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Facial Expression Recognition Using Fuzzy Logic

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Abstract: ***Facial expression recognition is a part and parcel process in human-computer interaction systems (HCI). We present a legitimate procedure for facial expression recognition from Facial features using Mamdani-type fuzzy system. It is Fuzzy Inference System (FIS), which is capable to set up an easy membership relation between different facial expressions. We present a legitimate algorithm for facial region extraction from static image. These extracted facial regions are used for facial feature extraction. Facial features are fed to a Mamdani-type fuzzy rule based system for facial expression recognition. This system recognizes six basic facial expressions namely fear, surprise, joy, sad, disgust and anger. Normal/Neutral is an additional expression and is often categorized as one of the basic facial expressions. So, total output expressions for our system is seven. Another distinct feature of our system is the membership function model of expression output which is based on different psychological studies and surveys. The validation of the model is further supported by the high expression recognition percentage.***

Keywords: HCI,FER,PPM,FIS,REM,FEM

1. Introduction

In 1872, Charles Darwin stated in his book title as "The Expression of the Emotion in Man and Animals" expression of man and animals are unique in the universe but gestures may be different from one culture to another. Paul Ekman has given evidence about the universality of facial expressions and also proposed six basic human emotions.

Facial expressions play a vital role in social communication. Computers are increasingly becoming the part of human social circle through human computer interaction (HCI). "Human-Computer Interaction in MIS is concerned with the ways humans interact with information, technologies, and tasks, especially in business, managerial, organizational, and cultural contexts". HCI is a bidirectional process. Human face is the richest source of human emotions

Facial expression recognition systems usually extract facial expression parameters from a static face image. This process is called feature extraction. These extracted features are then fed to a classifier system for facial expression recognition. In this paper we present the complete system for facial expression recognition. The core of our system is a Mamdani-type Fuzzy Rule Based system which is used for facial expression recognition from facial features. Fuzzy logic can be used to form linguistic models and comes with a solid qualitative base. Fuzzy systems have been used in many classification and control problems including facial expression recognition. Facial expression recognition that is involved in many research areas such as image processing, pattern recognition, psychological studies is full of challenges. Due to the complexity of expression variety and facial expression recognition involves image processing, computer vision, pattern recognition, and application psychology, facial expression recognition has become a subject with much challenges. We present a Mamdani-type fuzzy system for facial expression recognition. This system recognizes six basic facial expressions namely fear, surprise, joy, sad, disgust and anger. Normal/Neutral is an additional expression and is often categorized as one of the basic facial expressions. So, total output expressions for our system is seven.

Figure 1: Six basic expressions: sad, anger, disgust, fear, happy, surprise

2. Region and Feature Extraction Module

2.1 Pre-Processing Module

We follow a set of steps to get expression from a static image. Our first module is highly emphasized on image preprocessing. In this module we highly concentrated on how to remove the noise and variation of pixels from an image. Firstly, the input image is pre-processed for face extraction .so we cut the face from image and leave the background because in recognition of expression there is no any role of background image. Image is scaled according to the system specification Pre-Processing Module (PPM) involves some prerequisite for an image because sometime eyes may close, in this paper we use the position of the two eyebrows to fix on the radian should to rotate in the process of circumrotation revision.

2.2 Region Extraction Module

After that it is forward to the region extraction module. It consists of eight lines in which some are horizontal and others are vertical. Each line has own significant meaning to

get a region for feature extraction. Feature Extraction Module (FEM) further processes these 8 extracted regions for finding the facial action values associated with every region. Facial action values (scaled from 0 to 10) are fed into a Mamdani-type Fuzzy System for ultimate expression output.

Extracted face is then fed to the Region Extraction Module (REM). We have defined eight basic facial action elements namely eyes, eye-brows, nose, forehead, cheeks, lips, teeth and chin. We have defined 9 basic image lines for region extraction. Forehead region is marked above eyebrows. Line 1 represents 'Eyebrows Top'. As the face is traversed below line 1, next important line to be marked is line 3. Line 3 signifies 'Eyes Top'. Line 4 lies further below line 3. Line 4 represents 'Eyes Bottom'. Lines (1- 3 -4) help to mark Eye, Eyebrows and Forehead regions.

Line No.	Semantic Significance
1	Eyebrows Top
2	Face Middle
3	Eyes Top
4	Eyes Bottom
5	Eyes Inner Corner
6	Face Middle
7	Lips Outer Corner
8	Lips Bottom
9	Lips Top

Figure 2: Image lines for region extraction module and their significance respectively

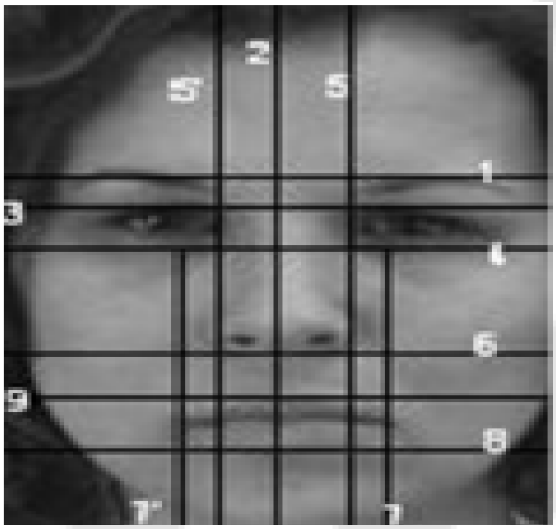

Figure.3: (A) Eye region: bounded by 3-4-5 (B) Eyebrow Region: bounded by 1-3-5, (C) Forehead Region: bounded by 1, (D) Nose region: bounded by 1-6-5-5', (E) Lips Region: bounded by8-9-5-5', (F) Chin Region: bounded by 8-5-5, (G) Cheek Region: bounded by 4-8-7.

2.3 Feature Extraction Module

Feature Extraction Module (FEM) uses these extracted regions to find the facial action values for all facial action elements.
Vertical flow traversal from the bottom of the extracted face image initially detects line 8 ('Lips Bottom'). Line 9 is marked above line 8 and represents 'Lips Top'. These two lines are important in marking Lips, Teeth and Chin regions. Line 2 represents 'Face Middle'. Horizontal traversal first detects line 5 and then line 7. These lines represent 'Eyes Inner Corner' and 'Lips Outer Corner' respectively. Line 6 is marked by vertical traversal between line 9 and line 4. These lines mark Nose and Cheeks region. Regions extracted for these basic facial action elements are shown in figure below.

We compare each region by normal values of forehead, eyebrow, eyes, nose, chin, cheek, lip, teeth respectively.it is very vital module to get actual expression linked with a static image. HCI techniques play an important role to get optimal and real values of above listed elements in comparison with normal static image.

If you get confused or apply some loose approach to get these values .then it is possibility that it can dilute your result. Our result is driven by these values so one must be very careful to get these values from static image.

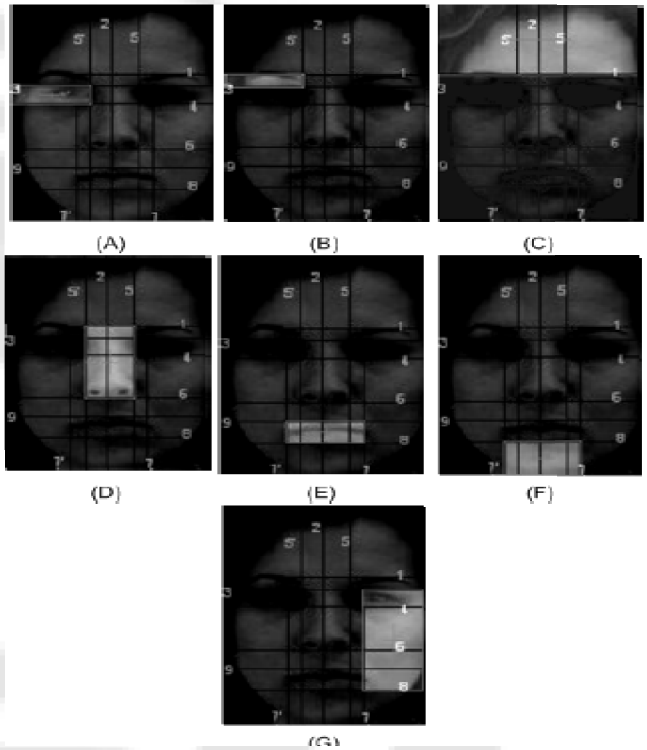

Figure 4: Regions which are used for getting facial action values

3. Expression Recognition Module

As stated by Darwin and approved by Dr. Paul Ekman that only seven expressions sad, anger, disgust, joy, surprise, fear Are universally, have same expression elements in terms of facial values. Fuzzy Logic is very near to real time analytical problems and control problems. So in our system we have used a Mamdani-type Fuzzy Rule Based System. It consists of two components. It is an inbuilt library in MATLAB.

3.1 Database

Database of fuzzy system contains scaling factors for input and output. it also contains the membership functions that

specify the meaning of linguistic terms. It has all governing rules that lead to successful expression recognition.

3.1.1 Input and Output

As I stated earlier that for recognizing the expression of any static image we require only eight basic facial action elements like forehead, eyebrow, eye, nose, lips, teeth, cheek, chin. These inputs are ranged from 0to10 values. These facial action elements are mapped to their respective fuzzy sets by input membership function (IMF). Pictorially it is denoted below.

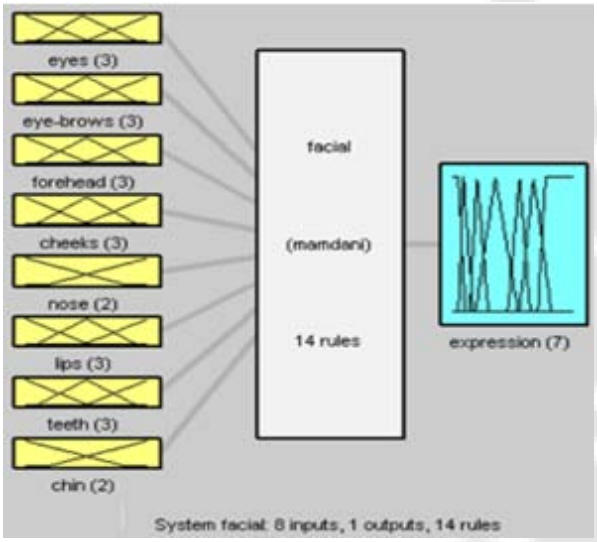

Figure 5: Fuzzy System Architecture

3.1.2 Input MFs

Input which have five Input Membership Functions, have two Membership functions at each extreme and three in middle.

Input which have three membership functions, have two at extreme and one in middle. Input which have two membership function one at each extreme. Figure 6 to 13 will tell you that All MF set examples for all facial action elements. Inputs are denoted as below.

μ_A (Eyes)
Where A = {Pressed closed, Closed, Normal Open, Extra Open}
μ_B (Eyebrow)
Where B = {Centered, Normal, Outward- Stretched}
μC (Forehead)
Where C = {Down & Small, Normal, Stretched & Bigger}
μE (Cheeks)
Where D = {Flat & Stretched, Normal, Filled & Up}
μF (Lips)
Where F = {Pressed-closed, Normal, Open}
μG (Teeth)
Where = {Not-visible, Slightly Out, Extra Open}
μH (Chin)
Where H = {Normal, Radical}

3.1.3 Output Membership Function

Output Expression has seven membership functions representing the basic facial expressions. Anger and disgust are commonly confused for similarity. It is evident from [1] that these two categories are overlapping each-other. Then it is mandatory to put them together. In [1] Author also concluded that sad is also confused with disgust. Research tells the no of people who are confused anger with disgust is more than those people who are confused sad with disgust. In center Normal Expression stands between joy and sad. When joy gets higher it turns in to surprise. Extreme tends to fear as it gets louder. The Membership function of output expression is described below.

μ_A (Expression) where O =
{Anger, Disgust, Sad, normal, Joy, Surprise, Fear}

3.2 Rule-Base

Rule base consists of fuzzy rules which are responsible for getting the correct expression from target static image. Fuzzy Rules are divided in two parts.

3.2.1 Major Rules (categorized Rules)

Major rules classify the six basic facial expressions for the face. They model the six basic expressions using AND combination of the states of the facial elements. Major rules represent the typical state of all basic expressions. Major rules have higher weight as compared to minor rules.

3.2.2 Minor Rules (Non-categorized Rules)

Minor rules give the flexibility to the system providing smooth transition between adjacent basic facial expressions. By adjacent facial expressions we mean the overlap between two facial expressions such as fear-surprise, anger, disgust and joy-surprise, as shown in figure 11. They have lesser weight as compared to major rules.

3.3 Defuzzification

Centroid method is used for Defuzzification. This method was particularly chosen because of its compatibility with rule-system employed. Maximum Height method was also employed but it resulted in choppy results and nullified effect of classification of rules as major and minor. Centroid method calculates center of area of the combined membership functions. A well know formula for finding center of gravity is given below.

$$F^{-1}{}_{COG}(\overline{A}) = \frac{\int_x \mu\overline{A}(x)x dx}{\int_x \mu\overline{A}(x)dx}$$

4. Results and Comparison

Fuzzy Neural Nets (FNN) has been used for 'personalized' recognition of facial expressions. The success rate achieved by them reaches 94.3%, but only after the training phase. The success rate achieved by them varied from 81% to 92%, using different image processing techniques. We have extensively tested our system using grayscale transforms of FG-NET facial expression image database. Every individual has performed six basic expressions (plus neutral) three times. Comparison of our fuzzy system with Case Based Reasoning system was also done. Table 2 gives the comparison of our system with others systems employing different techniques.

Table 2: Comparison with different systems

Expression	*Map (%)*	*HMM (%)*	*Case Based Reasoning (%)*	*Mamdani Fuzzy System (%)*
Surprise	80	90	80	96
Disgust	65	-	80	100
Joy	90	100	76	100
Anger	43	80	95	74
Fear	18	-	75	92
Sad	18	-	95	74

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