ABSTRACT

Single frontal face detection is important step towards multiple faces and side faces. In this paper, a detection algorithm for single frontal face detection in colour images is proposed. Algorithm first detects skin colour region and then skin region is further processed by finding connected components and holes. Each connected components is tested to extract facial features like eyes, nose and mouth and by drawing lines between facial features and comparing the drawn triangles with each other. We conclude by facial feature and triangle properties that the region is face. The detected face region is enclosed by drawing rectangle using the parameters of triangle.

Keywords: connected components, holes, normalization, open area, skin color.

1. INTRODUCTION

The computing technology has improved the real-time vision modules that interact with humans in recent years. It is first step to locate faces in a scene before any recognition algorithm can be applied in biometric system. Face detection is an important step for the success of any face processing system. The face detection problem is very difficult as it needs to account for all possible appearance variation caused by change in lighting effect, facial features, expressions, etc. In addition, it has to detect faces that appear at different scale, position, angle of rotations. In spite of all these difficulties, great progress has been made and many systems have shown real-time performance.

Human face detection is useful in applications such as surveillance of video, human computer interface, recognition of face and management of image database. Detecting faces is a prerequisite for face recognition and facial expression analysis.
Anthropometry features can be used to detect facial features. Anthropometry is a biological science that deals with the measurement of the human body and its different parts.

The task of human face detection is to determine in an arbitrary image whether or not there are any human faces in the image, and if present, localize each face and its extent in the image, regardless of its three-dimensional position and orientation. Such a problem is a very challenging task because faces are non-rigid forms and have a high degree of variability in size, color, shape and texture.

1.1 Background
Face detection and facial feature extraction using color snake [1] is composed of three main parts: the face region estimation part, the detection part and the facial feature extraction part. In the face region estimation part, images are segmented based on human skin color. In the face detection part the template matching method is used. Color snake is then applied to extract the facial feature points within the estimated face region.

In Face Detection Based on a New Color Space YCgCr [2], a new color space YCgCr is described and applied for face detection. The required decision values, which determine the decision thresholds are modeled and represented in the Cg-Cr plane. Based on the representation of the experimental results, the decision thresholds are modified. The segmentation results achieved with this new color space are compared with those obtained in YCbCr.

Domain Specific View for Face Perception [3] performs a skin color analysis of the image and random measurements are generated to populate the entrant face region according to the face anthropometrics using the eye location determined from the YCbCr color space.

Face Detection using Rectangle Features and SVM [4] is based on the characteristics of intensity and symmetry in eye region. Three rectangle features are developed to measure the intensity relations and symmetry. The found eye-pair-like regions and SVM are used to find the face candidates.

Automatic Facial Features Localization [5] determines the facial features automatically, without the participation of a human. This method uses the Active Shape Models and Evolution Strategies, to find the facial features in images of faces in frontal view automatically.

A simple and efficient eye detection method in color images [6] detects face regions in the image using a skin color model in the normalized RGB color space. Then, eye candidates are extracted within these face regions. Finally, using the anthropological characteristics of human eyes, the pairs of eye regions are selected.

1.2 Our Approach
The proposed method is based on finding xy coordinate value of pixel and relation between facial features for the detection of face. The main steps of the approach are as follows, and are described in their corresponding subsections in greater detail:

1. Noise Removal.
2. Skin color detection.
3. Find connected components and test each connected component.
4. Rejecting the region, having less than two holes.
5. Each accepted region is tested for facial feature.
6. Feature extraction like eyes, nose and mouth by performing the following test:
   i. Hole location test to find the xy coordinates of the holes.
ii. Circularity test to find circle shaped holes.

iii. Features are extracted by comparing xy coordinate value of one hole with that of other holes.

7. By drawing the lines between facial features, various triangles are formed. Compare the triangles to conclude the region as face and also use the triangle to draw rectangle enclosing the face.

2. METHOD

2.1 Noise Removal
Median filter is used to remove noise from image. It examines the neighborhood pixel values, sort the pixels and replace the current pixel value by the median value.

2.2 Skin Color Detection
Image is segmented by separating human skin regions from non-skin regions based on color, a reliable skin color model [7] that is adaptable to people of different skin colors and to different lighting conditions is used. The common RGB representation of color images is not suitable for characterizing skin-color. In the RGB space, the triple component (r, g, b) represents color and luminance. Luminance varies in faces due to the ambient lighting and is not a reliable measure in separating skin from non-skin region. Luminance is removed from the color representation by using chromatic color space [8]. Chromatic colors are also known as "pure" colors is obtained by normalization process. The chromaticity r, g and b are defined as:

\[
\begin{align*}
    r &= R/(R+G+B) \\
    b &= B/(R+G+B)
\end{align*}
\]

We use only r and b to describe the skin color, given that the third component depends on the other two (g = 1 - r -b).

Skin color model is created using 11 different images of varying colors to create skin model. Crop small portion of skin from each image. Convert the colors into chromatic color space to eliminate luminance. Each sample was low pass filtered to remove noise. The low pass filter is determined by:

\[
\begin{bmatrix}
    1 & 1 & 1 \\
    1 & 1 & 1 \\
    1 & 1 & 1
\end{bmatrix}
\]

\[
1/9
\]

The sample images are converted from RGB to YCbCr space and luminance Y component is discarded. Then the sample means for both Cb and Cr components and the covariance matrix are computed in order to fit the data into Gaussian Model. The Normal distribution is also known as the Gaussian Distribution and the curve is also known as the Gaussian Curve, named after German Mathematician-Astronomer Carl Frederich Gauss. The probable skin regions in original image using this distribution is obtained by:
\[ P(r,b) = \exp[-0.5(x-m)^T C^{-1} (x-m)] \]

Where \( x = (r,b)^T \) and \( T \) denotes matrix transpose, \( C \) = covariance, \( m \) = mean .

This algorithm determines the probability of one pixel being a skin region based on the skin region model. Create a grayscale image giving the probability based on the gray level .

![Fig 1. Skin Color Image](image)

### 2.3 Finding Connected Components And Holes

In image processing, connected components labeling [9,10] scans an image and groups its pixels based on connectivity feature, i.e. all pixels in a connected component share similar pixel intensity values and are in some way connected with each other. Find all such connected component and then label each pixel with a gray level or a color (color labeling) according to the component it was assigned to. A connected components means finding regions of connected pixels which have the same value. The connected components may be face or other skin area of human like hand, neck etc. Each connected component is tested to find whether the region contains face or not.

Now we find number of holes [9] in each connected component to detect whether the connected component contains face or not. Hole is an area of dark pixels surrounded by lighter pixels is shown in Fig 2(a). Dark pixels are black color pixel and lighter pixel means white color pixel. If the connected component contains more than one holes then the region may contain face, is accepted for further processing otherwise the region is rejected.

### 2.4 Rectangular Box

Find the size of each connected component and enclose it by rectangle and also store the minimum xy-value and maximum xy-value to process the rectangle further.

### 2.5 Facial Feature Extraction

Each bounding box image has to undergo the following test individually for feature extraction.

i. Hole Location test: The location of holes in the bounding box image can be detected by finding connected component in the negative image of bounding box.

![Fig 2(a). Connected component and Holes](image)  ![Fig 2(b). Bounding box of Connected component](image)  ![Fig 2(c). Negative image of Connected component](image)
ii. Circularity test: The circularity test is performed on each internal holes i.e. Connected component in negative image of the bounding box image.

Circularity = \frac{Perimeter^2}{4 \pi Area}

If the circularity value is in the range from 0.5 to 1.2, we can conclude that this is closer to circle shape. The holes concluded as circle has to undergo further testing for feature extraction.

Then each bounding box is to be tested by using the minimum and maximum xy-value of rectangular box to find facial features [11] like eyes, nose and mouth etc.

- Eye feature extraction
  (i) Find first hole (black pixel group) within Fig 2(c) confirmed as circle. Reject the holes which is not confirmed as circle. If it is first eye as shown in Fig 3(a), then find \( x_{eye11} \) minimum x-value of first eye, \( y_{eye11} \) is minimum y-value of first eye. \( x_{eye12} \) is maximum x-value of first eye, \( y_{eye12} \) is maximum y-value of first eye.

  (ii) Find next hole (black pixel group) confirmed as circle that lies in the same range of \( y_{eye11} \) to \( y_{eye12} \) and whose x-value is greater than x-value of first eye as shown in Fig 3(b). Here it is assumed that if these black pixel groups are eyes then both black pixel groups should be in horizontal line means almost same y value or some pixel’s y-values of one group matches with the other group. To confirm these two holes as eyes, find the area and perimeter of each and check the condition:

\[
\frac{Perimeter_1 \text{eye} - Perimeter_2 \text{eye}}{\text{Area}_1 \text{eye} - \text{Area}_2 \text{eye}} < 5
\]

The two eyes are almost equal in area and perimeter. Hence in above condition, the difference of perimeter of two eyes should be less than 5 and the difference of area of two eyes should be less than 12 are concluded by performing sample test of two eyes of various images. If the above condition becomes true, then we can conclude that it is likely to be eyes.

\( x_{eye21} \) is minimum x-value of second eye and \( y_{eye21} \) is minimum y-value of second eye. \( x_{eye22} \) is maximum x-value of second eye, \( y_{eye22} \) is maximum y-value of second eye. Then check for the given case conditions:

\( x_{eye11} < x_{eye21}, x_{eye11} < x_{eye22} \)
\( x_{eye21} < x_{eye22}, x_{eye12} < x_{eye22} \)
\( y_{eye11} = y_{eye12}, y_{eye21} \)

(There may be more than one y-value in which at least one pixel value of the group should satisfy this same y-value condition)
Once both eyes are located, we try to find nose and mouth pixel group. If both eye is not in the image, then also we try to find nose and mouth pixel group.

- **Nose and mouth feature extraction**
  
  **Case I:** If both eyes are found in previous step as shown in Fig 6(a).
  
  By using the maximum x-value of first eye $x_{\text{eye1}}$ and minimum x-value of second eye $x_{\text{eye2}}$, we can find nose and mouth features.
  
  For Nose, find the next black pixel group with y-values higher than that of found eyes and x-value lies between $x_{\text{eye1}}$ and $x_{\text{eye2}}$ as shown in Fig 3(c).
  
  $$x_{\text{eye1}} \leq x_n \leq x_{\text{eye2}}$$
  $$y_{\text{eye1}} < y_n \text{ and } y_{\text{eye2}} < y_n$$
  
  Where $(x_n, y_n)$ is xy-value of nose.
  
  For Mouth, suppose $(x_m, y_m)$ is xy-value of mouth.
  
  $$x_{\text{eye1}} < x_m < x_{\text{eye2}}$$
  $$y_{\text{eye1}} < y_m \text{ and } y_{\text{eye2}} < y_m$$
  
  The x-value of this pixel group is almost equal to the Eyes x-value range and y-value is greater than eye’s y-value. We can conclude that this group is either nose or mouth.
  
  Store the x-value and y-value of this black pixel group. Then find another group, if such group exists whose x-value lies in the range of eyes x-value range. Apply case I test for this dark pixel group. If the result of this test is true then this pixel group may be nose or mouth. To exactly find nose and mouth, compare the y-value of both pixel group, lesser y-value group may be nose and group having higher y-value may be mouth.
  
  $y_n < y_m$
  
  **Case II:** If both eyes are not in the image as shown in Fig 6(b).
  
  We try to find two black pixel group that lies in vertically and then test for nose and mouth.

  ![Fig 6(a). Box with two eyes, nose and mouth](image)
  
  ![Fig 6(b). Box with one eye, nose and mouth](image)

  **Case III:** If nose does not exist in the image as shown in Fig 7(a), then mouth’s x-value lies in the range of eyes x-value.
  
  **Case IV:** If mouth does not exist in the image as shown in Fig 7(b), then nose’s x-value lies in the range of eyes x-value.
i. If both mouth and nose is not in the image then also by finding eye’s location we can say that it might be a face but not sure.

ii. If eyes, nose and mouth exists as shown in Fig 7(c), then we can conclude that the region is face. Draw the rectangle to enclose exactly the face region by using the coordinate values of eyes, nose and mouth.

Draw line between two eyes AC. Draw line BF and FI passing through nose and mouth, perpendicular to AC, B is midpoint of AC, I is mouth region. Draw line DH which is almost 2.5 to 3 times of AC in length. F is midpoint of DH. The line between eyes, nose and mouth are drawn in such a way that the following conditions exists:

a. Triangle2 is congruent to Triangle3, Triangle4 and Triangle5.

b. Triangle1 is congruent to Triangle6.

c. Triangle7 is congruent to Triangle8.

If the above conditions are true then we can confirm that the tested black pixel group A and C are eyes, I is mouth, nose is in the line BF. D and H are the approximate location of ears. Now we have to draw the rectangle enclosing the face.

If the length of AC is X then it is concluded by testing many sample faces that the length of LM is nearly 2.5X to 3X and length JL is nearly 3.6X. Draw JL 3.6 times of AC in length and complete the rectangle.
EXPERIMENTAL RESULTS

In this paper, the experiments are performed in MATLAB to verify the effectiveness of the method. In order to verify the validity, 20 images are tested. The experiment shows reasonably good result using the proposed method for locating face on image containing frontal face. But false detections are still existing. The statistical data is shown in Table.1

<table>
<thead>
<tr>
<th>Face Numbers In A Photo</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photo Numbers</td>
<td>20</td>
</tr>
<tr>
<td>Face Numbers</td>
<td>20</td>
</tr>
<tr>
<td>Hits</td>
<td>20</td>
</tr>
<tr>
<td>Wrong Selected</td>
<td>1</td>
</tr>
<tr>
<td>False Detection Rate</td>
<td>5%</td>
</tr>
<tr>
<td>Missed Rate</td>
<td>0%</td>
</tr>
<tr>
<td>Precision Rate</td>
<td>100%</td>
</tr>
</tbody>
</table>

Table 1. Statistical data
Fig 10 (a) shows input image, (b) shows detected skin Region, (c) shows binary image after skin region detection, (d) shows hole detected image, (e) shows face with triangular figure.

Fig 11 (a) shows input image, (b) shows binary image after skin region detection, (c) shows hole detected image, (d) shows face with triangular figure.
CONSTRAINTS IN PROPOSED METHOD

The Frontal Face with no orientation is detected with high accuracy. If the face is tilted by some angle, it is important to pose the head straight. Because, the above algorithm are trying to find first eye and it is assumed that next eye will lie horizontally having nearly same y-value. If head’s position is not straight then it is difficult to find the next eye and other features with this algorithm.

CONCLUSIONS

We have presented a method for face detection using feature extraction model. This detection method initially takes the color image and by combining Gaussian skin-color model, detects skin color region. Then by finding connected components, feature is extracted from each connected component, face is detected. This method works with the image containing vertically straight head. Experimental results show high detection accuracy. In the future work, the algorithm can be improved to detect tilted face, multiple face and side face to achieve better performance and further reduce the false detecting rate in dealing with images with more complex background.

REFERENCES


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