressions. In recent years FAP is also used to recognize facial expressions. The table 2 shows some examples of the FAPs and its descriptions such as jaw opening, lowering the middle lip. More detailed information on FAP can be found in the article by MPEG and SNHC [4].

Table 2: Details of Various Facial Animation Parameters

FAP name	Description
FAP 3	Open Jaw
FAP 4	Lower the middle lip
FAP 5	Raise the bottom middle lip
FAP 6	Stretch the left corner lip
FAP 7	Stretch the right corner lip

IV. FACIAL EXPRESSION RECOGNITION SYSTEM

The facial expression recognition system consists of basically three steps. They are face detection, facial feature extraction, and classification. The figure 1 shows the basic steps of facial expression recognition. The face detection is

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(An ISO 3297: 2007 Certified Organization)

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the process of localizing the face in the given image. These detected faces are pre-processed. The pre-processing can be removal of the noise from the image, alignment of the images, normalization of the pixel intensities etc. Since face detection has become an independent area of research, we have emphasized only on the feature extraction and classification steps.



Figure 1: Basic steps of facial expression recognition

FACE FEATURE EXTRACTION

The facial feature extraction step is a process of representing the facial images in terms of facial features. In general, there are two approaches to represent the face images. They are Geometrical feature based approach and appearance feature based approach. In the recent years, some methods uses both the geometrical based and appearance based approach in combination. Such methods are known as hybrid methods. The figure 2 shows the different methods of face representation.

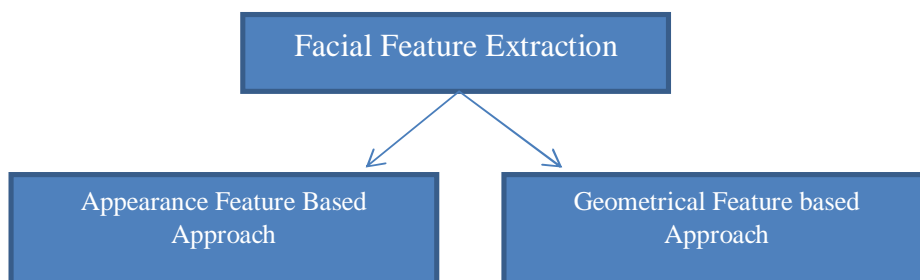


Figure 2: Methods of facial feature extraction

- Appearance based feature extraction**
 The appearance feature based approach considers the pixel intensity values to analyse the facial expression. When a facial action is exhibited different patterns on the face occurs such as the wrinkles, changes in the texture around the nose or mouth. The method which uses such information to recognize expressions are known as appearance based methods. These methods are applied to face as a whole or applied independently to the different part of the face. There are wide ranges of appearance based algorithms. Some of the important algorithms include Local Binary Pattern [5], Independent Component Analysis [6], Principal Component Analysis [7], Linear Discriminate Analysis [8] and Gabor wavelets [9].
- Geometric based feature extraction**
 The geometrical feature based approach or method is based on the feature such as the shapes, edges, corners, and the distance among different parts of the face in the images. The face representation using this method is formed using the features such as the feature points or the shape information. The variation of the geometrical features is used to detect the different facial expressions. Several geometrical feature based methods were developed for facial expression recognition. The optical flow method [10] and the statistical model based Active Appearance Model (AAM) method [11] are two important geometrical feature based techniques. The optical flow method is used to recognize the expression based on the motion of the features. Whereas, the AAM is used to recognize the expression by analysing the changes in the features points in the image with the model.

CLASSIFICATION

The classification is a process of categorizing the facial images into different classes of facial expression based on the facial features. Several classifiers are used for classifying the facial expression based on the features. Some of the important classifiers are

- **Neural network**

Neural network has applications in wide range of problems such as learning the unknown function that maps the input to output to the concept of pattern recognition. The neural network is a network of artificial neurons arranged in layers which convert the input vector to output. Each neurons act as the small processing units. It takes in a input applies the linear or nonlinear function on it and passes the output to the next layer. The network is trained using the pairs of input and output during the learning phase. The weights are set on the connections between the neurons. These weights are updated during the learning phase based on the problem being solved. After the learning phase the weights of the network is kept constant and the test input is given to the network. The network output is used to determine the class to which the test input belongs to.

- **SVM**

Support Vector Machine is a linear classifier which determines a good hyper plane with maximum possible margin between the classes. The hyper plane with maximum possible margin has a better generalization capacity. The figure 3 shows the hyper plane with small and larger margin hyper plane separating the data. If the data is non-separable, the SVM still tries to choose the hyper plane with maximum margin and which minimizes the misclassification error.

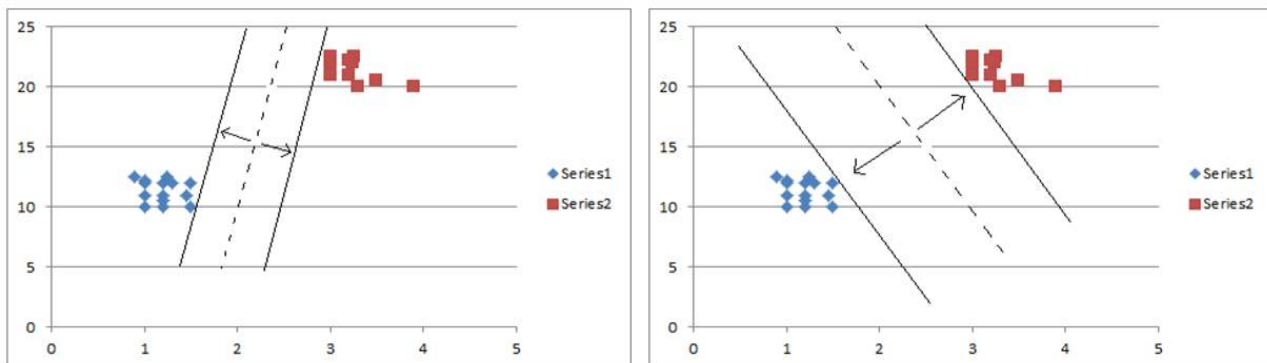


Figure 3: SVM hyper planes separating different classes

- **Probabilistic classifier**

A probabilistic classifier is a classifier which predicts the output given the input as a set of classes with different probability that the input belongs to. This classifies the input with certain degree of confidence. Naive Bayes classifier is one of the important probabilistic classifier used in the area of facial expression recognition.

- **Rule based classifier**

Rule based classifiers are the classifiers which based on a set of rules classify the input. Here a set of rules and corresponding class is defined. If the rule is met by the input then the input is classified to the corresponding class. The decision tree classifier is one of the important rule based classifier used in the area of facial expression recognition

V. FACIAL EXPRESSION DATABASES

There are various standard facial expression databases publicly available. These standard databases are used to test and compare the developed facial expression recognition system with other system. However, building such standard databases that satisfies current and future research requirement is a difficult task. Over the period of last two decades, there has been some effort to create such standard databases [12]. Some of these databases are shown in the following table 3.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Special Issue 9, May 2016

Table 3: Details of Various Facial Expression Database

Database name	Description
The AR Face Database [13]	Number of people as sample was 126, out of which 70 were men and 56 were women. The frontal face images in this database are only the posed expressions. There were no specific restrictions on accessories (glasses, make-up, scarf, etc.). They followed two sessions where the pictures taken were same.
The Japanese Female Facial Expression database (JAFFE)[14]	10 Japanese female models took part as samples , giving 7 facial expressions out of which 6 were basic facial expression and 1 was neutral .the total number of images used were 219.The expressions are multiple action unit expression. There was specific lighting conditions and hair style for photos clicked.
MMI facial Expression Database[15]	This database employed 52 subjects of both the gender of age ranging between 19 to 62 years. The speciality of this database is having both frontal as well as profile view images. The photos taken were under natural lighting condition and varied backgrounds for same subjects.
CMU Pose, Illumination, Expression Database[16]	68 people involved as subjects to give 4 different expressions .The total number of images in this database is 41,368. Various lighting conditions were used, as much as 43.
Spontaneous Expression Database[17]	The photos taken here were spontaneous for 8 subjects. The photos taken were without making them aware or through hidden cameras and later taken their will.
Cohn-Kanade Database[18]	100 subjects of age ranging between 18 to 30 years were employed to give 500 image sequences. The facial displays were of single action unit and action unit combination. They used two cameras to take images from various positions but the database presents only frontal images.

VI. CONCLUSION

The overview of various facial expression recognition challenges, the basics steps of facial expression recognition and recent advances gives new researcher in the area a kick start in the area of facial expression recognition. Face expression is a combined result of different action units and therefore recognizing the action units and determining the expression based on the recognized action units is a better approach. But the drawback of such an approach is that it makes the system more complex and takes greater time to train. The local binary pattern method which is invariant to the different illuminations has been very successful algorithm in recent year compared to other algorithms. The neural network classifier is robust and provides better performance when compared to other classifiers but the time taken during training is more. There are several attempts made to create standard facial expression database but not many database satisfy the current research needs. The MMI database meets the recent research needs by providing high resolution images with different action units and expressions. The creation of a fully automated system invariant to illumination, pose and occlusion still remains a challenge.

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