FACE DETECTION TECHNIQUE BASED ON SKIN COLOR AND FACIAL FEATURES

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Abstract: - Face detection is an essential first step in face recognition systems with the purpose of localizing and extracting the face region from the background. Apart from increasing the efficiency of face recognition systems, face detection technique also opens up the door of opportunity for application areas such as content based image retrieval, video encoding, video conferencing, crowd surveillance and intelligent human computer interfaces. In this paper, we propose a new face detection approach which is capable of detecting human faces from complex backgrounds. A skin color modeling process is proposed to the face segmentation process. Image enhancement is then used to improve the features of face candidates before feeding to the face object classifier which is based on the modified Hausdorff distance. The overall performance of the face detection system is evaluated with a successful rate of 87.5%.

Key-Words: - Face detection, skin color, facial features, face segmentation, modified Hausdroff distance, image enhancement

1 Introduction

Face detection is a necessary first step in face recognition systems with the purpose of localizing and extracting the face region from the background. Apart from increasing the efficiency of face recognition systems, face detection technique also opens up the door of opportunity for application areas such as content-based image retrieval, video encoding, video conferencing, crowd surveillance and intelligent human computer interfaces [1]. Human face is a dynamic object and displays high degree of variability in appearance. In real life situations, different illuminations and distance from imaging device, occlusion and rotation of head in different axis are bound to happen and this causes massive challenge to the detection algorithm. Most systems assume certain orientation of the face to simplify the problem such as frontal or near frontal face orientation [2]. Feature based technique has an explicit knowledge on the face detection problem whereby features representing face as defined by the designer are first extracted from images. Face detection are thus achieved by verifying to a certain degree of confidence that features extracted from images represent face [3].

Color analysis on images has long been used as a technique which can give additional dimension to image compared to grey scale image. Classification is easier to handle in color space compared to gray scale. It is a known fact that skin color of different races tend to cluster in close proximity in normalized color space or chromaticity space. This has also brought about the possibility of modeling skin color distribution as Gaussian distribution. Using this skin color model, skin candidate region is identified based on certain threshold value. The problem of matching two images has been an active topic of research in computer vision and target track for the last two decades.

Image matching methods can be well used to find correspondence between a template and given portion of an image having the most partial similarity. The partiality stems many factors, such as different time, viewing condition, occlusion, noise, etc. In the past, there were various methods that can be well used for locating a model in an image and be divided into two categories: area based matching and feature based matching [4]. The use of variants of the Hausdorff distance has recently become more and more popular in the image matching application. Hausdorff distance is a robust technique used in image matching problem. It has the advantage of being scale invariant, illumination invariant and robust in complex background. Skin color has long been used for detecting skin color region and even in head detection system for searching head region. The major problem with using skin color model however is that it is subject to variation in
illumination and hence not robust enough in detecting head candidate. One more prominent problem is that most of the time, object which appears to have skin color is not necessarily the human face, worse, it may not even be part of the human skin. It is therefore impossible to rely solely on skin color alone as an effective face detection strategy. Hausdorff distance is a robust technique in image matching [5]. Traditionally, it has always been used in gray scale image to locate image candidate which is a closest match to an object. In order to search for the possible image candidate, the system generally needs to scan through the whole image until it reaches the targeted candidate. As the image size grows, so does the computing power needed to locate the image candidate. It is therefore believed that using skin color filter along with Hausdorff distance will target the shortcomings of both these strategies. Skin color filter will help identify the image candidate so that Hausdorff distance will be able conserve computing power on the image candidate while Hausdorff distance will verify the validity of the image candidate which is not possible by using skin color filter alone.

2 Methodology

The overall face detection system consists mainly of three modules: (i) Image acquisition; (ii) Skin color segmentation; and (iii) Modified Hausdorff object classification. The system starts with the image acquisition module which takes in color images in various formats. In this experiment, image acquisition process is simplified into feeding downloaded color images into the system. The color images which may contain face or non face objects are then processed by the skin color segmentation module and modified Hausdorff object classification module respectively and consequently produce results as the number of face objects detected in each input image. The face region detected in an input image is the displayed separately to allow user to verify its authenticity. In this work, main emphasis is given to the implementation of skin color segmentation module and modified Hausdorff object classification module.

2.1 Skin Color Segmentation

The main objective of skin color segmentation is to segment out any object which resembles the human skin color within a certain degree of confidence which is determined by the thresholding process. Regions with low probability of being the face region will first be eliminated so that the computation power can be focused solely on regions with higher probability. Color images are fed to the skin color filtering subsystem where the probability of every pixel being the skin color pixel is evaluated. A thresholding process will then determine the best threshold value for the skin color filtering process where pixels with probability exceeding the threshold value will be retained for further processing while those below this threshold value will be discarded immediately.

Enhancement process is then needed as there are always possibilities that some face region pixels which are discarded or non face pixels which are retained. This process thus help reconstructs the face region should part of the face pixels is unintentionally discarded and also eliminate regions which are not face and yet unintentionally retained. The output of the enhancement process which is also the output of the whole skin color segmentation process, is a binary image where skin color pixels are represented as 1 while non skin color pixels are represented as 0.

2.1.1 Skin Color Filtering

The objective of skin color filtering is to perform color segmentation on the input image based on human skin color in a suitable color space. Pixels resembling human skin color will be segmented out while the rest will be discarded. This work chooses YCbCr color space which is more tolerant towards lighting condition compared to RGB color space. The original input image, \( f(x, y) \) in the RGB color space is represented in a matrix form as shown below:

\[
f(x, y) = I = \begin{bmatrix} i_R \\ i_G \\ i_B \end{bmatrix}
\]

\( f(x, y) \) is thus converted into YCbCr color space using formulae 2, 3 and 4 into:

\[
g(x, y) = H = \begin{bmatrix} h_Y \\ h_{CB} \\ h_{CR} \end{bmatrix}
\]

After a suitable color space has been chosen, a human skin color filter needs to be constructed. The skin color filter is assembled based on adequately large sample of different races in YCbCr color space. In this experiment, a total of 200 face images across different ethnic groups and gender from the Alexi Face Database [6] are used to construct the skin color filter. The sample collected is then fit into a bimodal Gaussian distribution where the Y
component is neglected. In order to create this sample, images containing skin region of different races are segmented manually and put through a skin color sampling process. The skin color pixels are then modeled as bivariate Normal Distribution. The probability of an image pixel belonging to the human skin color can be computed using the formulae as shown as proposed by [2].

\[
Likelihood = P(r, b) = \exp[-0.5(x-m)^T C^{-1}(x-m)]
\]  
where \(x = (r, b)^T\).

Using this formula, the probability of each input image pixel belonging to the human skin falls between the ranges 0 to 1 where 1 is the highest possibility while 0 means that particular pixel could never be part of the human skin. A binary image, \(h(x, y)\) with 1 representing skin object and 0 representing non skin object is derived where the probability of each pixel in \(g(x, y)\) being human skin color is computed using formula 4. When \(P(r, b)\) of a certain pixel exceeds the threshold value, the pixel value is set to 1 and vice versa as shown:

\[
h(x, y) = \begin{cases} 
1 & \text{if } P(r, b) \geq \tau_{\text{threshold}} \\
0 & \text{if } P(r, b) < \tau_{\text{threshold}}
\end{cases}
\]  
where \(\tau_{\text{threshold}}\) is the threshold value.

In the experiment, it found that the probability threshold value, \(\tau_{\text{threshold}}\) is dependent on the input image itself and that it is not possible to assign a single threshold value which will be applicable for every input image. Therefore, an iterative process is used whereby the starting threshold value is 0.9, a step of 0.05 is then decreased from the starting threshold value until the total pixels change in the resulting image begin to stabilize.

2.1.1.1 Enhancement
The basic idea of the enhancement phase is to lump skin pixels in close vicinity together using the image labeling technique and to compute the size of each skin pixel groups. Skin pixel groups with size less than 1% of the largest skin pixel group will then be treated as noise and eliminated. A median filtering process is then used to eliminate noise within the skin pixel region. This is followed by image dilation process which helps reconstruct the face region when pixels within the region are discarded unintentionally.

A) Connected Component Labeling
The output image from the color filtering process is a binary image where the skin color candidate pixels are in white while other pixels will be shown in black. Connected component analysis thus lumps skin pixels in close vicinity together to become skin candidate regions using the 8-connectivity relationship.

Since false detection could occur for object with similar color to the skin color, subsequent filtering process based on the size of skin candidate region is used to eliminate those unwanted objects. This includes median filtering to filter out non skin pixels outside the intended face region and image dilation to connect face regions which get dissociated because certain face pixels connecting those regions are discarded. The assumption used is that the largest skin candidate region is valid and it is used as a basis to compared against other skin candidate regions. Another assumption made is that false detection happens at a very much smaller scale compared to the largest valid skin region. In order to determine the suitable size of the structuring element or filter for the median filtering and image dilation process, the size of the largest skin candidate region, \(Area_{\text{max}}\) is first taken as the basis. \(Area_{\text{max}}\) is determined by counting the number of pixels belonging to the largest connected component. All other skin candidate regions are then parsed through to determine their respective sizes. Skin candidate region which is less than one percent of the largest skin candidate region is then rejected.

B) Median Filtering
Median filter is used to smoothen the segmented skin color regions. The median is calculated by first sorting all the pixel values from the surrounding neighborhood into numerical order and then replacing the pixel being considered with the middle pixel value. Using this principle, a square structuring element of equivalent area to one percent of the largest skin candidate region, \(Area_{\text{max}}\) is used for the median filtering process. The size of the square structuring element is calculated as shown:

\[
W_{\text{median}} = \sqrt{Area_{\text{max}}}
\]

where \(W_{\text{median}}\) is the width of the median filter structuring element.

C) Image Dilation
Image dilation is applied to the median filtered image to reconstruct the skin color regions when certain pixels within the actual skin color regions are
unintentionally discarded in the skin color filtering process. It also carries the objective of reconnecting dissociated skin color regions. Image dilation is a morphological operation where the operation is centered on a structuring element and is typically applied to binary image. The basic effect of the operator on a binary image is to gradually enlarge the boundaries of regions of foreground pixels. Thus the areas of foreground pixels grow in size while holes within those regions become smaller. The dilation operator takes two pieces of data as inputs. The first is the image, which is to be dilated. The second is a set of coordinate points known as a structuring element (also known as kernel). It is the structuring element that determines the precise effect of the dilation of the input image.

2.2 Modified Hausdorff Object Classification

The modified Hausdorff object classification module aims to identify face region with higher confidence. Basically, it is divided into two stages which are the Sobel Edge detector and Modified Hausdorff Distance matching. Based on the gray scale image regions extracted from the original input image using the bounding boxes returned by the skin color segmentation as the input, Sobel Edge detector will detect edges of the face candidate region along with the facial features. Modified Hausdorff Distance is then used to compare the face template with the image to verify whether it is a face.

2.2.1 Sobel Edge Detector

In Hausdorff distance object matching, outline of the object is sufficient for successful comparison. Therefore, edge extraction is required to successfully extract the outline and any details in the image. Sobel edge detector fulfils this role by producing single pixel thick edges of the skin regions and outlines of the facial features. The Sobel edge extraction will then produce an image, \( J(x, y) \) which will only consist of the boundary of each regions based on the formula below:

\[
J(x, y) = \begin{cases} 
1 & \text{when } |G| \geq \tau_{\text{threshold}} \\
0 & \text{otherwise}
\end{cases}
\]  

(6)

2.2.2 Modified Hausdorff Distance

Modified Hausdorff Distance is the final parameter derived from the comparison between a model face images with the input image. Both the images are represented as one pixel thick edges where the input image is the output image of the Sobel edge detection subsystem. The model face image or the face template on the other hand is a valid forward face which contains the edges of the face outline and also the outlines of other facial features such as eyes, eyebrows, noses and lips. The modified Hausdorff distance between the face template and skin color objects will then give an idea of how closely resemble the skin color object is to the face template. In other words, the more closely resemble the skin color object is to the face template; the more likely that it is a face. Hausdorff distance is the maximum distance of a set to the nearest point in the other set. More formally, Hausdorff distance from set \( A \) to set \( B \) is a maximum function, defined as:

\[
h(A, B) = \min_{a \in A} \{ \max_{b \in B} \{ \min d(a, b) \} \}
\]

(7)

Where \( a \) and \( b \) are points of sets \( A \) and \( B \) respectively, and \( d(a, b) \) is any metric between these points. For simplicity, will take \( d(a, b) \) as the Euclidian distance between \( a \) and \( b \). Owing to the nature of the Hausdorff distance which only takes into account the maximum distance between the two sets of points, any outlier or noise could easily lead to false detection of the face should face detection is only based on this measure. A modified version of the classical Hausdorff distance which is also known as the modified Hausdorff distance is therefore adopted. The modified Hausdorff distance measure also known as mean Hausdorff distance measure is formulated as follow:

\[
h_{\text{mean}}(A,B)= \frac{\sum_{a \in A} \max_{b \in B} \{ \min d(a, b) \}}{n_A}
\]

(8)

where \( n_A \) is the total number of points in set \( A \). By taking into account the mean distance between the two sets of points instead of the maximum distance only, the outlier effect could be significantly reduced. In terms of implementation however, a straightforward implementation based on Formula 6 will require a lot of processing power. Distance transform is used instead in this situation. Distance transform calculates the closest distance between the current pixel with the nearest non zero pixel. For all pixels of the image, the distance transform gives the distance to the closest edge-pixel. After performing distance transform, a matrix of the same dimension as the original image will be produced at the end of it. In order to compute the modified Hausdorff distance between the template image and input image, distance transform is first performed on the face template image. A matrix of the same dimension as the template image is created. An AND operation is performed between the distance...
transform matrix of the template image and the input image. The non zero distances in the product matrix is then accumulated and divided by the total number of non zero pixels of the product matrix. The result is the mean forward mean Hausdorff distance between the template image and input image. The same procedure is repeated for the input image where its distance transform matrix is created. The result of it is known as the reverse mean Hausdorff distance. The mean Hausdorff distance will then be the maximum between the forward and reverse mean Hausdorff distance.

2.2.3 Thresholding
Thresholding is needed to decide the adequate threshold value which acts as a cutoff point between face and non face. Using a series of frontal face from the face database and non face image, the mean Hausdorff distance is decided based on the mean Hausdorff distance generated. In the end, it is found that the mean Hausdorff distance of 18 is an adequate threshold value.

3 RESULTS AND DISCUSSION
3.1 Formation of Skin Color Filter
Skin color filter is modeled as a bivariate Normal distribution using two hundred images from the face database manually. Figure.2 illustrates part of the images used for the formation of skin color filter. The face database comprises samples of frontal face of different gender and ethnics so that it is able to cater more variety of input images. Using these samples, the mean matrix and the covariance matrix are found to be:

\[
\begin{bmatrix}
\mu_c \\
\mu_s
\end{bmatrix} =
\begin{bmatrix}
153.1373 \\
99.6061
\end{bmatrix}
\]  
(9)

\[
C = 
\begin{bmatrix}
144.2155 & -35.0688 \\
-35.0688 & 178.7794
\end{bmatrix}
\]  
(10)

Images in Figure.1 (a) and (b) will be used to illustrate the result of each steps taken in methodology from skin color segmentation leading to the detection of face based on modified Hausdorff distance measure.

3.2 Skin Color Segmentation
Skin color segmentation consists of skin color filtering, thresholding, connected component labeling, median filtering and image dilation steps. The results for each of these steps are illustrated in the following section by using images in Figure.1 as examples.

![Fig.1: Sample images from face data base](image)

![Fig.2: Skin color distribution](image)

3.2.1 Skin Color Filtering
Skin probability distribution of individual pixels in an image is first computed prior to filtering. Figure.2 shows the skin probability distribution for images in Figure.1 (a) and (b). In Figure.2, pixels in white represent higher probability of that pixel belonging to a skin object while darker pixel especially pixels outside the actual skin region have lower probability of belonging to skin object. Some of the pixels which belong in the skin region still have lower probability as shown in all of the images shown. This is due to the reason that lights often get reflected at these areas which make it appears to be different from the actual skin color. Some facial features such as eyes, eye brows, and lips which have significantly different color from human skin color also have lower probability as shown by the darker pixels at the locations of these features.

3.2.2 Thresholding
Thresholding determines the suitable threshold value to be used for the cutoff value between skin color pixel and non skin color pixel. The thresholding results for the images in Figure.2 (a) and (b) are shown in Figure.3. Most of the face area pixels are identified as skin where they are represented by white while other pixels below the threshold value are represented as black in the images. Facial features such as eyebrows, eyes and lips and even moustache which have significantly different color
from human skin are filtered out during this stage. Shown under individual image is the threshold value at which the result is obtained using an automatic thresholding process. This is the value when the skin filtering result begins to stabilize.

An optimum threshold value is important in the sense that significant amount of skin color pixels are identified without too much false detection on the non skin color pixels. Figure.4, illustrates this point based on image in Figure.3 (b). Shown in Figure.4, image in Figure.3 (b) is manually thresholded using step of 0.1 starting from 0.9 to illustrate the effect of threshold value on the result of thresholding. At the highest threshold value shown which 0.9, it can be seen that only a small fraction of the actual skin color pixels are identified. Using the result obtained from this threshold value, it would be impossible to reconstruct the actual face region since the number of skin pixels identified is too small and they are scattered across the face area. As the threshold value decreases, the number of pixels identified as skin increases up until a stage where the increases in the actual skin area begins to saturate which is around the threshold value of 0.5. After this value, the number of non skin object identified as skin begins to increase where the pixels in the shirt identified as skin increases tremendously with the decrease of threshold value. Therefore, an optimum threshold value is the value at which most of the face regions pixels are identified as the skin color pixels while the number of other objects such as part of the shirt being identified as skin color pixels are minimized.

![Thresholding result for images](image)

**Fig.3:** Thresholding result for images.

<table>
<thead>
<tr>
<th>Threshold value</th>
<th>Image</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.7</td>
<td><img src="image" alt="Image" /></td>
</tr>
<tr>
<td>0.55</td>
<td><img src="image" alt="Image" /></td>
</tr>
</tbody>
</table>

![Thresholding result for images](image)

**Fig.4:** Manual thresholding using step of 0.1 for image in figure.3 (b)

<table>
<thead>
<tr>
<th>Threshold value</th>
<th>Image</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.9</td>
<td><img src="image" alt="Image" /></td>
</tr>
<tr>
<td>0.7</td>
<td><img src="image" alt="Image" /></td>
</tr>
<tr>
<td>0.5</td>
<td><img src="image" alt="Image" /></td>
</tr>
<tr>
<td>0.3</td>
<td><img src="image" alt="Image" /></td>
</tr>
</tbody>
</table>

**Fig.5:** Connected component labeling for images

3.2.3 Connected Component Labeling

Using the 8-connectivity relationship the connected component for images is displayed in Figure.5. As shown in Figure.5, connected component or single groups of pixels which are connected are displayed in the same color in the image. Darker blue color is used to denote the major connected component of the face while smaller connected component of different color can be seen. The lesser number of different connected components derived, the better is the skin color filtering process. As seen in all of the images in Figure.6, skin color pixels which were originally connected are separated from each other after the skin color filtering process. The lesser number of different connected components derived, the better is the skin color filtering process. As seen in all of the images in Figure.5, skin color pixels which were originally connected are separated from each other after the skin color filtering process. This is due to the fact that these skin color pixels are blocked by some facial features such as moustache or beard. the face region and the neck region are separated from each other due to the fact that part of the neck region which is under the shadow of the face region are considered as non skin color pixels under the skin color filtering process.

![Connected component labeling for images](image)

**Fig.5:** Connected component labeling for images

3.2.4 Median Filtering

Median filtering removes some of the connected components not connected to the major connected components as evident in all the images. It also creates a smoother outline for all the face regions. In Figure.5 (b), median filtering process successfully remove most of the connected components outside the actual face region especially connected components on the shirt which are classified as skin color pixels after the skin color filtering process. In all of the images in Figure.6, median filtering process also smoothen the edge of all the images. Nevertheless, median filtering process also create extra problem where the major connected component on the face area are sometimes separated after the process. This can be shown in Figure.5 (a) where area above the forehead region is separated from the major face area. This shows that median
filtering process tends to cause the thinner to disappear due to the dimension of the median filter used.

3.2.5 Image Dilation
Image dilation is performed on the images in Figure.6 (a) and (b) to reconstruct the actual skin color region when part of the skin color region is unintentionally discarded in skin color filtering and median filtering. Figure.7, illustrates the same images in Figure.6 (a) and (b) after the image dilation operation. Image dilation helps to close back some of the empty regions within the skin color region which is evident in all the images used. In some instances such as in Figure.7 (a) and (b), image dilation helps to reconnect skin color regions which were dissociated from each other. In Figure.7 (a) in particular, the forehead region which gets separated from the rest of the face region after the median filtering operation is reconnected after image dilation operation. In Figure.7 (a), the neck region and the face region which were still separated from each other in the median filtering process are joined back into a single region after the image dilation process. In Figure.7 (b) in particular, image dilation expanded the lower chin region of the face which helps give a more accurate description of the face. Nevertheless, image dilation process has its own limitation in recreating back the actual face region. Since the effect of the dilation relies on the size and shape of the structuring element, it is not possible to reconstruct the complete face region when there is a wide gap between the dissociated connected components or when the hole within the face region is too large.

3.3 Modified Hausdorff Object Classification
Modified Hausdorff object classification consists of Sobel edge detector and modified Hausdorff distance matching. The following sections present the results for each of the step mentioned based on the images in Figure.7 (a) and (b).

3.3.1 Sobel Edge Detector
Outlines of the candidate skin color objects along with any possible facial features within the skin color objects can be created using Sobel edge detector. Edges of the images which will be further evaluated by the modified Hausdorff classifier is obtained from part of the images in Figure.1 (a) and (b).

These parts which are also known as the face candidate regions are as shown in Table 1. The face candidate regions in the Figure.1 are operated on by Sobel operator in the x-direction, y-direction and the final column illustrates the result of an OR operation between the results of the previous two columns. It is easily noticeable that facial features are sensitive to different types of Sobel operators. Horizontal facial features such as lips and eye brows can be easily extracted using Sobel operator in the x-direction by not the Sobel operator in the y-direction. Noses on the other hand are easily detected by the Sobel operator in y-direction instead. Facial feature such as eyes are picked up by both of the Sobel operator as they consist of horizontal and vertical elements. Therefore, an OR operation between the results of the two kinds of Sobel operators are able to retain most of the facial features which are of utmost importance in the Modified Hausdorff object matching. These features are then compared with those of the face model to calculate the modified Hausdorff distance.

3.3.2 Modified Hausdorff Object Matching
In order to identify face candidate regions as face or non face, the image in Table.1 (a) is chosen as the template image. The results of object matching between the face template and the images in Figure.1 (a) and (b) are illustrated in the following table. Based on the template, all the face region within the images are successfully identified as shown in Table.2 using threshold value of 18. Identified face region will then be displayed separately so that verification can be made to see if the face detection system has been accurate. As shown in Table. 2, all of the images have modified Hausdorff distance value within the range 12 – 18. Slight obstruction of some of the facial features such as moustache and beard in Table.2 (a) and (b) do not really affect the modified Hausdorff distance.
Table 1: Edges detected using Sobel Edge Detector for Images in Figure.1.

<table>
<thead>
<tr>
<th>Sobel Operator Type</th>
<th>( G_x )</th>
<th>( G_y )</th>
<th>( G_x ) OR ( G_y )</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td><img src="image" alt="a" /></td>
<td><img src="image" alt="a" /></td>
<td><img src="image" alt="a" /></td>
</tr>
<tr>
<td>b</td>
<td><img src="image" alt="b" /></td>
<td><img src="image" alt="b" /></td>
<td><img src="image" alt="b" /></td>
</tr>
</tbody>
</table>

Table 2: Face detection result based on mean Hausdorff distance method.

<table>
<thead>
<tr>
<th>Original Image</th>
<th>Detected Face Object</th>
<th>Mean Hausdorff Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td><img src="image" alt="a" /></td>
<td>13.86</td>
</tr>
<tr>
<td>b</td>
<td><img src="image" alt="b" /></td>
<td>17.7</td>
</tr>
</tbody>
</table>

3.3.3 Modified Hausdorff Distance Object Matching with Test Images

After the face detection system is constructed using the modified Hausdorff distance object matching method, it is necessary to verify how effective it is with other images which are not from the face database. Table 3 shows the results of the face detection system on three test images which are not from the face database. In Table.3 (a), the face image is detected successful where there is only one face object. In Table.3 (b), there are three face objects inside the image. However, only two of the images are successfully detected which are shown in the last column. The overall performance of the face detection system is acceptable with a detection rate of 87.5%. In general, the face detection system is able to detect faces under complex background and of different sizes and locations. Multiple faces are also able to be detected using this system which is part of the requirements of the primary objective.

Table 3: Face detection using test images.

<table>
<thead>
<tr>
<th>Test Image</th>
<th>Face Image Identified</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="a" /></td>
<td><img src="image" alt="a" /></td>
</tr>
<tr>
<td><img src="image" alt="b" /></td>
<td><img src="image" alt="b" /></td>
</tr>
</tbody>
</table>

4 CONCLUSION

This paper presents a novel method for face detection system based on the modified Hausdorff distance technique using color images. The skin color segmentation process is based on a human skin color filter constructed from 200 human objects from diverse races. The proposed face detection system is then implemented on test images with either single face or multiple faces to measure the detection rate and the false detection ratio of human faces. The final system is capable of detecting human faces of different scales and from different races with a successful rate of 87.5%.

References: