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Face Detection Approach Based on Fuzzy Logic and GST

Arash Kiani Zain Abad[1], Mostafa Asghari Pile Savar[2] and Vahid Rostami[3]

[1] **Faculty of Computer and Information Technology Engineering, Qazvin Branch, Islamic Azad University,Qazvin,Iran**
A.Kiani@Qiau.ac.ir

[2] **Faculty of Computer and Information Technology Engineering, Qazvin Branch, Islamic Azad University,Qazvin,Iran**
MostafAsghary@gmail.com

[3] **Faculty of Computer and Information Technology Engineering, Qazvin Branch, Islamic Azad University,Qazvin,Iran**
Vh_Rostami@yahoo.com

Abstract

This paper proposes a fast and confident approach to face detection. Initially we detect and segment the regions of image with human skin color. The regions with similar features are merged in order to generate a bigger region. Following the extraction of each region's features, the resulted data is given to the fuzzy system trying to determine regions which are most likely to belong to skin. After performing preprocessing, the regions with highest possibility of containing face are examined and similar regions are merged to generate a large region. After segmenting the face regions of image, the regions are divided into two categories of face and non-face by applying the Generalized Symmetry Transform (GST) algorithm. The results prove that new algorithm not only runs relatively fast but also provides an improved performance.

Keywords: *Face detection, edge detection, fuzzy logic, Generalized Symmetry Transform (GST), Image segmentation*.

1. Introduction

The human face processing algorithms such as face feature extraction and face detection are of crucial importance and have various applications. Lots of applications depend on the size and position of the face in the image. Most of the real-world applications rely on face size and position estimation methods. Generally two issues should be considered in face detection area: detection rate and speed; which are closely interrelated. Different algorithms are attempting to keep a balance between speed and calculation time. Yang et al. [1] and [2] are admirable instances of old methods with optimized calculation time. As another example, Gatomokal is a face detection system which is capable of real-time face detection in colorful video streams. In this system, after segmenting face color, PCA [3] is incorporated into determination of whether a specific region belongs to face skin or not.

The [4] was a background for AdaBoost which used the inseparable face concept for face detection. They proposed two-class AdaBoost training algorithm for efficient classification training and cascading for elimination of non-face images.

The [5] proposed a face detection approach in gray-scale images which detects regions similar to eye which are the same size as real eyes with darker color compared to surrounding regions. Assuming there are eyes in the given face, a pair of eye regions (eye scalable) is selected. In case of matching the position of selected regions with human face’s characteristic, they are declared as eyes.

The [6] after adjusting the color of input images and crooked face; straightened the skewed corners of the mouth and determined the discriminating function for specifying the position of the eyes. The [7] and colleagues applying the conditional distribution of brightness of the skin color information and using the image correction process, extracted and drew a modeled rectangle around the skin area. Finally they applied an adaptation framework by means of linear transformation in each rectangular area of skin for face detection.

Classifier neural network is widely used in face detection, mostly while face is in the center of the image.

Rowley [8] and his colleagues presented a neural network-based face detection system, a corneal connection (depending on the retina) neural network to verify the small windows of the image and decide which window contains human face. Mansour [9] et al proposed a face detection algorithm based on light control, techniques for detection and classification of skin color. Their approach detects the face rectangle that contains eyes and mouth and areas coming from skin detection process using color segmentation. Then it analyzes all features that might be the face (eyes and mouth) and ensures the determination of rectangle containing eyes and mouth by using a neural network.

Commonly used cascade-based face detection techniques such as the ones given by Viola and Jones [13] only coarse face detection results.

Aforementioned algorithm works without usage of skin color and different pixel in successive frames. In fact it grids the image into blocks including 32*32 pixels, (Considering the fact that the smaller blocks results in higher computational cost). Each block is evaluated using NN based method. This algorithm is fast enough; nevertheless it generates high number of false positive results.

In [15] face detection process is divided into two steps, which are named root and parts step respectively. It is also a cascade based algorithm. In first step a linear SVM is applied in order to detect eyes and mouth using frequency features. The sizes of blocks are 72*60 pixels. In second step an SVDD (support vector data descriptor) is used in order to distinguish face from non-face regions with blocks in size of 36*30 blocks. Even though the second step is slower than the first one, yet the reduction of the number of blocks in the first step, improves the overall performance of the algorithm. The performance of the method is defendable only in high-resolution images with faces bigger than 80*80 pixels.

The algorithm described in [14] incorporates the color of face skin. The aforementioned step is followed by thresholding method in outdoor and indoor environments using the HSV color space. The resultant image is converted into binary image which makes it simple to distinguish regions with face skin color from other ones. The binary image is enhanced to benefit next step which applies Point of Interest to count the interesting points. If the number of interesting points inside a region falls between the minimum and maximum threshold, it is detected as face with indication of a Bounding Box.

In [10] the authors illustrate their motivation of using the Generalized Symmetry Transform (GST) for detected location of eyes and mouths in image. They are extracting the features from image and using SVM to find skin section of picture. They also applied motion detection and then used horizontal adjustment to find symmetry of segmented region. At the end, they used a GST algorithm to verifying that whether the region is a face or not. A lot of research work has been done in the field of face detection. Some areas of study have attempted to convert images into smaller windows separated by application of GST algorithm to decide whether or not window contains a face. However, the above calculations in the number of regions and issues of adaptive network topology have limited its use. In some cases, these problems may result in high complexity. For example, if we use the neural network to find the faces in the input images without any prior knowledge, the calculation will be very heavy and will take long.

And also when using a GST [10] without any pre-processing, it takes longer to find symmetry of each region in the image.

The basic problem is to reduce the calculation cost by pre-processing steps. The number of regions given to the symmetry system, to a great extent will lead to less computation. This pre-classification is of considerable importance because if the rule base is too complex, some of the faces in the image might be ignored.

In our approach, we delete some non-face regions using an inference engine developed by a set of flexible rules and also applying a few simple and reliable features. Consequently, number of regions given to symmetry system is decreased.

The aforementioned fuzzy system has removed some of non-face regions, so number of regions proposed to symmetry system has decreased. Figure 1 shows the block diagram of the proposed system. As it is illustrated, the input of the system is provided with color images, and after segmentation the color space is divided into skin and non-skin segments.

In the pre-classification step, a small number of simple and reliable features are being extracted for fuzzy inference engine.

If the result of fuzzy inference engine indicates the existence of face in the current region, so the region is sent to symmetry system for making final decision.

The output of system displays the detected face in the image. In section II, the image segmentation is described. In section III, the proposed fuzzy system is described. The facial symmetry system is explained in Section IV. Our experimental results are presented in Section V and finally Section VI provides the conclusion.

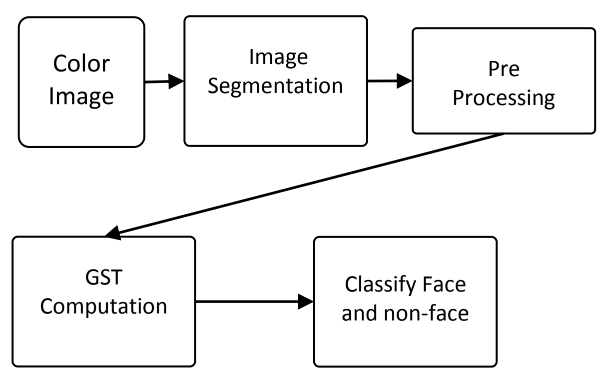

Figure 1: The presented face detection approach

2. Face Region Detection

Firstly, some regions of color images which are the input of the system should be removed to reduce the search space. By using Bayesian methods, the skin or skin like regions are separated from non-skin ones. To model skin color, skin samples from 50 thousand randomly

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selected individuals from various ethnic groups are provided through internet. Then, using Chromatic color space, the light intensity can be removed through normalization process with the following formula:

$$r = \frac{R}{R+B+G}, g = \frac{G}{R+B+G}, b = \frac{B}{R+B+G} \quad (1)$$

Figure 2 (left) shows the distributed skin samples of the Chromatic color space. This distribution could be modeled based on Gaussian distribution with following parameters:

$$m = E(x), c = E\left((x,m)(x,m)^T\right), x = (r,b)^T \quad (2)$$

Where m is mean, and c is the covariance and vector x is a value of r and b.

Using Mahalanobis measurement, regions of the image having a color closer to the color of the skin are identified which is shown in formula 3.

$$S(r,b) = \exp[-0.5\,(x-m)^T c^{-1} (x-m)] \quad (3)$$

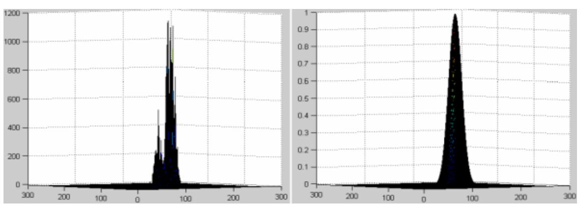

Figure 2: distributed skin samples of the Chromatic color space (Left) Distribution of skin samples in chromatic color space and (right) their Gaussian distribution model

The output of S is between 0 and 1 that shapes a binary image. You can see the result in figure 3.

After this step, the distance of each region from other ones is examined and if this distance is less than a threshold value (10 pixels); these regions are merged into each other.

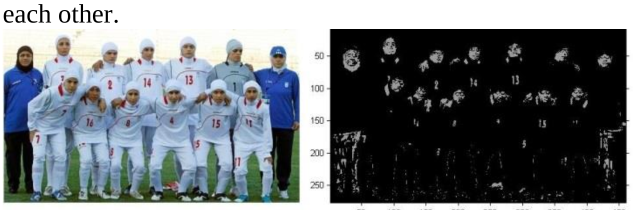

Figure 3: Found the skin like region (left) original image (right) the result of or skin like regions

3. Design of Fuzzy Inference System

Image Segmentation in the previous step, separated the skin and non-skin regions from each other. Now we need a fuzzy system to classify these regions as face or non-face. In order to reduce the computation of the system, a fuzzy inference engine, which we call it the pre-classifier, is used. First, we extract some features from each region. At the next level, a fuzzy inference engine based on output of the previous step determines that which regions are more likely to be face.

3.1. Region features extraction

First, the regions received from classification step are converted into binary regions. If the area of the region is smaller than fifteen pixels, it will be removed. Features involved in the decision are: the number of holes in one region and the ratio of length to width of the region.

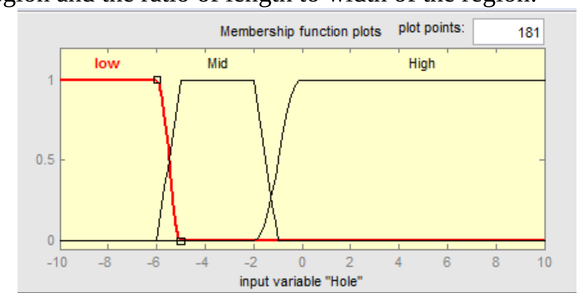

Figure 4: Membership function for number of Hole

3.2. Pre-classification: a fuzzy inference engine

After extraction of relevant features, the data will be given to fuzzy inference engine to make final decision on whether or not this region contains face. You can see the rules in table 1.

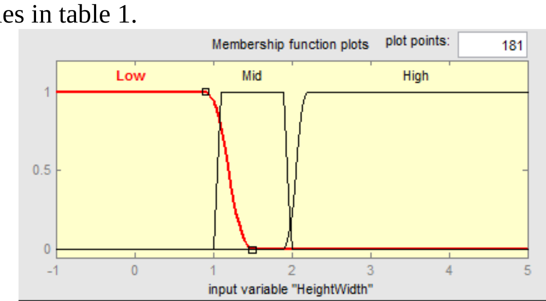

Figure 5: Membership function for the ratio of length to width of the region

4. Human Face Verification

4.1 Localization of human face based on the geometric features

The aim of facial feature localization is to locate eyes and mouth. Because the features of nose are not robust, we do not localize nose. With the locations of eyes and mouth, human face can be more precisely localized. Generalized Symmetry Transform (GST) [11] is a method to describe symmetry of points. Since the centers of eyes always have

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the highest symmetry in human face, we can use GST to locate eyes. Because this method only uses the biometrics distribution features of human face, it is more robust than some other methods under the variation of illumination, pose and expression.

In our proposed method, Firstly we applied color analyze and fuzzy interference engine based on number of holes and height and width proportion in order to eliminate regions which are least likely to be face regions. Aforementioned pre-classification processes are followed by GST based algorithm proposed in this paper.

Table 1: Fuzzy inference engine rules

If		**Then**
Hole	Height/Width	Is Face?
L	L	F
L	M	T
L	H	F
M	L	F
M	M	T
M	H	F
H	L	F
H	M	F
H	H	F

4.2. Algorithms of locating eyes and lips

GST and its extended methods, such as Direction Symmetry Transform and Discrete Symmetry Transform, have already been used in analyzing face images [12]. But the existing methods are computationally time-consuming. The reason of this trouble is that different dimensional factors will detect different symmetry centers. In another word, a specific dimension factor can only detect symmetry centers whose dimension is similar to it. So if we use the size of eyes as σ, we can find the centers of eyes. Because no dimension information is known in these existed methods, they have to compute in a large range of dimension. But in our method, the size of eyes can be estimated according to the face detection results, so it only needs to compute in a small range of dimension. Experiment results show that the suitable range is 1/12–1/10 of the width of face image.

The following three steps can localize eyes in a grayscale face image. Firstly, we use Canny operator to detect edges of the gray image (see Fig. 6(b)). The processing result is an edge image (see Fig. 4(b)). Secondly, the symmetry of every point in the edge image is calculated by GST (see Fig. 7). You can see that the best thresholding value is 0.5 for this dataset. In the process of calculating symmetry of every point, there is a problem like the bound effect in convolution. It is how to calculate the symmetry of points whose distances to the bound of the face image are smaller than σ. Since eyes seldom locate in this boundary region, we can set 0 as the symmetry of these points and do not need to calculate their symmetry. Thirdly, 4–7 points with the highest symmetry are selected to locate the centers of eyes. The exact number of selected points is determined based on experimental experience. If too few points are selected, they may locate in the region of one eye. If too many points are selected, some points with high symmetry, which are not in the regions of eyes, may also be selected.

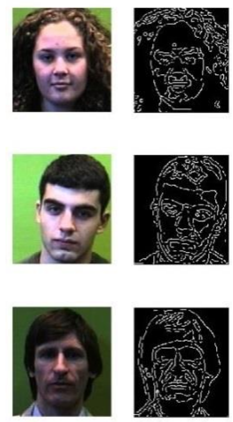

Figure 6: Edge detection (left) Original Image (right) Result of edge detection

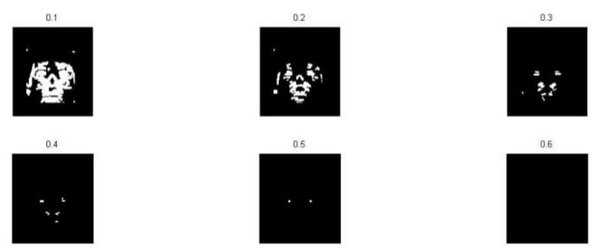

Figure 7: Thresholding of GST algorithm

5. Experimental Result

To compare the proposed fuzzy techniques and methods that are only using the GST algorithm; hundred, two hundred, three hundred and four hundred images were randomly selected from the dataset of the University of Massachusetts [1]. You can see the sample of image in Figure 9. As expected the obtained results indicated that

[1] http://vis-www.cs.umass.edu/lfw/#download

the FGST algorithm is more accurate and faster than aforementioned solutions.

As observed in Figures 8 and 9, fuzzy symmetry detection algorithm dramatically saves the computing time and provides better performance than a conventional symmetric algorithm.

Figure 8: Examples from different data sets. Row 1 from Set1, Row 2 from Set2, and Row 3 from Set3.

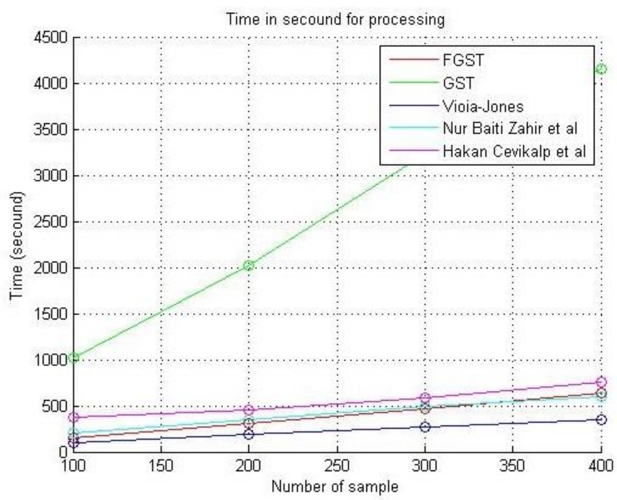

Figure 9: Comparison of processing time between FGST and GST, Viola and Jones [13], Nur Baiti Zahir et al. [14], Hakan Cevikalp et al. [15]

As illustrated in Figure 9, even though the Viola-Jones et al. [13] is relatively fast, yet it generates considerable number of false positive results which is considered as the main drawback of the algorithm. The Nur Bait Zahir et al [14] enjoys an acceptable performance, however it does not have such a high accuracy, since it merely applies thresholding and POI methods in order to detect faces. Finally the Hakan Cavikalp et al [15] is compared with other algorithms. It uses cascade based methods which results in searching all blocks of the image in different angels. The search process makes the whole system slow. Also it might not succeed in detecting all face blocks of the image.

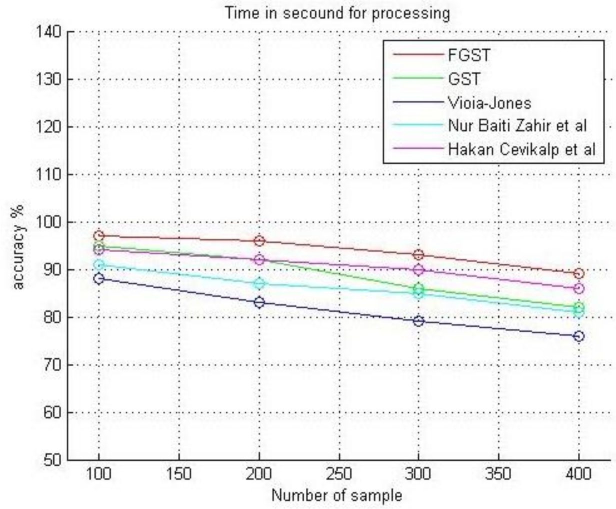

Figure 10: The accuracy result. The proposed method is compared against those given by Viola and Jones [13], Nur Baiti Zahir et al. [14], Hakan Cevikalp et al. [15]

6. Conclusions

In this paper, according to the high importance of face detection, a fast and efficient system for face detection is proposed. For this matter, first, the regions of the image that have the same or similar color to the human face skin color are selected. Then, using a fuzzy algorithm, we attempted to estimate regions of which the number of pixels and the ratio of length to width are similar to human face characteristic. Finally, with GST algorithm the non-face regions are removed.

The results indicate that are proposed method has good performance and acceptable output.

In future works, the implementation of other methods such as context-based approaches are proposed. Also integration of social network and face detection might be interesting topic for discussion.

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