ROTATED FACE DETECTION IN COLOR IMAGES USING RADIAL TEMPLATE (RT)

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ABSTRACT

In this paper, we propose a face detection algorithm to locate faces rotated in any orientation. Detecting rotated faces is important for a face detection system. First we present a novel model named Radial Template (RT) to detect rotated faces. This template is designed to find stable features of center-rotated objects in edge maps. Based on skin detection and edge extraction, our method searches for face-like areas and get their orientations by RT searching. Then the candidates are rotated upright and a frontal face detector is used to determine existence of faces. A system integrating these techniques is presented. Experimental results show that our algorithm is effective to detect human faces rotated in any angle with different sizes, lighting conditions and backgrounds.

1. INTRODUCTION

Human face detection is a significant technique in many applications such as multi-modality HCI (human computer interface), identity authentication, face recognition, human animation and video coding, etc. Related researches on this problem have increased during the recent years [1]. However, face detection is still a challenging task because of variability in scale, orientation, pose and lighting conditions.

A lot of methods have been proposed to detect faces within a single image. These methods can be classified into two categories: image-based approaches and feature-based approaches [2]. Typical methods in the first one use statistical learning algorithms for the whole face image, such as neural networks [3], Eigenface [4] and AdaBoost [5]. The feature-based approaches treat a face as a combination of some important features: eyes, mouth and nose. These methods extract the facial features and detect faces by analyzing the relationships of these features [6][7]. Skin color is also an important feature to discriminate human face. Some methods use skin color models to locate potential face areas and then examine other face features in these candidates [8][9].

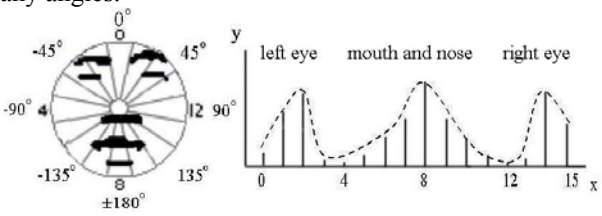
In practice, many images contain human faces in variant rotations, but most of previous algorithms are effective only for upright faces. To locate faces rotated in different orientations, we use a Radial Template (RT) to detect face-like areas in edge map. The model is designed to describe face feature configuration and its orientation.

This paper presents an algorithm for rotation invariant face detection in any angles using RT, skin detection, edge extraction and frontal face detector. In section 2 a RT based feature searching method is given. We describe the structure of our face detection system in section 3. In section 4 experimental results are provided and analyzed. Finally we give the conclusion in section 5.

2. RT BASED FACE FEATURE MATCHING

2.1 Radial Template (RT)

To locate rotated faces, conventional methods repeat their detections in different orientations and they usually cost more time with omissions. Here we proposed a template, that we name it Radiate Template (RT) to detect faces in any angles.



(a) (b)

Fig.1 RT and face histogram (a) Radial Template; (b) RT histogram

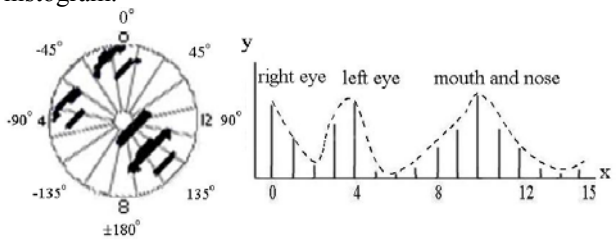
For a center-rotated object, if convert Cartesian coordinates to polar coordinates, its feature distribution is invariant to its axis. We design Radial Template (RT) to describe these patterns. A RT is a round template divided into n equal sectors (see Fig.1 (a)). It catches stable features of any objects rotated around its center.

For one human face, n is 16. We first extract face edges, then put the RT on its center and get a histogram (see Fig.1 (b)). The x-axis of the histogram is the signs of the

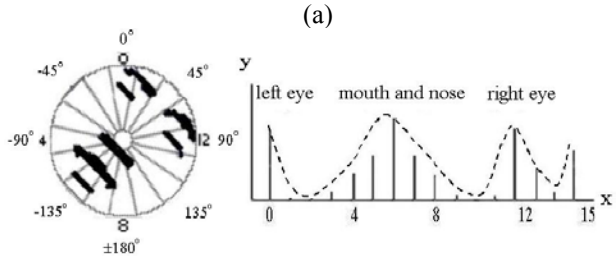
sectors in the RT numbered from 0 to 15 anticlockwise, and the y-coordinate means the sum of edge pixels in each sectors. In curve of the histogram, there are three peaks and three valleys (if we connect sector 0 and sector 15 together). These peaks and valleys indicate that there exist three most important parts in the face: left eye, right eye and mouth together with nose.

When the face turn clockwise or anticlockwise, the curve of the histogram will shift left or right, but the curve still shows these features (see Fig.2). For an object rotated around its center, its figure keeps stable to its center point. So its RT histogram will also keep the same figure and shift horizontally. For example, if the face rotates 90° clockwise, the histogram will shift four units to the left.

For human face, the peaks mean its two eyes and mouth and the valleys correspond to the part between them. Note that the partition between two eyes is the smallest, so we can get the face orientation from the RT histogram.



(a)



(b)

Fig.2 Rotated face edge map in RT and its histogram (a) – 45°; (b) 45°

2.2 RT Matching

To search human face features in an edge map, we use RT in several scales and find candidate areas. The matching algorithm is shown in Table 1.

3. FACE DETECTION SYSTEMS

Based on the RT feature matching, we can get face candidates and their orientations in edge images. We build a face detection system to detect rotated faces using RT. Its structure is illustrated in Fig.3. First a skin detection method is used to minimize searching areas and edge extraction is performed to get the orientation edge map. Then we use RT feature matching to find face candidates and their orientations. Finally we turn these candidates to upright and use an upright detector to determine the faces.

Table.1 The RT matching algorithm

- Given an area A in the edge map, center = (i, j)
- Initialize RT at different scales, R is its radius;
  $sum_k = 0$ is the number of edge pixels within section k, $\alpha_k = 0$, and $\beta_k = 0$ are two indicators, corresponding to the peak and valley of section k, $k = 0, 1, \ldots, 15$.
- Compute RT histogram:
  For (x, y) within the area $\sqrt{(x-i)^2+(y-j)^2} < R$:
  $sum_k = sum_k + 1$, if $(x, y) \in$ sector k and it is an edge pixel, where $k = 0, 1, \ldots, 15$.
- Feature Matching:
  1.For $k = 0, 1, \ldots, 15$:
  $\alpha_k = 1$, if and only if $sum_k > sum_{k+15 \bmod 16}$, $sum_k > sum_{k+1 \bmod 16}$, and $sum_k < PThreshold$
  $\beta_k = 1$, if and only if $sum_k < sum_{k+15 \bmod 16}$, $sum_k < sum_{k+1 \bmod 16}$, and $sum_k < TThreshold$
  2.A is a face candidates if
  $\sum_{k=0}^{15} \alpha_k = 3$,
  $\sum_{k=0}^{15} \beta_k = 3$,
  $|k - k'| < WThreshold$, $\alpha_k = 1$ and $\alpha_{k'} = 1$.
  PThreshold = max value of peak sector;
  TTthreshold= max value of valley sector;
  WThreshold= max sector num between two peaks.
  PThreshold and *TThreshold* belong to the RT size.
  Here we take *WThreshold*=5.
- Get face orientation:
  1.Get m, n where $|m-n| = \min|k - k'|, \alpha_{k,k',m,n} = 1$
  2.Sector t is the orientation (between the two eyes) if
  $m < t < n$ and $\beta_t = 1$

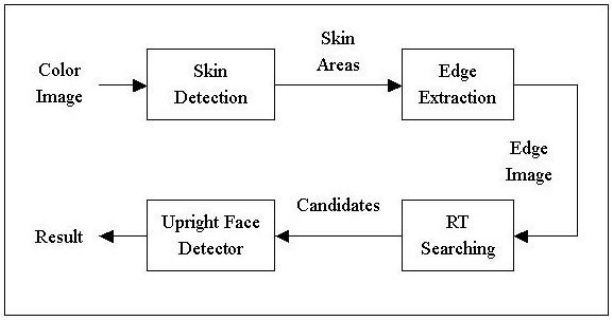
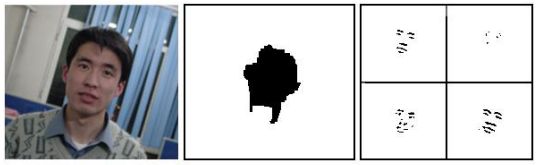


Fig.3 Face Detection System

3.1 Skin Detection and Edge Extraction

Though the RT feature matching can also be used to gray images, we use skin detection to speed up our system for the reason that more and more color pictures are in the web and videos. We choose statistical models proposed in [10]. Its result is shown in Fig.4 (b).

After skin detection we adopt Laplacian operator to extract edge map in human skin areas. Edges vertical to the two eyes and mouth, such as the two lines of the nose or cheek, will connect these three features and make the RT histogram unable to discriminate them. So we define four Laplacian operators to detect edges: horizon, vertical and two opposite diagonals (see Fig.4 (c)). Through this procedure we can get face edges in any angles that parallel to its eyes and mouth.



(a) (b) (c)

Fig.4 Preprocess of RT: (a) Original Color Image; (b) Skin Detection; (c) Laplacian Edge Extraction

3.2 RT Based Searching

Once the edge map is extracted, different scale RT is used to search face candidates within the skin areas. Here we take four scales and their radiuses from 12 to 50 in pixels which means the face sizes can be from 24×24 to 100×100 and even larger. Once a face candidate is found as in Section 2, its orientation is also detected and the system rotates the candidate to upright in the original image.

3.3 Upright Face Detector

The last step is to detect upright faces in the candidates that have been rotate to 0^o. Here we use a gravity-center template based face detector proposed by Miao et al. [7]. This method compares the relationship between human face features and searches for the upright faces in the mosaic edge image.

4. EXPERIMENTAL RESULTS

To verify the effectiveness of the proposed approaches, we do experiments on a large face image database. Since many databases commonly used by researchers are made up of gray-level images that have no color information for our detection, we build a color face database. The database is consisted of three parts: portraits in our lab, images from videos and pictures downloaded from the World Wide Web. The portraits of our lab are taken from 313 people in different backgrounds and lighting conditions. The others are mainly taken from news, sports photos and movie pictures. Also some no-face images are included. We collect more slant face images especially.

The system is tested in the large database with 1328 images on a 2.0GHz CPU. About half of the images in the testing set are 320×240, and others from 140×180 to 640×480. The average time is 0.252 second per image.

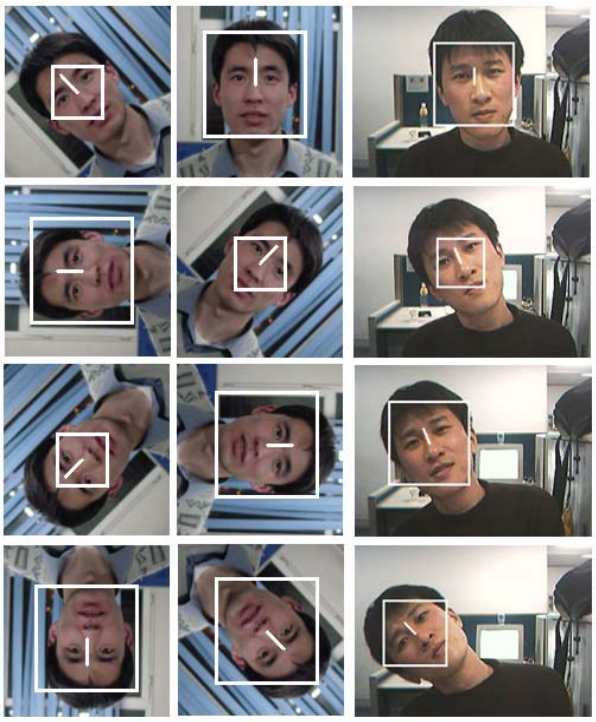
The average detection rate using RT and gravity-center template is 89.32%. For upright faces it is 91.93% that shows an effective result. The speed of our algorithm is fairly for it detects faces in any angles. The results are shown in Table.2 and Fig.5.

Table.2 Experimental results

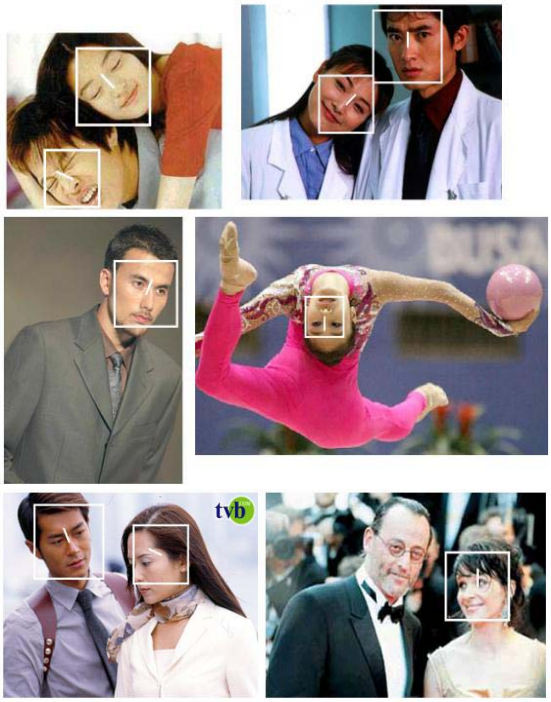
Face angle	-15^o ~ 15^o	$\pm 45^o$ ~ $\pm 15^o$	$\pm 90^o$ ~ $\pm 45^o$	$\pm 180^o$ ~ $\pm 90^o$	Total
Number of images	626	228	215	259	1328
Number of faces	669	235	221	261	1386
Number of faces correctly detected	615	204	193	226	1238
Number of faces false detected	11	2	4	6	23
Average detection rate(%)	91.93	86.81	87.33	86.59	89.32

From the experimental results we can find that the detection rates decreases when the face angles are more slant than 15^o. This is because that many of rotated faces in the testing images are slant in natural poses as in Fig.5a and b while others rotated by hand like Fig.5a. The facial expressions on these natural poses can be extracted and get unparallel edges that connect two eyes and mouth. So they disturb the RT searching. To solve this problem, better RT constructed by statistical learning algorithm will be needed.

Also there are some false detection results in Fig.5. The reason is that the RT is not sensible to profile faces and glasses. For a profile face, two eyes are too close for RT to distinct them. For a face wearing glasses, the bridge of glasses connects two eyes and edge extraction will detect it in edge map. So the RT can't search for the face when matching this area. One solution to these two problems is make a special template for these faces and build more sensible algorithm, which is our future work.



(a)



(b)

Fig. 5 Face detection results: (a) images from database of our lab; (b) images from the web and videos.

5. CONCLUSIONS AND FUTURE WORKS

We propose a face detection algorithm for color images with faces rotated with arbitrary orientations. First we detect skin areas in the whole images and extract edges in different orientations. Second we use RT to find out face candidates with their orientations and turn them to upright. Finally a frontal face detector is used to locate human faces. Comparing with other traditional methods, our system uses a novel Radial Template (RT) to detect rotated faces and their orientations. The detection rate shows our system is effective.

The novel RT for rotate object detection is proposed in this paper and it should be fully studied in the future. We will define advanced RT based on statistical learning and use the RT histogram in gray-level images to find objects in any orientations.

The speed and detection rate of our system are also need to be increased. The structure of the searching algorithm and the whole system will be refined suitable to detect human faces real-time in any angles.

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