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3D FACIAL EXPRESSION INTENSITY MEASUREMENT ANALYSIS

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ABSTRACT. This study used 3D distance vector measurements as the facial feature to classify six basic expressions and the distance vectors are chosen based on Facial Action Coding System (FACS) component, facial action units (AUs). The statistical values are calculated and analyze to determine the AUs involved in facial expression and distance vectors to be taken into account to measure the intensity of each facial expression in a quantitative manner. As a result, 14 facial points are classified as significant in facial expression classification. Those facial points are in the eye, eyebrow and mouth region only. This work reveals that it is not necessary to rely on all facial feature points in estimating facial expression intensity. For Sad expression, the random mean and standard deviation of distance measurements do not indicate which AU should be taken into account to classify this expression.

Keywords: 3D facial distance, facial intensity measurement, action units.

INTRODUCTION

Facial expressions are defined as the resulting changes in facial appearance due to one or more facial features deformations. The mapping between facial features deformation and facial muscles is not one-to-one. Some facial deformations involve contraction of two different parts of the same muscle, while others involve contraction of multiple muscles. The analyses of facial expressions are beneficial in various fields such as education, communication, security, medicine and behavioral science.

Before the compilation of the Facial Action Coding Systems (FACS), most of the facial behavior researchers are dependent on the human observers who will observe the face of the subject and perform analysis on it [1]. These visual observations cannot be quantified. FACS is an observer-based measurement of facial expression that measures facial expression intensity qualitatively. Each observable component of facial feature deformation is called an Action Unit or AU. All facial expressions can be broken down into an AU.

Facial expression has levels of intensity which rely on the levels of intensity of each facial feature. When it comes to facial expression interpretation, there is no doubt that the intensity level of a facial expression is significant as it might lead to false impression of people's emotion if misinterpreted. [2] used four levels of intensity in their developed database, [3] presented five levels of expression intensity and [4] introduced three levels of intensity.

This paper presents an analysis of 3D facial expression intensity measurement based on the 3D facial distance vectors. Our objectives are: (1) to measure facial expression intensity using two different 3D facial distance vectors; (2) to analyze the statistical values of facial expression intensity. Section 2 describes the related works in this field, followed by a discussion on 3D facial distance vectors section 3. Then, the results and analysis are discussed in section 4 and finally, the conclusions are drawn.

RELATED WORKS

Facial Expression Recognition and Analysis challenge (FERA) 2015 challenge participants to estimate FACS Action Unit (AU) intensity as well as AU occurrence on a common benchmark dataset with reliable manual annotations. For the baseline two types of features have been extracted: Local Binary Gabor Patterns and geometric features derived from tracked facial point locations. The geometric features are based on 49 landmarks detected.

According to [5], different researchers used different 3D facial features in 3D facial expression classification. [6] proposed 7 most expressive facial regions excluding the eyes and mouth. Their algorithm required data pre-processing by selecting the fiducial points manually. This approach is computationally expensive and may be challenging due to the curvature features used. [7] used facial distance vectors in 3D facial expression analysis and classification. The information provided by the extracted distance measurements is valuable and reliable that aids in the robustness of expression classification. [8] used a set of 96 features is comprised of normalized distances and slopes of line segments that connects 83 facial feature points. [13] also used 3d facial distance in their rule-based algorithm developed to encode and quantifie 4 AUS which is sufficient to recognize happy and sad expression.

The existing works employs different facial features to classify facial expression. However, associating the facial features to FACS and determine whether the facial features are beneficial to classify the component of FACS, AUs, are needed.

3D FACIAL DISTANCE VECTORS

One of the most popular methods for feature extraction in 3D static faces is the use of characteristic distances between certain points, and the calculated changes that occur in these due to facial deformations. This is comparable to the common geometric 2D methods that track fiducial points on the face. The BU-3DFE database provides 83 facial points, refer to figure 1. These points, as well as their distances, have been widely employed for facial expression analysis. The 3D distance vectors can be used to correct the pose of its corresponding 2D facial image and eliminate the interference of illumination.

In our work, we use distance measures extracted as the 3D face vectors. For the first 3D distance vectors, we used the distance vectors introduced by [7]. Six Euclidean distance characteristics are extracted from the distribution of 11 facial feature points (see figure 2). The calculation of each distance is described in equation 1. Each of the distances d_i is calculated by obtaining the Euclidean distance between the points. These distances will provide more detail of how each facial feature is moved further or closer by the expression. For instance, the distance between the eyes and mouth as they go further apart when the facial expression is surprise.

$$d_i = \sqrt{(x_k - x_j)^2 + (y_k - y_j)^2 + (z_k - z_j)^2}, \quad \forall_i \in \{1, 2, \cdots, 83\}. \tag{1}$$

where, k and j are end points of the line segment under consideration. Among the 83 facial points provided by BU-3DFE database, only six characteristic distances which maximize the differences of facial expressions are selected to represent each facial expression (as shown in Table 1). The sixth distance, D6, is used to normalize the first five distances.

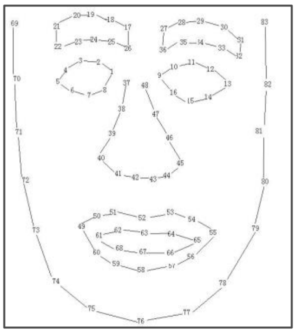

Figure 1: The 83 facial landmarks given in the BU-3DFE database [2]

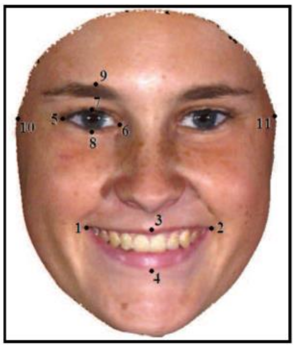

Figure 2: 11 facial feature points used in [7]

Table 1. Six characteristic distances to represent each facial expression

Distance No	Distance Name	Distance No	Distance Name
D1	Eye Opening	D4	Mouth Height
D2	Eyebrow Height	D5	Lip Stretching
D3	Mouth Opening	D6	Normalization

For our second 3D distance vectors, we used the similar distance vectors employed in [9]. All 83 facial feature points are used as depicted in figure 1. A total of $C_{83}^{2} = 3403$ unique pairs between each of the 83 points are produced using the 83 facial feature points. The distance, $d_{i,j}$ of each pair is normalized by the distance between two outer eye corners, w, to make the features scale invariant. Then, the normalized facial feature points are used to form 3D distance vectors, DV_i , for N facial expression models given, the equations are described as below:

$$d_{i,j} = \frac{||\alpha_i - \alpha_j||}{w}, i < j \qquad (2)$$

$$DV_i = \begin{pmatrix} d_{1,2} \\ d_{1,3} \\ . \\ . \\ . \\ d_{2,3} \\ . \\ . \\ . \\ d_{82,83} \end{pmatrix} d \times 1, \ \forall_i \in \{1, 2, \cdots, 83\} \qquad (3)$$

In our work, we map 3D facial points to AUs which are based on [10] and [11]. According to [11], there are expressions which involve AU5 (upper lid raiser), AU7 (lid tighter) and AU6 (cheek raiser). For instance, anger needs AU5 and AU7 while happy needs AU6. The appropriate facial points that correspond to these AUs are not provided by BU-3DFE, therefore AU5, AU6 and AU7 are ignored in our work. Based on FACS and [10], only 4 distances namely D2, D3, D4 and D5 are selected out of six characteristic distances provided by [7]. The distance of D1 and D6 are not involved in any AU measurement. It is computationally expensive to take all 3403 distances into account. Hence, 15 distances are selected from 3403 distances based on [12] and [11].

RESULTS AND ANALYSIS

Table 2. Mapping for AU based on different 3D facial vectors

Expression	AU	Description	Distance based on Soyel 2007	Distance based on Soyel 2010
Anger	AU4	Brow lowerer	D2(3-20)	25-4
			D2(3-20)	35-8
			D2(3-20)	18-4
			D2(3-20)	28-8
	AU23	Lip tightener	D3(55-49)	48-54
			D3(55-49)	54-48
Disgust	AU9	Nose wrinkler	-	38-4
			-	45-8
	AU15	Lip corner depressor	D5(5-49)	48-42
			D5(5-49)	54-42
	AU16	Lower lip depressor	D4(52-58)	57-42
			D4(52-58)	57-51
Fear	AU1	Inner brow raiser	D2(3-20)	25-4
			D2(3-20)	35-8
	AU2	Outbrow raiser	D2(3-20)	21-0
			D2(3-20)	31-12
	AU4	Brow lowerer	*As stated in Anger AU4	
	AU20	Lip stretcher	D3(55-49)	48-54
			D3(55-49)	54-48
			D4(52-58)	57-42
	AU26	Jaw drop	D4(52-58)	57-51
			D4(52-58)	57-42
Happy	AU12	Lip corner puller	D5(5-49)	48-0
			D5(5-49)	48-8
			D5(5-49)	48-42
			D5(5-49)	54-42
Sad	AU1	Inner brow raiser	*As stated in Fear AU1	
	AU4	Brow lowerer	*As stated in Anger AU4	
	AU15	Lip corner depressor	*As stated in Disgust AU15	
Surprise	AU1	Inner brow raiser	*As stated in Fear AU1	
	AU2	Outbrow raiser	*As stated in Fear AU2	
	AU26	Jaw drop	*As stated in Fear AU26	

In this work, we conducted a similar experimental setting for statistical analysis using two different 3D facial feature distances by [7] and [9]. Number of distances used is described in Table 2. The six universal expressions data with four different levels of intensity is obtained from BU-3DFE database. Table 3 shows the action units (AUs) distance measurements to classify six facial expressions. The analysis results reveal that there is a evident change of means and standard deviation on the distances of D(3-20), D(26-5), D(29-9), D(36-9), D(5-49), D(49-1), D(55-49), D(58-52) which are mainly focused on eye, eyebrow and mouth area when different facial expressions are generated. These distances are important to AU1, AU2, AU4, AU12, AU16, AU23, AU26 and have main contribution towards facial expression intensity measurement analysis. Hence, they will be taken into considerations to classify Anger, Disgust, Fear, Happy and Surprise expressions. The deformation of each facial feature is obvious and easy to classify for high intensity expression compared to low intensity expression. Anger expression has impact on the eye, eyebrow and mouth areas. Disgust and surprise expressions have impact solely on the mouth area while fear expression has impact around the eye and eyebrow areas. Eye and mouth areas are obviously play an important to role to determine Happy expression. Based on the analysis results, it can be seen that it is the easiest to classify Surprise expression due to its high variations in the mouth area. Despite there is slight changes around the sub nasal area for certain expressions, this area does not contribute as much as other areas because of its minimal facial features deformation. Only anger, fear and surprise expression have an impact on all areas located on eyes, eyebrows and mouth. The findings report that anger, fear, happy and surprise expressions match all AUs as in table 2.

According to [3], the deformation of AUs of Sad expression consists of both eyebrows and lip. However, the random mean and standard deviation of distance measurements do not indicate which AU should be taken into account to classify Sad expression. AU9 and AU15 show less significant in disgust and sad expression. While AU20 and AU26 are ignored due to its random mean and standard deviation results.

Table 3. Action units (AUs) distance measurements

Facial Expression	Action Unit(AU)	Distance Measurement	Face Region
Anger	AU4, AU23	D(3-20), D(26-5), D(29-9), D(55-49)	Eye, eyebrow, mouth
Disgust	AU16	D(58-52)	Mouth
Fear	AU1, AU2, AU4	D(3-20), D(36-9), D(26-5)	Eye, eyebrow
Happy	AU12	D5(5-49), D(49-1)	Eye, mouth
Sad	-	-	
Surprise	AU26	D(52-58)	Mouth

Based on the experiments conducted, we concluded that the following facial points (as described in figure 3) are significant in the facial expression intensity measurement.

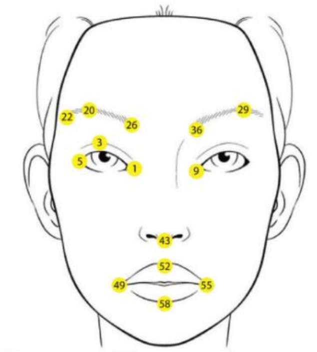

Figure 3: Facial points that are significant for facial expression intensity measurement

CONCLUSION

The major contribution of this work is to analyze facial expressions with four intensities in 3D space by exploring the facial distances. The extracted distance measurements provide valuable and reliable information for the measurement of facial expression intensity as well as classification of facial expressions. This work reveals that it is not necessary to rely on all facial feature points in estimating facial expression intensity. The limitation of our work is limited data, minor difference between expressions and unavailability of certain facial points that might be significant for certain AUs. We consider only static data which is insufficient in facial expressions classification. A lot of different expressions can be studied and observed if dynamic data is used. In our future work, we will be using dynamic data in the similar experimental setting.

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