Component Based Method for Face Detection using Fuzzy Membership Functions

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Summary
In this paper we address the problem of face detection in grayscale images. Before make candidates we calculate membership face components that influence to make more accurate answer and rejecting false positives in detection. The proposed method detects all candidate windows that has enough membership of face components. Eyes, eyebrows and Lip are organized to build fuzzifier membership functions using their pattern, distances of their location in 2D plan, and edginess of forehead.
α cut is used as defuzzifier and a parameter to achieve fuzzy based decision using empirical face features. A novel and simple fuzzy method for face detection using the face structural model is introduced. Due to using fuzzy membership functions for face detection, its rate using has increased over the original qualitative model for face detection. The experiments show promising results compared to the original structural method without using fuzzy.
Key words:
Fuzzy face detection, Fuzzy membership Function, Face Extraction.

1. Introduction

Detecting human faces in images are essential for intelligent vision-based systems and human computer interaction. The research efforts in face processing include face tracking, face recognition, pose estimation and expression recognition. Although, there are many powerful methods for face detection with neural network, fuzzy logic, SVM, … they are more complicated than simple methods such as template matching, skin color, etc.
In this section, we briefly review existing techniques proposed for face detection. These methods can be classified into four categories; some methods clearly overlap category boundaries and are discussed at the end of this section.
Here a knowledge-based method in which the human knowledge of what constitutes a typical face is employed. Usually, the rules which are utilized for detection of faces capture the relationships between facial features. These methods are designed generally for face localization.
Feature invariant approaches (facial features, texture, skin color, etc). These techniques, which are designed mainly for face localization, try to find structural features that remain utilizable even when the viewpoint, pose, or lighting conditions vary.
Template matching methods (predefined face templates, deformable face templates) mainly describe the face as a whole. For this aim, several standard patterns of a face are stored to consider the facial features independently. The correlations between an input image and the stored patterns are calculated to determine existence of face in image. These methods have been utilized for both face localization and detection.
In contrast to template matching techniques, Appearance-based methods (eigenface, distribute based, neural network, Fuzzy logic, SVM, etc) are learned from a set of training images which indicate variability of appearance of face. For detection of faces these learned models are utilized. Application of these methods are mostly for face detection.[1] [2]
Comparing with the template matching techniques where the templates are determined by experts, examples are used to learn the templates in appearance-based methods. Generally, to find the relevant characteristics of face and non-face images, appearance-based methods utilize techniques from statistical analysis and machine learning. The learned attributes, which are used for face detection, are in the form of distribution models or discriminated functions. For the sake of computation efficiency and detection efficacy, dimensionality reduction is usually accomplished.
Yachida et al. presented a method based on fuzzy theory to detect faces in color images [3], [4], [5].in their work for explanation of skin and hair color distribution in CIEXYZ color space, two fuzzy models are used. Five head-shape models including one frontal and four side views are used to describe the appearance of faces in images.

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In [4] two fuzzy models are built to describe skin color and hair color, respectively. These models are used to extract regions in an “unknown” image. Afterward, using a fuzzy pattern-matching method, these regions are compared with a head-shaped model.
Briefly, the technique proposed in [6] is composed of the sequential floating search methods, using tolerance-based fuzzy distance as criterion [7].The membership value of each pattern were defined as being inversely proportional to the distance between it and the prototype of its class. In [8] the standard deviation of pixels intensity is utilized as a fuzzy membership function to help the algorithm for detection of faces. Moreover, existence of lips and eyes in their corresponding regions are determined by two fuzzy membership functions. Finally, for decision making, a fuzzy based decision rule is employed.
In this approach we defined the prototype of a class as the mean vector of its training samples. Depending on similarity of face component in candidate region to the trained mean vector from database, membership function of related face component choose greater or lower value which indicates possibility of being member of current class (face component). After computing all of the membership values in the region of interest, fuzzy based decision rule is used to determine The face whether to be in the area or not. Rest of paper is organized as follows: in section 2, using of fuzzy theory in problem of face detection, including calculation of fuzzy membership function of each face component and fuzzy decision rule, is presented. In section 3, an experimental result for proving the efficiency of algorithm is given. Finally, Section 4 includes conclusion of the paper.

2. Face Detection in Aspect of Fuzzy Theory

2.1 Fuzzy Membership Function Using Face Component

Human faces have symmetric properties which changed in different conditions. These conditions depend on lighting conditions, position of the face in front of the camera, orientation, and rotation. A major challenge between researchers is to solve the face detection problem and then how to express the idea with a computer program.
Considering images of faces, it reveals that many face properties, such as edge intensity in different regions of face components such as Eyes, eyebrows, and lips have geometrical horizontal distributions. Forehead has lowest edge intensity in comparison with all of face components and in aspect of location of face parts; there are certain distances between all of face components. However, some uncertainties still remain in the afore mentioned methods that drove us to make use of fuzzy logic decision theory as a more reliable method for solving the problem.. We offer a main face’s edge matrix. This matrix is the average of face photos edges database.
Shortly, in the first stage of this algorithm, a window with specific size moves on the input image to determine the region of interest as a rectangular area. In the determined region, after normalization of intensity, membership value of each of the face components is computed. After that, existence of the face in the area according to the fuzzy decision is determined. Then the moving window slips on the whole of the image to detect other faces.
For more in-depth understanding of the issue, let’s have a detailed observation on the algorithm.
Before running the algorithm, some quantities are calculated including EMX, which is a matrix composed of average of edginess of faces, and average value of edginess in forehead, eye, lip and eyebrow regions. Edginess of an image is a matrix in which the pixels with higher intensity indicate maximum possibility of edge existence.
To achieve a more detection rate and reduce amount of calculations, we reject the searching regions with their edginess intensity out of the face edginess range. The range of face edginess is calculated by close-up face images database including two quantities which stand on the restriction of edginess in face regions. These two quantities are used as threshold for elimination of non-face regions.
Fuzzification is another part of the algorithm. Membership functions are used to model the human knowledge about faces into mathematical expressions.
The membership functions which we utilized in our approach are listed as follows:

$$E(i) = [I[x\,,y\,]] \qquad i = 1,2,3,\ldots,p \tag{1}$$

$$0\langle x\langle m,\ 0\langle y\langle n$$

$I[x,y]$ which is equal to m*n is the number of all of pixels in image.

$$E^{*}(i) = \nabla^{2}\bullet\left(E(i)\right) \tag{2}$$

Left side of eq.2 indicates image Laplacian in i^{th} pixel.

$$\tilde{E}^{*}_{1\times mn} \xrightarrow{\mathrm{Re}\,shap=\Gamma} \Gamma\left(E^{*}\ (i)\right)_{1\times mn} \tag{3}$$

Eq.3 shows converting of an m by n matrix into a 1 by m multiply n vector. This conversion will be used in future equations in this paper.

$$\begin{cases} \overline{\Theta}_{1\times mn}(i) = \tilde{E}^{*}_{1\times mn}(i) \\ \left\{ x,y \mid 0<x<7,\ 0<y<6,\ x,y \subset I_{Eye,Eyebrow}[x,y] \right\} \end{cases} \tag{4}$$

$$\begin{cases} \overline{\Theta}_{L_{1\times mn}}(i) = \tilde{E}_{Left\ Eye}{}^{*}{}_{1\times mn}(i) \\ \overline{\Theta}_{R_{1\times mn}}(i) = \tilde{E}_{Right\ Eye}{}^{*}{}_{1\times mn}(i) \end{cases} \quad (5)$$

$$\mu_{Pairwise} = e^{-\left(\left| \frac{\frac{1}{p'}\sum_{a=1}^{p'} \left| \overline{\Theta}_{L_{1\times mn}}(a) - \overline{\Theta}_{R_{1\times mn}}(a) \right|}{\frac{1}{p}\sum_{k=1}^{p} \overline{\Theta}_{1\times mn}(k)} \right| \right)} \quad (6)$$

Eq. 6 indicates the membership function for symmetry property of the face images which named $\mu_{Pairwise}$. In Eq. 6, $\overline{\Theta}_{L_{1\times mn}}(a)$ and $\overline{\Theta}_{R_{1\times mn}}(a)$ are mean of eye edginess from Left eye and right eye, respectively.

The nominator of the power of exponential calculates the amount of symmetry in eye region. And the denominator of the fraction refers to the special edginess of image in eye region.

Membership functions for lips are as follow.

$$E_{Lip}{}^{*}(i) = \left[\nabla^2 .\, I_{Lip}[x,y] \right] \quad i = 1,2,3,\ldots,p'' \quad (7)$$

$$\left\{ x,y \middle| \, 0 < x < t,\, 0 < y < s,\, x,y \subset I_{Lip}[x,y] \right\} \quad (8)$$

$$\mu_{Lip} = e^{-\left(\left| \frac{\frac{1}{p''}\sum_{w=1}^{p''} \left| \mathbf{E}_{Lip}{}^{*}(w) - \eta(w) \right|}{\frac{1}{p}\sum_{k=1}^{p} \mathbf{E}^{*}(k)} \right| \right)} \quad (9)$$

$$\eta = \frac{1}{ts} \sum_{x=0}^{t} \sum_{y=0}^{s} I_{Lip}{}^{*}[x,y] \quad (10)$$

Eq.10 shows computing of the mean value of lips laplacian pixels in our face database. This amount is used in eq.9. As eq.9 indicates, for near value of pixels in lip region to the corresponding value in face database, left side of eq.9 is near to 1.

For eye and eyebrows

$$E_{Eye,Eyebrow}{}^{*}(i) = \left[\nabla^2 .\, I_{Eye,Eyebrow}[x,y] \right] \quad (11)$$

$$i = 1,2,3,\ldots,p'''$$

$$\left\{ x,y \middle| \, 0 < x < m,\, 0 < y < n,\, x,y \subset I_{Eye,Eyebrow}[x,y] \right\} \quad (12)$$

$$\mu_{Eye,Eyebrow} = e^{-\left(\left| \frac{\frac{1}{p'''}\sum_{z=1}^{p'''} \left| \mathbf{E}^{*}_{Eye,Eyebrow}(z) - \xi(z) \right|}{\frac{1}{p}\sum_{k=1}^{p} \mathbf{E}^{*}(k)} \right| \right)} \quad (13)$$

$$\xi = \frac{1}{m.n} \sum_{i=0}^{m} \sum_{j=0}^{n} I_{Eye,Eyebrow}[x,y] \quad (14)$$

Similar to the eq.9 and eq.10, eq.13 and eq.14 indicates the membership functions of eye and eyebrows.

For forehead the membership function is given as follow:

$$E_{Forehead}{}^{*}(i) = \left[\nabla^2 .\, I_{Forehead}[x,y] \right] \quad (15)$$

$$i = 1,2,3,\ldots,p^{(4)}$$

$$\left\{ x,y \middle| \, 0 < x < k,\, 0 < y < l,\, x,y \subset I_{Forehead}[x,y] \right\} \quad (16)$$

$$\mu_{Forehead} = e^{-\left(\left| \frac{\frac{1}{p^{(4)}}\sum_{q=1}^{p^{(4)}} \left| \mathbf{E}^{*}_{Forehead}(q) - \gamma(q) \right|}{\frac{1}{p}\sum_{k=1}^{p} \mathbf{E}^{*}(k)} \right| \right)} \quad (17)$$

$$\gamma = \frac{1}{kl} \sum_{i=0}^{k} \sum_{j=0}^{l} I_{Forehead}[x,y] \quad (18)$$

Since forehead of human is a smooth region in images, its edginess has a low value.

As previously mentioned, we calculate a matrix from face's edge database photo by averaging. Edge matrix involves 0, 1 value which is called edge matrix (EMX), we multiply EMX to Averaging matrix of edginess that we called (AM). Summation of matrix elements indicates the distance of face components.

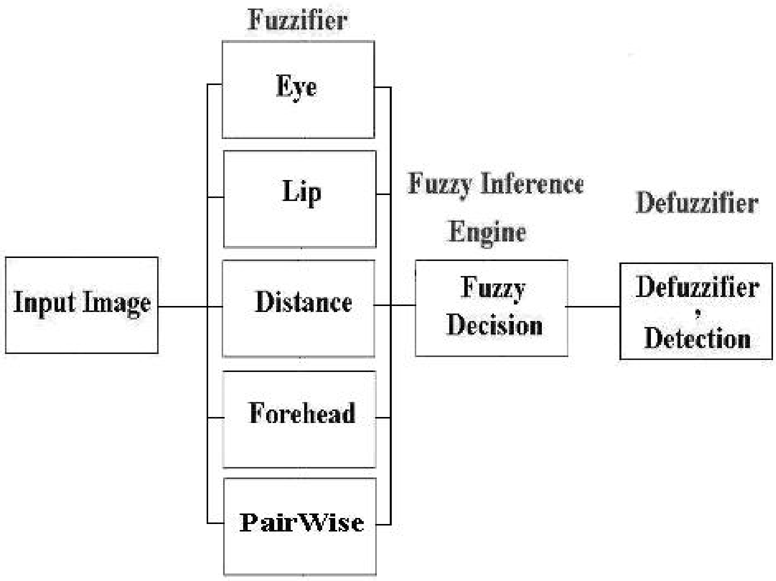


Fig. 1, Flowchart of proposed method: The face components vastly utilized for fuzzication, Fuzzy decision discriminates between faces and non-faces, and Defuzzification and outcome detection is performed by α cut.

$$\mu_{Distance} = e^{-\left(\left| \frac{\frac{1}{p^{(5)}} \sum_{c=1}^{p^{(5)}} \left| [EMX(c)] \bullet [AM(c)] \right|}{\frac{1}{p} \sum_{k=1}^{p} \mathbf{E}^{*}(k)} \right| \right)} \quad (19)$$

Decision part is the last part of the algorithm. In this approach clauses and decision step calculate forehead evaluation and increase face detection statistically, but lack of forehead evaluation doesn't prove non existence of face because in some photos forehead was covered by hat, hairs, etc. The following formula returns the final decision:

$$\mu_{Decision} = \min\left(\mu_{PairWise}, \upsilon \right) \quad (20)$$
$$\upsilon = \min\left(\mu_{Distance}, \delta \right)$$
$$\delta = \max\left(\mu_{Forehead}, \varpi \right)$$
$$\varpi = \min\left(\mu_{Eye}, \mu_{Lip} \right)$$

2.2 Defuzzification

Also, we can use forehead as an important clause for face detection. This method increases accuracy but it results error for covered foreheads. In defuzzifier step, we indicate a certain point as detected faces. We calculate value with threshold empirically.

$$V_{\alpha} = \left\{ y \in V \middle| \mu_{B'}(y) \geq \alpha \right\} \quad (21)$$

$$y^{*} = \frac{\int_{V_{\alpha}} y\, \mu_{B'}(y) \quad dy}{\int_{V_{\alpha}} \mu_{B'}(y) \quad dy} \quad (22)$$

Our proposed approach is illustrated as a flowchart in figure 1. Where input image entered in a fuzzy decision algorithm upon face components.

3. Experimental Results

The training section required training database from faces in various lighting and pose conditions. Mentioned database obtained from 217 images taken from 31 people at 7 different viewing angels and different lighting conditions for training in our approach. The image resolution in the database is 320*240 pixels.

Table 1, T he accuracy of proposed method

Number of Photos	Number of Faces	Detection Rate	Rate of False Positive	Rate of False Negatives
46	305	290	176	15

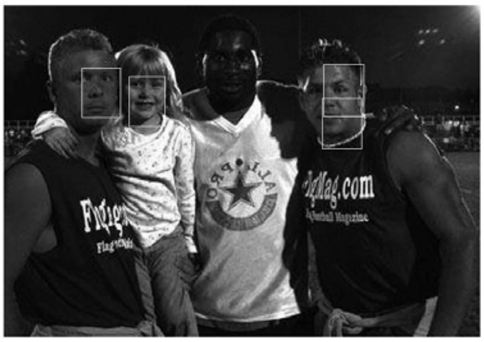
According to the results of the mentioned method, face detection using fuzzy membership function published in table 1, the conclusion can be drawn from it; the number of images used for experimental results are 46. These photos are collected as database which comprises images under different lighting conditions, different poses, and orientations. Some of mentioned images of database are attained from internet and other from personal photo album gallery. Whole numbers of faces in our test database are 305 faces. Furthermore, these faces have taken in different situations and various subjects as sport players, social and personal photos. The proposed approach detected 290 faces from entire faces which exist in test database.

Also, there are some detected areas which are not face called false positives. The proposed method detects noteworthy regions in error (about 176 regions). It is noticeable that false positives frequently occurred in images having cluttered areas as trees, some regions with same edginess, etc. Figure 2 depicts some photos having false positive.

Fig. 2, Some false positives are indicated

In contrast, some faces in some photos aren't detected. These errors named false negative. The rate of false negative in our database is 15 through 46 image database.

It is considerable that severe lighting conditions, some poses, and some nationalities are the most influential causes to create false negatives. It can be appeared in figure3. False negatives occurred for African American, sever lighting conditions, and covered foreheads.



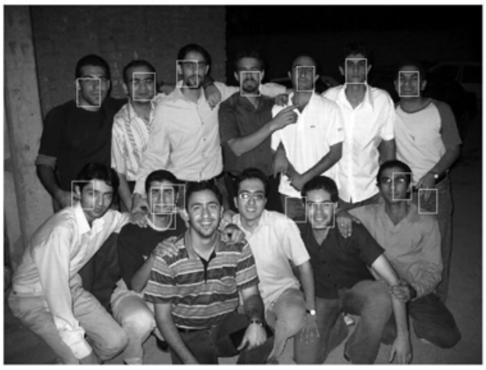


Fig. 3, Some false negatives indicate that African American, sever lighting conditions and abnormal pose aren't extracted.

The proposed method has acceptable results compared to other similar methods. Perhaps, there are some methods which have better accuracy but mentioned approach can be considered a rapid technique for face detection. However, It can be modified to obtain better accuracy.

A ROC (Rate of Correct detection) curve, which shows the performance of our detector on our data base, is shown in Figure 4. To create the ROC curve the Threshold of the symmetry is adjusted from 80 to 100. Increasing the symmetry threshold, both of correct detection rate and false positive rate grow up.

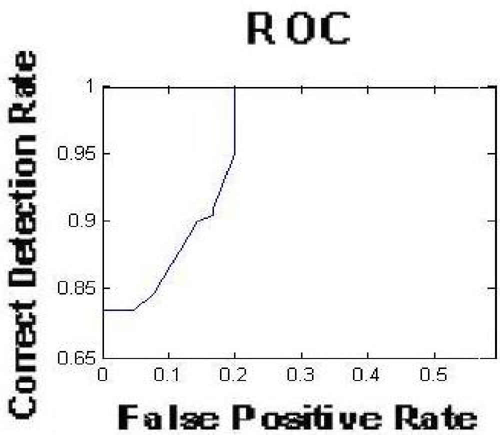


Fig. 4 ROC graph represents the rate of correct detection for mentioned data base which is utilized for our approach.

5. Conclusion

The proposed method indicates a reasonable detection rate over the testing data, even with normal and relatively abnormal images. Due to using of distance membership function, sensitivity of algorithm to detect different poses of human face is reduced, which is a promising point in other method. This improved rate of accuracy, speed to detection of faces and consequently leads to promising results.

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