Fuzzy classification, image segmentation and shape analysis for Human face detection

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Abstract--- **In this paper, we describe a new algorithm for human face detection. The algorithm uses both color and shape analysis because they are almost the same for all faces. Color analysis is based on the novel idea of fuzzy classification that manipulates ambiguity in colors; using this technique we can robustly classify skin regions and non-skin regions. In order to decide whether the skin region is a face or not, we test its shape by applying an edge detection using Canny operator and an ellipse detection using Hough transform.**

We show with experimental results how the important detection ratio makes our system an effective tool for face detection.

I. INTRODUCTION

Human face detection has been deeply studied in the last ten years mainly because it is a crucial step in many interesting applications [5]: such as face recognition, face tracking and expression analysis. Consequently the performance of face detection certainly affects the performance of all applications mentioned above.

Many methods have been proposed to detect human face in images, they can be classified into four categories: knowledge-based methods, feature-based methods, template-based methods, and appearance-based methods [5]. When used separately, these methods can not solve all problems of face detection like pose, orientation, occlusion, illumination. Hence, it is better to operate with several successive or parallel methods.

In this paper, we present a new face detection technique based on the color classification using fuzzy logic system, image segmentation using edge detection and shape analysis using Hough transform.

In the following section, we give a brief description of our face detection algorithm. In section 3, we show, according to experimental results, the robustness of our system.

II. FACE DETECTION ALGORITHM

Our face detection system is presented in figure 1 and it contains four steps.

- The first step converts the image from the RGB space to YCbCr space.
- The second step classifies each pixel in the given image as a skin pixel or a non-skin pixel. Fuzzy logic is used in this step to give a better classification.
- The third step uses the edge approach in order to generate the segmented image.
- The last step detects ellipses in the segmented image and decides whether each skin region is a face or not. This decision depends on two parameters: the height and the width of the ellipse.

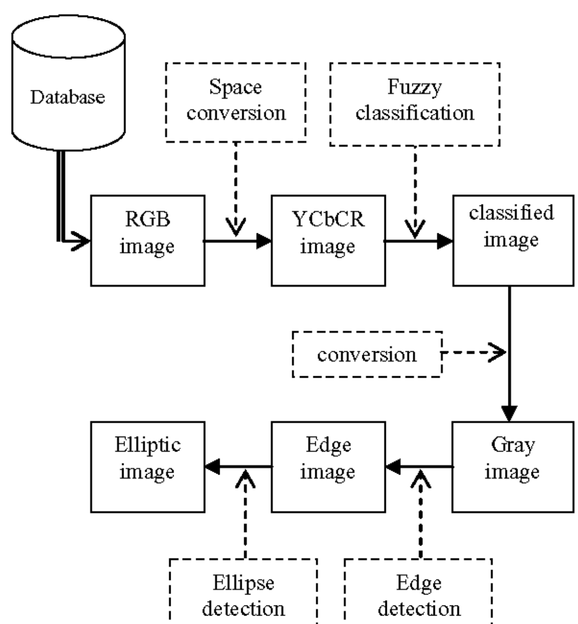

Figure 1. Face detection system

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A. Skin color space

Skin-color technique is considered as an effective tool for face detection because it's invariant to changes in size, orientation and occlusion.

Many color spaces have been proposed in the literature for skin detection [3] such as HSV, YCbCr, YIQ spaces. So, we must firstly choose the appropriate skin-color space.

In this paper, we propose to use the YCbCr color space for two reasons:

- By using the CbCr color plan (chrominance) of the YCbCr color space, we eliminate as much as possible the variation of luminance component caused by the lighting conditions. In contrast the common RGB representation of color images is not suitable for characterizing skin-color because the triple components (r, g, b) represent not only color, but also luminance. This characteristic is variable when changing lighting conditions.
- The YCbCr domain is extensively used in digital video coding applications [6].

In figure 2, we demonstrate the importance of the YCbCr color space for skin detection. The first image (a) is represented on the RGB color space, the second image (b) is represented on the Cb plan and the last image (c) is represented on Cr plan.
It is interesting to note that the two chrominance values have separated the skin color of the image from the background.

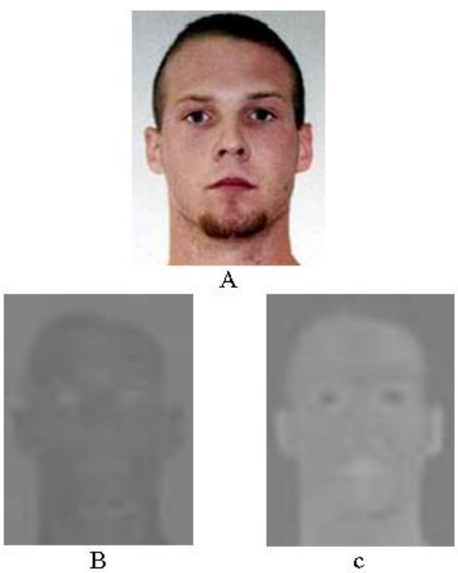

Figure 2 . Conversion of an RGB image into Cb and Cr plan.

B. Fuzzy classification

This step was introduced in order to classify each pixel of the image in skin pixel and non-skin pixel. According to the last sub-section, the skin color region can be successfully identified by the chrominance (cr and cb).
The most suitable arrangements that we found for all input images in database are: Cb in [77, 127] and Cr in [139, 210].

These arrangements are not sufficient to find a good classification because of the diversity of human skin color and for many other reasons such as luminance, noise and shad.
Figure 3 shows the limitation of classic classification. In fact, a big part of the face is considered as background.

Figure 3 . Classic classification of image

To overcome the problem listed above, we propose to apply a fuzzy approach for pixel classification. This is considered as a good solution since that, fuzzy set theory can represent and manipulate uncertainly and ambiguity [1].

In this work, we use the Takagi-Sugeno fuzzy inference system (FIS). This system is composed of two inputs (the 2 components cb and cr) and one output (the decision: skin or non-skin color); each input has three sub-sets (light, medium and dark).

Our algorithm uses the concept of fuzzy logic IF-THEN rules; these rules are applied in each pixel in the image in order to decide whether the pixel represents a skin or non-skin region.

The fuzzy logic rules applied for skin detection are the following:

1. IF Cb is Light and Cr is Light THEN the pixel =0
2. IF Cb is Light and Cr is Medium THEN the pixel =0
3. IF Cb is Light and Cr is Dark THEN the pixel =0
4. IF Cb is Medium and Cr is Light THEN the pixel =0
5. IF Cb is Medium and Cr is Medium THEN the pixel =1

6. IF Cb is Medium and Cr is Dark THEN the pixel =1
7. IF Cb is Dark and Cr is Light THEN the pixel =0
8. IF Cb is Dark and Cr is Medium THEN the pixel =1
9. IF Cb is Dark and Cr is Dark THEN the pixel =0

The first step is to determine, for each input, the degree of membership to the appropriate fuzzy sets via membership functions. Once the inputs have been fuzzified, the final decision of the inference system is the average of the output (z_i) corresponding to the rule (r_i) weighted by the normalized degree p_i of the rule (1 or 0)

Figure 4 represents the input image and the output one, after YCbCr color space conversion and fuzzy classification.

Figure 4 . Fuzzy classification of image

A comparison of figures 3 and 4 proves the importance of fuzzy logic in skin detection. We note that the number of the skin pixels detected by fuzzy logic is more important than the number using classic classification.

This step allows to detect skin regions in images (faces, hands ...), but it is not sufficient to detect only faces. So it must be combined with a shape analysis beginning with an edge detection

C. Edge detection

Edge detection is the most common approach for detecting significant discontinuities in gray level [2]. Edge detection algorithms locate and accentuate edges in order to identify objects in images.

Many different methods have been proposed for edge detection, such as Sobel filtering, Prewit filtering, Laplacian filtering, Moment-based operator, Shen & Castan operator and Canny & Deriche operator.

Among the edge operators mentioned above, the most powerful edge-detection method is the Canny method. It differs from the other ones because it uses two different thresholds allowing it to detect strong and weak edges, and includes the weak edges in the output only if they are connected to strong edges.

In figure 5, we show the robustness of Canny operator for detecting edges.

Figure 5. Edge detection with Canny filter

After edge detection, the step allowing to decide whether the region represents a face or not is ellipse detection.

D. Ellipse detection

Many works have been focused on the elliptical shape of the face. By considering this criterion we implement the algorithm for ellipse detection choosing Hough transform.

The Hough transform consists of three steps [4]:

1. A pixel in the image is transformed into a parameterized curve,
2. Valid curve's parameters are binned into an accumulator where the number of curves in a bin equals to its score.
3. A curve with a maximum score is selected from the accumulator to represent a curve in the image.

The algorithm described above may detect many ellipses with different sizes in the image. In order to detect only forms that represent a face, we eliminate ellipses that have small sizes.
An illustration of ellipse detection is shown in figure 6.

Figure 6. Examples of ellipse detection

III. EXPERIMENTAL RESULTS

The proposed algorithm has been evaluated with 1200 images containing 1500 faces and 300 images that represent non faces. These images are in various sizes, complex backgrounds, varying head orientations, lightings conditions.

To test the robustness of our system, we have calculated the detection ratio and the false alarms in two levels:

- Level1: after fuzzy classification.
- Level2: after ellipse detection.

In the first level, the only information that can decides whether the skin region is a face or not, is the number of pixels in such region. A threshold is fixed representing the number of pixels above of which we can consider the region as a face.

All regions that have been detected in the previous level are not necessary faces; they may represent a hand or other objects. The level two correct these insufficiencies by introducing shape analysis. Starting from the fact that, all faces have elliptic form, this level must detect all elliptic regions in the image and eliminate all other forms.
The following table illustrates the results of our system.

TABLE I. Performance of our system detection

	Faces		Non-Faces	
	Real positives	False positives	Real negatives	False negatives
Level1	79,66	14,00	6	0,33
Level2	73,66	1,66	12,66	6,33

	Detection ratio	False alarms
Level1	99,58	70,00
Level2	92,08	11,59

The obtained results are encouraging, our system gives 92,08 % as a detection ratio.

Using only the level 1 based on color information, we obtain 70 % of false alarms.
In order to solve the significant presence of false alarms, we have introduced the shape analysis to detect only elliptic shapes. This consideration allows us to decrease the rate of false alarms (11.59 %).
This improvement is due to the ellipse detection that eliminates many skin regions that doesn't have elliptic shape.

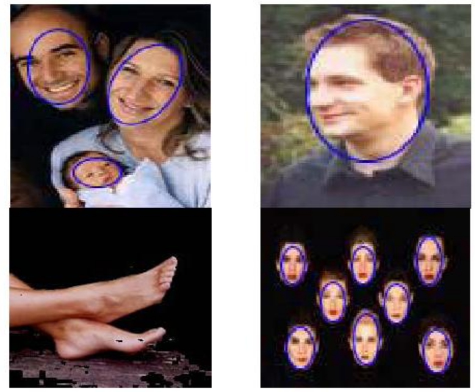

Figure 7. Examples of face detection

IV. CONCLUSION AND FUTURE WORK

A new algorithm for face detection based on skin color using fuzzy classification, edge detection and shape analysis has been proposed. In spite of some false alarms, the overall performances of the proposed algorithm are still quite satisfactory.
Our system can detect faces in different orientations, sizes and conditions of lighting. It can also differentiate faces from other skin regions like hands.

Our future work will be focused on the extension of our system by adding eyes and the mouth detection for face recognition and face analysis purposes.

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