Optimized Fuzzy System Using Genetic Algorithm to Detect Faces in Color Images

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Abstract— A human face detection method for color images is presented in this paper. The system is composed of three subsystems: skin color segmentation, lip color segmentation and face blobs selection subsystem. Whole these algorithms are fuzzy rule base ones, which are designed empirically, and then optimized by genetic algorithm. In the first stage, skin color regions are selected in the input image. Within each of the skin area, lip pixels are searched using second subsystem, and applied as a feature to identify face candidates in the skin regions. Utilizing the lip area and position relative to the skin area, and face shape information, the third subsystem is materialized to choose face blobs. To precise evaluation of the proposed system, the false positive and false negative of each subsystem, are reported for the empirically designed system as well as the optimized system. Obtained results show a remarkable decrease in false positive and false negative for optimized algorithms compared to empirically designed ones. Finally, 98% detection rate is achieved using proposed method.

Keywords- face detection; lip detection; fuzzy rule based system; genetic algorithm.

I. INTRODUCTION

Identifying the location of all human faces in the image, called face detection, is a well-known pattern recognition problem. This task has received considerable attention due to its wide range of application such as personal identification and access control, model-based video coding, human recognition, intelligent human-computer interaction and low-band width communication for video phone [1].

Face detection is a challenging problem. The key issue and difficulty in face detection is to account for the wide range of allowable facial pattern variation in images. The detection performance may be affected by the presence or absence of glasses, bread, mustaches, imaging condition, camera characteristics, occlusion, etc [2].

In the spite of all above mentioned difficulties, extensive research has been conducted on various aspects of face detection by machines. Most detection systems carry out the task by extracting certain properties of a set of training images acquired at a fined pose in an off-line setting. These systems typically scan through the entire image at every possible location and scale to locate faces. The extracted properties can be either manually coded or learned from a set of data as adopted in the recent systems that have demonstrated impressive results. Repeating the detection process, a pyramid of images whose resolutions are reduced by a factor, is performed to detect faces at different scale. By means of certain visual cues (e.g. color and motion) as pre-processing steps, the procedure speed would be increased. A large number of proposed face detection methods can be grouped as: pixel-base, parts-based, local edge features, Haar wavelets, and Haar-like features methods. The recent systems with Haar-like features have demonstrated impressive empirical results in detecting faces under occlusion [3].

Also face detection can be formulated as a pattern recognition problem. As a result, numerous algorithms have been proposed to learn their generic templates such as eigenface and statistical distribution, such as neural network, fisher linear discriminant, sparse network of winnows, decision tree, Bayes classifier, support vector machine, and AdaBoost [4].

In this paper a novel method is proposed which applies three accurate designed subsystems to materialize a robust algorithm to locate faces in color images. This method is based on the skin and lip color extraction.

Three subsystem’s order is depicted in “Fig. 1”. As it can be seen in the first step the skin regions are introduced in an input image. Through each of the separated skin regions the lip pixels are searched. The final making decision system would select face areas. All these systems are fuzzy rule base ones, optimized by genetic algorithms (GA).

Fuzzy theory provides a framework to materialize a fuzzy rule base system which contains the selection of fuzzy rules, membership functions, and the reasoning mechanism. Such a system has been applied to many disciplines such as control systems, decision making and pattern recognition [5]. Applying fuzzy rule base classifiers, instead of a crisp threshold, increase the flexibility of algorithm.

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However, it is often difficult for a human expert to define the fuzzy sets and fuzzy rules, used by these systems. GAs have proven to be a useful method to optimize membership functions of fuzzy sets used by these fuzzy systems [6].

So, in this paper three optimized fuzzy rule base systems are designed and utilized to create a face detection algorithm. Following sections describe different stages of proposed method in details.

II. SKIN COLOR SEGMENTATION SYSTEM

T Skin color provides computationally effective and robust information against rotations, scaling, and partial occlusion. Therefore, it can be used as complimentary data to other features, such as shape and geometry, and can be utilized to build accurate face detection systems.

To apply this unique feature to detect faces in color images, firstly the suitable color space should be selected. Then, after modeling the color distribution, the way of color segmentation processing would be introduced. Different sections of our skin color segmentation algorithm are as follows.

A. Color space

Color model selection is the primary step in the skin color classification. The RGB color space is the default one for most available image format and the other color spaces could be obtained from a linear or non-linear transformation from RGB. Most widely used color spaces for the skin detection include: basic color spaces (RGB, normalized RGB, CIE-XYZ), perceptual color spaces (HIS, HSV, HSL, TSL), orthogonal color spaces (YCbcYIQ, Yuv, YES), and perceptually uniform color spaces (CIE-Lab and CIE-Luv) [7].

In the RGB color space brightness and color information are coupled together, so it is not suitable for color segmentation under unknown lighting conditions. The transformation of RGB to perceptual color spaces is invariant to high intensity at white lights, ambient light and surface orientations relative to the light source. Hence, it has acceptable performance to model skin color, but it may not be suitable for real-time application because the output format used by digital camera or capturing equipment is usually either YCbCr or RGB. Therefore, to avoid the extra computation required in conversion, the YCbCr color model is utilized in this work, which has the advantage of separating intensity component (Y) from the chroma components (Ccb and Ccr), and is obtained using (1).

As the intensity is the main difference of various skin colors, in many skin classification research the intensity component is omitted. Since simply discarding luminance information affects the model's accuracy, to obtain optimum color space, different fraction of color space components are tried, and (Y, Cb, Cr) is applied as the best to classify skin color.

\[
Y = 0.299R + 0.587G + 0.114B \\
C_b = R - Y \\
C_c = B - Y
\]

B. Skin Color Classification

After transforming the input image in to the selected color space, next step is searching the skin pixels, through the image. The fuzzy rule base system is designed in this stage.

The Euclidean distance between the color vector of each pixel to the average skin color sub-space vector is computed as the input to the fuzzy system. Mamdani fuzzy system used is the 1-input, 1-output one and centroid method is chosen for defuzzification [5]. [Skin, Rather Skin, Low Probability Skin, Not Skin] are defined as the fuzzy linguistic terms for both input and output membership functions (MFs).

This system results in the skin-likelihood image, which is the gray-scale image whose gray values represent the likelihood of the pixel belonging to the skin. There should be an appropriate threshold to create a binary image by setting skin pixels to 1 and all other ones to 0.

MFs and the threshold value are designed empirically, firstly, GA, then applied to optimize fuzzy system MFs and select the suitable threshold. Our empirical knowledge is utilized to reduce the searching space and expedite the process. So, the MFs shapes are chosen according to previous designed system and the parameters of MFs plus the threshold are utilized as the inputs of the GA, whose fitness function is defined by comparing the whole detected skin pixels in the image (D) with the actual number of these pixels (A). The fitness value, which should be minimized, is computed as follows:

\[
\text{Fitness} = \begin{cases} 
1 & \text{If } D = 0 \\
\frac{A}{D} & \text{Else} 
\end{cases}
\]

The obtained input and output MFs are shown in “Fig. 2”.

The threshold sets to 50%. Hence, the pixels with 50% or more probability are regarded as the skin pixels and, the binary image is formed. Morphological processing, consists of filling holes and opening followed by closing, is accomplished in the binary image, to acquire separated and connected skin regions [8]. After labeling the connected components, each region is applied as the input for the next step.
III. FACE DETECTION SYSTEM

A. Feature Extraction

To select face blobs in the skin regions, another facial feature should be checked. Searching lip pixels is found more reliable, compare to other characteristics.

The normalized RGB color space, which has shown the best results in finding lip area, is applied to look for lip pixels [9]. The r-g value of each pixel is computed as the fuzzy system input, and the output show the probability of being lip. Both the input and output are recognized by linguistic terms: {Lip, Rather Lip, Not Lip}. Next steps to complete lip classification system are the same as the skin classification one. 78% is the threshold value and optimized MFs by the GA, can be seen in “Fig. 3”.

B. Selecting Face Candidate

After searching lip pixels within all skin regions, the face candidates are introduced using the 3-input, 1-output fuzzy system. Three inputs of this system can be computed as:

1. First input (A): A is the ratio of the lip area to the face area. Defining this input, the algorithm fault due to the false positive of the lip detection system is remarkably reduced.
2. Second input (B): B is the tangent between the maximum length line of the face area and the minimum length line of the lip area. These two lines should be approximately parallel. This input increases the detection accuracy.
3. Third input (C): C reveals the similarity of region shape to an ellipse by comparing the region area with an estimated elliptical region area.

The output (Y) expresses likelihood of the desired skin region being face. The shape of the inputs and output MFs are chosen and parameters of these functions plus the threshold value are utilized for GA. The fitness function of this GA attempts to maximize the likelihood of being face for some faces blobs. “Fig. 4” depicted designed MFs by GA. The threshold value is selected to be 67%.

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Figure 2. (a) input and (b) output MFs for skin color segmentation fuzzy classifier.
IV. EXPERIMENTAL RESULT

A. Database

As there is no standard image database to evaluate and compare face detection methods, we create our own database. Wide range of size, race, lighting condition, expression, and background are considered in it. 300 images, making this database, are gathered among different color image databases [10, 11, 12].

B. Obtained Result

To evaluate the method performance more precisely, the false positive (FP) and false negative (FN) of three subsystems are reported and investigated for both empirically design and optimized by genetic algorithm systems. Table 1 shows obtained results. As it can be concluded, optimized algorithms remarkably decrease the FP and FN, and clearly increase the accuracy of the face detection method. 98% detection rate achieved utilizing proposed face detection system, is acceptable result, considering different face images with various lighting condition, background, race, etc., in our database.

“Fig. 5” shows different steps of applying such an algorithm on a sample image, and “Fig. 6” illustrates some more obtained results. Whole described stages are converted to computer program using MATLAB software.

V. CONCLUSION AND FUTURE WORK

A novel algorithm was proposed for face detection in color image, where three optimized fuzzy subsystems were employed respectively for skin color segmentation, lip color segmentation, and face regions selection. Optimizing whole fuzzy systems using genetic algorithm, a robust face detection system would be achieved. From the experiments performed, it can be suggested that applying optimized systems, the FP and NP would be considerably decreased. And as a result the detection rate would be increased up to 98%.

To devise a system that uses more features such as shape and intensity information to the lip detection, and utilizing other specification of face such as eyes and nose to the final deciding system, are possible ways to try.
Figure 4. (a), (b), (c) inputs and (d) output MFs of the face selecting system.
TABLE I. Obtained results for three systems

<table>
<thead>
<tr>
<th>Skin segmentation</th>
<th>Lip segmentation</th>
<th>Face blob selection</th>
</tr>
</thead>
<tbody>
<tr>
<td>FP (%)</td>
<td>FN (%)</td>
<td>FP (%)</td>
</tr>
<tr>
<td>Experimentally</td>
<td>Design system</td>
<td>64</td>
</tr>
<tr>
<td>Optimized</td>
<td>system using GA</td>
<td>34.6</td>
</tr>
</tbody>
</table>

Figure 5. (a) main image, (b) skin regions, (c) skin regions after morphological processing, (d)-(f) connected components after labeling skin regions, (g)-(i) lip areas found in regions (d)-(f) in normalised RGB color space, (j) face detected area.

REFERENCES


Figure 6. Examples of applying algorithm on images with various pose and background.