NANYANG TECHNOLOGY UNIVERSITY
SCHOOL OF ELECTRICAL AND ELECTRONIC ENGINEERING

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UROP REPORT

Tracking and Surveillance

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1 INTRODUCTION

There is a lot of technique in detection of object. Certain technique will suit better depending on the application it is applied to.

Main Detection Technique: Motion, Color, Texture, Shape, etc.…

The techniques have their pros and cons. Color would be the main focus in this project because of its advantages. From its properties, color has the ability of differentiating objects. Therefore it provides very useful information especially during the case of occlusion.

Color technique can be robust against non-stationary background. Therefore it is applicable in cases of mobile robot. Camera can be fixed on the robot to do tracking and navigation.

In Human tracking application, skin color is often use to signify the presence of human target. However, tracking skin color is unreliable due the small skin area available. The skin color can be easily block by objects or with the target's back facing the camera. In this paper, the method to using the color of human clothing is discussed.

2 COLOR SYSTEM

Color information is commonly represented in the widely used RGB coordinate system. This representation is hardware oriented and is suitable for acquisition or display devices but not particularly applicable in describing the perception of colors. On the other hand, the HSV (hue, saturation, value) color model corresponds more closely to the human perception of color. The hex-cone model shown in Figure 9-b conveniently represented HSV color space.

More details on color domain, see Appendix 9.1 Color Domain.

HSV domain allows color and brightness isolation. This is useful as brightness information is not useful in color object detection. The extra brightness information could be cause by external factor (external light source), therefore holds no meaning.

Details on RGB to HSV conversion, see Appendix 9.2 RGB to HSV.

2.1 Advantage using Color

1. Color can be unique to an object
   -Object identity can be determine easily even after occlusion
2. Color representation of object is robust against
   -Complex, deformed & changeable shape (human)
   -Orientation/rotational

-Size (zoom in, out)
-Partially blocked view (object)

3. Color representation independent on resolution
   -Low resolution
   -Fast to process image
   -Low cost for the equipment
4. Background can be dynamic
   -Camera can be mobile (fix on mobile robot)

2.2 <u>Disadvantage using Color</u>

1. Object is not unique to the color
   -Affected by object with same color as object targeted
2. Color of object cannot be obtain exactly
   -Color is affected by illumination/brightness & low saturation
   (Too bright looks like white, too dark looks like black)
   -Environmental factor. Source of poor lightings can be from
   highlight, shadow, light spectrum emitted by different/
   numerous lightings, daily variation due to sunlight and temperature
   -Color white balance in every camera is different
3. Object color may not be distinctive
   -Wide range of skin color (reddish, yellow, brown, white, black)

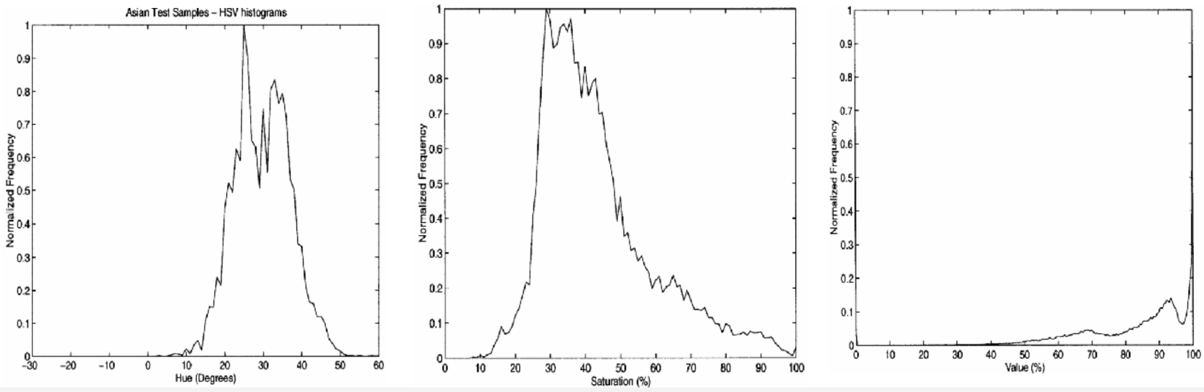
Depending on the application of color detection, some parameters can be controlled.

- Camera can be calibrated (white balanced) before operating
- Lightings source can be adjusted
- Human skin color predefined with assumption made.
- There are also techniques to reduce the problem listed. <Article: threshold adjustment/adaptive [03]/[04], statistic estimation [06], neural network [08], white/black calibration>

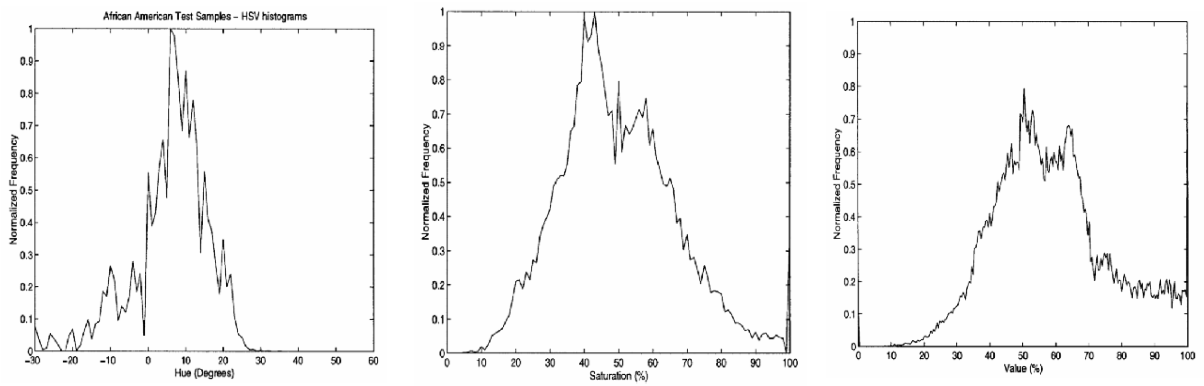
3 SKIN COLOR

Human skin is composed of several layers of tissue which consist essentially of blood cells, and a yellow pigment called melanin. The appearance of the skin is affected by a number of factors which include the degree of pigmentation (varies amongst individuals and different races), the concentration of blood, and the incident light source. The combination of all of these factors give rise to a variation in skin color which spans over the range of red, yellow and brownish-black. Nevertheless, this corresponds to a restricted range of hue values.

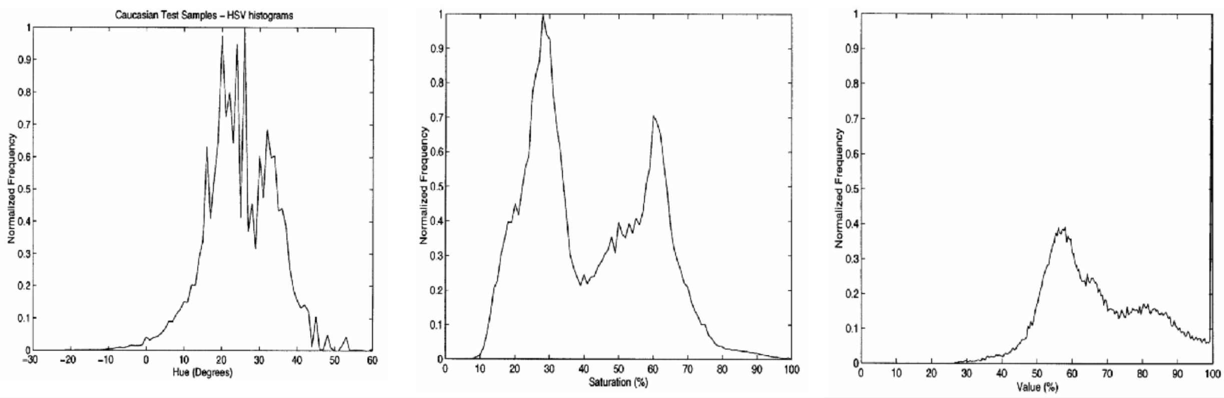
HUE	SATURATION	VALUE



Asian Test Samples



African American Test Samples



Caucasian Test Samples

Figure 3-a: Skin Histogram Distribution

From (Figure 3-a: Skin Histogram Distribution) it is clear that in all three categories the hue component consists of a limited range of values. The hue values of Caucasian and Asian samples fall predominantly between 0° (Red) and 60° (Yellow) while those of African-American are shifted closer towards 0° with a small portion of the distribution in the red-magenta hue sector. One may also note that the hue values between 180° and 360° can be represented by their equivalent negative values (i.e. 340° = -20°). In the figures, the Saturation component ranges from about 10 to 100% in all cases, with the majority falling in the 20-60% range. This suggests that the skin colors for all races are somewhat saturated but not deeply saturated. Finally, we see in Figure 3-a that the Value or brightness component for both Caucasian and Asian distributions ranges from approximately 40% to the maximum value of 100%. The Asian test images are shifted even more so towards the maximum value of V (i.e. top of the hex-cone model, Figure 9-b) signifying a high level of brightness in the facial skin regions of these samples. The African-American test set on the other hand, has a wider value range but is shifted towards lower values. The mean, *m*, and standard deviation, σ (both given in degrees), of the three hue distributions are conveniently summarized in Table 3-b [01].

Race	Mean, *m*	Standard Deviation, σ
Asian	28.9	5.1
African-American	8.6	8.2
Caucasian	25.3	6.8

Table 3-b: Statistic of Hue distribution

The tabulated values indicate that the Asian test samples have the highest mean value of the three distributions, *m* =28.9° (i.e. greater shift towards Yellow) with the lowest standard deviation, σ. The Caucasian sample set has similar statistics with a slightly smaller mean value, *m* =25.3° and a slightly larger value of σ. The African-American distribution has the smallest mean value of the three, m =8.6° (shift towards red) and the largest standard deviation. The large value in σ can be attributed to the variation in skin colors within the African-American sample set.

Main skin color:				
Red	**Yellow**	**Brown**	**White**	**Black**

The color of object/skin could be changing. They can be affected by our mood, makeup, sun-tan, reflection of the environment, lightings (daylight, incandescent lamp, fluorescent, horizon sunlight), etc…[05].

4 METHODOLOGY

4.1 Skin Color Extraction

The hue component is the most significant feature in defining the desired polyhedron (skin color). The histograms of Figure 3-a indicate that the hue values can be represented by a limited range 340-360° (magenta-red) and 0-50° (red-yellow) for all skin types. This range is very effective in extracting skin colored regions under higher levels of illumination and sufficiently saturated colors. However, the hue can be unreliable when the following two conditions arise:

(1) When the level of brightness (i.e. value) in the scene is low

Or (2) when the regions under consideration have low saturation values.

The first condition can occur in areas of the image where there are shadows or, generally, under low lighting levels. In the second case, low values of saturation correspond to achromatic regions. As mentioned previously, saturation values of zero lie on the V axis in the hex-cone model (Figure 9-b) and appear as gray areas. Many objects, by nature, are achromatic (i.e. white clouds, gray asphalt roads, etc.), however, shadows or conditions of non-uniform illumination (i.e. speculate reflection) can cause chromatic regions such as skin areas to appear achromatic. Thus, we must define thresholds for the value and saturation components where the hue attribute is reliable.

Skin color is the main starting point of locating human. The skin color model is base on general skin model having hue from –20° to 50° (magenta-red-yellow). This is the color of most skin from all races.

For experimental reason, the following range is used

	Actual Range	Normalize 0-255
Hue:	1.4°-11.2°	1-8
Saturation:	27.3%-58.6%	70-150
Value:	40.2%-100%	103-256

Table 4-a: Experiment color threshold

After HSV is obtained, pixels of skin color will be picked out. This process is masking. Color comes in 3D domain, therefore 3 mask layer will be use to mask out the required pixels. They are Hue, Saturation and Value mask.

Details on HSV masking, see Appendix 9.3 MASKING.

The success of object segmentation will greatly depend on the quality of the Skin Color Extraction Process.

Experiment Result (Skin extraction)

Figure 4-b: Original Image

Figure 4-c: Hue Mask

Figure 4-d: Saturation Mask

Figure 4-e: Value Mask

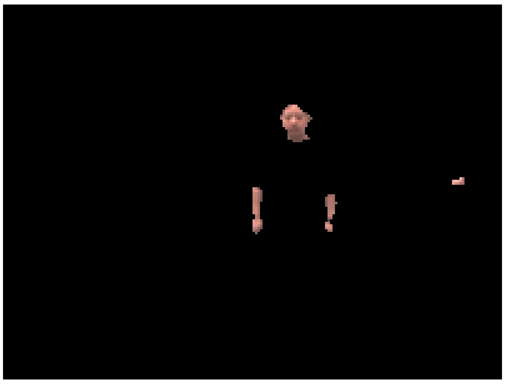


Figure 4-f: Combination of Hue, Saturation & Value Mask

The results of each mask shown, include the diluting process.

There will be a lot of false skin like color detected, due to the wide range of skin color to detect. By readjusting the threshold of skin color with reference to the detected skin, this error can be reduced [03] [04]. Therefore a more accurate skin color model could be obtained and extracted.

Blob process helps to identify object after doing Skin Color Extraction. A blob consists of a group of adjacent pixels. Since they have similar color and are closely packed to each other, they are assume to be pixels of the same object.

Before a possible blob can be accurately identified, a dilution process can helps to eliminate possible false detection or undetected pixel. The process estimates the possible existence of a pixel from its surrounding pixels.

Details on Dilution, see Appendix 9.4 DILUTING.

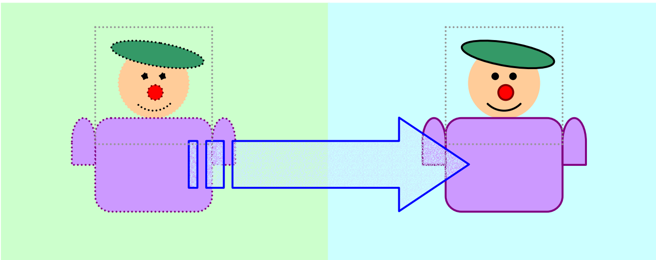
After obtaining the true skin target, number will be assigned to the group of pixels for identification purposes. Each number is treated as a target.

Details on Blobbing process, see Appendix 9.5 BLOBBING.

In a high-resolution image, the blob formed may contain holes. This may be cause by a patch of noise color on the target color. Due to high resolution, many pixels is use to represent the patch, causing a hole in the image. A blob hole filling algorithm can be use to fill up the holes, so that the final masked image is neater. In small resolution image, such cases rarely happen because the color has been diluted with the surrounding color.

4.2 Object Representation

After a target is found, a HSV (color) histogram data will be form to represent the target. The histogram data is collected within the box-up target. It defines the pixels that are associated with the blob (skin color pixels). The histogram relates the colors associated to the blob. It is use as an ID to differential between different targets.



Any color changes during movement implies that they belong to the background. The stabled color will be the color associated to the target.

Figure 4-g: Histogram ID updating process

The histogram obtained, does not represent target accurately due to the presents of background color. To extract the target's histogram (colors associated to target), a learning process is introduced. The idea is to monitor and update the colors that are always present within the boxed target. The color that is always present should be the blob (skin color) and it's clothing color. This is under the assumption that background color changes as the target moves.

With the target's histogram extracted it can then be use as ID to differential itself from other targets.

A thing to note is that the first target reference histogram is captured only when the whole target entered the scene. This is because if only partial histogram is obtained, it will be treated as the original histogram.

Two-target width is a possible distance to extraction the ID's color. Faster extraction can be done if the background is of special coded color.

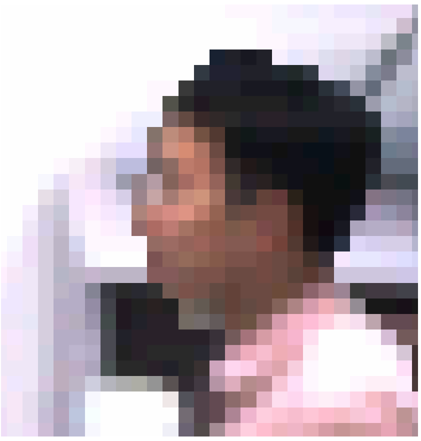
During typical scenario, a target is detected with 3 skin color parts, two hands and a head. The 3 ID comes with the same surrounding color of the clothing. Using this cue, the 3 ID can be merge together because they belongs to the same target. Distance information between IDs can be used to further confirm identity of the object. This algorithm is possible with assumption of low histogram resolution used (discuss in next section). Slight variation in hue value is still consider the same hue as they are rounded to the nearest hue.

Face detection algorithm could also be use instead since each target has only a face [02] [05].

4.3 Analyzing Target

The target ID is extracted from the peaks of the histogram. In the experiment, a sample skin color human head is found. The color associate around the head is form in the histogram shown in Figure 4-i. From the histogram, it can be clearly seen that the Hue histogram consist of mainly 3 colors only (red, blue/purple, pink). However the peak algorithm is unable to pick up the 3 main cluster of color. This is because the generated noise forms peaking, which cause false detection. To counter this, the histogram is formed using lower resolution. This will force the neighbouring weight-age to their nearest bin (color representation). Therefore a noiseless histogram can be obtained.

The disadvantage of using the reduce resolution is that the peak detected may slightly off from its actual hue. A better method would be pulling smaller neighbouring weight-age to it's own bin [07]. The hue position is maintained and noise is removed. Due to the large computation required, this method is not applied.



With the 3 peak clearly computed, the color associated with the target is obtained.

Figure 4-h: Target image

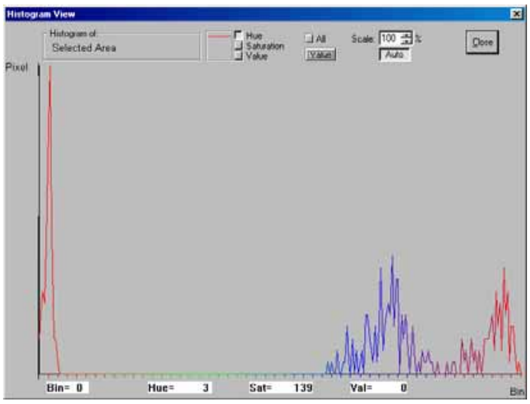


Figure 4-i: Hue histogram of target (256 bins)

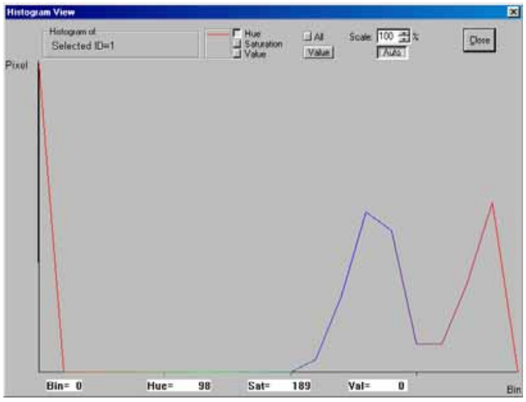


Figure 4-j: Hue histogram of target (20 bins)

4.4 <u>Extracting Target's ID</u>

Having the color associated with the target obtained, the target can now be extracted. The target's histogram is form by a few Gaussian distribution at various peaks Figure 4-j. This is so because environment color is form by gradual change in color. Therefore to extract the object related to the clustered color range, Gaussian distribution is assumed. In the experiment, the five hue's bin nearest from the peak will be use to determine the hue range use for extracting the colors.

A more accurate approach would be to use mean and standard deviation to obtain the range of the cluster. This can produce a higher accuracy covering up to 90 over percent of the area.

Experiment Result (Object extraction with Histogram ID updating)

Using Bin resolution of 20 (28th Dec 2001)

Threshold: 20 pixel above, to consider Color as ID

Extract top 5 colors for display

Real time image processing applied using mock image frames.

Initial Frame	After 15 Frame	Simulate movement backward
		
Figure 4-k: Without Histogram Updating without diluting		Same as initial frame

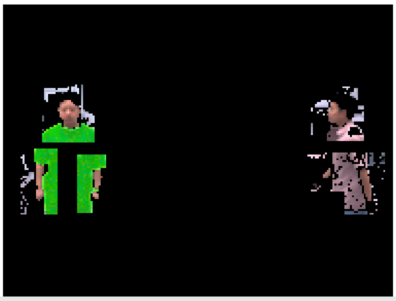
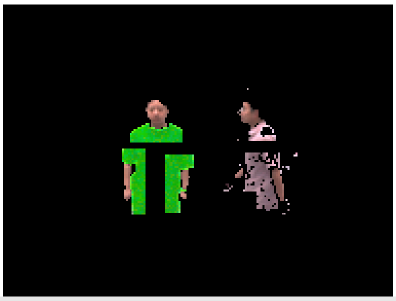
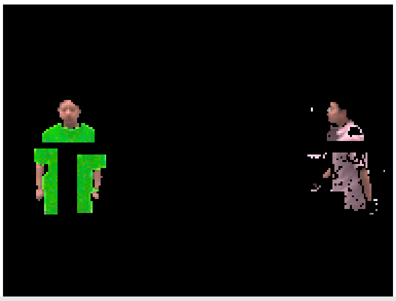

		

Figure 4-l: With Histogram Updating without diluting	Updated till Histogram ID obtain	The background is not extracted

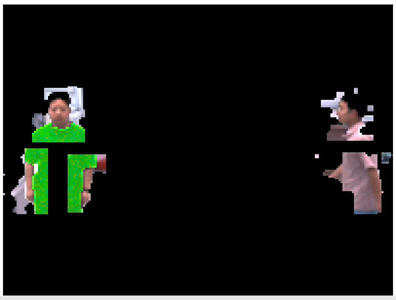
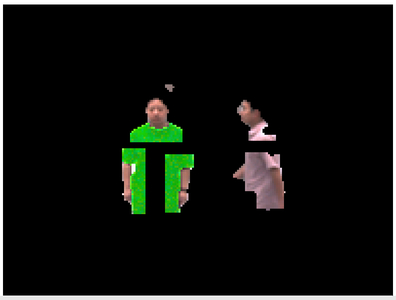
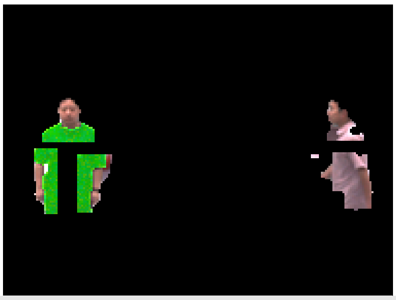

		

Figure 4-m: With Histogram Updating & diluting	Updated till Histogram ID obtain	Only color associated with target is extracted

With the histogram ID updating, color associated with the target is learned as target move across background. After some frames, background will not be display. This is because the histogram ID has been identified.

Note that there is some noise in the extracted image (Figure 4-m). This is because the noise color is similar to the color of the target's histogram. Increase in the bin resolution will improve the accuracy. At the same time, the number top color should be increase to cater for the increase in bin resolution. Therefore the number of top colors to extract can be represent in term of percentage of the histogram resolution.

Although the pink shirt is close to skin color, two colors have been detected due to two detected peaks (Figure 4-j).

The algorithm is robust against multiple moving objects.

4.5 Object Tracking

With the clothing information extracted, human tracking will be mainly base on clothing's color. It is easier to track clothing color than skin because of the large area available for detection. The chances of detecting rotational target also increase due to the large area.

Under occlusion, no more updating is to be done to object occlusion. They will be closely monitored until they are out of occlusion. Object's histogram is use for comparing and differential between the occlusion objects when they are out from occlusion.

Due to the large tracking area (clothing color), it is possible to track the object under occlusion. This is under the assumption that the object cannot be totally blocked. A portion of its clothing color is expose throughout the occlusion.

Experiment Result (Object Occlusion)
Not Available
See 5.2 Problem Encountered

5 ASSUMPTIONS & PROBLEMS

5.1 Assumption

- Object color is distinctive and not dynamic.
- Skin color Hue (Chinese race).
- Skin color is unique from background color.
- Clothing is of uniform color (can have different color but must be able to see them 360°).
- Humans present in frame have distinct color for identification (example clothing, things human carries).
- Assume human movement is small distance between adjacent frames captured.
- Color histogram obtain is in terms of guassian distribution

5.2 Problem Encountered

- Performance poor with homogenous background.
- Pants color cannot be always extracted.
- Color under tracking changes under different lighting condition. (Saturation value shifted up in darker environment)
- Not ready for white and black color detection

Clothing Color Extraction Demo

The image Figure 5-a illustrates the valuable of human tracking base on clothing color. The experiments on this live image sequence were not successful. The problem encountered mainly lies in the lightings of the environment and the background noise.

The lightings of the environment are changing from dark (left) to bright (right). The evident can be seen from the light green wall stretching from left to right. This prevents the algorithm to extract the possible exact color because there is a shift in saturation range. The hue range is still effective however the saturation range shifted up when the colored object approaches a dark corner. The possible solutions to this problem are:

1. Extend the HSV color range to extract. Easy to apply but more unwanted background color may appear. Detection accuracy will drop.

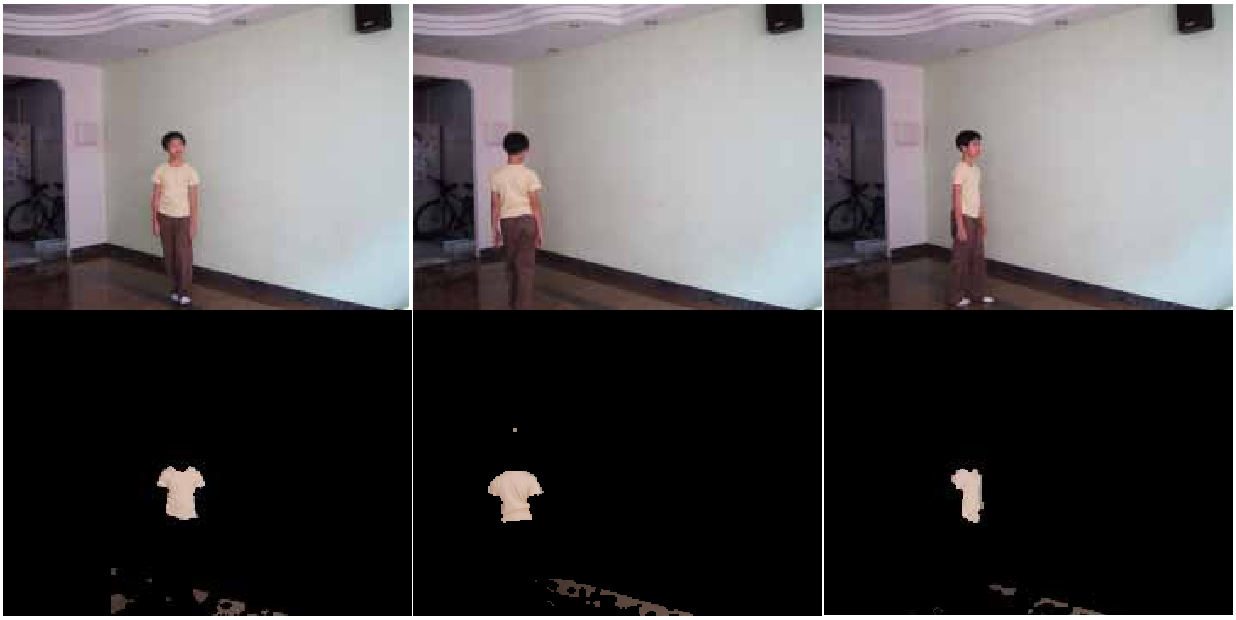
2. Control the lightings of the environment. Depending on the application of tracking. Accuracy depends on the lightings.

3. Use Adaptive color adjustment [03]. The current paper on this topic only allows adaptive detection of a person. More complicated algorithm and processing power.

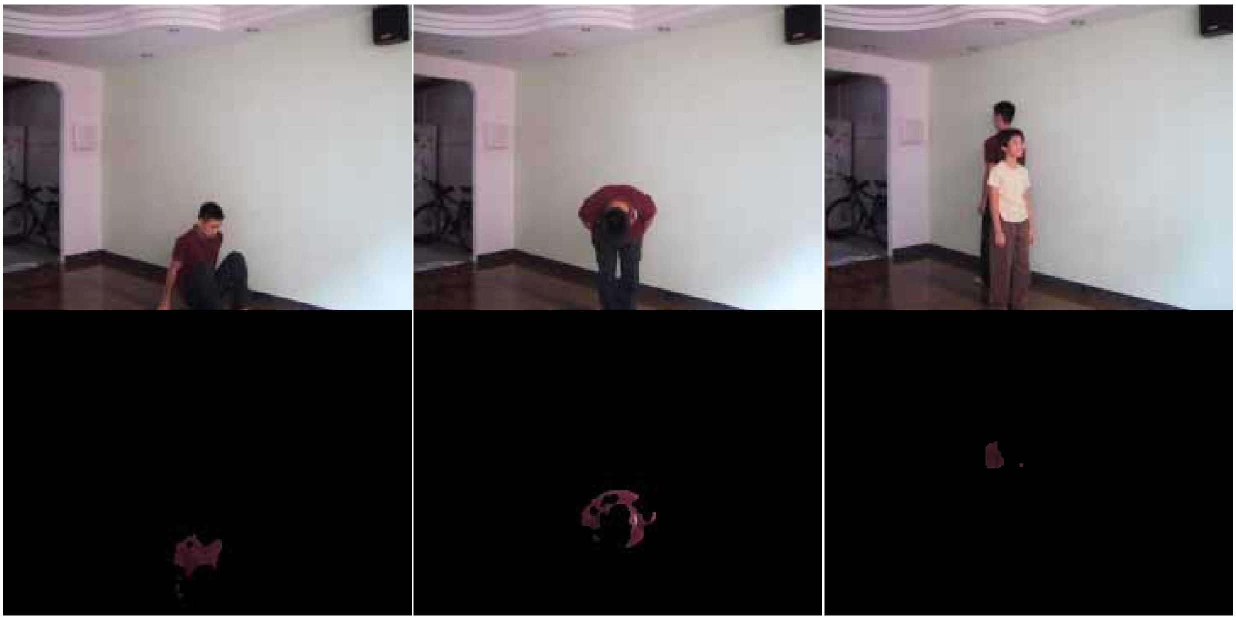
The rising background noises appeared is due to the fact the sat and value mask are not used for extract the color. Value mask provide little information and therefore can be ignored. The saturation is an important domain to extract. However there are difficulties extracting the saturation range for the detected color:

1. Saturation changes under different lightings condition

2. The saturation range cannot be simply determined from the histogram just as in hue. Possible method is to extract the target hue region first. After which saturation values are calculated by averaging those within the hue region/mask. The target can then be extracted more accurately using the hue and calculated saturation mask. This is under the assumption that clothing color region is larger than background noise detected within the hue region/mask.



(a) Front (b) Back (c) Side



(d) Lay (e) Bow (f) Occlusion

Figure 5-a: Clothing Tracking

The diagram above shows the potential in tracking color of the clothing under different typical scenario.

6 SOFTWARE

The software is written in Visual C++. The software can be use for experimenting with various imaging processing. Below briefly describe the features written. For more detail on user interface and control, do refer to the program's help feature.

6.1 Software Features

- BMPImage processing Class written to process general image manipulation. The software reads only BMP format files.
- Histogram display of any region selected in the image. Easy to use and analysis with the user-friendly dialog box. Various settings available to analysis the histogram data captured.
- Target windows for analysis of detected object. Various settings available for analyzing individual target.
- Status bar displaying file's name, pixel color, keyboard and mouse status.
- Ability to customised image processing for analysis.
- Extra image storage for special image processing analysis
- Playback controls to simulate frames captured in real time.
- Various friendly and easy to use settings and controls for users.
- White balance calibration.
- Sizable image for telescopic analysis.

6.2 Simplified Algorithm Overview

1. Obtain Image.
2. Build Hue, Saturation, and Value mask of skin color.
3. Dilute the 3 masks for number times.
4. Form the Skin Color mask with the 3 HSV mask AND together.
5. Identify target blob object (ID) with the blob process.
6. Build the ID image and its histogram.
7. Compare Current ID with the Previous ID to identify
   - Direction of movement
   - Color associated with the object
   - Size, position of the object
   - Possible similar object

- Possible object detected
- Number of object present
- Possible new object
- Possible loss object
- Possible object occlusion

8. Object identified will be histogram updated

Under occlusion, no more updating is to be done to object occlusion. They will be closely monitored until they are out of occlusion. Histogram comparing is use to differential between the occlusion objects.

7 CONCLUSION

In this report, the method to extracting the color of human clothing is discussed. The clothing color is use for tracking the human because of the high probability of detecting the target. The clothing colors are obtained by monitoring from the surrounding of skin region.

Simple experiments were conducted using Visual C++. The image processed is done under real time processing using sequential images in BMP file format.

The clothing was successfully extracted using histogram-updating process. The experiment results show that the proposed method is robust to rotational, deformed and occluded human targets. It is also robust under non-stationary background (moving camera).

8 ACKNOWLEDGEMENT

I would like to thank Dr Chua Chin Seng and Li Jiang for their assistance and suggestions.

9 APPENDIX

9.1 Color Domain

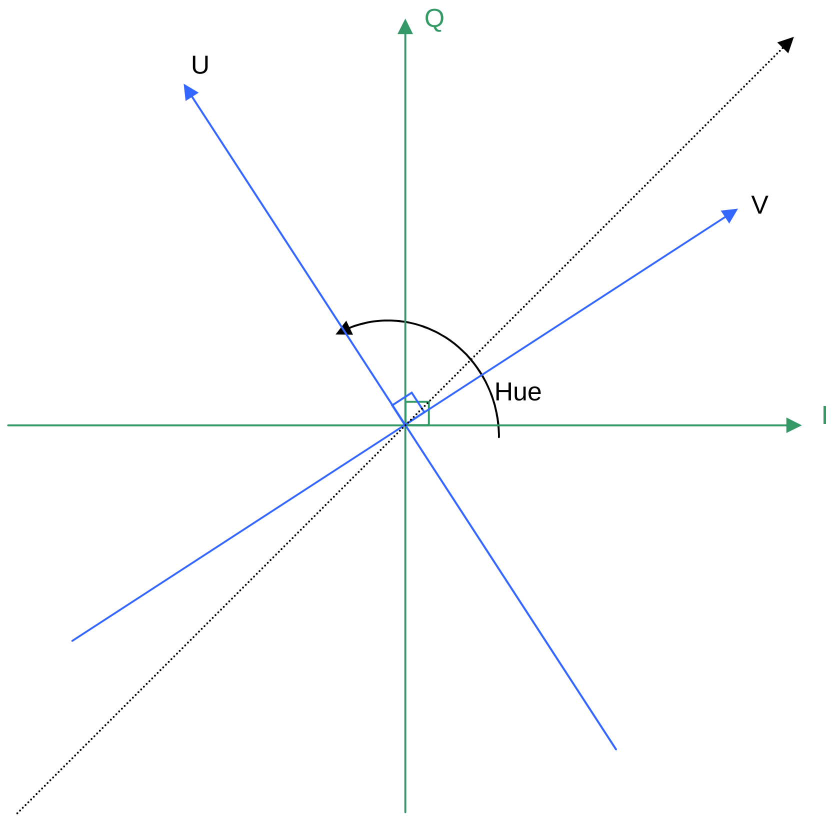


Figure 9-a: HSV, YIQ, YUV relationship

$$\begin{bmatrix} Y \\ U \\ V \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.144 \\ -0.147 & -0.289 & 0.436 \\ 0.615 & -0.515 & -0.100 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

$$\begin{bmatrix} Y \\ I \\ Q \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.144 \\ 0.596 & -0.274 & -0.322 \\ 0.211 & -0.523 & 0.312 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

$$I = V \cos 33° - U \sin 33°$$

$$Q = V \sin 33° + U \cos 33°$$

HSV is the polar form of YIQ

H- Hue

S- Saturation

V, Y- Value (brightness, intensity)

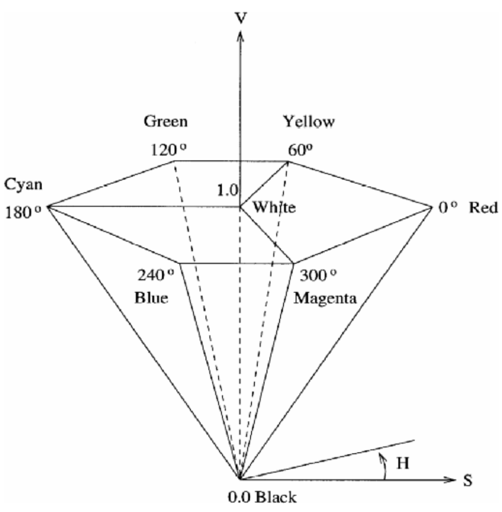
U, V, I, Q- chromatic signal

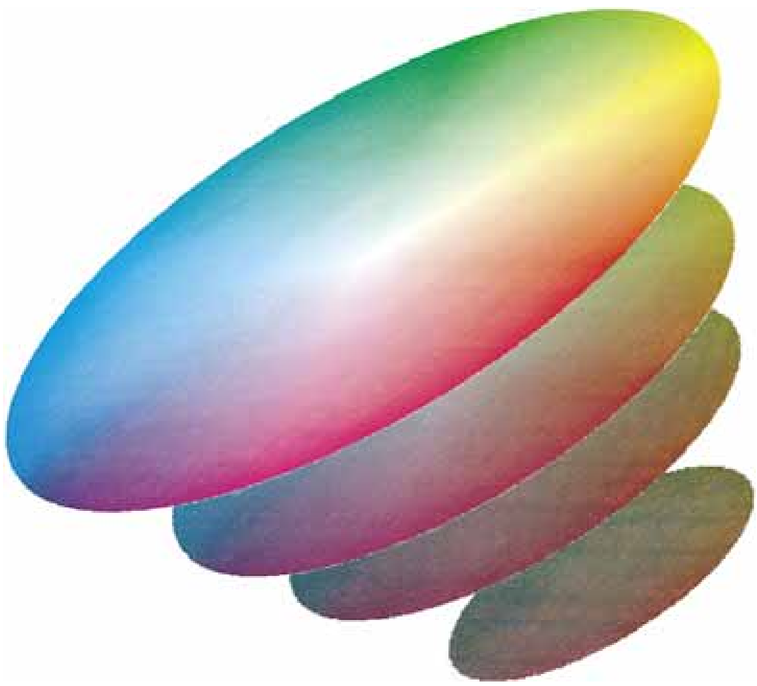
R- Red

G- Green

B- Blue

The *hue* (*H*) is measured by the angle around the vertical axis and has a range of values between 0 and 360 degrees beginning with red at 0°. It gives us a measure of the spectral composition of a color. The saturation (*S*) is a ratio that ranges from 0 (i.e. on the V axis), extending radically outwards to a maximum value of 1 on the triangular sides of the hex-cone. This component refers to the proportion of pure light of the dominant wavelength and indicates how far a color is from a gray of equal brightness. The value (V) also ranges between 0 and 1 and is a measure of the relative brightness. At the origin, V=0 and this point corresponds to ‘black’. At this particular value, both *H* and *S* are undefined and meaningless. As we traverse upwards along the V axis we perceive different shades of gray until the endpoint is reached (where V=1 and *S*=0) which is considered to be ‘white’. At any point along the V axis the saturation component is zero and the hue is undefined. This singularity occurs whenever *R*=*G*=*B*. The set of equations below can be used to transform a point in the RGB coordinate system to the appropriate value in the HSV space.





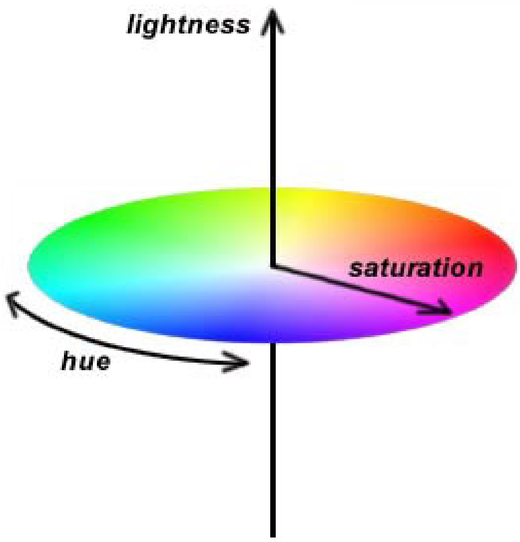


Figure 9-b: Color Dimension

9.2 RGB to HSV

RGB signify the 3 basic color components red, green and blue in term of color reproduction. In term of human perception of color domain it would be best describe by the HSV domain (Hue, Saturation and Value).

Formula to transform from RGB to HSV domain.

$$H_0 = \cos^{-1}\left\{\frac{0.5[(R-G)+(R-B)]}{\sqrt{(R-G)^2+(R-B)(G-B)}}\right\}$$

$$Hue = H_0 \qquad if\ (B \le G)\&(R \ne G \ne B)$$

$$Hue = 360° - H_0 \qquad if\ (B > G)\&(R \ne G \ne B)$$

$$Hue = invalid\ or\ (-1) \qquad if\ (R = G = B)$$

$$Saturation = \frac{Max(R,G,B) - Min(R,G,B)}{Max(R,G,B)} \qquad if\ Max(R,G,B) \ne 0$$

$$Saturation = 0 \qquad if\ Max(R,G,B) = 0$$

$$Value = \frac{Max(R,G,B)}{255}$$

Figure 9-c: RGB to HSV conversion

The Hue, Saturation, Value in the formula above is normalized to the range between 0 and 1. Due to low computation speed of floating point, I have converted the result range from 0 to 255. The formula above is modified so that divide by zero will not occur. If there is a divide by zero occurring in the formula above, it signifies that the color component is in the dimension of gray scale. Therefore Hue is invalid and Saturation is zero.

Most of the time, due to unbalanced camera settings and disturbance from other light source, the color obtain is not reliable or exact gray scale. It means that getting R=G=B which represent gray scale is quite impossible. Therefore a limiting factor is need so that correction can be made.

$$if\ Max(R,G,B) - Min(R,G,B) \le 20\ (threshold\ for\ unreliable\ Hue)\ \ Hue = invalid\ or\ (-1)$$

$$Saturation = 0$$

This works well if tracking object is not of dark color. Without this limiting factor, fake hue value can contribute to the histogram and cause unreliable information in computation. In terms of histogram graph, the pixels contribute to sharp and large noise to the graph displayed.

9.3 MASKING

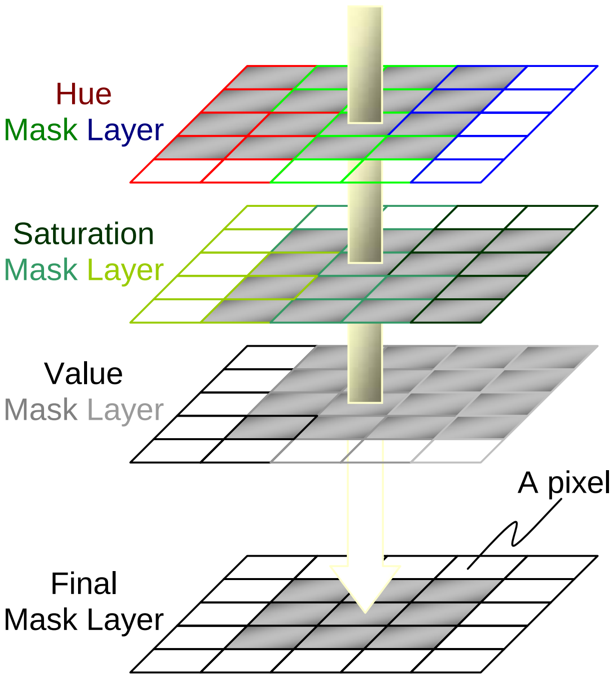


Figure 9-d: Masking process

The mask process helps to extract a particular range of color. A color consists of Hue, Saturation and Value. To obtain a specific color, the 3 components must be an exact match. Obtaining a range of colors, the HSV domain can be individually mask with a range of value and will be AND together to form the mask of the range of required colors.

Figure 9-d demonstrate the basic process of masking an image. The Hue mask shows the pixels, which match the required hue value. The saturation and value mask also shows the pixels that matched. However the actual color to be extracted is the AND result of the 3 mask, which is shown in the final mask layer.

The masking process also involves other advance operation to extract and merge different masks.

More detail on the Masking Process can be found from the BMPimage processing Class in the source code.

9.4 DILUTING

Dilution process can helps to eliminate possible false detection or undetected pixel. The process estimates the possible existence of a pixel from its surrounding pixels. P is the current pixel to decide on, if it should be mask on/off.

S	S	S
S	P	S
S	S	S

When P is mask on, check will be made to see if it can be turn off. Like wise when P is mask off, check that it can be turn on. Decision depends on the majority surrounding pixels. If most of them is mask on then P will be mask on.

S	S	S
S	P	S
S	S	S

If P is mask on then it should turn itself off since the surround are mask on.

S	S	S
S	P	S
S	S	S

If P is mask off then it should turn itself on since the surround are mask on.

The procedure for dilution is as follows:

- Scanning pixels is done from left to right, top to bottom
- Monitor all mask off pixels only. If the surrounding mask off pixels is <=3, turns P mask on
- Monitor all mask on pixels only. If the surrounding mask on pixels is >=6, turns P mask off

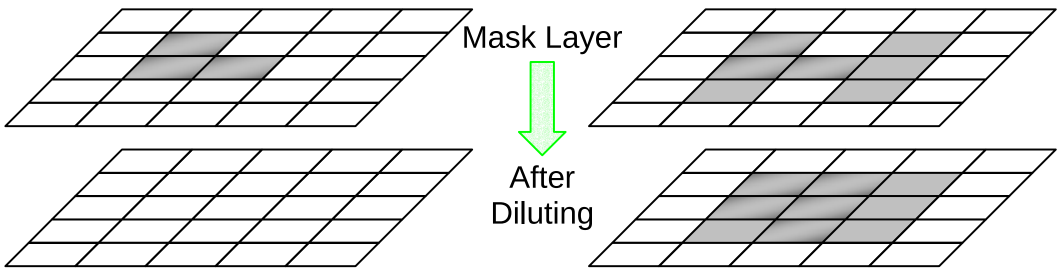


Figure 9-e: Diluting process

9.5 BLOBBING

Blob process helps to identify object after doing Skin Color Extraction. A blob consists of a group of adjacent pixels. Since they have similar color and are closely packed to each other, they are assume to be pixels of the same object.

Blobbing is the process of identifies pixels that are adjacent to each other. The pixels are consider a group if they are lump together. The group is then assigned a number. It is useful for identifying and analysing object because it consist of a group of adjacent pixels.

The algorithm of blobbing is as follows:

- Scanning pixels is done from left to right, top to bottom.
- If current pixel is mask on proceed, else go to the next pixel.
- If the pixel on the top and left is mask OFF, assign new id to the pixel.
- Else if either top or left is mask ON, assign id same as the top or left pixel.
- Else both top and left is mask ON, assign id same as top pixel. Convert all pixels with id of left pixel to the id of top pixel.

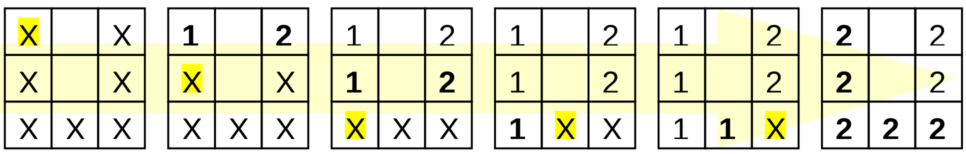


Figure 9-f: Blobbing process

X represent mask ON pixels. The example shows a possibility of blob1 and blob2. Due to the connecting pixel, the blob1 was all change to blob2. The resulting is only a blob2 detected.

An image after blobbing process will generate a few group of ID indicating their blobbed group. If blob group is too small, it is assume to be a patch of noise. The noise will be removed and will not be recorded.

10 REFERENCE

Ref no.	Research Paper Title
	Color
[01]	N. Herodotou, K.N. Plataniotis, A.N. Venetsanopoulos, Automatic location and tracking of the facial region in color video sequences, Signal Processing: Image Communication 14 (1999), pp.359-388.
[02]	Yanjiang Wang, Baozong Yuan, A noval approach for human face detection from color images under complex background, Pattern Recognition 34 (2001), pp.1983-1992.
[03]	Kyung-Min Cho, Jeong-Hun Jang, Ki-Sang Hong, Adaptive skin-color filter, Pattern Recognition 34 (2001), pp.1067-1073.
[04]	Maricor Soriano, Birgitta Martinkuappi, Sami Huovinen, Skin detection in video under changing illumination conditions, Machine Vision & Media Processing Unit University of Oulu FINLAND, pp.839-842.
[05]	Jeonghee Park, Jungwon Seo, Dongun An, Seongjong Chung, Detection of human faces using skin color and eyes, Computer Engineering Chonbuk National University South Korea, pp.133-136.
[06]	Xiaojin Zhu Jie Yang Alex Waibel, Segmenting Hands of Arbitrary Color, School of Computer Science Carnegie Mellon University 2000 IEEE, pp.446-453.
[07]	F. Kurugollu, B. Sankur, A.E. Harmanci, Color image segmentation using histogram multithresholding and fusion, Image and Vision Computing 17 (2001), pp.915-928.
[08]	Son Lam Phung, Douglas Chai & Abdesselam Bouzerdoum, A universal and robust human skin color model using neural networks, Visual Information Processing Group Edith Cowan University 2001 IEEE, pp.2844-2849.
[09]	Hongxun Yao, Wen Gao, Face detection and location based on skin chrominance and lip chrominance transformation from color images, Pattern Recognition 34 (2001), pp.1555-1564.
[10]	J. Cai, A. Goshtasby, Detecting human faces in color images, Image and Vision Computing 18 (1999), pp. 63–75.
[11]	Hayit Greenspan, Jacob Goldberger, Itay Eshet, Mixture model for face-color modeling and segmentation, Pattern Recognition Letters 22 (2001), pp.1525-1536.
[12]	Moritz Störring, Hans Jørgen Andersen, Erik Granum, Physics-based modelling of human skin colour under mixed illuminants, Robotics and Autonomous Systems 35 (2001), pp.131–142.
[13]	Xiaoming Yin, Dong Guo, Ming Xie, Hand image segmentation using color and RCE neural network, Robotics and Autonomous Systems 34 (2001), pp.235–250.
[14]	Hongming Zhang, Debin Zhao, Wen Gao, Xilin Chen, Combining Skin Color Model and Neural Network for Rotation Invariant Face Detection, Department of Computer Science and Engineering, Harbin Institute of Technology (2000), pp.237-244.
[15]	Ginés García Mateos & Cristina Vicente Chicote, Face Detection on Still Images Using HIT Maps, Dept. Informática y Sistemas University of Murcia (2001), pp.102-107.
[16]	Jean-Chirstophe Terrillon, Daniel McReynolds, Mohamed Sadek, Yunlong Sheng & Shigeru Akamatsu, Invariant neural-network based face detection with orthogonal Fourier-Mellin moments, ATR Human Information Processing Research Laboratories 2-2 Hikaridai, Seika-cho, Soraku-gun, Kyoto (Japan), pp.993-1000.

[17] Qian Chen, Haiyuan Wu, Tadayoshi Shioyama, Tetsuo Shimada, Head pose estimation using both color and feature information, Faculty of Systems Engineering, Wakayama University (Japan), pp.842-845.

[18] Yadong Li, Ardeshir Goshtasby, Oscar Garcia, Detecting and tracking human faces in videos, Computer Science and Engineering Department Wright State University, pp.807-810.

[19] K.Hidai H.Mizoguchi K.Hiraoka M.Tanaka T.Shigehara T.Mishima, Robust face detection against brightness fluctuation and size variation, Department of Information and Computer Sciences (DICS) Saitama University, pp.1379-1384.

[20] Shinjiro Kawato & Jun Ohya, Automatic skin-color distribution extraction for face detection and tracking, ATR Media Integration and Communications Research Laboratories, Seika-cho, Soraku-gun, Kyoto (Japan), pp.1415-1418.

[21] Hongxun Yao & Wen Gao, Face locating and tracking method based on chroma transform in color images, Department of Computer Science & Engineering Harbin Institute of Technology (China), pp.1367-1371.

[22] Haiyuan Wu, Qian Chen, & Masahiko Yachida, Face Detection From Color Images Using a Fuzzy Pattern Matching Method, IEEE TRANSACTIONS ON PATTERN ANALYSIS AND MACHINE INTELLIGENCE, VOL. 21, NO. 6, JUNE 1999, pp.557-563.

[23] Bernd Menser & Michael Brunig, Segmentation of human faces in color images using connected operators, Institut fur Elektrische Hochschule (RWTH) Aachen 52056 Aachen (Germany), pp.632-636.

[24] Hans Peter Graf, Eric Cosatto, Dave Gibbon, Michael Kocheisen, Eric Petajan, Multi-modal system for locating heads and faces, Lucent Technology (USA), pp.88-93.

[25] Luis Jordao, Matteo Perrone, Joao Paulo Costeira, Jose Santos-Victor, Active Face and Feature Tracking, Instituto de Sistemas e Robotica - Instituto Superior Tecnico (Portugal), pp.1-5.

[26] Rick Kjeldsen & John Kender, Finding skin in color images, Department of Computer Science Columbia University, pp.312-317.

[27] Haiyuan Wu, Takeshi Fukumoto, Qian Chen & Masahiko Yachida, Face detection and rotations estimation using color information, Department of Systems Engineering Osaka University, pp.341-346.

[28] V.Alchanatis, K.Peleg, M.Ziv, Classification of Tissue Culture Segments by Colour Machine Vision, Faculty of Agricultural Engineering, Technion-Israel Institute of Technology (Israel)(2000), pp.299-311.

[29] Jianping Fan & Yongchang Ji, Automatic Moving Object Extraction toward Content-Based Video Representation and Indexing, Journal of Visual Communication and Image Representation **12** (2001), pp.306–347.

[30] Jan Puzicha & Joachim M. Buhmann, Multiscale Annealing for Grouping and Unsupervised Texture Segmentation, Computer Vision and Image Understanding Vol. 76, No. 3, December (1999), pp. 213–230.

[31] A. Drimbarean & P.F.Whelan, Experiments in colour texture analysis, Pattern Recognition Letters 22 (2001), pp.1161-1167.

[32] Yu Zhong, Anil K. Jain, Object localization using color, texture and shape, Pattern Recognition 33 (2000), pp.671-684.

[33] K. Messer, J. Kittler, A region-based image database system using colour and texture, Pattern Recognition Letters 20 (1999), pp.1323-1330.

[34] Dae-Sik Jang, Hyung-Il Choi, Active models for tracking moving objects, Pattern Recognition 33 (2000), pp.1135-1146.

[35] Ercan Ozyildiz, Nils Krahnstover, Rajeev Sharma, Adaptive texture and color segmentation for tracking moving objects, Pattern Recognition Society

[36] Jian-Gang Wang, Eric Sung, Frontal-view face detection and facial feature extraction using color and morphological operations, Pattern Recognition Letters 20 (1999), pp.1053-1068.

[37] L.M. Bergasa, M. Mazo, A. Gardel, M.A. Sotelo, L. Boquete, Unsupervised and adaptive Gaussian skin-color model, Image and Vision Computing 18 (2000), pp.987–1003.

[38] Erik Hjelmas, Face Detection: A Survey, Computer Vision and Image Understanding 83 (2001), pp.236–274.

[39] Zhenyun Peng, Linmi Tao, Guangyou Xu & Hongjiang Zhang, Detecting Facial Features on Images with Multiple Faces, Dept. of Computer Sci. & Tech., Tsinghua University Beijing China, pp. 191-198.

[40] Jongmoo Choi, Sanghoon Lee, Chilgee Lee & Juneho Yi, PrimeEye: A Real-Time Face Detection and Recognition System Robust to Illumination Changes, AVBPA 2001, LNCS 2091, pp.360-365.

[41] Leonid Sigal, Stan Sclaroff & Vassilis Athitsos, Estimation and prediction of evolving color distributions for skin segmentation under varying illumination, Image and Video Computing Group - Computer Science Dept. Boston University - Boston

[42] Christophe Garcia & Georgios Tziritas, Face Detection Using Quantized Skin Color Regions Merging and Wavelet Packet Analysis, IEEE TRANSACTIONS ON MULTIMEDIA, VOL. 1, NO. 3, SEPTEMBER 1999, pp.264-277.

[43] B.Menser & F.Muller, Face detection in color images using principal components analysis, Image Processing and its Applications, Conference Publication No. 465 IEEE 1999, pp.620-624.

[44] Hideaki Ishii, Minoru Fukumi & Norio Akamatsu, Face detection based on skin color information in visual scenes by neural networks, Graduate School of Engineering Tokushima University Japan, pp.350-355.

[45] L H Koh, S Ranganath, M W Lee, Y V Venkatesth, An integrated face detection and recognition system, Department of Electrical Engineering National University of Singapore, pp.1-6

[46] Jean-Christophe Terrillon, Martin David & Shigeru Akamatsu, Detection of Human Faces in Complex Scene Images by Use of a Skin Color Model and of Invariant Fourier-Mellin Moments, ATR Human Information Processing Laboratories 2-2 Hikaridai, Seika-cho, Soraku-gun, Kyoto 619-0288, Japan, pp.1-6.

[47] Sang-Hoon Kim, Nam-Kyu Kim, Sang Chui Alm, Hyoung-Gon Kim, Object Oriented Face Detection Using Range and Color Information, Department of Electronic Engineering Korea University, pp.1-6.

[48] Jie Yang & Alex Waibel, A real-time face tracker, School of Computer Science Carnegie Mellon University, pp.142-147.

Texture

[00] Bo Tao & Bradley W. Dickinson, Texture Recognition and Image Retrieval Using Gradient Indexing using database comparing, Journal of Visual Communication and Image Representation 11 (2000), pp.327-342.