서브블록 프로세싱을 이용한 정지영상에서의 얼굴 검출 기법

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요 약

본 논문에서는 임의의 배경을 가진 컬러 정지 영상 내에 존재하는 얼굴을 검출하기 위한 방법을 제안한다. 제안 방법은 영상의 배경, 얼굴의 수, 크기, 각도, 피부색상, 그리고 조명에 대하여 불변적인 특징을 가지며, 컬러 클러스터링, 컬러 스캐닝, 서브 블록 프로세싱, 얼굴 영역 검출, 그리고 얼굴 검증과정으로 구성된다. 제안 방법은 사전 트레이닝 단계나 추가적인 데이터베이스를 필요로 하지 않는다. 본 논문의 제안방법은 보안 분야, 동영상과 정지영상의 색인, 그리고 기타 자동화된 컴퓨터비전 분야에 적용될 수 있을 것이다.

키워드 : 얼굴 검출, 서브 블록, 정지영상, 영상처리, 컴퓨터비전

Detecting Faces on Still Images using Sub-block Processing

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ABSTRACT

Detection of faces on still color images with arbitrary backgrounds is attempted in this paper. The newly proposed method is invariant to arbitrary background, number of faces, scale, orientation, skin color, and illumination through the steps of color clustering, cluster scanning, sub-block processing, face area detection, and face verification. The sub-block method makes the proposed method invariant to the size and the number of faces in the image. The proposed method does not need any pre-training steps or a preliminary face database. The proposed method may be applied to areas such as security control, video and photo indexing, and other automatic computer vision-related fields.

Key Words : Face Detection, Image Sub-Block, Still Image, Processing, Computer Vision

1. Introduction

Face detection is a widely applicable techniques for uses such as security control, video indexing, and future human-computer interaction. It includes elements such as face detection, face feature extraction, face pattern analysis, and understanding of facial expression. Many face detection methods have been proposed and are being researched from various points of view[3, 7, 8], but they still have many difficulties[1, 6]. Like the conventional problems in the area of image processing, face recognition also has obstacles such as scale, noise, rotation, and illumination of images. More difficulties exist in the face detection area because of facial pose, accessories, age, facial expression, hair style, and arbitrary background[4]. Skin color is frequently used as a criterion to detect face areas and has been used in many studies, but it also has many difficulties for general images depending on different skin colors of human races[2, 5].

In this paper, the main concern is how to separate the face area from a still image with a complex arbitrary background. The proposed method is invariant to the number of faces, color, size, position, and orientation of the faces in a still image and does not need any previously trained image set. The remainder of this paper is organized as follows. In chapter 2, the face detection procedure is described. In chapter 3, the face verification method is presented. In chapter 4, experimental results show the results of the proposed method. Finally, in chapter 5, the conclusion and future research plan are presented.

2. Face Detection

In this chapter, the sub-block processing method of a clustered CbCr image for face detection is described.

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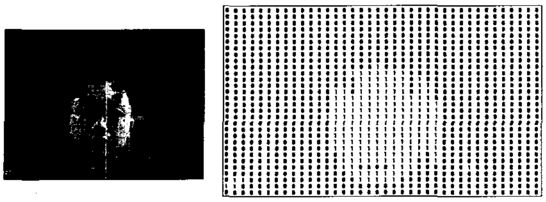


(Fig. 1) Sub-blocks for an image

(Fig. 2) Multiple Faces

2.1 Clustering and Scanning CbCr Color Plane

A general color image consists of millions of colors. Therefore the color range of human skin is difficult to bind. In many approaches, the values for skin color range were extracted from the experimental statistics or a trained image database. In the proposed method, we used YCbCr color model and only CbCr values are clustered into clusters using K-means clustering with eliminating Y factor not to be affected by illumination. Through the clustering process, every pixel of an image belongs to one of the K clusters. The pixels of each face area will belong to either one or two consecutive clusters among the k clusters because the color property of each human face color tends to be homogeneous. Based on this assumption, every color cluster or every consecutively combined two clusters are examined for the existence of a face. This color scanning process gives the proposed method the advantage of being invariant to the different skin colors of different human races.

2.2 Sub-block Processing

We need to decide which CbCr color cluster(s) among all the clusters of the image contains a valid face image. The sub-blocking method tries to test candidate areas on every CbCr color cluster plane. For each CbCr color cluster, the original image area is reconfigured by 16x16 pixel sized sub-block units, and the values of the sub-blocks are set to 1 if any pixel in its covered area is included in the currently testing CbCr color cluster; otherwise the values are set to 0. For example, let's assume that the size of an image is 640x480 and the size of the sub-block is 16x16. This gives us total of 120 sub-blocks. (Fig. 1) shows the image and its sub-blocks.

After the sub-blocks are generated, each candidate area needs to be bounded by rectangles for face verification. The decision of bounding rectangles becomes complicated when an image contains multiple and variously sized face candidates. Bounding rectangles for each candidate area is decided by using horizontal and vertical sub-block handling.

Horizontal and vertical sub-block planes are generated by using the original sub-block plane with the same values. The rectangles on the face-candidate areas can be acquired through the sub-block accumulation method. The horizontal sub-block plane is used to get the starting and the ending horizontal coordinates of each rectangle bounding face candidates in the image. In a similar way, the starting and the ending vertical coordinates of the rectangles can be calculated using the vertical sub-block plane. The accumulation of sub-blocks is performed through the value growing algorithm as shown in the following steps.

Step 1 : Scan the horizontal sub-block cells $HB_{i,j}$
Step 2 : When non-zero sub-block $HB_{i,j}$ appears,
If $HB_{i,j+1} \neq 0$ then $HB_{i,j+1} = HB_{i,j+1} + 1$
Step 3 : Scan the vertical sub-blocks $VB_{i,j}$
Step 4 : When non-zero sub-block $VB_{i,j}$ appears,
If $VB_{i+1,j} \neq 0$ then $VB_{i+1,j} = VB_{i+1,j} + 1$

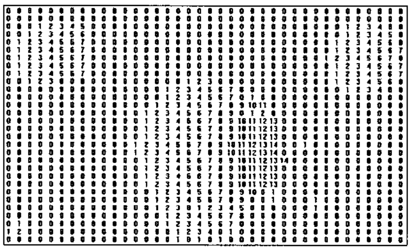
The numbers in each sub-block are the key flags to set up rectangles covering the face candidate areas regardless of the number and size of the faces. A recursive tracing is applied to find the boundary coordinates of each face candidate area based on four-connectivity. First, the process searches the horizontal sub-block plane. Whenever the process meets a non-zero and not visited sub-block, it traces every sub-block that is connected by four-connectivity and thereby visits all the sub-blocks in the same candidate area. While tracing all the sub-blocks, the process finds the maximum values and their coordinates in the horizontal and the vertical planes, respectively, for boundary decision. (Fig. 3) shows results of horizontal and vertical sub-blocks for multiple, different sized, and rotated faces in (Fig. 2).

3. Face Verification

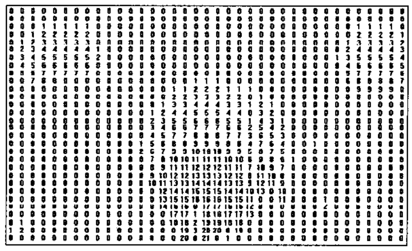
In chapter 2, we placed the rectangles on the face candidate areas for all the clusters. Now, we need to check whether the given rectangle includes a valid face or not.

3.1 Feature Extraction and Representative Points

The generally used facial features are the eyebrows, the eyes, the nose, the mouth and other features that take an important role in describing the properties of a face. The intensity values of pixels in the rectangle on the face candidate area are used to initially find facial feature areas. The pixels whose intensity is below a certain threshold are considered

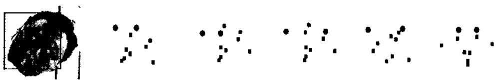


(a) Horizontal sub-blocks



(b) Vertical sub-blocks

(Fig. 3) Sub-block Values



(Fig. 4) Geometrical Analysis

as a part of a featuring area. After initial feature areas are decided, we try to core out a representative center point for each feature area by formula 1:

$$m_{pq} = \sum_x \sum_y x^p y^q l(x, y)$$

$$C_x = \frac{m_{10}}{m_{00}}, \quad C_y = \frac{m_{01}}{m_{00}} \qquad (1)$$

where $l(x,y)$ is 1 if a pixel on (x,y) is 1, otherwise 0. C_x is the x coordinate and C_y is the y coordinate of the core point of a given feature area.

3.2 Geometrical Analysis of the Representative Points

We select every pair of points assuming that every selected pair consists of the eyes and test its property. If a pair is determined to consist of the eyes, we conclude that the rectangle contains a valid face. (Fig. 4) shows the first 5 iterations of selecting pairs from representative points. The remaining iterations are omitted in (Fig. 4).

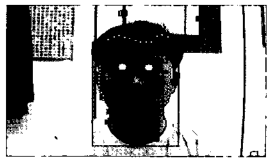
Every two selected points are adjusted to let the coordinate origin be placed between them as a mid point. Assuming each pair of the points are the eyes, the symmetry of the others points are analyzed by formula 2. The feature points of (Fig. 4) is shown as rotated based on the orthogonal line to the mid point of each iteration. The difference should satisfy a certain threshold to be determined as having a valid face.

$$difference = |V_L - V_R|$$

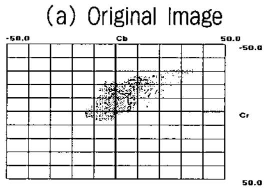
$$V_L = \frac{\sum_x x_L^2}{n_L} \quad V_R = \frac{\sum_x x_R^2}{n_R} \qquad (2)$$

where n_L and n_R are the number of pixels on the left and right sides of the origin, and x_L and x_R are x and y coordinates of the pixels on the left and right side of the origin. Another filtering condition is that other points should not appear on lower vertical positions of the area surrounding the eyes.

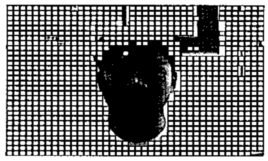
(a) Original Image



(b) Detected Result

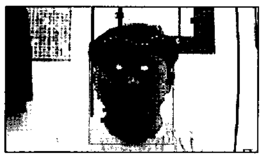


(c) CbCr Distribution



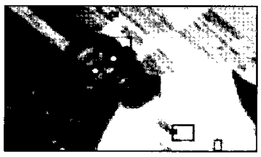
(d) Sub-block View

(Fig. 5) Processing Step Views

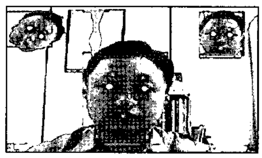


(a) Result 1

(b) Result 2



(c) Result 3



(d) Result 4

(Fig. 6) Experimental Results

4. Experimental Results

To show the experimental process, the processing step views are provided in the (Fig. 5). The image (a) of Fig. contains CbCr distribution as image (c) of (Fig. 5), and clusters of it go through the sub-block steps as image (d) of (Fig. 5). The image(b) of (Fig. 5) is the final result of the proposed method for the image (a) of (Fig. 5).

To prove the function of the proposed method, three different PC cameras and one digital camera were used to acquire images under different illuminations and orientations. The test images were variously sized color images including up to three faces with various size and rotation applied. In (Fig. 6), a face or faces were correctly detected with the result being invariant to rotation, size, the number of faces, and skin color.

(a) Failed Image 1 by Existing Method

(b) Detected Image 1 by the Proposed Method

(c) Failed Image 2 by Existing Method

(d) Detected Image 2 by Existing Method

(Fig. 7) Comparison with Existing Method

Another test set of images is used to show the strength of the proposed method compared to the existing method in (Fig. 7). The images in (Fig. 7) were acquired under natural illumination using digital camera with different sizes. Especially, the images are tested on one of the well known methods[5] on its demonstration site for comparison purpose. This method uses color quantization and wavelet packet analysis. Image (a) and (c) in (Fig. 7) contain failed results in the case of rotated faces about 45 degrees, while image (b) and (d) of (Fig. 7) show the detected face areas with being invariant to the obstacles stated at above sections by the proposed method. This results means that the geometrical analysis of the proposed method is robust for the rotation of images.

5. Conclusion and Future Research

The proposed method was tested to detect faces on still images regardless of the number of faces, the orientation, the position, skin color, and illumination without any pretraining process or a given face database. The whole process was performed through color clustering, cluster scanning, sub-block processing, face rectangle bounding, and face verification. The experimental tests showed that the proposed method achieved its goal under various conditions. It also showed the correctness of the proposed method by comparing results with existing method. The sub-blocking method has advantages such as less data handling by minimizing pixels into sub-blocks, and size and position independent face searching. The face verification process in the proposed method also handled only small numbers of representative points instead of whole image pixels for efficient and fast performance.

In the future, usage of the proposed method may be extended to non-frontally viewed face images, which would require more variation in the geometrical analysis of the proposed method.

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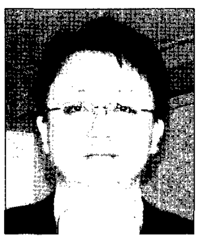

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