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Facial Expression recognition using Fuzzy Inference System

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***Abstract*— Within the last several years, Recognition of Human's Facial Expression has been very active research area of computer vision. It has the important role in the human-computer interaction (HCI) systems. This paper proposes a novel fuzzy method for facial expression recognition on still images of the face. The new technique involves in extracting mathematical data from some special regions of the face and fed them to a fuzzy rule-based system. Fuzzification operation uses triangular membership functions for both input and output. The Distinct feature of a system is its simplicity and high accuracy. Experimental results on JAFFEE database indicate good performance of the developed technique.**

***Index Terms*—Fuzzy Inference system, Facial expression recognition, region extraction, JAFFEE**

I. INTRODUCTION

Facial expression recognition (FER) is one of the most important subjects in the fields of human-computer interaction, which has wide range of applications such as Telecommunication, Medical, Human Computer Interactions (HCI) and Biometrics. The ideal human computer Interaction system is the one that the computer is able to communicate and respond to the user actions, based on emotional state of human's face. In this way the user will be able to communicate with it more effectively. For this aim, automatic recognition of human's facial expressions has been very active research area of machine vision within the last several years. It began from 1970s, when Ekman and Friesen introduced six universal facial expressions that are happiness, sadness, anger, fear, surprise, and disgust [1]. In addition, they developed Facial Action Coding System (FACS) that is a famous framework which describes human's facial expressions based on action units (AUs) [2]. FACS uses 44 AUs which are related to the movement of eyes, eyebrows and mouth show the facial actions. Each expression may be modeled by single action unit or combinations of them. Another important facial feature set is MPEG-4 system that uses 84 feature points on the neutral face which are located in the areas like eyes, eyebrows, nose and mouth. Lots of researchers focused on FACS to interpret facial expressions like [6], [7], While some others rely on MPEG-4 standard such as [11], [5].Also there are some other Coding schemes such as EMFACS [12], MAX [13] and AFFEX [14]. In recent years Many Facial Expression Recognition systems have been developed. FER systems usually extract facial Expression parameters from face image (feature extraction) and fed them to a classifier for identifying the emotion. In Order to recognize expressions of the face precisely, a useful feature extraction method and classification scheme must be chosen. Most of current researches focus on achieving more effective feature extraction and classification methods for better identification of emotions.

The rest of this paper is organized as follows. A brief review of Feature extraction algorithms is given in Section 2. Along with this, some classification methods are described in section3. In Section 4, detailed description of proposed method is made. Experimental results are presented in Section5.

II. FEATURE EXTRACTION TECHNIQUES

Facial expressions are generated by movement of face muscles that makes facial features such as stretching corner lips, raising eyebrows, opening eyes, etc. Various researches have been done on effective extraction of facial features as well as classifying them to the different emotions. PCA (Principal Component Analysis) and LDA (Linear Discriminate Analysis) are the most common approaches [15]. They project data linearly from high dimensional image space to a low dimensional subspace. In [16] T. Xiang employed Fourier transform to extract features. In [17] author used statistical analysis to extract features. For this aim, fifteen basic facial action points were extracted manually from images of Cohn-Kanade database, and then 6 distances were introduced between pair of points that have the most movement in facial expressions. In [18] authors defined 9 basic image lines for region extraction and fed them to the Feature Extraction Module to find the facial action values associated with every region. Ratliff [19] defined an Active Appearance Model (AAM) to represent shape and texture variation in expressions. Fisher Linear Discriminant (FLD) is another algorithm which is used by [20]. FLD is a supervised learning algorithm which seeks a transformation matrix so that the ratio of the between-class scatter and the within-class scatter is maximized.

III. CLASSIFICATION ALGORITHMS

Within the last several years, a wide range of classification algorithms have been used thus far, including Principal Component Analysis (PCA), Linear Discriminant Analysis (LDA), and Independent Component Analysis (ICA) [6], Hidden Markov Models (HMMs) [22], Bayesian network classifier [23] and Neural networks (NN) [24]. Fuzzy classifier systems have been designed and used for facial

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expression recognition widely [18], [21], [11]. They have been gaining increasing acceptance during the past few years. Unlike classical logic which requires a deep understanding of a system, exact equations, and precise numeric values, fuzzy logic incorporates an alternative way of thinking, which allows modeling complex systems using a higher level of abstraction originating from our knowledge and experience In [18]authors employed Mamdani-type fuzzy system for recognizing 6 facial expressions. In[11] FER is performed through a neuro-fuzzy system which first translates FP(Feature Points) movements into FAPs(Facial Animation Parameter) and reasons on the latter to recognize the underlying emotion in facial video sequences.

In [21] fuzzification is used to extract the pixel wise association of face images to different classes. Further nearest neighbor classification using correlation coefficients and principal component analysis are used to obtain more distinct classification results. Some algorithms employ Support Vector Machines for expression recognition [4]. In most cases SVMs yield good separation of the clusters by projecting the data into a higher dimension. A Complete survey on various Facial expression recognition algorithms can be found in [8].

IV. Facial Expression Recognition System

In this paper a novel FIS method based on fuzzy logic reasoning strategy is proposed for facial expression recognition on still images of the face. Firstly the input image is preprocessed by wiener filter for smoothing and more distinction between face and background. Secondly 5 basic regions were extracted on face area of the preprocessed image by defining 10 lines. In the next step feature extraction is performed. In this step some mathematical characteristics of the extracted regions, such as image energy, mean and variance, were calculated and considered as features that are fed to mamdani-type fuzzy system for expression recognition. The proposed Fuzzy inference system consists of triangular membership functions for both input and output and series of if-then rules. This system is capable of recognizing 6 basic human facial expressions that are happiness, surprise, anger, fear, disgust and sadness. Figure1 shows the overall block diagram of a proposed method.

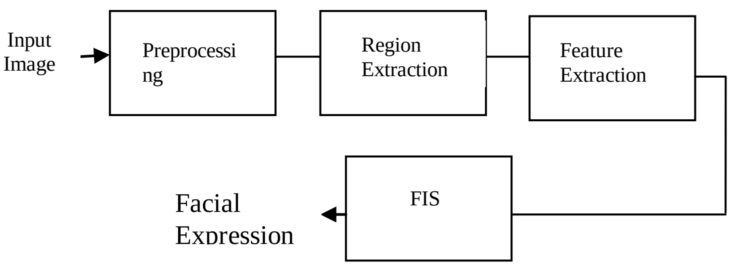


Fig.1: Block diagram of a proposed method

A. *Pre processing*

Preprocessing an image consists of all conversions on image data so as to make them more effective for consequent steps. For this aim, first the input image was smoothed by wiener filter of size 5*5. Wiener filter is an adaptive low pass filter which estimates the output pixel using mean and variance of a local neighborhood of a pixel:

$$\mu = 1/MN \sum_{n1,n2\in\eta} a(n1,n2) \quad (1)$$

$$\sigma^2 = \frac{1}{MN} \sum_{n1,n2\in\eta} a^2(n1,n2) - \mu^2 \quad (2)$$

μ And σ^2 are mean and variance in the neighborhoods of size m-by-n around each pixel [3]. Applying Wiener filtering causes more distinction between face and background. This image will be processed in next step which is feature extraction.

B. *Feature Extraction*

A very important role in image analysis is played by what are termed as feature. Our feature extraction method is partly inspired by the algorithm proposed in [18], [9]. Following that, 10 basic image lines have been defined for region extraction. These lines segment the face image into 5 basic regions that have effective facial movements in every face expression. The lines and subsequent regions are shown in Fig2 and Fig3.

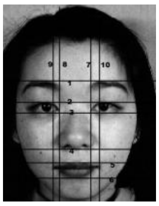
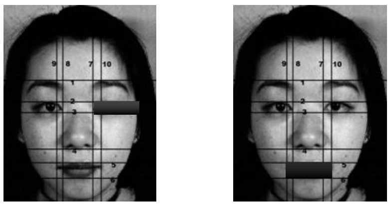


Fig2. Image Lines

As figure shows, line 1 is located on top of eyebrows of neutral face image. Line 2 and 3 are on top and below eyes respectively. These lines help to mark eyes. Also the region between line 1 and 2 is considered as distance between eye and eyebrow. In addition to these, 2 vertical lines have been employed, at the same distance from the middle of the face, on the inner corner of eyes (lines 7, 8). These lines together with Lines 1 and 2 specify the region between eyebrows. The next defined line is Line 4 that is located below nose. Line 5 and 6 are on the upper lip and under lower lip. Also, 2 other vertical lines have been introduced which are located on outer corner of lips (Lines 9, 10). These important lines, in contribution with lines4 and 5 specify the region between nose and lips. So, using these 10 lines, 5 basic regions have been extracted from the face image. These areas are shown in figure 3.



(a) **(b)**

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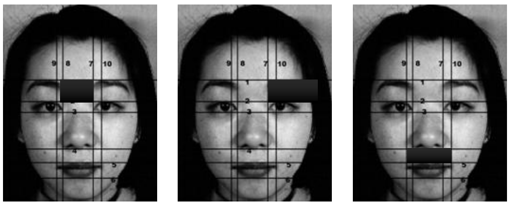

(c) *(d)* *(e)*

Fig3: (a) Eye region (b) Lips Region (c) Region between 2 eyebrows (d) region between eye and eyebrow (e) Region between nose and upper lip

After extraction of 5 basic regions, some mathematical characteristics of these areas were taken into consideration. Energy of image is the first feature that is defined as:

$$E = \sum_{x=1}^{n} \sum_{y=1}^{m} I^2(x, y) \quad (3)$$

In which E is the total energy for the image of size n*m. Other features are mean and variance value of image. For image of size M-by-N, Variance function is the square of the standard deviation, given by the following equation:

$$\sigma^2 = \frac{\sum_{i=1}^{m} \sum_{j=1}^{n} |u_{ij}|^2 - \frac{|\sum_{i=1}^{m} \sum_{j=1}^{n} u_{ij}|^2}{M * N}}{M * N - 1} \quad (4)$$

These three features were calculated for each pre-defined regions of every image. Results will be utilized for the next step which is fuzzification.

C. *Fuzzy Inference System*

Fuzzy logic represents a good mathematical framework to deal with uncertainty of information. It resembles human decision making with its ability to work from approximate data and find precise solutions. Since the concept of fuzzy logic was formulated in 1965 by Zadeh [10], many researches have been employed in various areas of digital image processing such as image quality assessment, pattern recognition, image segmentation, etc. In this paper, Fuzzy Rule based system is used for classification of six facial expressions. Generally, each Fuzzy image processing system has three main stages: image fuzzification, modification of membership values, and, if necessary, image defuzzification. Implementation of proposed fuzzy inference system is carried out by introducing triangular member ship functions due to the extracted features from the last section. The triangular curve is a function of a vector, x, and depends on three scalar parameters a, b, and c, as given by:

$$f(x, a, b, c) = \begin{cases} 0 & x \leq a \\ \frac{x-a}{b-a} & a \leq x \leq b \\ \frac{c-x}{c-b} & x \geq c \end{cases} \quad (5)$$

This function is used to map inputs to membership values. Therefore, we will have 6 linguistic variables (due to each expression) for each feature of every basic region. An example of one defined region and its relevant membership functions due to the extracted features are shown in Fig 4.

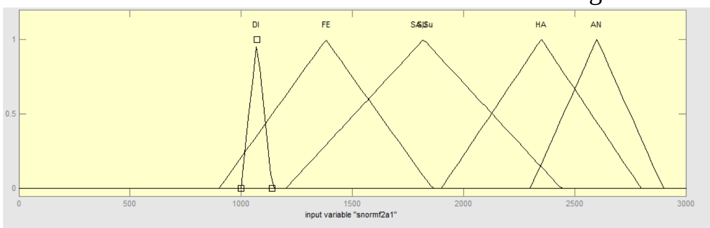

Fig4: Membership Functions for Energy of Region between eyebrows

As figure shows, each of the mapped values are partitioned into 6 fuzzy regions according to the specific expression (MFs for Sad and surprise are the same in this case). For instance, for energy of lips region, we have 6 language variables according to each MF, such as Very small, small, pre medium, medium, Large, Very large. In this way, it is possible to define 6 MFs for mean, variance and energy of each predefined region. So extracting three features (mean, variance and energy) of each five basic regions we will have 15 inputs for the FIS system and one output which is the expression. Triangular mf is also employed for output membership function. Figure5 shows output membership functions and its corresponding language variables that are 6 expressions (happy, sad, fear, anger, disgust and surprise).

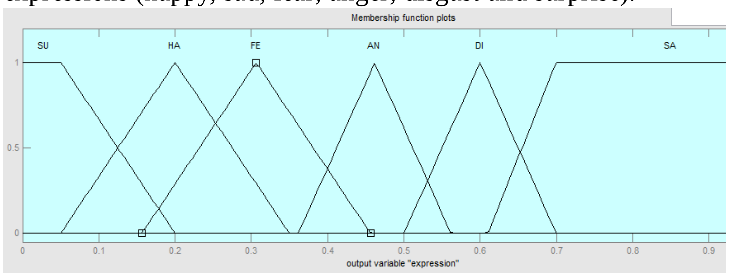

Fig5: Output membership functions

There are many difuzzification approaches including: max member ship principle, Centroid principle, weighted average method, etc. In this paper centroid method is employed for defuzzification stage. In order to demonstrate the performance of the proposed approach a lot of experiences have been done on JAFFEE database images. Accuracy of the algorithm for recognition of each expression is given in Table I.

Table I: Results of Proposed method

Expression	Accuracy of recognition
Happy	70%
Surprise	100%
Fear	100%
Anger	100%
Disgust	100%
Sad	84%
Average Recognition Rate	92.3%

V. EXPERIMENTAL RESULTS

An analysis of the results in Table1 shows that the system correctly classified expressions for each individual using

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only still images. It distinguishes 4 expressions (surprise, anger, disgust and fear) precisely and identifies 2 other ones, Happiness and sadness, by the accuracy of 70% and 84% respectively. Due to the survey from Sherri C. Widen and Brooks, (2004) anger and disgust are commonly confused. Also many people made mistake identifying sadness from disgust. According to Carlo Drioli and Tesser, 2003 research Surprise is mis-recognized as happy. Following this information, Output membership functions are built and overlapping of some expressions is considered due to the mentioned facts (Fig 5).

Experimental results demonstrate the superiority of the proposed method to existing ones. Table II gives the comparison of the proposed system with other different techniques.

Table II. Results and comparisons

Method	Recognition Rate (%)
HMM[22]	86.1
Fuzzy system[18]	87.5
Genetic-Fuzzy Classifier Model[17]	88
Case Based Reasoning[9]	83.5
Proposed Method	92.3

VI. Conclusion

Fuzzy set theory and fuzzy logic offer us powerful tools to represent and process human knowledge in form of fuzzy if-then rules. Because of the uncertainties that exist in many aspects of image processing, fuzzy processing is desirable. In this paper a novel fuzzy facial expression recognition system is introduced which takes a static image as input and gives the expression as output. The emphasis has been to develop a very simple and small but a greatly efficient, fuzzy rule based algorithm to identify six basic facial expression of a human face. This system evaluates facial expressions through the robust analysis of appropriate facial features. Facial features are mathematical characteristics of 5 basic regions which were produced using 10 lines on the image of neutral face. The system uses triangular membership functions for both input and output. The proposed algorithm was tested with different images from JAFFE database. Experimental results indicate the good performance and potential of the developed technique.

Future work will include emotion recognition based on considering more facial regions, improving rules and combining other classifiers to the fuzzy system and for better performance.

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