FACIAL EXPRESSION RECOGNITION BASED ON FUZZY LOGIC

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Abstract: We present a novel scheme for facial expression recognition from facial features using Mamdani-type fuzzy system. Facial expression recognition is of prime importance in human-computer interaction systems (HCI). HCI has gained importance in web information systems and e-commerce and certainly has the potential to reshape the IT landscape towards value driven perspectives. We present a novel 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. Linguistic models employed for facial features provide an additional insight into how the rules combine to form the ultimate expression output. 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.

1 INTRODUCTION

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 (or Human Factors) in MIS is concerned with the ways humans interact with information, technologies, and tasks, especially in business, managerial, organizational, and cultural contexts" (Dennis Galletta,).

HCI is a bidirectional process. Till now interaction has been one sided, i.e., from humans to computers. In order to achieve the maximum benefits out of this link, communication is also required the other way around. Computers need to understand human emotions in order to respond and react correctly to human actions. Human face is the richest source of human emotions. Hence facial expression recognition is the key to understanding human emotions. Ekman has given evidence about the universality of facial expressions (Ekman and Friesen, 1978),(Ekman, 1994) and also proposed six basic human emotions (Ekman, 1993).

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 that takes a static image as input and gives the expression as output. The core of our system is a Mamdani-type Fuzzy Rule Based system which is used for facial expression recognition from facial features. The major advantages that come with the use of fuzzy based system are its flexibility and fault-tolerance. Fuzzy logic can be used to form linguistic models (Koo, 1996) and comes with a solid qualitative base, hence fuzzy systems are easier to model. Fuzzy systems have been used in many classification and control problems (Klir and Yuan, 1995) including facial expression recognition (Ushida and Yamaguchi, 1993).

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 are seven.

2 FACIAL REGION EXTRACTION AND FEATURE EXTRACTION MODULES

We have employed top-down approach for facial expression recognition. Firstly, the input image is pre-

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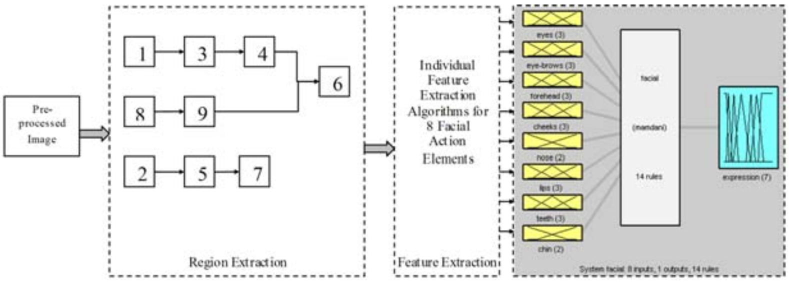

Figure 1: Overall System Block Diagram.

processed for face extraction from background. This image is then fed to the *Region Extraction Module* for extraction of regions for eight basic facial action elements (Shafiq, 2006). *Feature Extraction Module* 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. Our system is divided into four basic modules as shown in fig. 1.

2.1 Pre-Processing Module

Pre-Processing Module (PPM) involves the extraction of face from background. This image is then scaled according to system specifications.

2.2 Region Extraction Module

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. Regions for all facial action elements are extracted by REM. We have defined 9 basic image lines for region extraction. These lines along with their semantic significance are listed in table I (see fig. 2).

Forehead region is marked above eyebrows. Line 1 represents 'Eyebrows Top'. Its position is determined by the vertical flow traversal of image from top to bottom. 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 and 4 help to mark Eye, Eyebrows and Forehead regions as shown in fig. 3 (A,B,C).

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 (see fig. 3. (E,F)). Line 2 represents 'Face Middle'. Horizontal traversal first

Figure 2: Image Lines for Region Extraction.

Table 1: Lines for Region Extraction.

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

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 (see fig. 3. (D,G)).

This region extraction algorithm is also shown in fig. 1. Regions extracted for these basic facial action elements are shown in figure 3.

2.3 Feature Extraction Module

Feature Extraction Module (FEM) uses these extracted regions to find the facial action values for all facial action elements. Specialized algorithms are designed for finding the facial action values that are scaled from 0-10 (Shafiq, 2006). These outputs further act as crisp inputs to the fuzzy based expression recognition module. Expression Recognition Module (ERM) is explained in section III.

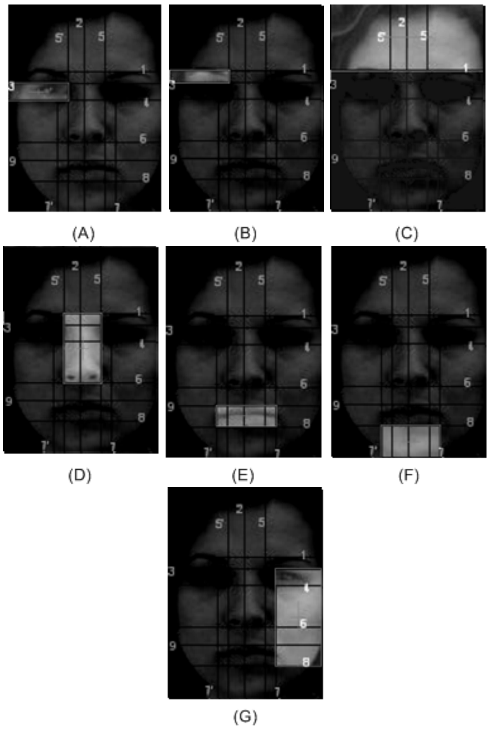

Figure 3: (A) Eye Region : Bounded by 3-4-5, (B) Eyebrows Region: Bounded by 1-3-5,(C) Forehead Region : Bounded by 1, (D) Nose Region: Bounded by 1-6-5-5', (E) Lips Region : Bounded by 8-9-5-5', (F) Chin Region: Bounded by 8-5-5', (G) Cheeks Region : Bounded by 4-8-7.

3 EXPRESSION RECOGNITION MODULE

ERM is a Mamdani-type fuzzy rule based system. The knowledge base (KB) in general rule based fuzzy systems is divided into two components.

3.1 Data-Base (DB)

Data base of a fuzzy system contains the scaling factors for inputs and outputs. It also has the membership functions that specify the meaning of linguist terms (Ralescu and Hartani, 1995).

3.1.1 Inputs and Output

Eight basic facial action elements considered for expression output are eyes, eye brows, forehead, nose, chin, teeth, cheeks and lips. States of these facial elements act as input to the fuzzy system. These inputs are scaled from 0-10. The inputs are mapped to their respective fuzzy sets by input membership functions (MFs). The system diagram shows the inputs and output in fig. 4.

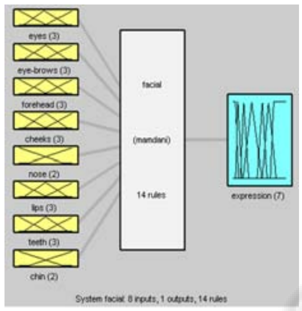

Figure 4: Fuzzy System Architecture.

3.1.2 Input MFs

The inputs that have three input Membership Functions (MFs) have two MFs at each extreme and one MF in the middle. Inputs with two MFs have one at each extreme. Figures 5 to 12 show MF set examples for all facial action elements. The inputs are denoted as:

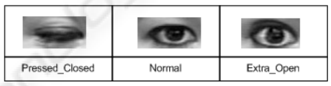

Figure 5: MF Set Examples for Eyes.

$$\mu_A(Eyes)$$
$$where\ A = \{Pressed\_Closed, Normal, Extra\_Open\}$$

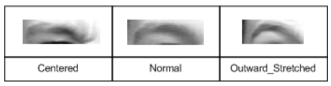

Figure 6: MF Set Examples for Eyebrows.

$$\mu_B(Eyebrows)$$
$$where\ B = \{Centered, Normal, Outward\_Stretched\}$$
$$\mu_C(Forehead)$$
$$where\ C = \{Down\&Small, Normal, Stretched\&Bigger\}$$
$$\mu_D(Cheeks)$$
$$where\ D = \{Flat\&Stretched, Normal, Filled\&Up\}$$
$$\mu_E(Nose)$$
$$where\ E = \{Normal, Radical\}$$
$$\mu_F(Lips)$$
$$where\ L = \{Pressed\_Closed, Normal, Open\}$$
$$\mu_G(Teeth)$$
$$where\ G = \{Not\_Visible, Slightly\_Out, Extra\_Open\}$$
$$\mu_H(Chin)$$
$$where\ H = \{Normal, Radical\}$$

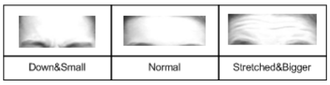

Figure 7: MF Set Examples for Forehead.

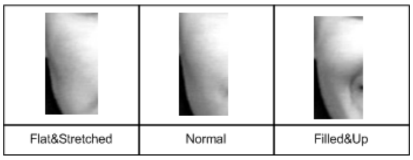

Figure 8: MF Set Examples for Cheeks.

3.1.3 Output MFs

Output ‘expression’ has seven output MFs representing the basic facial expressions. The distinctive feature of our system is the design of ‘expression MFs’. They are scaled from 0-10. This grouping of the facial expressions is the characteristic of our system and is shown in fig. 13.

Starting from the extreme left of fig. 5, anger and disgust are commonly confused for similarity. It is evident from survey in (Sherri C. Widen and Brooks, 2004)that these two categories are overlapping. So it makes sense to group them together. In (Sherri C. Widen and Brooks, 2004), authors have also shown that sad is also confused with disgust. The percentage of people who confused disgust with sad was lesser than those who confused anger and disgust. So, it makes sense that overlapping area for disgust-sad is lesser than that of anger-disgust. In the center, normal (or neutral) expression bridges sad and joy. Facial features tend to be like surprise as the joy becomes extreme (Carlo Drioli and Tesser, 2003). Towards the extreme right, fear takes over surprise. Studies have shown that fear is often mis-recognized as surprise (Diane J. Schiano and Sheridan, 2000). Output ‘expression’ membership functions are given as:

$$\mu_O(Expression) \quad \text{where } O = \{Anger, Disgust, Sad, Normal, Joy, Surprise, Fear\}$$

3.2 Rule-Base (RB)

Rule base (RB) consists of the collection of fuzzy rules. Fuzzy rules used in our system can be divided in two types.

3.2.1 Major (Categorizing) Rules

Major rules classify the six basic facial expressions for the face. They model the six basic expressions

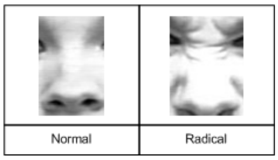

Figure 9: MF Set Examples for Nose.

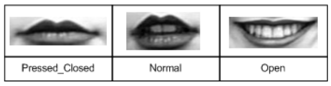

Figure 10: MF Set Examples for Lips.

Figure 11: MF Set Examples for Teeth.

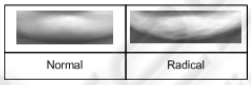

Figure 12: MF Set Examples for Chin.

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 (Non-Categorizing 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 13. 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. Centroid method gave smoother results than other methods. 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 (D. H. Rao, 1995). A well know formula for finding center of gravity is given in (Runkler, 1996) as:

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

Defuzzification gives one crisp output. But crisp output is not suitable to our system. It is commonly

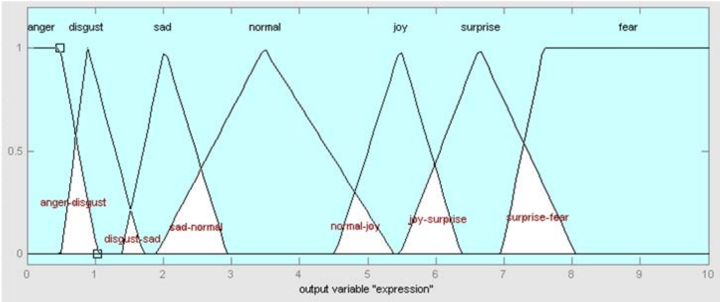

Figure 13: MFs Plot for 'expression' showing Overlap Regions (Muid Mufti, 2006).

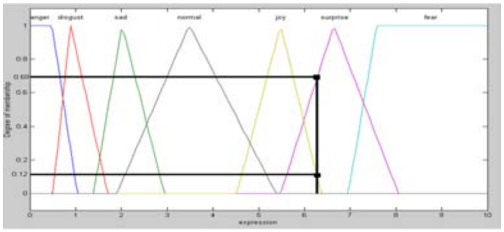

Figure 14: Mixed Expression Output.

observed that more than one basic expressions overlap to form the ultimate complex output expression (Sherri C. Widen and Brooks, 2004). So the output of our system may also be the overlap of two expression outputs. This is explained with the help of the figure 14. It shows the result of our system when centroid defuzzification method's crisp output is 6.3. The output 6.3 corresponds to 14.8% joy and 85.2% surprise.

4 RESULTS & COMPARISON

The focus of our system is on reducing design complexity and increasing the accuracy of expression recognition. Fuzzy Neural Nets (FNN) have been used by authors in (Kim and Bien, 2003) for 'personalized' recognition of facial expressions. The success rate achieved by them reaches 94.3%, but only after the training phase. In (Lien, 1998), authors used Hidden Markov Models (HMM) employing Facial Action Coding System (FACS) (Ekman and Friesen, 1978). The success rate achieved by them varied from 81% to 92%, using different image processing techniques. In (Ayako Katoh, 1998), authors used self-organizing 'Maps' for this purpose. Other techniques like HMM are further used in (Xiaoxu Zhou, 2004). We have extensively tested our system using grayscale transforms of FG-NET facial expression image database (Wallhoff, 2006). This database contains images gathered from 18 different individuals. Every individual has performed six basic expressions (plus neutral) three times. Comparison of our fuzzy system with Case Based Reasoning system was also done (M. Zubair Shafiq, 2006),(Shafiq and Khanum, 2006).

Table 2: Results and Comparison.

Expression	Maps (%)	HMM (%)	Case Based Reasoning	Mamdani Fuzzy System
Surprise	80	90	80	95
Disgust	65	-	80	100
Joy	90	100	76	100
Anger	43	80	95	70
Fear	18	-	75	90
Sad	18	-	95	70

Table II gives the comparison of our system with others systems employing different techniques.

5 CONCLUSIONS AND FUTURE WORK

Facial expression recognition is the key to next generation human-computer interaction (HCI) systems. We have chosen a more integrated approach as compared to most of the general applications of FACS. Extracted facial features are used in a collective manner to find out ultimate facial expression.

Fuzzy classifier systems have been designed for facial expression recognition in the past (Ushida and Yamaguchi, 1993),(Kuncheva, 2000)(Kim and Bien, 2003). Our Mamdani-type fuzzy system shows clear advantage in design simplicity. Moreover, it gives a clear insight into how different rules combine to give the ultimate expression output. Our system successfully demonstrates the use of fuzzy logic for recognition of basic facial expressions. Our future work will focus on further improvement of fuzzy rules. We are also developing hybrid systems (in (Assia Khanam and Muhammad, 2007)) and Genetic Fuzzy Algorithms (GFAs) for fine tuning of membership functions and rules for performance improvement (Francisco Herrera, 1997).

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