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Implementing RoshamboGame System with Adaptive Skin Color Model

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ABSTRACT:*This paper utilizes the adaptive skin color model to design a roshambo game system under various light conditions. First, using an usb-webcam to capture the image of a hand, the hand gesture is identified through the method proposed by Holden [2]. The important point element of successfully identifying a hand gesture is using a skin color model to detect the complete contour of the hand. As image color is easily affected under different light sources, using a static skin color will yield errors. This study mainly explores the performance of Holden's method under various sources of light and references the RGB, HSV, and YCBCR models in different color spaces by several scholars to propose an adaptive skin color model. Experiment results found that this model performs well under low light(<533lx) and decently under regular light. The experiment separates the background to find its' Y value to use the proper skin color model using the value's range. Finally the morphology of the closure (dilate once, erode thrice) is used to repair the border of the image to increase effect. Using adaptive skin color models, performance of low light was increased from 50% to 78% while other light sources achieved accurate rates of 85%~92%. The research results were used to create a robotic roshambo game system. The robot performs a relative interaction to roshambo results to achieve a fun and efficient system.*

Keywords -*Hand gesture recognition, color space, skin color model*

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I. INTRODUCTION

This paper is based on a game system which can play roshambo with humans by identifying three hand gestures – scissors, rock, and paper. Current hand signal recognition method is based on quickly and correctly searching hand region and position within an image and this technology can mainly be separated into: (1) using a glove to identify, requiring the wearing of sensor glove hardware to achieve results; (2) use video coupled with image processing software. Wagne[1] et al proposed an applicable portable hand gesture interface to capture hand gesture characteristics by separating hand gestures into smaller regions and deduces the correct hand gesture by calculating the pixels in each region. This calculation method does not require too many hand recognition formulas, but requires more precision in recognizing regions of the hand. Holden [2] proposes using radar scanning methods to conduct hand region identification. W. J. Tsao [3] uses skin color detection to find hand region and uses Holden's proposed radar scanning method to complete an interactive game of roshambo. J. H. Chang [4] first used Haar-Like characteristics of the hand to find the position of both hands and build dynamic models to achieve an adaptive dynamic skin color.

The scholars listed above mostly use Holden's proposed radar scanning method as the primary means of identification. The skin color detection is always used to search hand region. The most difficult part of image skin color detection is to determine whether the object is affected by surrounding light to cause the object to be unable to appear on the image. The previous scholars did not explore the effects of skin color in images resulted from environmental light changing. The light greatly affects models created by skin color detection systems. This study explores object detection under various light and color spaces using RGB, HSV, and YCBCR as color spaces for skin color detection. Skin color models are first experimented by Wang's[7] proposed RGB and HSV color space values and Hiremath's[5] YCbCr color space values while also using environment design to create 7 types of light conditions for experimentation purposes. Hand gesture recognition method will utilize Holden's radar method to determine finger characteristics. This paper uses the OpenCV[6] to do Holden's method as it provides a massive image processing library to quickly experiment with various image algorithms.

The study primarily explores Holden's method of identification under various light sources to find the optimal light environment, color space, and skin color model combination to achieve the goal of improved detection. Experiment results found that Hiremath's model works poorly under low light. Through several experiments found that the adaptive skin color model proposed by this study effectively improves the effect of Hiremath's color space model for use under low and normal light conditions. Finally, coupled with the morphology closure to repair hand image, the system's detection effectiveness achieves 80% under low light and 85%~92% under normal light.

II. LITERATURE REVIEW

2.1 Holden's Hand Gesture Recognition [2]

Using the binary image of hand gestures to define weight location of the hand as in figure 1(a). The weight of the hand is used as the center of the circle, the radar scanning figure method is used to draw the entire image and the radius gradually increases from 0. When the circle passes important points on the hand, the point's radius and relative angle is recorded. The circle's largest radius is the maximum distance between the finger and the circle's center. With this we can convert the hand's binary image (x,y) to an angle distance polar plot (θ,ρ) with center of the circle as the origin as in figure 1(b). The horizontal axis represents angle θ while the vertical axis represents distanceρwhich is the distance from the center of the palm to each point on the hand.

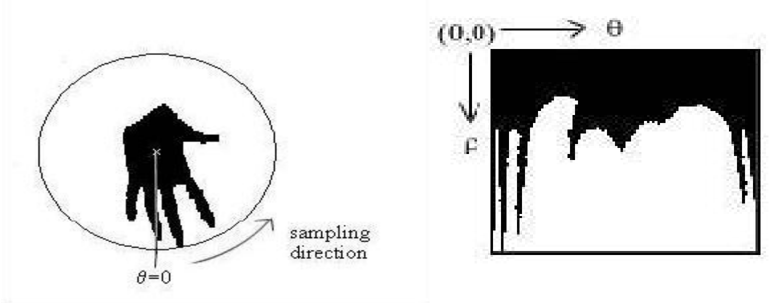

Figure 1(a) **Figure 1(b)**

Figure 1. Binary image of hand converted to angle distance polar plot

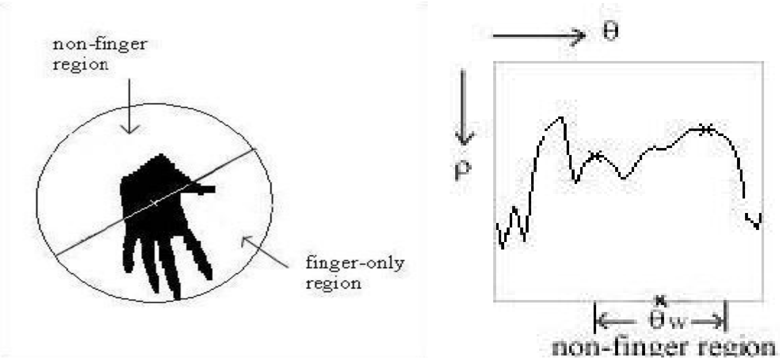

Figure 2(a) **Figure 2(b)**

Figure2. Find the hand gesture curvature contour to label finger and non-finger areas

As in figure 1(b), border detection can be applied to the angle distance polar plot to obtain a curvature figure as in figure 2(b) which is a calculation of the distance from the center of the hand to every contour point. Next, find the points on the graph with a lesser degree of change in distance and set points in this area as reference points and assume this point isθw. With this point we can separate the hand into finger regions and non-finger regions. In figures 1(b) and 2(b), each peak represents a finger and using finger region found previously to determine peak values, we can successfully identify hand gestures.

2.2 Skin Color Detection and Color Space

The purpose of skin color detection [9] is to precisely find palm position in image processing technology. The RGB color space used by standard images are represent red, green, and blue and image sensors can be easily affected by environmental light. The HSV color space model is represented by hue, saturation, and value with hue being the various values of color, saturation being the pureness of the color (lower pureness means the color leans towards grey) and value being the color's brightness. When using the HSV color model to adjust brightness, we can effectively reduce the effect of light on color. The conversion equation of RGB to HSV is as seen in equation 1.

$$h = cos^{-1}\left(\frac{0.5[R-G)+(R-B)]}{\sqrt{(R-G)^2+(R-B)(G-B)}}\right),$$
$$H = \begin{cases} \frac{h}{360^\circ}, if B \le G \\ 1-\frac{h}{360^\circ}, if B > G \end{cases},$$
$$S = \begin{cases} 0, if \max(R,G,B) = 0 \\ 1-\frac{\min(R,G,B)}{\max(R,G,B)}, if max(R,G,B) \neq 0 \end{cases},$$
$$V = \frac{\max(R,G,B)}{255} \quad (1)$$

The $\cos^{-1}$ is a inverse cosine operation with max() being the maximum function and min() being the minimum function.

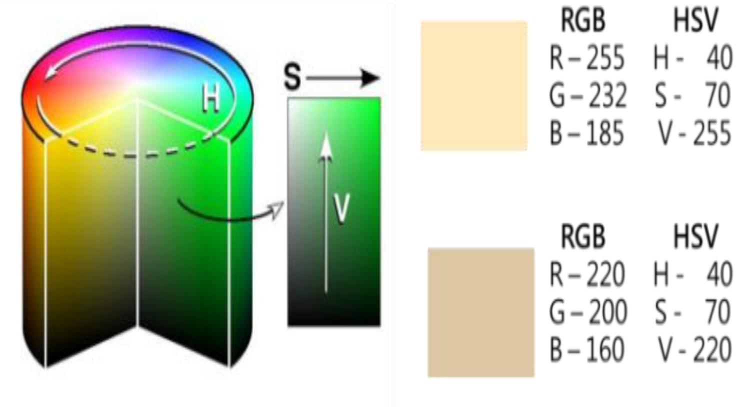

Figure 3. HSV Skin Color Model

W. J. Tsao[3] believes that in order to find the true regions of the hand, using the YCbCr color model will yield superior results. This is due to the fact that RGB color images are easily affected by change in light, and changes in environmental light greatly affect judgment when determining skin color. Therefore, converting the RGB color space to YCbCr can reduce color's reliance on brightness as Y(luminance) is a brightness element while Cb(blueness) and Cr(redness) are both color elements. As separation from brightness is high, color and brightness can be easily separated and used for skin color detection. The conversion equation of RGB to aYCbCr color space is as seen in equation 2.

$$\begin{bmatrix} Y \\ Cb \\ Cr \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ -0.1687 & 0.33126 & 0.5 \\ 0.5 & 0.41869 & 0.08131 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} + \begin{bmatrix} 0 \\ 128 \\ 128 \end{bmatrix} \quad (2)$$

III. EXPERIMENTAL ENVIRONMENT AND METHOD

3.1 System Environment and Hardware

The specifications of the system environment and hardware of this experiment is as seen in table 1. Experimental method processes can be seen in figure 4. First the image's color space is converted to obtain the binary image of the hand, and then the hand gesture identification is executed.

Table 1. System Environment and Hardware

Hardware	Software
CPU：Intel Core 2Duo E4600 2.4GHz RAM：2 Giga Byte VGA：ASUS 7300GT 256MB DDR2 IPCamera：DM355IPNC-MT5	Operating System： Microsoft Windows XP Service Pack 3 Development Software： Microsoft Visual Studio 2008 Open CV 2.2

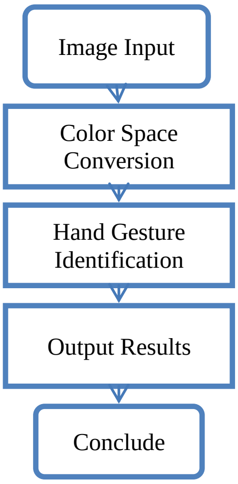

Figure 4. System Flow Figure

3.2 Hand Position Experiment Samples

Experimental samples are taken using the Microsoft LifeCam HD-5000with the subjects being the hands of other students. The camera lens is 115cm from the ground while the hand is 45cm away from the camera lens. Parameters are as shown in table 2. The Minolta CL200 is used to measure brightness value in the area of experimentation. Subjects are both male and female who are asked to perform the 3 hand gestures – scissors, rock, and paper as seen in figure 5. The environment's background is a whiteboard and a total of 800 pictures were used for the experiment. Details of the form can be seen in table 3.

Table 2 Camera Parameters and Environment

HD-5000 Parameters	
Brightness	70
Contrast	5
Exposure	-9
Experiment Environment	
Lens distance from ground	115cm
Background	Whiteboard
Target object distance from lens	45cm

Table 3 Experiment Sample Figures

Illumination	1330xl	1055xl	930xl	885xl	721xl	533xl	366xl
Subjects(M)	5	13	13	13	13	7	13
Subjects(F)	0	7	7	7	7	0	7
Gestures	3	3	3	3	3	3	3
Images	75	120	120	120	120	105	120

Figure 5. Hand Gesture Samples

3.3 Microsoft LifeCam HD-5000

The video lens used in this experiment is the Microsoft HD-5000. Detailed specifications can be seen in table 4.

Table 4. HD-5000 Specifications

Product Name	Microsoft LifeCam HD-5000
Sensor	VGA CCD
Resolution	1280*720

Microphone	Built-in Microphone
Max Frames Per Second	Maximum of 30 frames per second
Video Resolution	1280*720
Photo Resolution	Maximum of 1280×720

3.4 Experiment Method

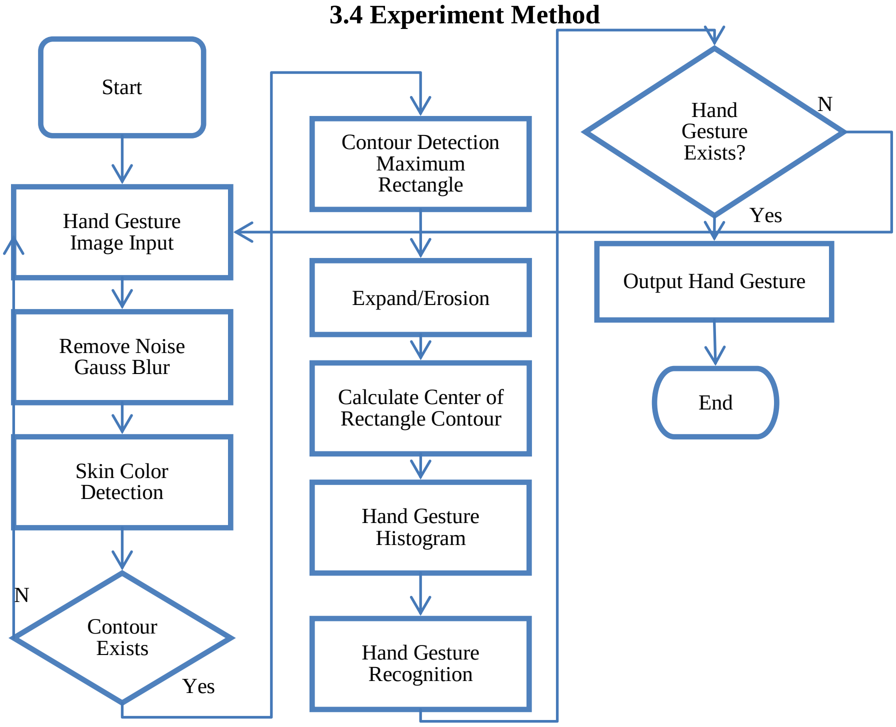

Figure 6. Hand Gesture Identification Flow Chart

The entire program is completed using the OpenCV image processing library as shown in the flow chart of figure 6. First the image is read using Wang's[7] proposed RGB skin color model to conduct skin color detection. The pixels are set to white in the range of the RGB skin color model while the rest are black. Next, using OpenCV'sFindContours library the image's contours are obtained with the largest area's contour being the hand region. This region requires morphology processing such as dilated, eroded, and more to find the center of the hand region to conduct analysis on the characteristics of hand gestures to determine the correct gestures according to the peak values of each gesture. The difference between HSV and YCBCR and experiments with other color space libraries is the conversion of color space library to the relative color space and then conducting skin color detection.

IV. EXPERIMENT RESULTS AND CONCLUSION

4.1 Hand Gesture Assessment Standards

We separate the results of whether hand gesture recognition is correct into 3 categories: first is correct, second is the detection of skin color but due to interference the result is wrong, and third being error in skin color detection or contour rectangular region too small causing no image due to inability to detect hand contour.

4.2 Hand Gesture Recognition in the RGB Color Space

Standard images use the RGB color space so this experiment is as a basis of comparison for later experiments. Refer to Wang's [7] proposed statistics of human skin color range in the RGB color space. Skin color range is distributed in $0.36<r<0.465$ and $0.28<g<0.363$ with detection results as seen in figure 7. Under 366xl light the precision is almost 0, and with the increase of light the precision also increases. Detectable hand region (correct & wrong) is averaged around 80% but with merely a 66%~77% precision rate. Overall average is 60% but no image is at 25%. Results show that detection under low light has much room for improvement.

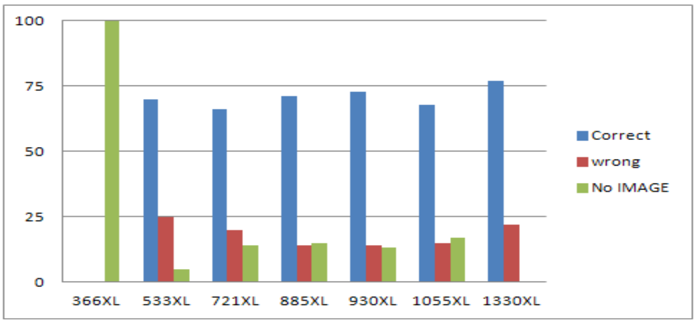

Figure 7. RGB Space Detection Results

4.3 HSV Color Space Hand Gesture Recognition
4.3.1Wang[7] HSV Skin Color Model

As adjusting brightness of the HSV color space model can effectively reduce the effect of light, this experiment uses Wang's[7] proposed statistics on the color range of human skin in the HSV color space. The range is distributed at $0 \leqq H \leqq 50$, $0.20 \leqq S \leqq 0.68$, and $0.35 \leqq V \leqq 1.0$ with detection results as seen in figure 8.

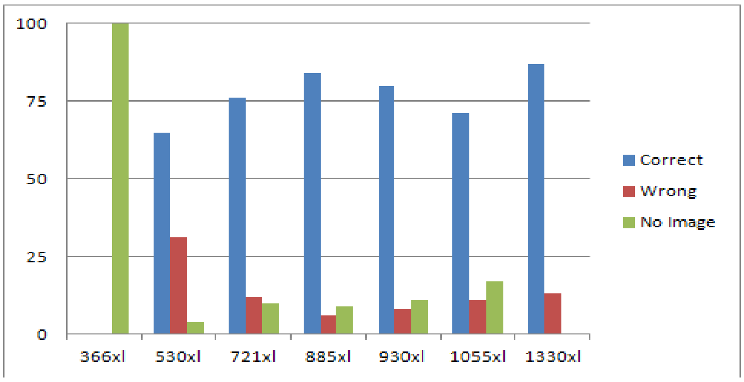

Figure 8.Wang[7] HSV Color Space Detection Results

Under 366xl the precision rate is still nearly 0, but under other light sources precision increased by 66%~87% with overall average at around 66%. However, at light sources under 530xl the conditions cannot be improved.

4.3.2 Dynamic Modeling

Face detection is used to find the current player's face and the skin color of the area under the nose is used to build the skin color model. This method is called dynamic modeling and detection results are as seen in figure 9.

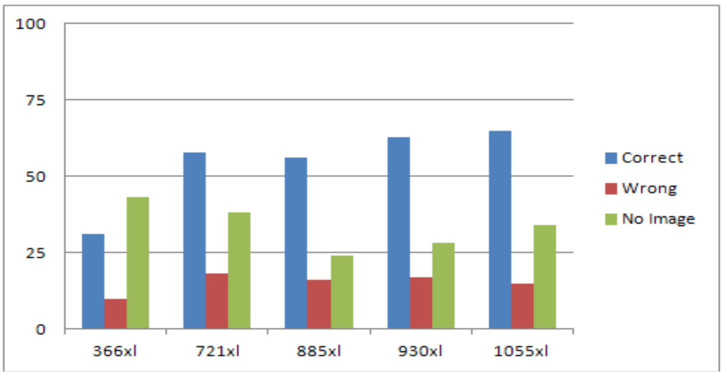

Figure 9. Dynamic Modeling Detection Results

Under 366xl light source there is a 25% increase in precision and the ratio of no image results has decreased by approximately 20%. However, the results of detection under other light sources have also been affected by a 20% decrease in precision. The ratio of no image has also increased by approximately 15%. This is due to the fact that a human face's skin color and hand skin color will be slightly different under identical light sources.

4.4 YCBCR Color Space Hand Gesture Recognition
4.4.1 YCBCR [Hiremath] Color Space

Some studies feel that using the YCbCr color model will yield better results on skin color detection. Using Hiremath's[5] proposed method, the color space skin color range distribution of YCbCr is 97.5≦Cb≦142.5 and 134≦Cr≦176. As Y is the brightness element, in order to separate skin color in the experiment to avoid being affected by light, the Y characteristics are generally not included in skin color determination. Experiment results are as in figure 10.

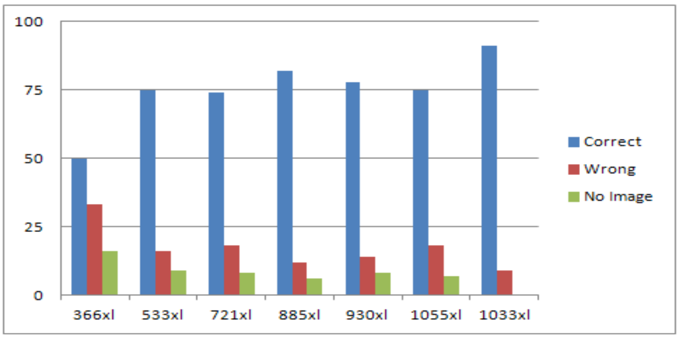

Figure 10.YCbCr Color Space Detection Results

366xl which was nearly 0 in both previous color spaces achieves an approximately 50% precision rate here. Successful detection of hand region (correct & wrong) increases to 90% and overall average precision rate increases to 78%. Although there is only a 50% precision rate at 366xl, compared to experiment 4.2 and 4.3.1 the precision rate is greatly increased. This proves that YCbCr is superior to RGB and HSV in terms of skin color separation.

4.4.2 Adaptive YCBCR Model

To further improve performance under low light conditions, a black background is used to find the YCbCr value of the hand region to use as a model for the YCbCr value under various light sources. These values are as seen in table 5. Adaptive skin color models proposed under various light sources are as seen below: under 366XL light sources we use the YCbCr of 113≦Cb≦126 and 135≦Cr≦151, 533XL is at 109≦Cb≦121 and 142≦Cr≦156, and 721XL or above have similar Cb and Cr values, so they will uniformly use 101≦Cb≦118 and 145≦Cr≦172 as the model above 721xl.

Table 5. Adaptive YCbCr Model

	Y (min)	Y (max)	Cb (min)	Cb (max)	Cr (min)	Cr (max)
366xl	29	52	113	126	135	151
533xl	51	73	109	121	142	156
721xl	72	107	102	118	145	168
885xl	85	126	102	117	148	171
930xl	89	133	101	117	148	172
1055 xl	98	136	101	117	147	171
1330xl	121	162	101	118	148	172

In order for use with the adaptive skin color model listed above, the YCbCr Y value experiment under 7 types of light sources is as seen in table 6. The goal is to separate the difference between 366xl, 533xl, and 721xl in order to determine the Y value in the current environment and load a relative skin color model. Under 366xl the Y value will be 109~116, 533xl is 186~189, and 721xl or above is 206.

Table 6 Y Value of Various Light Sources

Light Source	Y(min)	Y(max)
366xl	109	116
533xl	186	189
721xl	206	206
885xl	209	209
930xl	210	211
1055xl	219	223

1330xl	227	227

Figure 11 shows the results from using the adaptive YCbCr skin color model. There is an obvious improvement in detection rate at 366xl and 533xl with a 20% increase at 336xl and 5% increase at 533xl. Experiment results at values greater than 721xl are close to the results of 4.4.1. Overall average precision increases to almost 80%, with successful detection of hand region (correct & wrong) is over 90%.

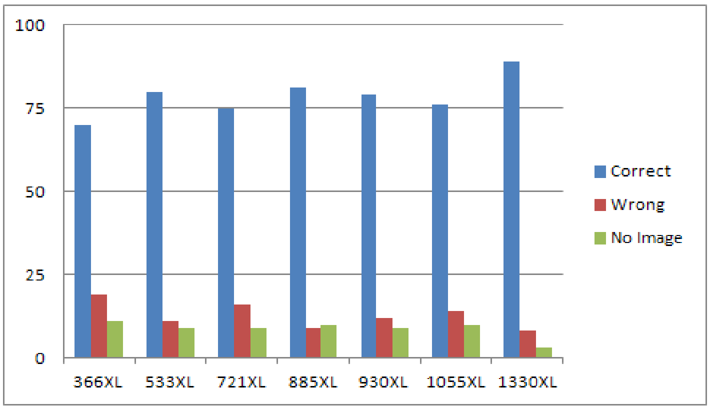

Figure 11. Adaptive YCBCR Model Experiment Results

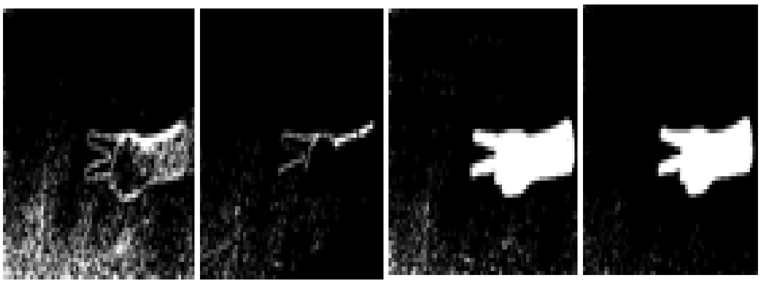

Figure 12. (a) (b) (c) (d)

Figure 12.(a), (b), (c), (d) show the results of RGB, HSV, YCBCR, and YCBCR repaired skin color model at 366xl light source. We can obviously see that YCBCR is superior to the other two, and the repaired adaptive skin color model is even better than that proposed by Hiremath.

4.5 Dilated Eroded

The experiment above found that whether using scholar or adaptive skin color models, there is a 5~10% rate at which samples gain the result of no image. As these samples offer incomplete signals around the border, further recognition could not be conducted. Using morphology’s close to repair, the experiment found that by dilating and then eroding (at least one dilate and more erode than dilate) will yield optimal results. The image processing in 4.4.2 was output with 1 dilate and 3 erodes with recognition results as seen in figure 13. Experiment results showed that precision rate at 366xl achieves 78% while others achieve 80~92%.

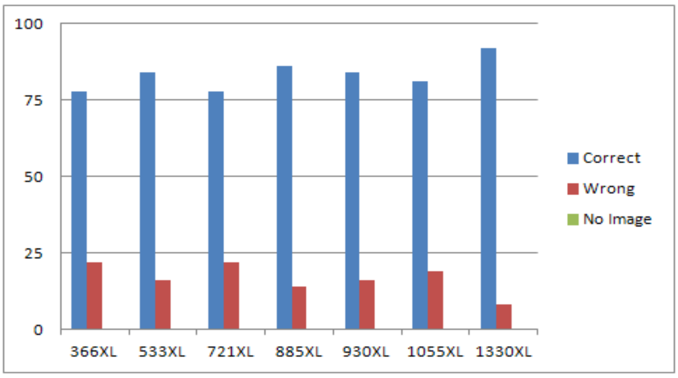

Figure 13. Dilated/Eroded Experiment Results

V. CONCLUSION

The experiment above found that the YCBCR separation is best out of the RGB, HSV, and YCBCR color spaces. We propose that the adaptive YCBCR model performs well under low light and also normal light sources. This paper has proposed an adaptive YCBCR skin color model which uses the Y value of the image background to calculate the brightness of the current environment to use in the assessment of a relative skin color model. Furthermore, the close of morphology (dilated once, erode 3 times) is used to further increase system efficacy. A recognition precision rate of 81% was achieved under low light (366xl, 533xl). A higher precision rate of 85%~92% was achieved under normal light conditions (721xl and above). Finally, the study results were used to create a robot roshambo gaming system as shown in figure 14.

Figure 14. Roshambo Game System Interface

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