Face Detection using Fuzzy Skin Color Segmentation

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ABSTRACT

This paper presents a reliable method for detecting human faces in color images. The system is based on the visual information of the face and is commenced with the detection of face regions by connected component analysis of the skin color segmentation of images in HSV, YC_BC_R, YIQ color model and the Fuzzy membership function. The Fuzzy Membership function is applied to search for possible face regions in an image. The proposed method is robust in that it can deal with illumination changes and moderate rotations.

Keywords

Fuzzy Inference, Mamdani Style, Color Model, Membership Function, Skin Color.

1. INTRODUCTION

Automatic face detection in a cluttered image is an important step for face recognition system. Human face detection is difficult because there can be huge variations in the appearance of face patterns and many of these variations are difficult to parameterize. The starting problem in most of the cases of facial feature extraction is face detection, which deals with locating faces in images [1], [2].

In this paper, a reliable method for detecting human faces in color images is introduced. The location of the face regions is detected using the Fuzzy membership function. The Fuzzy Membership function is applied to search for possible face regions in an image. The proposed method is robust in that it can deal with illumination changes and moderate rotations.

2. PROPOSED METHODOLOGY

Face detection is one of the visual tasks which humans can do effortlessly. However, in computer vision terms, this task is not easy. The great challenge for the face detection problem is the large number of factors that govern the problem space. The long list of these factors include the pose, orientation, facial expressions, facial sizes found in the image, luminance conditions, occlusion, structural components, gender, human race, the scene and complexity of image's background [3].

Although a large number of face detection methods have been presented in the literature, few approaches address more than one or two variables. They assumed their own problem constraints to limit the problem space instead of challenging this wide range of factors.

The major difficulty in designing a robust face detection system is the limitation of vision and understanding of a computing machine. The ability to understand that the given image is not just a collection of pixels but is of human face (if any) is truly incredible [4], [5]. Face detection is concerned with determining which part of an image contains face. This is the first step of face recognition which requires both high- and low-level visual and geometric information processing. This work presents Fuzzy membership function for detecting human faces in a complex background. Face detection is

achieved by employing template matching between a known face image and the input image. The main steps employed for the face detection process in a color image is shown in **Fig. 1**.
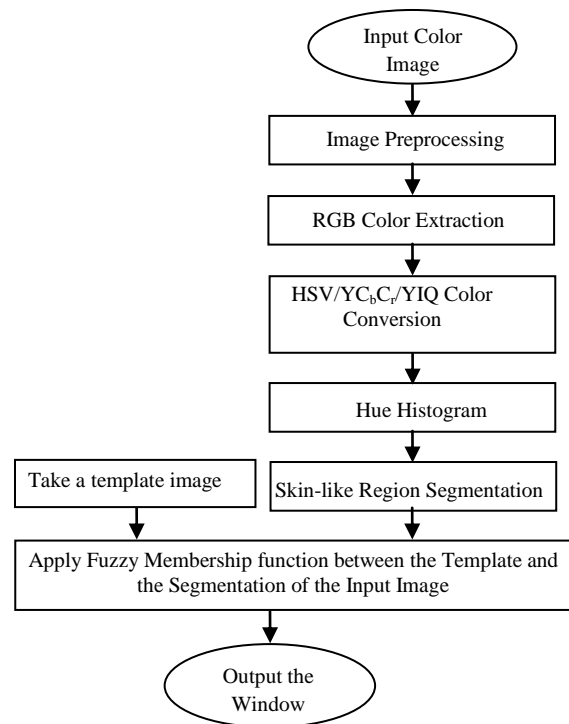
Fig. 1: Basic steps for face detection

The original image is obviously a color image. For detecting the face area, at first the image is processed using histogram equalization because, the face image may be of very poor contrast because of the limitation of the lighting conditions. Various sources of noise may also exist in the input image. So, low-pass filters are used to suppress the noise [6], [7]. The image content is then converted from *RGB* to three different color models such as *HSV*, YC_bC_r, *and YIQ* color space for face detection purpose.

To apply the Fuzzy membership function for face detection, a template of the face image obtained from averaging the hue value of pixels of a number of similar looking face images of several persons is constructed. The template face image is then moved through the whole image to find the location where the most suitable match exists. In order to determine whether the segmented region of the input image is a face or not, the membership value of the segmented region is computed by means of hue similarities for *HSV* space.

Face detection is performed by using color images. The existence of facial features like eyes, nose, mouth, and so on are the evidences that the candidate region is indeed a face. First different color models are used to detect a candidate

cluster as a face in an image using fuzzy membership function and then a face is detected.

For face detection the proposed method follows the following steps:

1. Input: *RGB* image data

2. Convert *RGB* image into *HSV*, *YIQ*, *YC_bC_r* space model.

3. Select an upper and lower bounds for C_b, C_r and Y,I values. Pixels that lie between the upper and lower bounds are assigned to their membership values in the interval [0,1], and pixels that are outside the bounds are set to the membership value 0.

4. Detect possible face-like clusters using the method described in Step 3.

5. Select one cluster and apply fuzzy logic modeling approach to decide if the cluster contains a face or not (depending on whether facial features, such as, eyes, nose, mouth, eye-brow, etc. contains or not).

6. If all clusters are processed, then go to step 4, otherwise go to step 5.

A number of experiments were carried out for various input color images with complex backgrounds. In every case, the experiments have shown very promising results. The highest detection rate of the system is approximately 96%.of image processing and analysis methods that are involved in this thesis.

3. FUZZY INFERENCE FOR FACE DETECTION

The basic idea applied to problem solving for face detection is illustrated in this section.

Fuzzy Logic

A logic based on the two truth values *True* and *False* is sometimes inadequate when describing human reasoning. Fuzzy logic uses the whole interval between 0 (*False*) and 1 (*True*) to describe human reasoning. In this context, Fuzzy logic (FL) is a problem-solving control system methodology that lends itself to implementation in systems ranging from simple, small, embedded micro-controllers to large, networked, multi-channel PC or workstation-based data acquisition and control systems. It can be implemented in hardware, software, or a combination of both. FL provides a simple way to arrive at a definite conclusion based on vague, ambiguous, imprecise, noisy, or missing input information.

Fuzzy Membership Functions

The membership function is a graphical representation of the magnitude of participation of each input. So the function that ties a number to each element x of the universe is called the membership function $\mu(x)$. A membership function is bell-shaped (also called a π-curve), s-shaped (called an s-curve), a reverse s-curve (called z-curve), triangular, or trapezoidal [8].

A cosine function can be used to generate a variety of membership functions. The *s*-curve can be implemented as

$$s(x_l, x_r, x) = \begin{cases} 0, & x < x_l \\ \frac{1}{2} + \frac{1}{2}\cos\left(\frac{x - x_r}{x_r - x_l}\pi\right), & x_l \le x \le x_r \\ 1, & x > x_r \end{cases} \quad (1)$$

Where x_l is the left breakpoint, and x_r is the right breakpoint. The z-curve is just a reflection,

$$z(x_l, x_r, x) = \begin{cases} 1, & x < x_l \\ \frac{1}{2} + \frac{1}{2}\cos\left(\frac{x - x_l}{x_r - x_l}\pi\right), & x_l \le x \le x_r \\ 0, & x > x_r \end{cases} \quad (2)$$

The membership function employed for the fuzzy logic, is a π - shaped curve, implemented as a combination of s- curve and z-curve, respectively. Standard Membership functions are shown in **Fig. 2.**
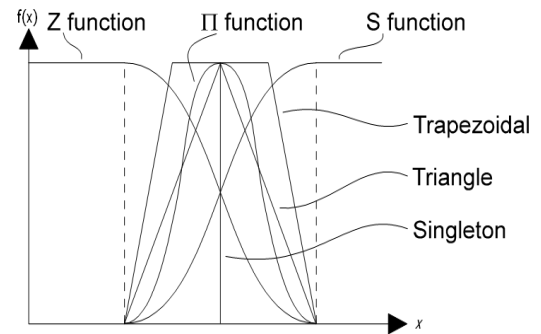
Fig. 2: Standard Membership Functions.

Fuzzy Inference

Inference is a technique by which, a given set of facts or postulates or axioms or premises F_1, F_2, …, F_n, a goal G is to be derived. The process of reasoning based on Fuzzy logic is called fuzzy inference. For example,

   If the color is more_or_less_skin_like,
   Then image_contains face.

Fuzzy Rule

A conditional statement in the form: IF x is A THEN y is B, where x and y are linguistic variables, and A and B are linguistic values determined by fuzzy sets.

- **Rule 1**: IF (C_b is *extremely skin like*) and (Cr is *more_or_less skin like*) then (Image is *Face_like*)

- **Rule 2**: IF (C_b is *not_so skin like*) and (Cr is *more_or_less skin like*) or (Y is *extremely low*)then (Image is *Not_Face_Like*)

Inputs to a fuzzy system can be
- fuzzy, e.g. (Color_Value = Moderate), defined by membership functions
- exact, e.g.: (C_b = 100); C_r=80), defined by crisp values.

Outputs from a fuzzy system can be
- fuzzy, i.e. a whole membership function, or
- exact, i.e. a single value is produced on the output.

Mamdani-Style Inference

The Mamdani-Style inference rule is as follows:

Rule 1:	**Rule 1:**
IF *x* is A3	IF hue is extremely skin_like
OR *y* is B1	OR saturation is good
THEN *z* is C1	THEN image is face_like

Rule 2:   **Rule 2:**
IF *x* is A2   IF hue is marginally skin_like
AND *y* is B2   AND saturation is very poor
THEN *z* is C2   THEN image is a_little_bit face_like

Rule 3:   **Rule 3:**
IF *x* is A1   IF hue is inadequate
THEN *z* is C3   THEN image is not_face_like

A: Fuzzy Rules for Skin Color Detection in YC_bC_r Color Model (Mamdani-Style Inference)

The fuzzy logic rules applied for skin detection are as follows [9], [10]:
1. IF *Cb* is Extremely skin like And *Cr* is Extremely skin like THEN the pixel is white.
2. IF *Cb* is Extremely skin like And *Cr* is Skin like THEN the pixel is white
3. IF *Cb* is Extremely skin like And *Cr* is Morl skin like THEN the pixel is white
4. IF *Cb* is Skin like And *Cr* is Extremely Skin like THEN the pixel is white
5. IF *Cb* is Skin like And *Cr* is Skin like THEN the pixel is black
6. IF *Cb* is Skin like And *Cr* is Morl skin like THEN the pixel is black
7. IF *Cb* is Morl skin like And *Cr* is Extremely skin like THEN the pixel is white
8. IF *Cb* is Morl skin like k And *Cr* is Skin like THEN the pixel is black
9. IF *Cb* is Morl skin like And *Cr* is Morl skin like THEN the pixel is white

B: Fuzzy Rules for Skin Color Detection in YIQ Color Model (Mamdani-Style Inference)

The fuzzy logic rules applied for skin detection are as follows [9], [10]:
1. IF *Y* is Extremely skin like And *I* is Extremely skin like THEN the pixel is white.
2. IF *Y* is Extremely skin like And *I* is Skin like THEN the pixel is white
3. IF *Y* is Extremely skin like And *I* is morl skin like THEN the pixel is white

Membership Function by Fuzzy Rules

The membership function employed for different C_b and C_r values in order to detect face color segmentation on the basis of the fuzzy rules are, as shown in **Fig. 3**.
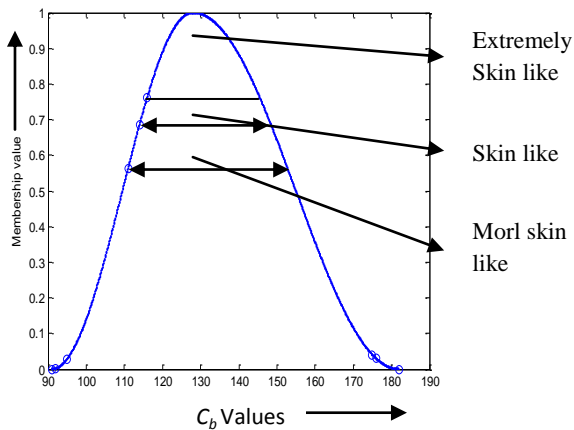

Fig. 3: Membership function for skin color segmentation

4. IF *Y* is Skin like And *I* is Extremely skin like THEN the pixel is white
5. IF *Y* is Skin like And *I* is Skin like THEN the pixel is black
6. IF *Y* is Skin like And *I* is Morl skin like THEN the pixel is black
7. IF *Y* is Morl skin like And *I* is Extremely Skin like THEN the pixel is white
8. IF *Y* is Morl skin like k And *I* is Skin like THEN the pixel is black
9. IF *Y* is Morl skin like And *I* is Morl skin like THEN the pixel is white

C: Fuzzy Rules for Skin Color Detection in HSV Color Model (Mamdani-Style Inference)

The fuzzy logic rules applied for skin detection are as follows [9], [10]:
1. IF *H* is Extremely skin like And *S* is Extremely skin like THEN the pixel is white.
2. IF *H* is Extremely skin like And *S* is Skin like THEN the pixel is white
3. IF *H* is Extremely skin like And *S* is morl skin like THEN the pixel is white
4. IF *H* is Skin like And *S* is Extremely skin like THEN the pixel is white
5. IF *H* is Skin like And *S* is Skin like THEN the pixel is black
6. IF *H* is Skin like And *S* is Morl skin like THEN the pixel is black
7. IF *H* is Morl skin like And *S* is Extremely Skin like THEN the pixel is white
8. IF *H* is Morl skin like k And *S* is Skin like THEN the pixel is black
9. IF *H* is Morl skin like And *S* is Morl skin like THEN the pixel is white

In the same way like as the above figure, membership can be calculated for different C_r, Y, I, H and S values.

4. EXPERIMENTAL RESULTS

In experiments face images are analyzed to demonstrate the feasibility of the proposed method. The effectiveness and robustness of this approach are justified using different images with various kinds of expressions. Experiments are carried out on Intel(R) Core(TM) i5-3470 CPU @ 3.20GHz PC with 4.00 GB RAM. The algorithm has been implemented using Visual C++. When a complex image is subjected to the input, the face detection result highlights the facial part of the image. Images of different persons are taken at their own work places and at different environments both in shiny and gloomy weather. Most of the images are taken using a digital camera, but some are from scanner. The algorithm is capable of detecting single face in an image. For multiple faces, the system finds the dominant face only, i.e. the face containing more number of skin colored pixels. A total of 273 images, including more than 76 different persons, are used to investigate the capacity of the proposed algorithm for different color model. Experimental results demonstrate that

the success rate of above 96% $\left(\dfrac{265}{273} \times 100\% = 97.06\%\right)$ is

achieved for YC_bC_r color model. The main reason behind the failure of those images in finding face regions are occlusion and side view of faces, etc.
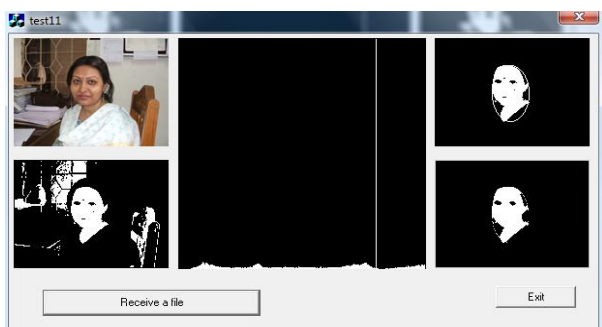
The experimental results are analyzed below for different colored input images (single face image and multiple face images) under different environment and lighting conditions.
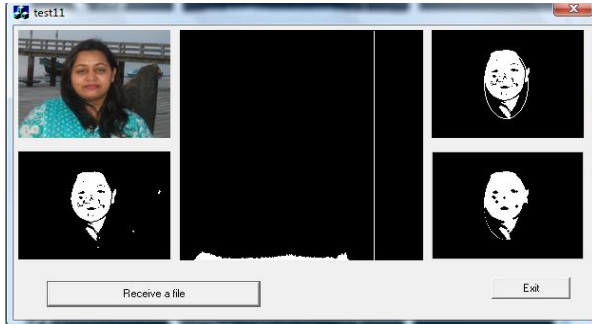
a) Single Face Images using HSV Color Model

b) Single Face Images using YCbCr Color Model
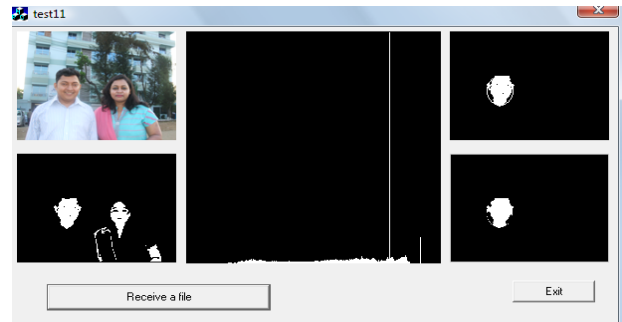

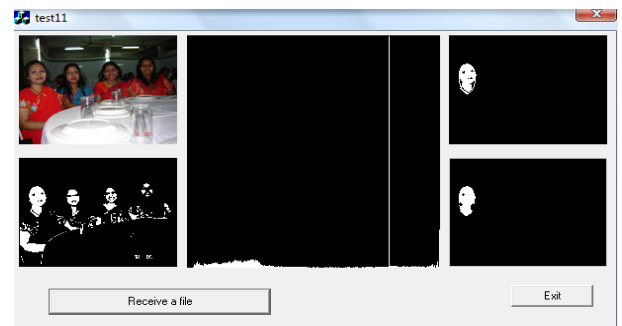**c) Single Face Images using YIQ Color Model**

Fig. 4: Single Face Images with Pose Variations

a) Multiple Face Images using HSV Color Model

b) Multiple Face Images using YCbCr Color Model

c) Dark face images using YIQ Color Model

Fig. 5: Multiple Face Images with Pose Variations

5. PERFORMANCE ANALYSIS

In this paper, face detection has been implemented using Fuzzy membership function to search for the face of a particular individual in an image. The effectiveness of the face detection algorithm has been tested both in simple and complex backgrounds for different types of face and non-face images of 160×120 resolution. These images are taken under different environment: some are under sunny environment; some are under cloudy environment; some are dark images; some are bright images, and so on. In all cases, experiments have shown promising results. **Table I** summarizes the performance analysis for Fuzzy membership based face detection under all possible environments for YC_bC_r color model.

Table I: Performance analysis for Fuzzy membership based face detection for YC$_b$C$_r$ color model

Image Condition		No. of Images	Correctly Detected	Success Rate
Outdoor Images	Sunny	55	54	98%
	Cloudy	50	48	96%
	Dark	40	38	95%
Indoor Images	Bright	50	49	98%
	Dark	41	39	95%
Images with Occlusion		37	34	92%

It is observed that among 273 face images only 8 faces are found false and the maximum success rate of the implemented system is 98% under sunny (Outdoor) and bright (Indoor) environments. Thus, the overall success rate of above 96% is achieved in this method.

Experiments are performed using different color model and Fuzzy membership function. **Table II** summarizes the performance analysis for Fuzzy membership based face detection under all color models.

Table II: Performance analysis for Fuzzy membership based face detection using three color models

Color Model	No. of Images	Correctly Detected	Average Success Rate
HSV	260	245	94%
YIQ	260	248	95%
YC$_b$C$_r$	273	265	96%

Experimental results show that the algorithm is capable of detecting the faces in color images with different backgrounds. It can detect a rotated human face, even if the face is under shadow, wearing glasses, or under bad lighting conditions.

6. CONCLUSIONS

The area of face detection has attracted considerable attention in the advancement of human-machine interaction as it provides a natural and efficient way to communicate between humans and machines. Although human beings accomplish these tasks countless times a day, they are still very challenging for machine vision. Most of the researchers attack this kind of problem with face localization and feature selection with frontal view faces and without facial expression and normal lighting conditions although the variation between the images of the same face is too large due to facial expression, hair style, pose variation, lighting conditions, make-up, etc.

This paper proposes a face detection method for color images in the presence of varying lighting conditions as well as complex backgrounds. The location of the face region is detected using the Fuzzy Membership function. The Fuzzy Membership function is applied to search for possible face regions in an image. Experimental results demonstrate that this face detection process works predictably reliable, and regardless of the perspective.

Some achievements of this work are described below.

- The proposed method has been successfully examined with color images.

- With more than 273 images, our method is successfully tested with various types of faces affected by intensity, occlusion, structural components, facial expression, illumination, noise, and orientation. It can detect above 96% of the faces with an acceptable number of false detections.

- For multiple face images the system finds the dominant face, i.e. the face containing more number of skin colored pixels.

- This method can reliably detect faces that vary in viewpoint from frontal to side view. Previously only frontal face detection had been demonstrated reliably.

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