

# Individualizing the New Interfaces: Extraction of User's Emotions from Facial Data

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## Abstract

*When developing new multimodal user interfaces emotional user information may be of great interest. In this paper we present a simple and computationally feasible method to perform automatic emotional classification of facial expressions. We propose the use of 10 characteristic points (that are part of the MPEG4 feature points) to extract relevant emotional information (basically five distances, presence of wrinkles and mouth shape). The method defines and detects the six basic emotions (plus the neutral one) in terms of this information and has been fine-tuned with a database of 399 images. We analyze the effect of different facial parameters and other issues like gender and ethnicity in the classification results. For the moment, the method is applied to static images.*

Categories and Subject Descriptors (according to ACM CCS): I.3.6 [Computer Graphics]: Interaction Techniques I.4.8 [Image Processing and Computer Vision]: Scene Analysis

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## 1. Introduction: Facial Expression Classification

A system capable of extracting emotional information from user's facial expressions would be of great interest for developing new interfaces which follow the human face-to-face communication model in the most realistic way [Bru92]. In particular, the creation of virtual environments populated by 3D virtual characters capable of understanding users' expressions and reacting accordingly represents, nowadays, a challenging but affordable task.

Nevertheless, to develop a system that interprets facial expressions is difficult. Three kinds of problems have to be solved: face detection in a facial image or image sequence, facial expression data extraction and facial expression classification (e.g. into emotional categories). In this paper we are going to deal with the third problem: classification. This implies the definition of the set of categories we want to deal with, and the implementation of the categorization mechanisms.

Facial expression analyzers make use of three different methods of classification: patterns, neural networks or rules. If a pattern-based method is used [ECT98, HNVDMB98,

LBS99], the face expression found is compared with the patterns defined for each expression category. The best matching decides the classification of the expression. Most of these methods first apply PCA (Principal Component Analysis) and LDA (Linear Discriminant Analysis) algorithms to reduce dimensionality. In the systems based on neural networks [ZLSA98, WRTSS04, EKR05], the face expression is classified according to a categorization process "learned" by the neural network during the training phase. In general, the entrance to this type of systems is a set of characteristics extracted from the face (points or distances between points). The rule-based methods [PR00] classify the face expression into basic categories of emotions, according to a set of face actions previously codified. In [RP00] an excellent state-of-the-art on the subject can be found.

In any case, the development of automatic facial classification systems presents several problems. Most of the studies on automated expression analysis perform an emotional classification. The emotional classification of Ekman [EKM99] is the most followed one. It describes six universal basic emotions: joy, sadness, surprise, fear, disgust and anger. Nevertheless, the use of Ekman's categories

for developing automating facial expression emotional classification is difficult. First, his description of the six prototypic facial expressions of emotions is linguistic and, thus, ambiguous. There is no uniquely defined description either in terms of facial actions or in terms of some other universally defined facial codes. Second, classification of facial expressions into multiple emotion categories should be possible (e.g. raised eyebrows and smiling mouth is a blend of surprise and happiness) but, still, there is no psychological scrutiny on this topic. Another important issue to be considered is individualization. The system should be capable of analyzing any subject, male or female of any age and ethnicity and of any expressivity. The method we present here tries to cope with all this issues.

The structure of the paper is as follows: Section 2 explains our method. Results are presented in Section 3, gender and racial influences are considered in Section 4, whereas conclusions and comments about future work are discussed in Section 5.

## 2. A Simple Method for the Automatic Analysis of Face Expressions

### 2.1. General Description of the Method

Our method is based on the work of Hammal et al [HCCR05]. They have implemented a facial classification method for static images. The originality of their work consists, on the one hand, in the supposition that all the necessary information for the recognition of expressions is contained in the deformation of certain characteristics of the eyes, mouth and eyebrows and, on the other hand, in the use of the Belief Theory [SHA76] to make the classification. Nevertheless, their method has important restrictions. The greater restriction comes from the fact that it is only able to discern 3 of the 6 basic emotions (without including the neutral one). This is basically due to the little information they handle (only 5 distances). It would not be viable, from a probabilistic point of view, to work with many more data, because the explosion of possible combinations would remarkably increase the computational cost of the algorithm.

Compared to the method of Hammal, ours is computationally simple. The combinatorial explosion and the number of calculations to make are reduced considerably, allows us to work with more information (more parameters) of the face and to evaluate the 6 universal emotions, and not only 3 of them, as Hammal does.

Our method studies the variation of a certain number of face parameters (distances and angles between some feature points of the face) with respect to the neutral expression. The objective of our method is to adjudge a score to each emotion, according to the state acquired by each one of the parameters in the image. The emotion (or emotions in case of draw) chosen will be the one that obtains a greater score.

For example, let's imagine that we study two face parameters (P1 and P2) and that each one of them can take three different states (C+, C- and S, following the nomenclature of Hammal). State C+ means that the value of the parameters has increased with respect to the neutral one; state C- that its value has diminished with respect to the neutral one; and the state S that its value has not varied with respect to the neutral one. First, we build a descriptive table of emotions, according to the state of the parameters, like the one of the Table 1. From this table, a set of logical tables can be build for each parameter (Table 2). That way, two vectors of emotions are defined, according to the state taken by each one of the parameters (C+, C- or S) in a specific frame. Once the tables are defined, the implementation of the identification algorithm is simple. When a parameter takes a specific state, it is enough to select the vector of emotions (formed by 1's and 0's) corresponding to this state. If we repeat the procedure for each parameter, we will obtain a matrix of so many rows as parameters we study and 7 columns, corresponding to the 7 emotions (6 plus the neutral one). The sum of 1's present in each column of the matrix gives the score obtained by each emotion.

<b>Emotion</b>	<b>P1</b>	<b>P2</b>
Joy (E1)	C-	S/C-
Surprise (E2)	C+	C+
Disgust (E3)	C-	C-
Anger (E4)	C+	C-
Sadness (E5)	C-	C+
Fear (E6)	S/C+	S/C+
Neutral (E7)	S	S

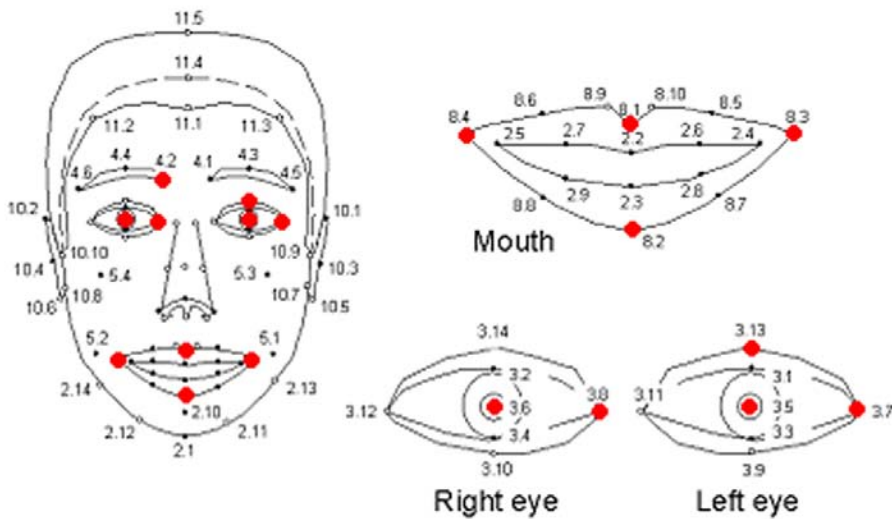
**Table 1:** Theoretical table of parameters' states for each emotion.

		<b>E1</b>	<b>E2</b>	<b>E3</b>	<b>E4</b>	<b>E5</b>	<b>E6</b>	<b>E7</b>
<b>P1</b>	C+	0	1	0	1	0	1	0
	C-	1	0	1	0	1	0	0
	N	0	0	0	0	0	1	1
<b>P2</b>	C+	0	1	0	0	1	1	0
	C-	1	0	1	1	0	0	0
	N	1	0	0	0	0	1	1

**Table 2:** Logical rules table for each parameter.

### 2.2. Feature Selection

The first step of our method consists of extracting the 10 feature points of the face that will later allow us to analyze the evolution of the face parameters (distances and angles) that we wish to study. Figure 1 shows the correspondence of these points with the ones defined by the MPEG-4 standard. For the moment, the extraction of the points is made manually, by means of a landmarking program made in Matlab. We are now developing an automatic features extraction,



**Figure 1:** Facial feature points used for the later definition of the parameters to analyze, according to MPEG-4 standard.

which will allow as well to analyze a greater number of images and to even study the evolution of the parameters in video sequences, and not only in static images.

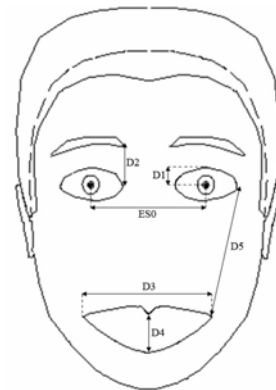
MPEG-4 FAPs NAME	FEATURE POINTS USED FOR DISTANCES
close_upper_l_eyelid	$D1=d(3.5, 3.1)$
close_lower_l_eyelid	
raise_r_i_eyebrow	$D2=d(4.2, 3.8)$
stretch_l_cornerlip	$D3=d(8.4, 8.3)$
stretch_r_cornerlip	
open_jaw	$D4=d(8.1, 8.2)$
raise_r_cornerlip	$D5=d(8.3, 3.7)$

**Table 3:** Relationship between the five characteristic distances used (shown in Figure 2) and the MPEG-4 FAPs and feature points.

The characteristics points are used to calculate five distances shown in Figure 2. These five distances can be translated in terms of MPEG-4 standard, putting them in relation to the feature points shown in Figure 1 and with some FAPs (Facial Animation Parameters) defined by the norm (See Table 3). All the distances are normalized with respect to the distance between the eyes (the MPEG FAPU called "ESo"), which is a distance independent of the expression. This way, the values will be consistent, independently of the scale of the image, the distance to the camera, etc.

### 2.3. Database

In order to define the emotions in terms of the parameters' states, as well as to find the thresholds that determine if pa-



**Figure 2:** Characteristic distances used in our method.

rameter is in a state or another, it is necessary to work with a wide database. In this work we have used the facial expressions and emotions database FG-NET of the University of Munich [WAL04] that provides video sequences of 19 different people showing the 6 universal emotions from Ekman (Figure 3).

## 3. Results

### 3.1. Initial Results

First we considered to work with the same parameters as the Hammal method, ie, with the 5 characteristic distances shown in Figure 2. In order to build a descriptive table of

each emotion in terms of states of distances, we must determine the value of the states of distances that define each emotion (C+, C- or S), as well as evaluate the thresholds that separate a state from another, for each distance. To do this, we studied the variation of each distance with respect to the neutral one, for each person of the database and for each emotion. An example of the results obtained for distance D4 is shown in Figure 4. From these data, we can make a descriptive table of the emotions according to the value of the states (Table 4).

	D1	D2	D3	D4	D5
<b>Joy</b>	C-	S/C-	C+	C+	C-
<b>Surprise</b>	S/C+	S/C+	S/C-	C+	S/C+
<b>Disgust</b>	C-	C-	S/C+/C-	S/C+	S/C-
<b>Anger</b>	C-	C-	S/C-	S/C-	S/C+/C-
<b>Sadness</b>	C-	S	S/C-	S	S/C+
<b>Fear</b>	S/C+	S/C+/C-	C-	C+	S/C+
<b>Neutral</b>	S	S	S	S	S

**Table 4:** Theoretical table of the states taken by  $D_i$  for each emotion, according to the results of the statistics obtained from the FG-NET database. Some distances do not provide any information of interest for emotions (gray).

The last step to complete our algorithm is to define the values of the thresholds that separate a state of another one, for each studied distance. Two types of thresholds exist: the upper threshold (marks the limit between neutral state S and state C+) and the lower threshold (the one that marks the limit between neutral state S and state C-). The thresholds' values are determined by means of several tests and statistics. Figure 4 shows an example of thresholds estimation for the distance D4.



**Figure 3:** Example of selected frames of the FG-NET database [WAL04].

Once the states that characterize each emotion and the value of the thresholds are established, the algorithm has been proved on the 399 images of the database. In the evaluation of results, the recognition is marked as "good" if the decision is coherent with the one taken by a human being. To do this, we have made surveys to several people to classify the expressions shown in the most ambiguous images.

For example, in the image shown in Figure 5, the surveyed

people recognized as much "disgust" as "anger", although the FG-NET database classifies it like "disgust" exclusively. Our method obtains a draw.



**Figure 5:** Frame classified like "disgust" by the FG-NET database [WAL04].

The obtained results are shown in the third column Table 4. As it can be observed, the percentage of success obtained for the emotions "disgust", "anger", "sadness", "fear" and "neutral" are acceptable and similar to the obtained by Hammal (second column). Nevertheless, for "joy" and "surprise" the results are not very favorable. In fact, the algorithm tends to confuse "joy" with "disgust" and "surprise" with "fear", which comes justified looking at Table 3, where it can be seen that a same combination of states of distances can be given for the mentioned pairs of emotions. Related to classification success, it is interesting to realize that human mechanisms for face detection are very robust, but this is not the case of those for face expressions interpretation. According to Bassili [BAS97], a trained observer can correctly classify faces showing emotions with an average of 87%.

### 3.2. Addition of Characteristics: Wrinkles in the Nasal Root and Mouth Shape

In order to improve the results obtained in "joy", we introduce a new face parameter: the presence or absence of wrinkles in the nasal root, typical of the emotions "disgust" and "anger". This way, we will mark a difference between "joy" and "disgust". The obtained success rates are shown in the fourth column in Table 4. We observe, as it was expected, a considerable increase in the rate of successes, especially for "joy" and "disgust". However, the rates still continue being low for "sadness" and "surprise", which makes us think about the necessity to add more characteristics to the method.

A key factor to analyze in the recognition of emotions is the mouth shape. For each one of the 7 basic emotions, its contour changes in many different ways. In our method, we have extracted 4 feature points of the mouth that are shown in Figure 6. Results are shown in the fifth column in Table 5. As it can be seen, the new information has introduced a great improvement in our results. The importance of the mouth shape in the expression of emotions is thus confirmed.

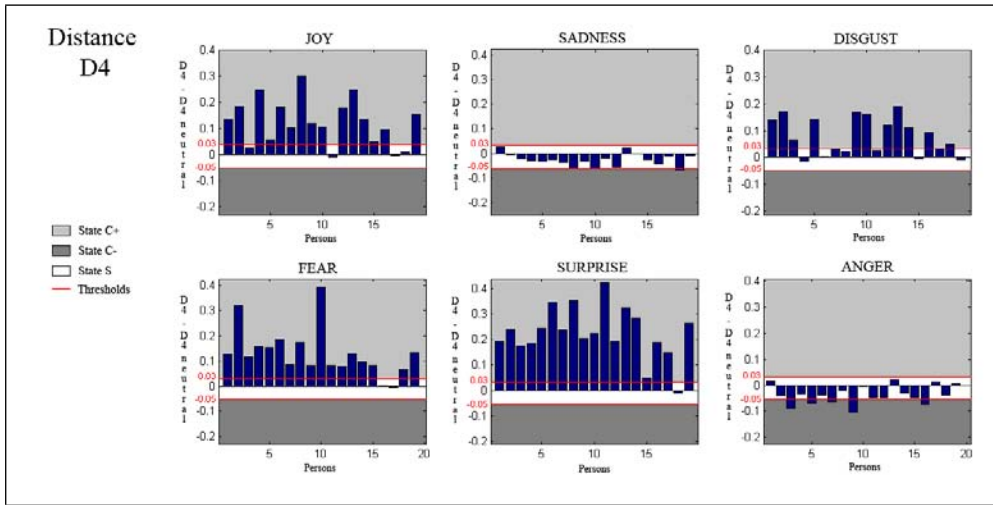


Figure 4: Statistics results obtained for distance D4. Thresholds estimations are also shown.

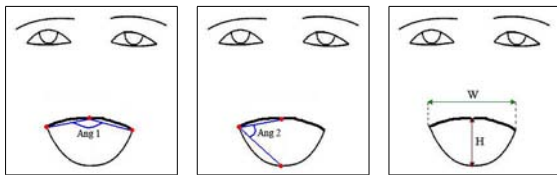


Figure 6: Extra information added about the mouth shape.

#### 4. Analysis of Gender and Race in the Classification Results

##### 4.1. Variation of the Characteristics with Gender

The FG-NET database is composed by images of 19 individuals, 10 men and 9 women. It turns out interesting to analyze the evolution of the different studied face parameters,

Emotion	% Success Hammal Method	%Success our Method	%Success Wrinkles Nasal R.	%Success Mouth Shape
Joy	87.26	36.84	100	100
Surprise	84.44	57.89	63.16	63.16
Disgust	51.20	84.21	94.74	100
Anger	not rec.	73.68	94.74	84.97
Sadness	not rec.	68.42	57.89	94.74
Fear	not rec.	78.95	84.21	89.47
Neutral	88	100	100	100

Table 5: Classification rates of Hammal [HCC\*05] (second column), of our method with the 5 distances (third column), plus wrinkles in the nasal root (fourth column) plus mouth shape information (fifth column).

to determine the influence of the gender factor in the expressiveness of the people.

The study of the obtained graphs shows that the tendencies of variation of the characteristics with respect to the neutral expression are similar between men and women (Figure 7 shows the example of the distance D1). Therefore, gender seems not to influence the way of expressing emotions.

It is usually said that women are more emotive and expressive than men. Perhaps this fact is not reflected in our results since, in the database used the emotions come caused by strong stimuli implying, therefore, an also strong, immediate and natural reaction.

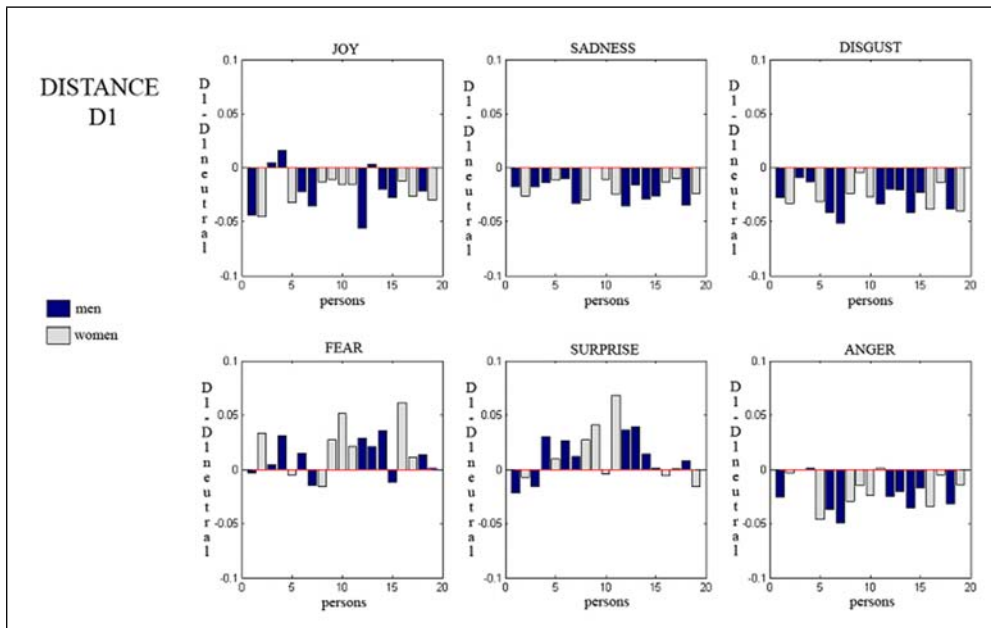
##### 4.2. Variation of the Characteristics with Race.

In this section we try to analyze the influence of the race in the studied face characteristics. To do it, we have used the JAFFE database (Japanese Female Facial Expression Database [LBS99], that contains photographs of 10 Japanese women expressing the 6 basic Ekman's emotions (Figure 8), and we have compared it with the caucasian database used to implement our system (FG-NET).



Figure 8: Examples of photographs of the JAFFE database [LBS99].

Studying the obtained graphs, we can observe that the evolution of the different characteristics with respect to the neutral expression for the Asians is much smaller than for



**Figure 7:** Comparison of the values taken by the distance  $D1$  for men and women.

the Caucasian race (Figure 9). This makes difficult the establishment of a criterion of classification for the system since, although the evolution of the parameters follows the same tendency that in the Caucasian race (states C+, C- and S), such small variations make difficult the establishment of the thresholds that allow to clearly discriminate among emotions. The limited accuracy of the facial points' automatic extraction algorithm also makes this task difficult as it can happen to be of the same order that the variation of the characteristics.

The smaller expressiveness of the Asian race can come from several factors. On the one hand, from the characteristics of the mongoloid appearance (torn eyes, sunk nose, form of the cheekbone, etc.), that reduce flexibility to the face. On the other hand, from geographic, historical, cultural, educational and traditional factors, that also can play an essential role in the way of expressing emotions in the different races.

The indicated previously is not in discord with the Ekman's theory of Universality of emotions [Ekm99]. The emotions are universal, therefore a Caucasian is perfectly able to recognize and to classify into an emotional category the expression shown by an Asian and viceversa, the only difference between them is the intensity of the shown emotions.

## 5. Conclusions and Future Work

We have presented a simple and effective method for the automatic classification of facial expressions. The introduction

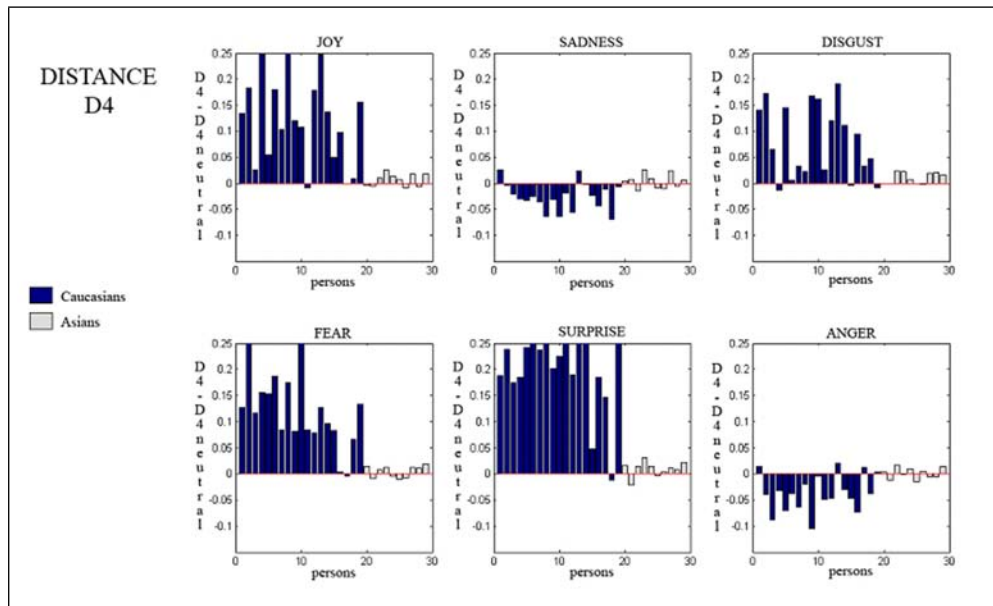
of several additional parameters barely increases the computational cost of the algorithm, given its simplicity, and produces very significant rates of improvement. In a future it is hoped to introduce new characteristics, in the form of face distances, angles (for example the angle formed by the eyebrows) or shapes. In particular the group has some experience in the use of deformable models, in particular snakes, in the segmentation of images, which could be use to extract in our case the shape of the mouth. Another noticeable objective in the short term is to make the tracking of the landmarks in an automatic way. Thanks to it, we will be able to introduce dynamic information in our method, that is to say, to study the evolution in the time of the evaluated parameters, and classify user emotions from live video. Every time with more force, the psychological investigation argues that the timing of the facial expressions is a critical factor in the interpretation of expressions. In the midterm, the objective is to add the system to the ambient intelligent applications that the group is developing, to enrich user interaction.

## 6. Acknowledments

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**Figure 9:** Comparison of the values taken by the distance  $D4$  for Caucasians and Asians.

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