Smart Human Face Detection System

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Abstract: Digital Image Processing (DIP) is a multidisciplinary science that borrows principles from diverse fields such as optics, surface physics, visual psychophysics, computer science and mathematics. Some of image processing applications can be finding in: astronomy, ultrasonic imaging, remote sensing, video communications and microscopy.

Face detection/recognition has attracted much attention and its research has rapidly increased in many potential applications in computer, communication and automatic access control system. Furthermore, face detection as a first step is an important part of face recognition. Since the image has lots of variations in appearance, face detection is not straightforward, such as pose variation, occlusion, image orientation, illuminating condition and others.

The full face detection and gender recognition system is made up of a series of connected components. There are much software that can facilitate the detection process such as: Matlab, Labview, C# and others.

In this paper we propose a fast algorithm for detecting human faces in color images using HSV color model without sacrificing the speed of detection. The proposed algorithm has been tested on various real images and its performance is found to be quite satisfactory.

Key words:— Face detection, Color , Skin detection, Image processing, Skin color.

I. INTRODUCTION

Skin and face detection using automatic detection tool or software plays very important roles in many visualization applications, such as face and gesture recognition in intelligent human-machine intelligence and visual surveillance [1-6], video phone or sign language recognition [7,8] as well as content-based multimedia retrieval [9,10]. Furthermore, the human face provides a variety of different communicative functions for identification and the perception of emotional expressions; therefore, biometric systems using face recognition are attracting attention for authentication and authorization as in [5].

Face detection is a first step for face recognition of colored images [11, 12] obtained from cameras, video or still images.

Face detection has been used in many applications such as biometrics, video surveillance [13], human computer interfaces, image database management and smart home applications.

The most five known algorithms [14-22] for face detection are: Principle Component Analysis, Linear Discriminator Analysis, skin color, wavelet and artificial neural networks.

More elaboration will be made on the skin color algorithms. Face skin color is the important item of human faces. The first main step in detecting skin pixels is to classify as skin color or non- skin color. A proper color model is needed to perform the classifications. The HSV color model is popular when compared to RGB or YCbCr color models because it is compatible with human color perception. The second step will be connectivity analysis to confirm a skin pixel or not, the third and final main step is to find an optimal boundary box to extract the face from the input image.

Referring to the results obtained by [23], we have found the following rule for skin classification.

19< H < 240 , Not Skin

Where H stands for hue component that describes the shade of the color, and S stands for saturation component that describes how pure the hue color as seen in figure 1.

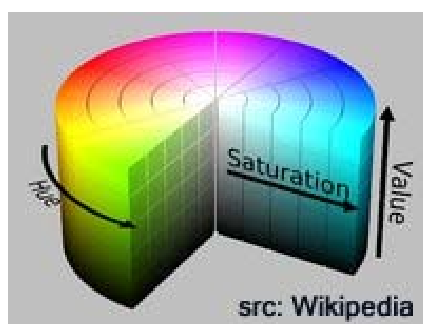

Figure 1: HSV

From its nature, HSV color space has the property of precise discrimination between luminance and chrominance. This made the HSV color space become widely popular in the researches on lightning effect related applications. Furthermore, the Hue components are invariant to changing lighting conditions; as a result of low dependence to brightness, as in figure 2.

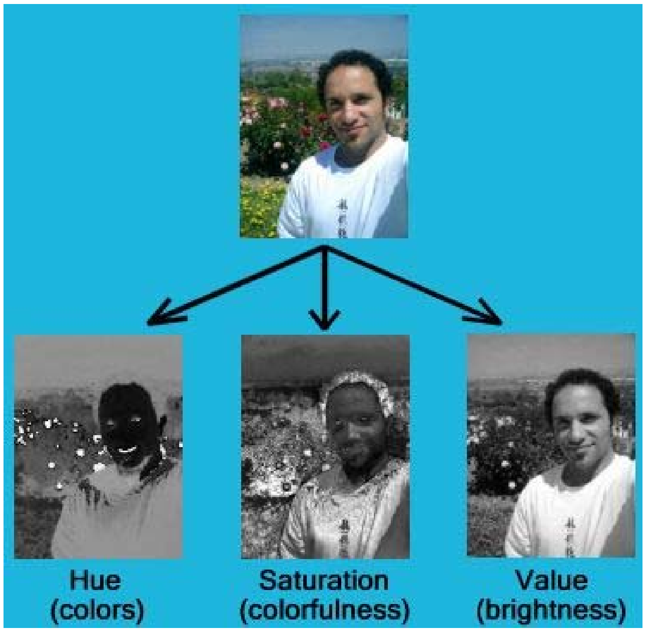

Figure 2: HSV analysis output [24]

In order to cover all skin colors [25], many colored images that contain human faces should be studied and extracted the skin regions in these images manually. As a result we can see that the skin color falls into a very small region in the entire HS space.

Most face detection methods use only the luminance component, extracting features as texture, depth, shape, and Eigen-faces. There are various applied techniques (algorithms) such as bootstraps, SVM, neural networks and fuzzy methods. Another group of methods added the chrominance information as a validation of the luminance channel technique. And the last group starts from the chrominance information to locate the faces, which use other facial features for validation purposes. All present efforts are focusing in finding suitable facial features for validation; since the color analysis yields information related to the presence of skin rather than the presence of face.
This paper summarizes three algorithms for face detection. Then the results of the three algorithms will be compared and discussed.

II. Face detection

i. Color Segmentation:
In real life a person framed in a photograph, his face is not white, green, red, or any unnatural color of that nature. Furthermore, the differences in the levels of melanin and pigmentation, the range of colors that human facial skin takes on are clearly a subspace of the total color space. So it will be a good idea to take advantage of face-color correlations to limit faces search in a dedicated image.

The colored image for the detection of skin color is a useful technique for face detection. Many techniques [31], [32] have reported for locating skin color regions in the input image. Typically, the colored image is in the RGB format, but some of the techniques use color components in the color space, such as the HSV or YIQ formats. The first step in this face detection algorithm is that of color segmentation. The goal is to remove the maximum number of non-face pixels from the images in order to narrow the focus to the remaining predominantly skin-colored regions.

ii. Color space selection
In the skin color detection process, each pixel classifies as skin or non-skin based on its color components. The detection window for skin color was determined based on the mean and standard deviation of Cb and Cr component.

Furthermore, a discussion of different color spacing will be covered, in order to find the suitable for or application, so, but it looked at three color spaces HSV and YCrCb spaces, as well as the RGB space.

A. HSV Color Space

As known RGB is the most commonly used basis for color descriptions, it has the negative aspect that each of the coordinates (red, green, and blue), but some times it does not necessarily provide relevant information about whether a particular image"patch" is skin or not skin; because it is subject to luminance effects from the lighting intensity of the environment. The HSV provides color information in a manner more in line how humans think of colors and how artists typically mix colors. "Hue" describes the basic pure color of the image, "saturation" gives the manner by which this pure color (hue) is diluted by white light, and "Value" provides an achromatic notion of the intensity of the color. It is the first two, H and S that will provide with useful discriminating information regarding skin [33].
This is the most noticeable trend used to derive the following rule is:

$$0.5 < H < 1.4 \rightarrow \text{not skin [33]}$$

B. YCbCr Color Space

By analyzing YCbCr color space for any images, which considered as an advantage; because by that non skin areas can be removed. And after experimenting with various thresholds, the best results were found by using the following rule: [34]

$$102 < Cb < 128 \rightarrow \text{Skin [15]}$$

C. RGB Color Space

Since RGB doesn't decouple the effects of luminance, it is still able to remove certain colors that are clearly out of the range of the normal skin color.

From studying and experimenting with various thresholds in RGB space, we found that the following rule worked well in removing some unnecessary pixels: [35]

$$0.836G - 14 < B < 0.836G + 44 \Rightarrow \text{Skin}$$ [35]

And

$$0.79G - 67 < B < 0.78G + 42 \Rightarrow \text{Skin},$$ [35]

Summary:

- HSV representation has certain advantages over RGB when it comes to face detection since the skin colors are sensitive to the lighting condition
- In the RGB space, each of the three components may exhibit substantial variation under different lighting environments.
- In HSV space, however, the hue and saturation components are virtually unchanged
- Therefore HSV color space will be used to build this application

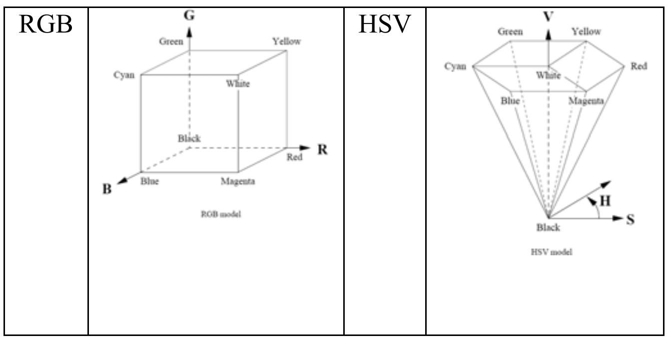

Figure 3 [35]

iii. Face detection mechanism

Face detection is divided into many stages, in this step only related topics will be discussed.

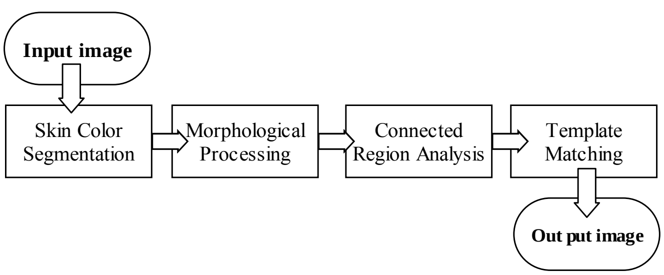

Figure 4: Face detection mechanism

iv. Skin Detection

Skin color is one of the most important features in the human face. Feature-based face detection techniques may use skin color information to detect faces in color images having complex background [36]. Certain regions of the face can be detected by the skin detector in a color image represent human skin or not.

The selection of the color space that will be used in skin color detection is very important; it is known that different people have different skin color, and these differences are in the intensity not in the color. This means that skin detection methods drop the luminance component of the color space. There are lots of color spaces that have been used in early work of skin detection, such as RGB, normalized RGB, YC_bC_r and HIS. RGB is one of the most used color spaces for processing and storing digital images, it is not widely used in skin detection algorithms because the chrominance and luminance components are mixed. Normalized RGB and YC_bC_r are often used by skin detection techniques.

- Non-face background removal

The color segmentation algorithm is a good technique to distinguish face/non-face color, but this is not the whole story (as on my built application), some times unwanted background objects shared with face colors (wood, piece of painted metal, painted walls or hands, arms, and others). To distinguish between those and faces, the object features should be taken into the consideration such as size, location, and shape. In addition some other tools should be used to repair facial periphery suffering from false-negative miss-classification errors. These tools will help us to have clean segmentation, which can be used in later stages.

v. Image preprocessing

The next step is to continue processing using a minimal amount of morphological. This depends on the following:

- The preparation Given the image segmentation
- The smallest objects are first removed
- Closing operation is then performed
- Smallest objects are then removed
- A more closing operation follows, succeeded by modest erosion.
- All other objects smaller than the minimum face area are removed.
- The maximum size of object to be removed was experimentally determined.

After those preparations MORPHOLOGICAL PROCESSING can be applied:

a. Applying the Open Operation

After removing the major part of the original pixels from consideration, but there will be little specs throughout the masked image; this is because the image will be sent through a matched filter and the specs will be averaged out of consideration which could be left in, and can be ignored. The removing of the spaces will speed future processing (i.e. the matched filter needn't perform any wasteful calculations at these pixels).

b. Removal of Small Blobs and Grayscale Transformation

Blobs: are the connected groups of pixels that remain at the end of this stage. And hence should have head sizes (measured by number of pixels) that are relatively similar. The largest blobs should be these heads and blobs considerably smaller than the larger blobs may be safely assumed to be more "noise".

By removing blobs that are below the threshold. After experimenting with different images the pixel size of 200 is a good threshold value. Therefore blob size rule is:

Area < 400 and > 1400→ Non-Face

Any size out of above range will be removed. Finally, the transform of images to grayscale provides with final pre-processed image.

vi. Connected-component analysis

a. face detection

This is step is called the template design stage which consists of:

- Determine which template to use.
- Find a good subset of the faces found in the training images that are clear, straight, and representative of typical lighting/environmental conditions.
- The images should properly align and scaled with respect to one another.
- Manual segmenting, selecting, and aligning face photos.

b. Connected-component analysis

Following histogram-based color segmentation, the image is then subject to a series of low pass filtering, hole-filling and erosion steps. This stage is optimized to keep the non-skin areas as small as possible. After removing the non-face background as described in the previous sections, the face areas can be successfully identified.

Algorithm I [26]

This work is based on RGB color model; it is summarized in the following steps:

Step 1: Resize the image to fit a 30x30 pixel template.

Step 2: Convolve the masked grayscale image.

Step 3: Look for peaks in the output and compare them to a given range of thresholds.

Step 4: Consider pixels within the threshold range faces.

Step 5: Threshold range is reduced to a preset lower limit. Then apply another state of convolution process to the next step if the lower limit is reached.

Step 6: Enlarge the template to detect larger scale faces. Repeat convolution, detection and threshold reduction steps.

Step 7: Quit when the upper scale limit is reached.

III. Algorithm [14]

This work is based on HSV color model; it is summarized in the following steps:

Step 1: Convert RGB image to HSV image.

Step 2: Using Sobel operators on RGB image to find the edge map image.

Step 3: Find the H and S values for each pixel.

Step 4: If the H and S values of the color histogram > skin threshold and edge values < edge threshold, then the skin is skin pixel otherwise it is non skin pixel.

Step 5: Use 8- connected neighbors to find the different regions.

Step 6: Find for each region, the height, the width and the centroid and also the percentage of skin in each region.

Step 7: Use Golden ratio [27] to confirm the region is a face or not.

III OUR PROPOSED APPROACH

Our approach is based on HSV color model; it is summarized in the following steps using the sample image of Figure 5.

Step 1: Convert the sample RGB image into HSV image as shown in Figure 6. Which done via: converting the image into double, and then convert the output into HSV format.

Step 2: For verification purpose, get the edge map image from RGB image using Sobel operator, as in figure 7. This will be used to return back to the original photo after the faces had been detected and to remove the background unneeded objects.

Figure 5: Test Image

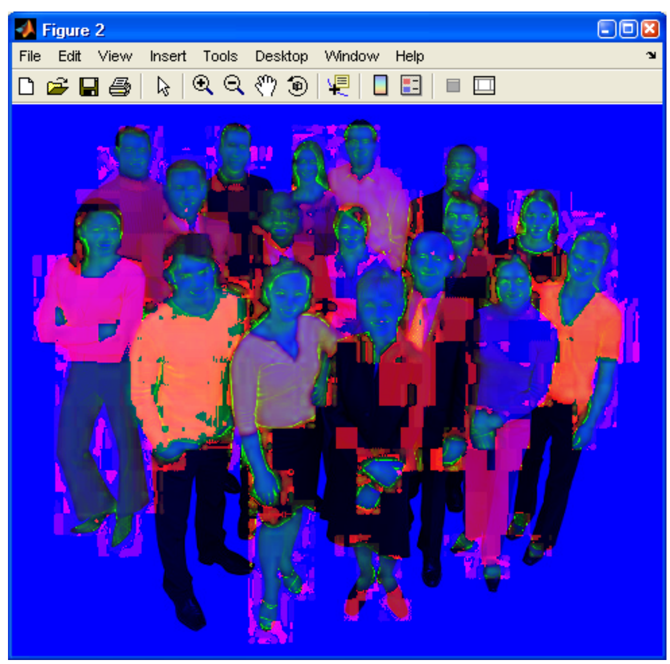

Figure 6: HSV image

Step 3: For each pixel, get the corresponding H and S values; in order to use them in comparing with skin-threshold and edge-threshold, as in figure 8, depending on the H value for skin color (0.1>H>1.8) as our proposed solution, these rages cam as a result of tries and testing during the development phase, and it is little bit different than what mentioned in the first section (introduction), but this is one of the points that raised up in this study.

Step 4: Find the different regions in the image, as in figure 9 and figure 10, in order to specify our focus on what we need; therefore many types of views are displayed. In this step two functions are used the open and fill functions; to be sure that only skin areas were selected and no holes detected to be ready for the next step which affected by holes and empty areas.

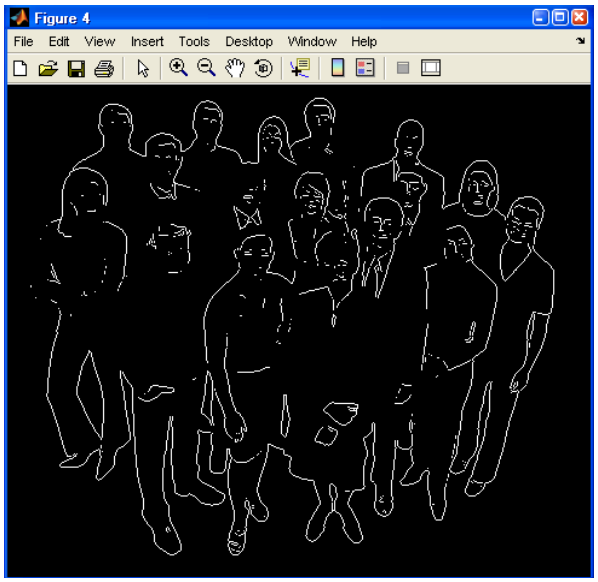

Figure 7: Edge Detection

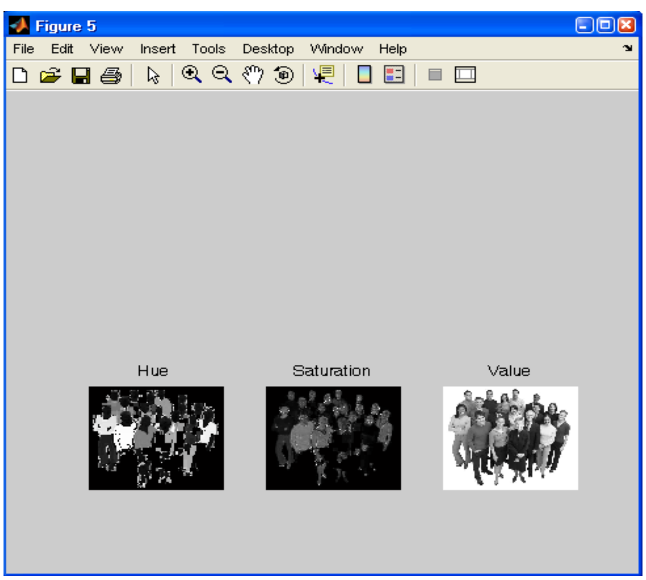

Figure 8: HSV values

Step 5: Connected Component Analysis, which will separate connected heads by using open and close operations, or can be done via a low pass filtering for hole filling and background rejection, and identification the connected faces based on statistical analysis, and as a practice we did for different images with different sizes, which helped us to separate the connected regions as in figure 8. We have used 8- connected followed by 4-connected as in figure 11; but the result of using 4-connected made that the running time 12-28, as a new modification which gave the same result in terms of quality but with faster time (5-9) seconds is removing the small and big objects without using 4- connected:

500<= Area < 2500

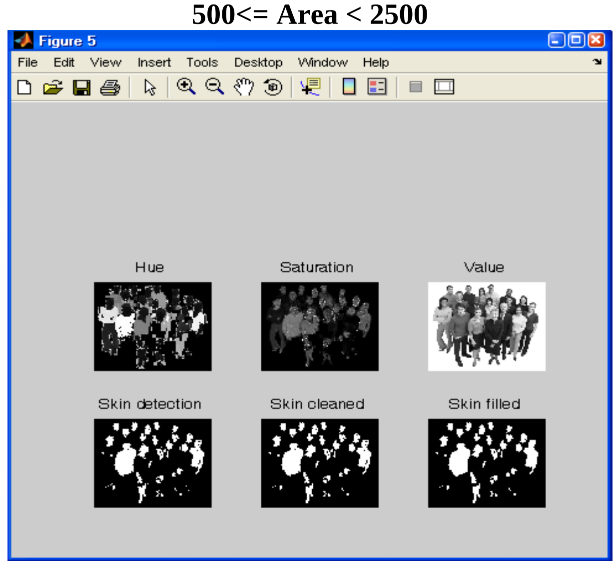

Figure 9: Regions

Step 6: Compare the dimensions with cretin thresholds for each region and percentage of skin in each region, which will help in removing non-face object (such as hands, nick, ..), as in figure 12.

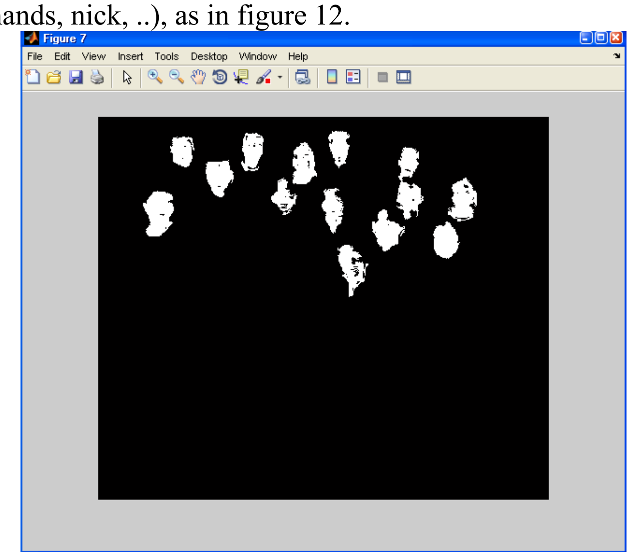

Figure 10: Regions

Step 7: For each region, if height and width (together) are within the range and (percentage of skin percentage threshold) then the region is a face, else it is not a face, as in figure 13. It means depending on the dimension of the object not too much or very small (500<Area<2500), as in our proposed solution.

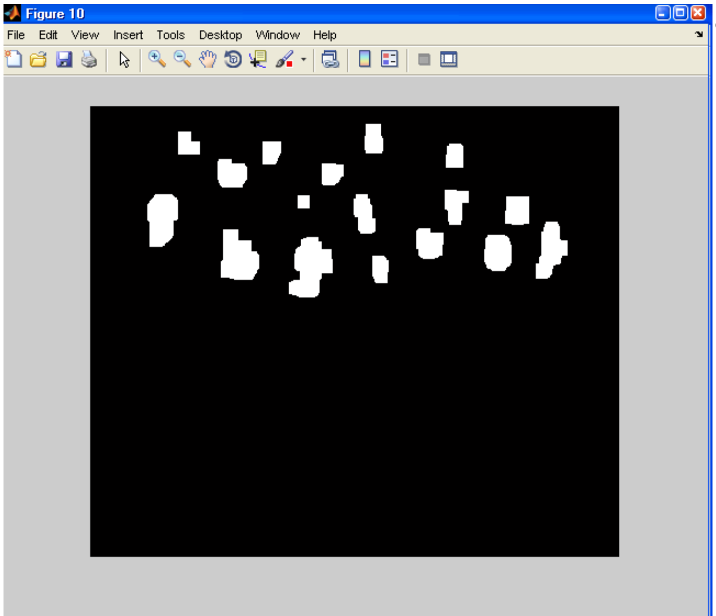

Figure 11: Connected Regions

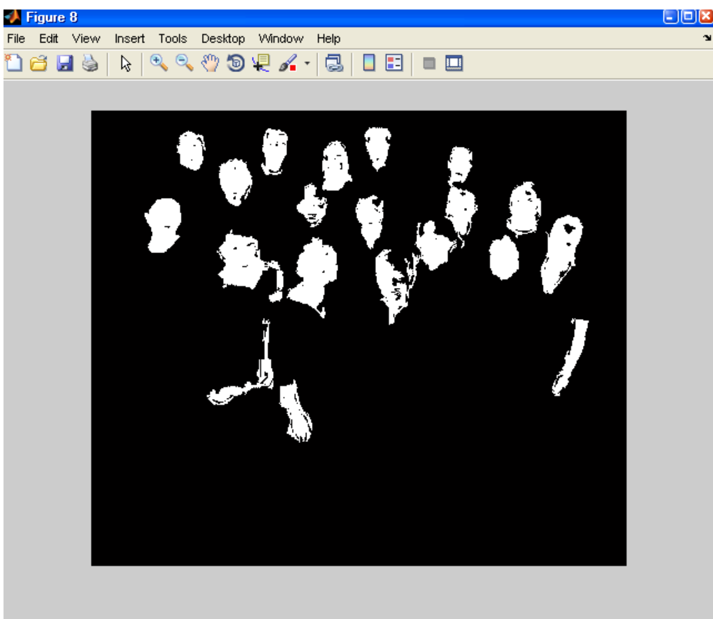

Figure 12: Dimensions

Additional Step: in order to make the running time faster, and to use the system the time matter affect, we did some modification on the program, which is removing some finalization tool (4-connected neighbor process). This action affects on booth the quality and the running time, the running time became faster, but the quality decreased, some large sizes of skins (such as uncovered hands or legs) detected as in figure 14.

We have achieved reasonable results compared to other published work [14], [28]. As shown in Figure 9 picture is complete and no removal of any body parts.
Our detection performance approaches 93-100% and the detection time range is 12-28 s.

Figure 13: Output (with 4-connect)

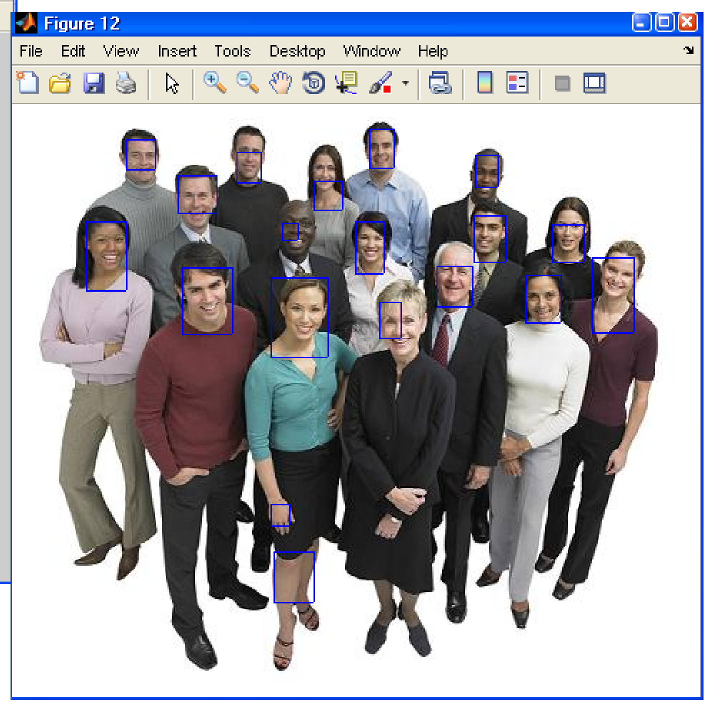

Figure 14: Output (without 4-connect)

IV. Results and Discussions

Table 1 shows comparison with others results, where result 1-4 is related to [28], and result number 5 is related to [14].

Table 1: Comparison between this work and [14], [28].

#	Project name	Running Time (Sec)	Performance %	Part/ Full image
1	[ ]t#1	23	90-100	Part
2	[ ]#2	18	80-100	Part
3	[ ]t#3	101	95-100	Full
4	[ ]t#4	26	80-100	Full
5	[ ]	11	85-100	Full
6	Our Work + 4-connect	12-28	93-100	Full
7	Our Work without 4-connect	5-9	90-100	Full

As seen in table 1, our work is very close to [14], but there are some differences, in [14] the running time is less than our first option (6); as a result of using 4-connected, but this affected on their performance , and [14] showed some inaccuracy in the output, with missing hands, nick or legs. Our results showed complete body, because we repeated connected neighborhood twice (one for 8 and another one for 4) which affected on the running time (but not so much) and give more accurate results, but in our next option (7) we over comes the time issue by using the same technique with different approach (reduce number of ready functions), which make the running time faster. If we compare the result of option (7) with all other options we can say it is the fastest and gave the highest performance, but it has one draw back which is it needs some tuning for the area when we deal with zoomed or closed faces.

V. Conclusion

This paper presents a method for the detection of human face in an image. It uses simple formulas to represent skin-color models depending on the HSV values. In addition, we choose HSV because it is fast and compatible with human color perception.

The overall performance of the proposed algorithm is reasonable compared with other algorithms. The algorithm is fast, and become faster more when number of functions becomes less which makes it useful for some real-time applications.

As a future work, after faces have been detected, the next step is the gender recognition which can be considered as a final extension of the template-matching subsystem which can be done via fit or hit human faces into average area intensity as in figure 15[29, 30].

However, due to the high likelihood of false positives given the small number of female faces, the threshold is particularly conservative in order to prevent finding more false positives than genuine female faces. Another future work, which is under process, is an attending system for 50 employees as a prototype project.

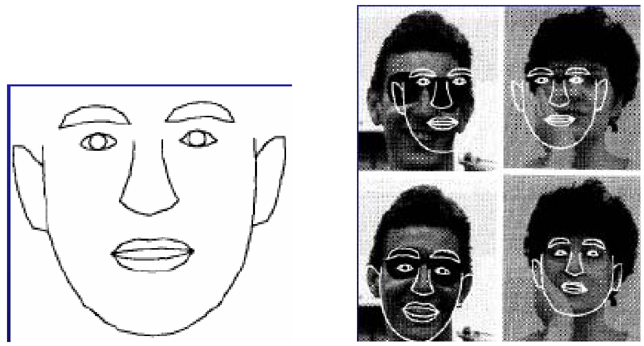

Figure 15: average shape, [Lanitis et al. 95]

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