Eyebrow Segmentation and Characterization using Energy Estimation and K-Means Clustering

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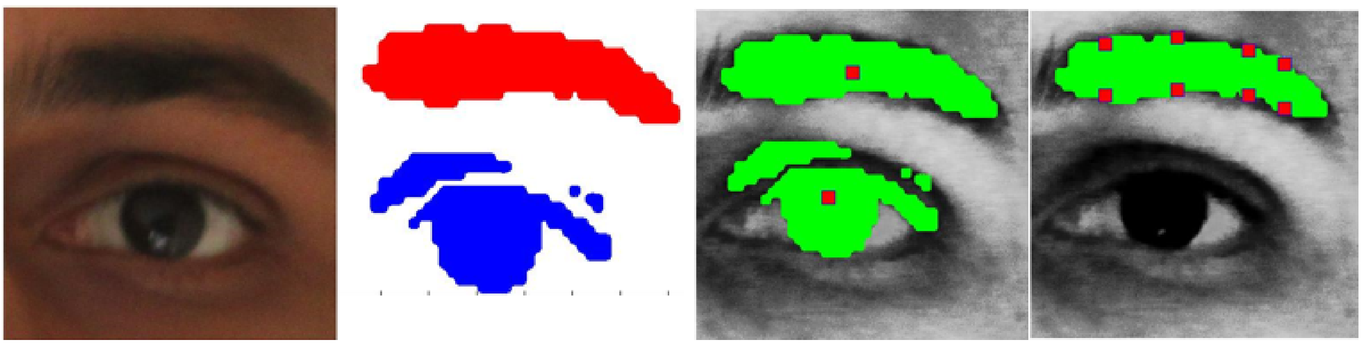

Fig. 1. Teasing result of our method to segment the eyebrow which uses windowed energy estimation followed by K-means clustering

***Abstract*—The eyebrow is an important feature point in a facial image. The data from a segmented eyebrow can be used as a cue for gender determination, mood analysis, facial expression recognition, non-verbal communication and biometric purposes. In this paper, we present a novel method to segment the eyebrow and characterize the state of the eyebrow based on the evaluation of a few key parameters such as thickness and archness of the eyebrow and distance of the eyebrow from the eye. Our technique involves obtaining a box containing the eye and eye brow region using Viola-Jones algorithm. We then segment out the skin region in this box by using the fact that the skin is abundant in its red component as compared to the eye and eyebrows. Further, we perform energy based thresholding to detect the darker regions in this box and then perform K-means clustering to obtain the best possible segmentation for the eyebrow.**

***Keywords*-Eyebrow Parameters; Segmentation; K-Means; Biometric; Facial Expression**

I. Introduction

In the area of facial feature point extraction, the eyebrow is one amongst several feature points such as nose, mouth, chin etc. However, most of the work pertaining to eyebrow segmentation deals with extraction of end points and does not utilise the valuable information provided by the shape of the eyebrow. This is possibly because the accuracy of segmented results is highly affected due to partial occlusion by hair, shadows around the eye etc. Nevertheless, the shape of the eyebrow is highly representative of emotions and gender and therefore can be used as an additional classification feature in the areas of gender classification and facial expression recognition and non-verbal communication.

A. Related work

In the area of eyebrow segmentation Y.Dong and D.L.Woodard [1] have conducted a study on the use of eyebrow as a possible feature in gender classification and for other biometric applications. And in [2] , they have gone onto devise a segmentation technique which employs adaptive image enhancement methods and modified level set algorithm. Radeva and Marti [3] proposed a model-based snake to segment eyebrow from a single facial image but this requires symmetric information from complete facial images. Other research efforts like [4] have used Binary Edge Images to get the perimeter of eyebrow block and use some geometrical transformations to segment the eyebrows. Other research efforts in eyebrow detection/segmentation include the work by Sohail and Bhattacharya [5] where the primary aim has been to locate the boundary points of various facial feature

B. Contributions

In this paper, we have first tried to express the information contained in the shape of the eyebrow in a quantitative form represented by 3 key parametric quantities which are as follows (1) Thickness (2) Archness (3) Distance from the eye. We have then developed a simple technique to segment the eyebrow region from which these parameters can been computed. Our method requires only an image containing the eye and eyebrow region and evaluates all results individually on each eyebrow. It does not require knowledge of both eyebrow regions as we do not use symmetry considerations. The results shown in this paper highlight the effectiveness of the parameters chosen in describing the state of the eyebrow and also the accuracy of our segmentation algorithm.

C. Technique Overview

The flow diagram shown in Fig. 2 describes the processes carried out to segment the eyebrow.

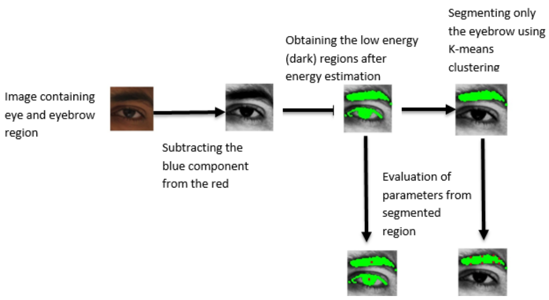

Fig. 2. Describes the process carried out

II. Organization

This paper has been organized in the following manner, in section III we describe the segmentation process and evaluation of parameters. In section IV some experimental results and explanations have been provided. Section V contains a discussion on some limitations of the methodology used and efforts to correct them, along with some possible areas of improvement. Section VI provides some concluding remarks.

III. Methodology

This paper has been organized in the following manner, in section III we describe the segmentation process and evaluation of parameters. In section IV some experimental results and explanations have been provided. Section V contains a discussion on some limitations of the methodology used and efforts to correct them, along with some possible areas of improvement. Section VI provides some concluding remarks.

A. Image Acquisition:

The eyebrow segmentation algorithm requires an input image which contains only the eye and eyebrow. Hence we can either feed it a direct image containing only the eye and eyebrow or another option would be to give a full frontal face image from which a coarse estimate for the eyebrow region as seen from Fig. 3 can be obtained by using the Viola-Jones [6] algorithm and Yu Shiqis [7] Eye Detection algorithm.

B. Segmentation of Skin using Chromic Imbalances:

From the coarse estimate obtained in the previous step, in order to get finer estimates of our region of interest we need to segment out the skin surrounding the eye and eyebrow. For this, we use the idea that the skin has high quantities of red component as compared to the eye and eyebrow region. This method works best for dark shades of eye and eyebrow and is less effective in segmenting for people with different eye colors (artificial lens colors such as blue, green, red). The resultant image after subtracting the blue component from the red is shown in Fig. 4 below . It can be clearly seen that the eye and eyebrow region stand out from the skin in the form of dark patches.

Fig. 3. If a facial image is fed then the eye can be extracted using Viola Jones algorithm otherwise eye image can be fed directly

Fig. 4. It can be clearly seen that the eye and eyebrow region stand out from the skin in the form of dark patches

C. Energy Estimation:

We need to select all dark patches from the image shown above and give it to the clustering algorithm which then selects the best dark patch which represents the eyebrow. For this we find that binarization does not give us satisfactory results. Hence we perform a 2-D energy computation to get these dark regions. We compute the average energy in every non-overlapping 8X8 box and we choose all those boxes whose average energy falls below a threshold chosen.

$$E = \sum \sum |a[m,n]|^2$$

From our experiments we observe that selecting the boxes which have lesser than 90 percent of the maximum energy of all boxes gives the best threshold value. The result of this process is as shown in Fig. 5 . The highlighted regions represent the dark portion of the image which satisfy the energy threshold set by us. This gives the possible clusters for the eyebrow.

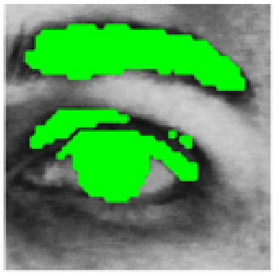

Fig. 5. The highlighted regions represent the dark portion of the image which satisy the energy threshold set by us. This gives the possible clusters for the eyebrow.

D. K-Means Clustering to select the exact contour of eyebrow:

K-means is a clustering tool to find clusters of comparable spatial extent, it employs a squared error criterion [8]. It partitions data into k mutually exclusive clusters S = s1, s2 . . . sk by minimizing the mean square distance from each data point to the cluster centre.

$$\text{argmin} \sum_{i=1}^{k} \sum_{x \epsilon S_i} ||x - \mu_i||^2$$

The K-means algorithm is given as follows [9] -
(1) Choose k cluster centers to coincide with k randomly-chosen patterns or k randomly defined points inside the hypervolume containing the pattern set.
(2) Assign each pattern to the closest cluster center.
(3) Recompute the cluster centers using the current cluster memberships.
(4) If a convergence criterion is not met, go to step 2. Typical convergence criteria are: no (or minimal) reassignment of patterns to new cluster centers, or minimal decrease in squared error.
We apply K-means clustering on the spatial data of the highlighted regions of the image shown in Fig. 5 to obtain two separate clusters as shown in Fig. 6. In most of the images one cluster represents the eye and the other cluster the eyebrow, due to the spatial separation between the eye and the eyebrow we can successfully segment out the eyebrow using K-means with K=2. The centroids are not initialized arbitrarily; instead we do it with one centroid initialized in the upper part of the image and one centroid initialized in the lower part of the image in order to ensure that the upper centroid clusters the eyebrow data points.

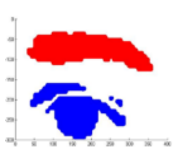

Fig. 6. shows the two clusters(Red and Blue) selected by the K-means algorithm. It can be seen that the eyebrow (always red cluster due to choice of centroid) forms an entirely separate cluster as compared to the eye region.

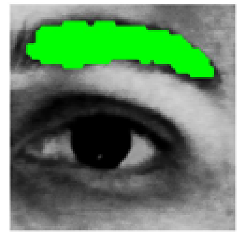

Fig. 7. shows the highlighting. Only the pixels contained in the red cluster which gives the eventual segmented eyebrow.

E. Evaluation of Parameters :

After the segmented eyebrow has been obtained like in Fig. 7, we need to compute the values of the various parameters (thickness, archness and distance from the centre of the eye) which characterize the state of the eyebrow. The values obtained for these parameters are relative to the image and need to be normalized with other feature lengths such as face width before being used for quantitative purposes.

1) Thickness of the Eyebrow: The thickness of the eyebrow is taken as the maximum difference in y-coordinates at the median of the x-coordinates in the segmented eyebrow. Men tend to have thicker eyebrows as compared to woman and hence this parameter can be used as classification feature for gender detection applications. The thickness for image in in Fig. 8. is shown below.

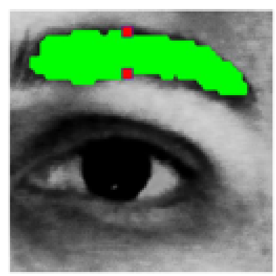

Fig. 8. The distance between the marked points indicates the thickness of the eyebrows. Here the thickness= 64

2)Archness of the Eyebrow: This parameter is used to indicate the degree of curvature of the eyebrow. We express this by computing two slopes of the two lines shown in Fig. 9. If the values are very low then that indicates flatness. If the signs of slope 1 and slope 2 are different then that indicates presence of an arch. If both are of the same sign then that indicates tilting or slanted eyebrows.The points for the line are chosen as the highest point at median along the length, highest point at median standard deviation along the length and the highest point at median + standard deviation along the length of the eyebrow. This parameter is again different in males and females with females tending to have more archness in their eyebrows.
3)Distance of the Eyebrow from the Eye: This parameter measures the vertical distance between the centroids of the eye and eyebrow clusters as shown in Fig.10 below.

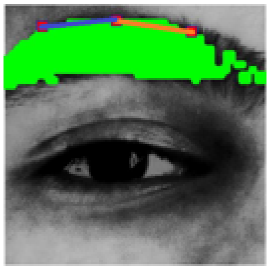

Fig. 9. The two lines whose slope is measured have been marked as blue (slope-1) and orange (slope-2) as an estimate of the archness. Here slope-1=.08 and slope-2=-0.15, the change in sign indicating presence of arch.

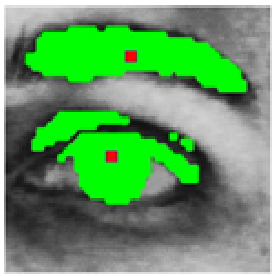

Fig. 10. The centroids of the two clusters were obtained after clustering using K-means. The vertical distance between these 2 points gives the distance between the eye and the eyebrow. Here the distance=149

This parameter can be used as a cue of an individuals facial expression and therefore has possible applications in the areas of facial expression recognition, as illustrated by the Fig. 11 below.

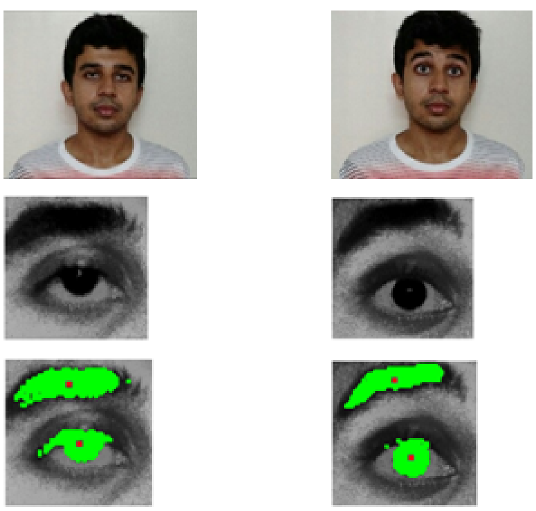

Fig. 11. The same person with different facial expressions.As we can see from the images, the vertical distance between the eyebrow and the eye changes with different facial expressions. Vertical distance between eye and eyebrow (for left image)= 163 and vertical distance between eye and eyebrow (for right image) = 206

IV. Experimental Results

For the block of test images shown in Fig. 12, the computed parameters are listed in the Table 1.

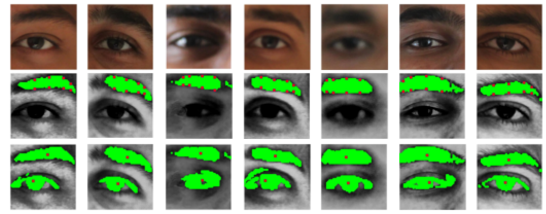

Fig. 12.

TABLE I
Results for various test images.

Sl.No	Thickness	Slope1	Slope2	Distance: eye and eyebrow
1	71	0.21	-0.08	168
2	85	-0.12	-0.37	160
3	79	0.09	-0.12	169
4	63	-0.16	-0.16	150
5	87	0	-0.08	160
6	79	0.08	-0.15	168.02
7	69	0.08	0.06	152

V. Limitations and Future Work

The limitations of this technique are as follows
(1) Partial Occlusion by hair
(2) Shadows in Eye Region which are shown in Fig. 13

The first limitation is because eyebrow and hair have similar chromic and textural characteristics and cannot be differentiated easily. The second limitation is a problem which is general to all image processing in the visible spectrum. For overcoming this limitation, care needs to be taken during image acquisition to ensure sufficient light falls on the region of interest.

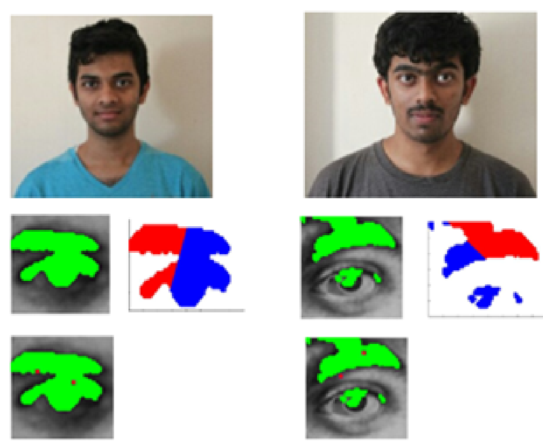

Fig. 13. The image on the left shows the error caused by eye shadows which is caused by insufficient light cast on the region of interest. The image on the right shows the error due to partial occlusion by hair

VI. Conclusion

This work presents a method to segment the eyebrow using energy based thresholding and subsequent clustering using K-means and also characterizes the state of the eyebrow using three quantifiable parameters. The results shown by our experiments are very encouraging and could also provide useful insights in the problems of gender classification and expression and emotion recognition.

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