Recognition of Human Face Expression

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Abstract. In this paper, a novel approach for the recognition of human face expressions has been presented. The presented approach has been successfully applied to detect 5 different human face expressions: smiling, laughing, sulky, confused and calm. Our method uses 3 distinguishing features of the human face for the recognition purposes. These features are the shape of the lips, the concavity of the upper and lower lip and the ratio of the distance from eyebrow to upper lip to the lip length itself.

1 Introduction

Communication changes the world rapidly. In addition to communication among people, communication between human and computers has been getting more important. Therefore, programmers are making interactive programs to use computers more effectively. All these developments increase the variety of data input methods to computers increase. Computers understanding voice and image and making suitable operations are now on the agenda in research areas.

In this study as a visual part of "computer–human communication", we realized a system which recognizes face expressions. The system determines that the expression of a person in a portrait image is whether smiling, laughing, sulky, calm or confused. It has been noticed that to comment about human face expressions, the human lips have the most determining feature. So, we decided to use the characteristics of the lips to make comments about expressions.

Section 2 describes the steps of human face expression recognition. Section 3 presents the criteria of decision.We exhibited experimental results in Section 4 where the computer makes comments about 24 bit color images. Section 5 concludes this study.

2 Recognition of Human Face Expression

When many images are examined carefully, it has been noticed that the human lips are the most determining part of human face expressions. Since the lips have a great

importance in human face expressions, in this work, we decided to use the lips characteristics to recognize face expressions.

Our proposed system consists of mainly 4 steps. Figure 1 summarizes these steps.

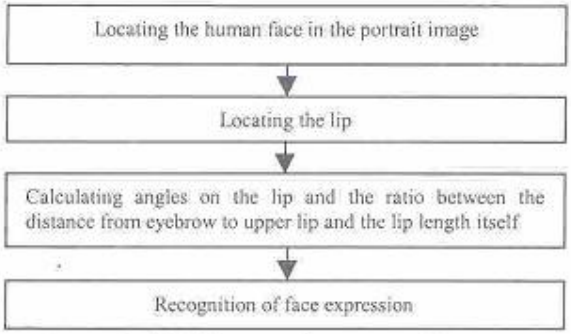


Fig. 1. The blockdiagram of our proposed system

2.1 Locating the Human Face in the Portrait Image

To find the lips, first the human face must be determined in the image. To this effect we defined the edges of the image and then located the human face in the image. Gray Scaling and Robert filters [1],[2] are used to detect the edges. After applying Robert filter, we scanned the image line by line. First, we located the top of the human face. Then the left and right edge were located. By using these 3 points we defined a square including the human face. These steps are shown in Figure 2.

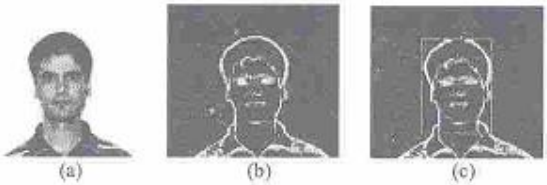


Fig. 2. (a) gray scaled image, (b) image with Robert filter applied, (c) image in which the human face is found

2.2 Locating the Lips

After locating the human face, it is obvious that the lips are to be found on the lower part of the face region. We benefited from the coordinates of the eyebrow in order to locate the lips. When the eyebrow is located then lips area is determined by using human face ratios. Vertical filters [3] and color adjustment method [4] are applied on this lips area. It has been seen that in the lips area there may be also other parts of face

except for the lips, for example some part of noise or chin. We then distinguished the lips from these unwanted parts and maintained the lips. The following 6 steps explain how the lips are located.

Step 1. Locating the Eyebrow

Since the face is symmetrical, it would be enough to locate only the left eyebrow. Gray Scale and Robert Directional filters [5] are used to make the eyebrow evident. Thresholding is also applied to translate the image in binary level. After applying thresholding, some noises may occur on the image. Simplification method is also applied on the image to remove these unwanted pixels from forehead area. In simplification method, 8 neighbours of each pixel are examined and if the number of white neighbours are less than 4, then this pixel is eliminated.

In order to locate the left eyebrow, we derived a beginning point to search using statistical results of eyebrow area on the face. (Figure 3). From this point, we searched downward a white area which present the eyebrow. Figure 4 shows the result of each step.

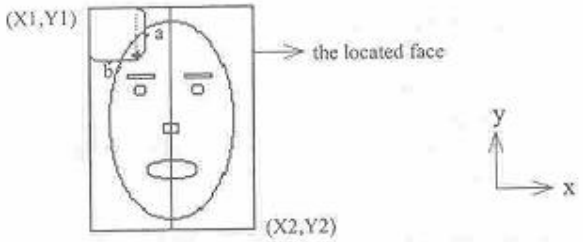


Fig. 3. The starting point to search the eyebrow, (x1,y1) and (x2,y2) coordinates show the beginning and ending points of the face rectangle

The equations of a and b are given in Equation 1.

$$a = y1 - (y1-y2) / 7 \text{ : The start line to search the eyebrow} \quad (1)$$

$$b = x1+(x2-x1) / 5 \text{ : The start column to search the eyebrow}$$

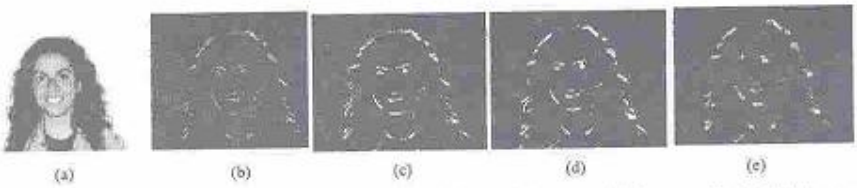


Fig. 4. **(a)** gray scaled image, **(b)** image with Robert Directional filter applied, **(c)** binary image, **(d)** simplified image, **(e)** image on which the eyebrow is found

Step 2. Locating the Lips Area

After having carried out measurements on a number of 207 face images, we obtained the relations[6] given in Equation 2 .

r : the distance from top of the face to eyebrow

a= 3/10*(y2-y1)	half of the the lips area length	(2)
b= (y2-r)*1/4	the distance between the eyebrow and the start line of the lips area	
c= (y2-r)*2.5/4	the distance between the eyebrow and the end line of the lips area	

Figure 5 shows the ratios on the face to locate the lips area.

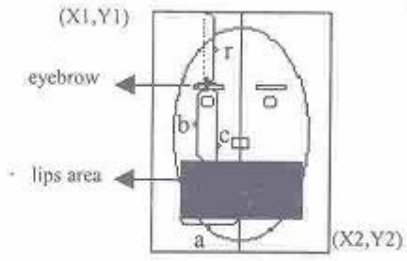


Fig. 5. Locating the lips area using human face ratios

Step 3. Applying Vertical Filter onto the Lips Area

Vertical filter [1],[2] is applied to detect the edges. It has been seen that only using this filter is not enough to comment effectively. So color adjustment method is also used to make the system success increase. Figure 8b shows images with vertical filter applied.

Step 4. Applying Color Adjustment Method onto the Lips Area

To detect the lips area using color adjustment method the pixels which are not in liptone color interval are eliminated.

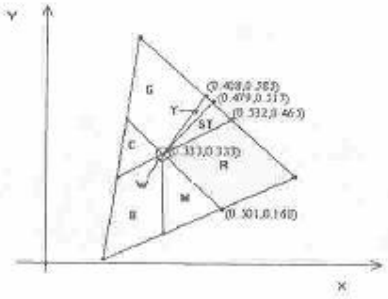


Fig. 6. Color Division in Chromaticity Diagram

The block diagram of the color adjustment method is depicted in Figure 7. The relations used on the transformations of the RGB values to xy coordinate system are

shown in Equation 3 [4]. Px and Py are the projections of RGB values in the xy coordinate system given in Figure 7.

$$Rx = 2.0*R+1.715*G+1.13*B \quad Ry = R+4.5907*G+0.0601*B \quad Rz = 0.0565*G+5.5943*B$$
$$D = Rx+Ry+Rz \quad Px = Rx/D \quad Py = Ry/D \tag{3}$$

The equations of the lines used in color adjustment method are in equation 4 [4].

$$Line_{Y\text{-}G}: y=3{,}36x-0{,}78588 \quad Line_{ST\text{-}Y}: y=1{,}260274x-0{,}086671$$
$$Line_{R\text{-}ST}: y=0{,}663317x+0{,}112116 \quad Line_{M\text{-}R}: y=-1{,}029762x+0{,}675911 \tag{4}$$

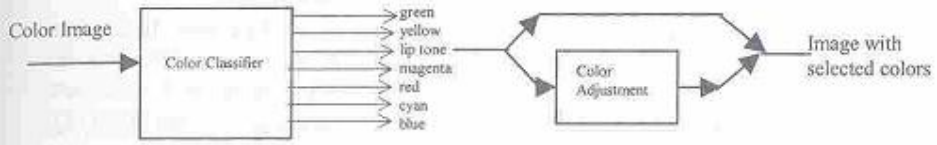


Fig. 7. Flow Chart of Color Adjustment Method

Since this method is very sensitive to light, to obtain a better result of lipshape, this method should be combined with the vertical filter's result. The results of color adjustment method are given in Figure 8c.

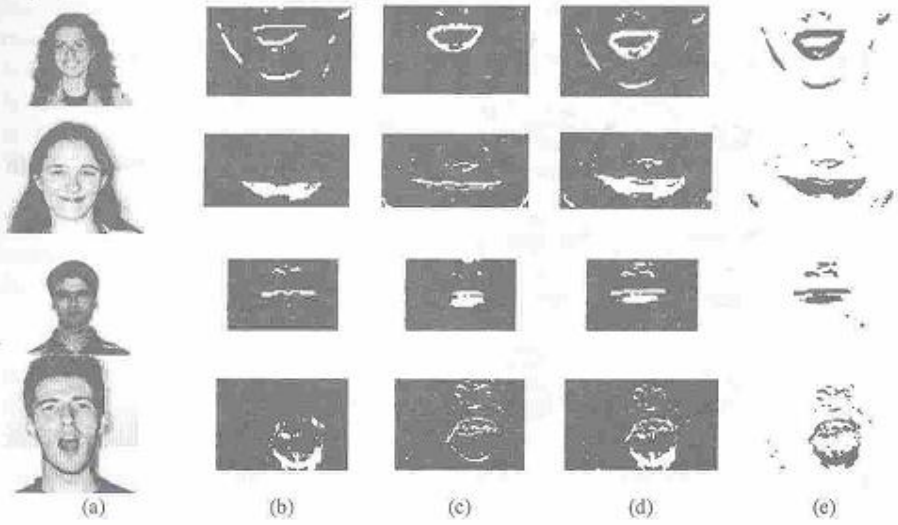


Fig. 8. Emphasizing the lips area using vertical filter and the color adjustment method, (a) original image, (b) image with vertical filter applied, (c) image with color adjustment method applied, (d) adding (b) to (c), (e) inverted image of (d)

Step 5. Combining Lips Areas from Color Adjustment and Vertical Filter

It has been observed that combining the output images of vertical filter and color adjustment method provides to emphasize the lips shape. Figure 8d shows the output

image after combining the vertically filtered image and color adjusted image. Figure 9e shows the inverse of this output image. The inverted image has been used in the following processes.

Step 6. Extracting the Lips from the Lips Area

In order to comment by using the lips shape, the lips should have the following three features.

- The lips should not be seperated: To provide this feature , the dilation algorithm [7],[8] is applied. Figure 10b shows dilated images.
- The lips should be in the form of one pixel: Thinning algorithm [5],[9] is applied to make the lips one pixel thick. Figure 10c shows thinned images.
- There must be no other part of face except the lips in the lips area: In the lips area, every independent pixel group is painted with different colors. This process is given in Figure 9. After painting, the number of pixels in each color are counted. All the pixels are eliminated except the dominating pixel color [10],[11]. Figure 10d shows only lips in the lips area.

Fig. 9. Painting independent pixel groups (Each number represents a different color)

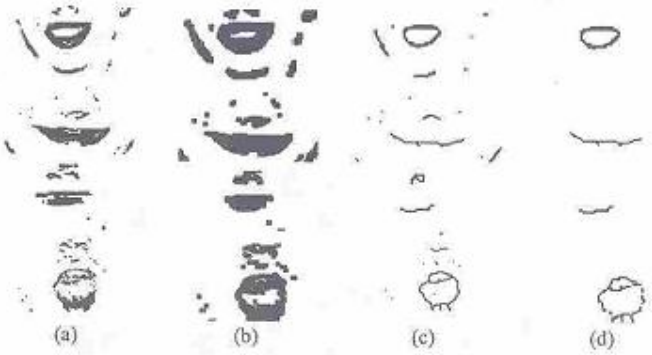


Fig. 10. Getting only the lips in the lips area, (a) added image, (b) dilated image, (c) thinned image, (d) only lips in the lips area

3 The Criteria to Define Face Expressions

Finally,we obtained the lips which only contain meaningful data. The comment is made according to the lips shape. The upper and lower concavities help us to define

the shape of the lips. First, the vertical minimum and maximum points are found, then the horizontal middle points are found. The upper and lower angles are between lines which unite these points. Figure 11 shows the upper and lower angles.

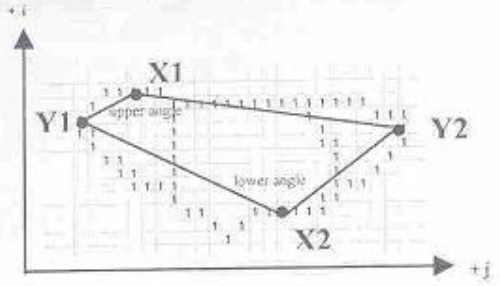


Fig. 11. Upper and lower angles

We proposed an algorithm to the selection of maximum and minimum points (X1,Y1,X2,Y2) can be seen in Algorithm 1.

Algorithm 1. The Selection of Maximum and Minimum Points

Step1 : Lips matrix is scanned from left to right and top-down. The middle point of first horizontal array which has at least (lips length /15)+2 pixels gives the horizontal maximum point (X1).
Step2 : Lips matrix is scanned from left to right and bottom-up. The middle point of first horizontal array which has at least (lips length /15)+2 pixels gives the horizontal minimum point (X2).
Step3 : Lips matrix is scanned top-down and left to right. The middle point of first vertical array gives the vertical minimum point (Y1).
Step4 : Lips matrix is scanned top-down and right to left. The middle point of first vertical array gives the vertical maximum point (Y2).
Step 5: X1 is eliminated, if (the row number of X1) < (the row number of Y1 or Y2)
X2 is eliminated, if (the row number of X2) > (the row number of Y1 or Y2)

After the appointments we have 3 or 4 points. If we have 4 points we calculate upper and lower angles, if X1 is eliminated, we calculate only lower angle. If X2 is eliminated, we calculate only upper angle. The calculating of angles is presented in Equation 5. Some examples of maximum and minimum points selection are given in Figure 12.

i : row number *j :* column number

$$\begin{aligned} \text{Lower Angle} &: \text{ArcTan}\left((X2_i - Y1_j)/(Y1_i - X2_j)\right) + \text{ArcTan}\left((Y2_j - X2_j)/(Y2_i - X2_i)\right) \\ \text{Upper Angle} &: \text{ArcTan}\left((X1_j - Y1_j)/(X1_i - Y1_j)\right) + \text{ArcTan}\left((Y2_j - X1_j)/(X1_i - Y2_i)\right) \end{aligned} \quad (5)$$

Images are then classified according to five different expressions. For each image lower and upper angle is calculated. In each expression angle set , some relations are defined, but it has been also observed that the angles are not enough to comment exactly. So one more criterion is also decided to use. This criterion is the ratio between the eyebrow-lips distance and the lips length. Combining these three criteria increases the sucess ratio. Algorithm 2 outlines the deduction process according to the given criteria.

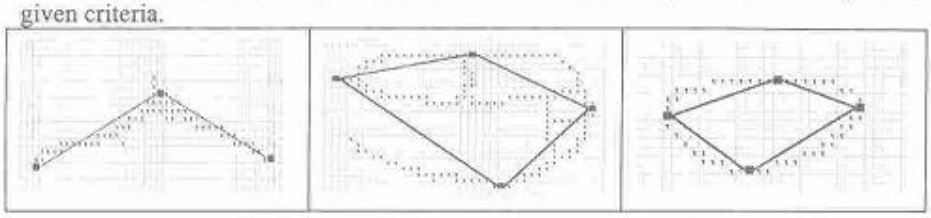


Fig. 12. Examples of maximum and minimum points selection

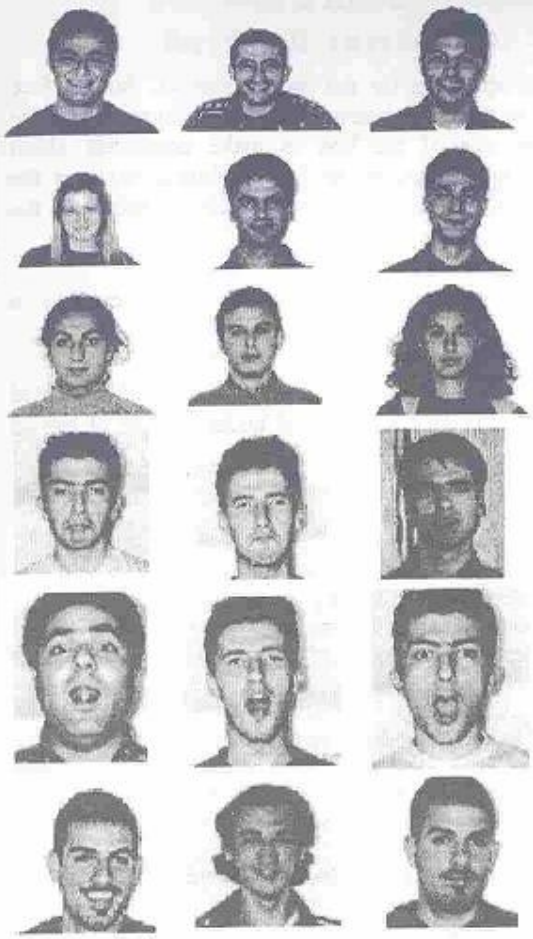
Algorithm 2:

upa: upper angle *lowa:* lower angle *ratio:* eyebrow-lips distance /lips length

```
If(125<=upa<180) and (100<=lowa<155) and (ratio<2) then
       expression=laughing
Else if (lowa<150) and (upa=0) then
        expression=smiling
Else if (upa<140) and (lowa=0) then
        expression=sulky
Else if (upa<=140) and (lowa<=120) then
        expression=confused
Else if ((130<=upa<165) and (170<=lowa)) or
        ((100<=upa<160) and (lowa=0))  then
        expression=sulky
Else if (ratio<=2) then
        expression=smiling
Else expression=calm
```

4 Experimental Results

The algorithm detailed in sections 2 and 3 has been implemented and run on 207 color images from five different classes of face expression. Figure 13 presents some samples of the classification results. The tutorial images are presented using 24 bit color images. The test results are given at Table 1.



(a) Laughing expressions

(b) Smiling expressions

(c) Calm expressions

(d) Sulky expressions

(e) Confused expressions

(f) Unsuccessful application samples

Fig. 13. Successful and Unsuccessful application samples, (a) , (b), (c),(d) and (e) show successful application samples from five different expression class, (f) shows unsuccessful application samples

The reasons of comment failures to images in Figure 13f are the following:

- the moustache unites with the lips
- the skin color is very close to red, so the lips can not be located efficiently

Table 1. Recognition rates for 207 different faces

	laughing	smiling	confused	Sulky	calm	Total
# of samples	40	50	33	32	52	207
# of successful samples	36	45	32	30	49	192
Success ratio (%)	90	90	96	93.7	92.7	92.7

5 Conclusion

In this paper, we presented a novel approach for the recognition of human face expressions. Since the human lips have the most determining feature to recognize the expressions, we used the characteristics of the lips to make comments about expressions. Using three distinguishing features of the lips combined increases the success ratio of the system. It provides a good basis for future research concerning the evaluation of face expressions.

Furthermore, in following studies other parts of face (eye, eyebrows etc.) in addition to the lips can also be used.

To the contrary of the common pattern recognition applications, the system presented in this paper is a challenging step towards the computerized understanding of human emotions.

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