

Skin Lesion Analysis Using Digital Imaging Techniques

by

Siti Nadiyah Binti Jamaludin

Dissertation submitted in partial fulfilment of
the requirements for the
Bachelor of Engineering (Hons)
(Electrical & Electronics Engineering)

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CERTIFICATION OF APPROVAL

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Approved by,



(Dr. Aamir Saeed Malik)
Project supervisor

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

JANUARY 2011

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

SITI NADIAH BINTI JAMALUDIN

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ABSTRACT

Visual inspection of skin lesion may be time consuming and is prone to inaccuracy. Conventionally, dermatologist has to visually inspect and manually calculate the percentage of affected area on patient's body. Though the estimation is highly subjective, therefore a computerized system of detecting and calculating affected area will be very helpful. This report presents a computer vision method for analysis of lesion area. The most crucial part of this work is segmentation. In this paper, we present three methods of segmenting lesion area (represented as colored patches) which are 1. segmentation in HSI color space, 2. segmentation in RGB color space and 3. segmentation in quantized RGB color space. The result of three methods will then be compared to select the method that yield the best segmentation result.

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CHAPTER 1

INTRODUCTION

The project's, *Skin Lesion Analysis Using Digital Imaging Techniques* preface and background will be explained in this chapter. The chapter covers background of study, problem statement, objectives and scope of study of the project. This chapter will help readers to grasp the basic idea of the project and understand the concepts and principles applied.

1.1 Background of Study

The ultimate aim of this project is to produce a computerized skin lesion analysis module which will be able to detect lesion in a given image and calculate the percentage of the lesion area provided that the lesion are in form of discoloration. *The most vital part of the module is the segmentation, where the lesion has to be separated from its background which is the healthy skin.* Given the color information, a method towards segmenting the lesion can be developed. There are many methods reported in the literature among which the most common approach is to threshold on grayscale images. However, the drawback of this method is that the segmentation will be faulty due to the non-uniform illumination on the image. In this report, I will discuss methods of segmenting and processing lesion image in color space. Processing is done on number of methods and the result is then compared to select method that yield the best result.

1.2 Problem Statement

1.2.1 Problem identification

Conventionally, dermatologist has to visually inspect and manually calculate percentage of lesion on the patient body. The estimation is acceptably accurate though the process may be time consuming. Dermatologist does the calculation based on the Lund & Browder chart (appendix 3), where in this chart, human body is divided into sub categories with each part having own percentage value.

The accuracy of the inspection is usually high however depends on several factor. The working hour of the doctor maybe one of the factors, the doctor might be fresh and sharp during early hour of work and at the end of the day he/she may get worn out and unintentionally make a wrong decision. The proficiency or experience might be a factor too, doctors who has longer working experience may give great result compared too the newly hired. There are a lot of other factors that may contribute inaccuracy of lesion percentage calculation. It is very important that the result be highly accurate, therefore having a computed lesion analysis system would be very helpful.

1.2.2 Project Significance

The end-product will be able to accept image of patient's skin, analyze it and give a result as a percentage of lesion. Reaching the goal of this project will contribute towards the medical sectors. The project itself emphasize on image processing which will be a great platform towards analytical thinking.

1.3 Project Objectives & Scopes of Study

1.3.1 Project Objectives

The project focus on problem solving technique and front end engineering fundamentals. The objectives of *Skin Lesion Analysis Using Digital Imaging Techniques* is as follows:

- i. To design an automated skin lesion detection module based on captured image.
- ii. To develop an automated skin lesion calculation module based on Lund & Browder chart.

1.3.2 Scope of Study

Towards implementing the project, the knowledge required are :

- i. Image processing
- ii. Color processing
- iii. Frequency domain processing and
- iv. Statistical processing

Overall, the knowledge required in this project are within the scope of image processing and some mathematical analysis.

1.3.3 Project Relevancy

It is noted that the techniques to be developed under this project will be directly applicable to medical imaging stream. The techniques proposed will also have applications in other application such as detection of tumors, cancer and other medical imaging applications. Skin lesion analysis using computer imaging techniques will help reduce the number of false results.

1.3.4 Feasibility of Project

The project is executed within two semester's time frame. The time frame allocated for the project is limited but adequate with proper time management and planning. The time allocated assures the project to be completed and accomplishment within the time frame provided. Attached in the appendix is the proposed Gantt chart for this project.

CHAPTER 2

LITERATURE REVIEW

2.1 Type of skin lesion

Skin lesion can be classified as any abnormality that exists on the surface of the human skin that is different from the area around it. There are two categories of skin lesion, primary and secondary. Primary skin lesion can be interpreted as variations in color that is natural such as moles, or obtained caused by diseases and secondary skin lesions is a result of manipulating primary skin lesions such as by scratching. Table 1 lists types of skin lesions and its features. From table 1 [10] we can conclude that skin lesion may exist in variety of color and shape and can be present in any part of the body.

Table 1: Types of Lesions

Lesion type	shape	Colour	Location on body	Size(diameter)
Actinic keratosis	Patchy	Pink to red brown	Head,face and neck	>2.5 cm
Seboeic keratosis	Round or oval	yellow, light tan, brown	Head and neck	3mm – 3cm
Verruca vulgaris	Round, resemble cauli flower	Skin colour,white	Hand, genital	-
Molluscom contagiosum	Round and raised	Red and inflamed	face, neck, armpits, hands and arms	2 to 5 mm
lentigo	Round	Tan,brown or black	forehead and face	-
Basal carcinoma	-	White, yellowish, brown	Head and neck	-

2.2 Segmentation

Segmentation divides image into sub-groups which each member of the group have the same properties. Segmentation algorithms are usually based on discontinuity and similarity of the pixels in an image. Segmentation can be done either in grayscale or color image, which segmentation in grayscale is much easier than segmentation in color image.

Converting color image into its grayscale could be one good approach, providing that the color image has a consistent illumination or shadow, or else we will get a bad segmentation result. Illumination in an image has been quite an issue in image processing. Therefore, rather than processing the image in its pseudocolor (grayscale), processing it in color might be a good approach too.

There are numerous segmentation methods reported in the literature and among the famous are:

- i. **Histogram thresholding:** there are number of regions composed in an image which having different gray or color value. Histogram represents each region with corresponding peaks.
- ii. **Edge-Based Segmentation:** Edge pixel is assumed to be having abrupt change of value. Famous edge detection operators are Canny, Sobel and Laplacian.
- iii. **Region-based Segmentation:** based on homogeneity of the data. Among famous approach are region growing, merging and splitting.

Let us see now each of the method in more detail and decide which method works best for our algorithm.

2.2.1 Histogram Thresholding

Suppose that the histogram in the figure below correspond to an image, $f(x,y)$, which is an image of a light object on a dark background. Thus, object and background pixels have intensity values which is group into two modes. The easiest way to extract the object from its background is by setting a threshold value, T . Any pixel within the image (x,y) with a value greater than T is considered object point or else the pixel belongs to the background. Thresholding the histogram in figure 1 will result in output $g(x,y)$ which composed of white and black pixel for the object and background respectively.

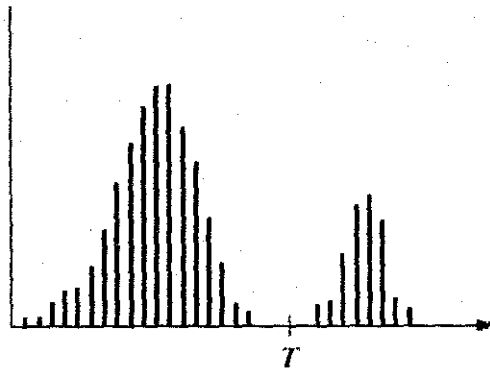


Figure 1: Histogram of an image

The relationship between the threshold value, T and the image pixel can be represented by :

$$g(x,y) = \begin{cases} 1 & \text{if } f(x,y) > T \\ 0 & \text{otherwise} \end{cases} \quad \text{Eq. (1)}$$

The success of histogram thresholding is depending on the width and depth of the valley separating the peaks in the histogram. Consecutively, the factors affecting the properties of the valleys are :

1. The separation of the peak
2. Noise level
3. Size of the objects and background
4. Uniformity of illumination and
5. Uniformity of the reflectance of the image

If the valleys between each peak is distinct, it is sufficient to just use single (global) threshold value over the entire image. However, for the histogram in figure 2 the separation is not distinct enough and using global thresholding is not applicable.

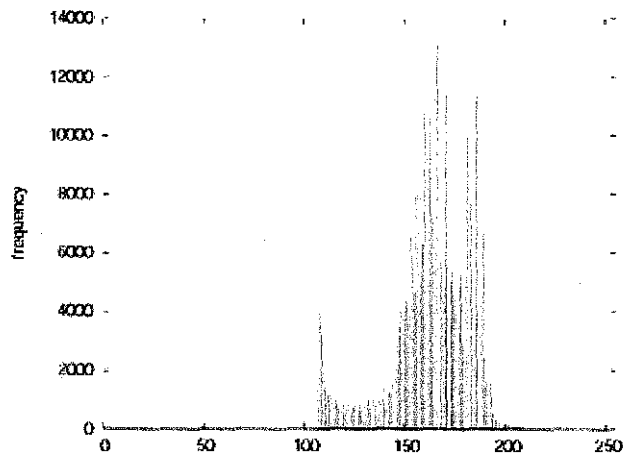


Figure 2: Histogram with no clear separation

Therefore, one of the renowned methods to handle this problem is Otsu's thresholding, [Otsu, 1979]. For a histogram that does not have distinct valleys, using Otsu's method is a great approach.

2.2.2 Edge-based Segmentation

The simplest way to carry out edge based segmentation is by using a computer mouse to control a screen cursor and draw boundary lines between regions using any photo editing software. However, manually segmenting the region would be tiring and time consuming.

There are algorithms for semi-automatically drawing edges and it can be made automatic too. In edge-based segmentation, image is divided into regions by connected chains of edge. An algorithm, namely *connected component algorithm* is invented by Rosenfeld and Pfaltz (1966) for this method. Each pixel is examined one by one consecutively beginning at the top-left corner of the image

then scanned along each row, finishing at the bottom-right corner until it comes to a point j which is the pixel that is to be labeled. The four neighbors of j are then examined. This is how the labeling of j carried out :

- If all four neighbors are 0, assign a new label to j , else
- if only one neighbor is 1, assign its label to j , else
- if more than one of the neighbors having value 1, assign one of the labels to j and make a note of the equivalences.

Another edge-detection method is the gradient operation. Gradient operation work wonderful in a grayscale image with obvious edges but when the gray levels change gradually from dark to bright the gradient operation will produce a very wide edge. In this condition, using the Laplacian operator would be helpful.

The Laplacian operator detects zero crossing which exist in the middle of the wide edge of an image. The edge is located at zero crossing of second order derivative of the image.

2.3 Color Space

2.3.1 RGB Color Space

RGB is a colors space originated from CRT display applications. Color is a combination of three colored rays which are red, green and blue. It is one of the most widely used color space for processing and storing of digital image data. However, high correlation between channels, significant perceptual non-uniformity, mixing of chrominance and luminance data make RGB not a very favorable choice for color analysis and color-based recognition algorithms.

2.3.2 HSI Color Space

When human view an object, they describe colors by its hue, saturation and brightness or HSI (also called HSV and HSL). Hue (H) defines the purity of the color, saturation (S) measure the amount of white added to dilute the color (as in pink, light blue) and intensity (I) represents the luminance of the color. The

insightfulness of this color space components made it popular in the works of skin color segmentation [Zarit et al. 1999].

CHAPTER 3

METHODOLOGY

This chapter, discusses the methodology involved towards the project development. The methodology part is divided into sub processes within two semester time frame.

3.1 Data Gathering

Samples of image from various parts of the body are taken using a Nikon DSLR camera based on the Lund & Browder chart. To represent lesion or discoloration, patches of paper with different colors are pasted on the body part of the model. The background color is set to uniform green color. Samples of image are shown in figure below:

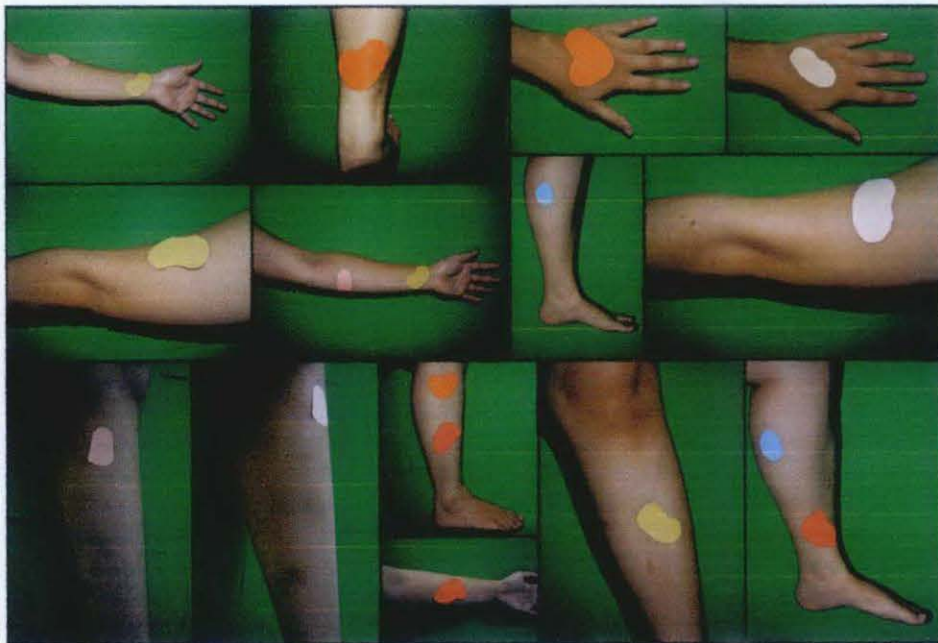


Figure 3 : Samples of data

3.2 Image registration

Image registration is the process of transforming image data into set of sytem.to do this, we first read the image into Matlab using command 'imread'. In Matlab, data is stored as RGB system which has three dimensions namely red, green and blue:

$$x(n, m) = \begin{bmatrix} x_r(n, m) \\ x_g(n, m) \\ b(n, m) \end{bmatrix} \quad \text{Eq.2}$$

Where $x_r(n, m)$ is the red component, $x_g(n, m)$ is the green component and $x_b(n, m)$ is the blue component. Each pixel in a digital image values between 0 and 255 (Gonzales & Woods, 2002).

The image can always be transformed into any color space in Matlab. In our project, we consider intensity space, RGB color space and HSI color space.

Hue, saturation and intensity (HSI) color space model the color similar to the human vision. In this project, we also carry out processing in HSI color space. Transforming RGB image into HSI space is a straightforward process in Matlab, by just using command 'im2hsv' we will get the image in its hue, saturation and intensity space.

The H component of each RGB pixel in an RGB image is given by :

$$H = \begin{cases} \theta & \text{if } B \leq G \\ 360 - \theta & \text{if } B > G \end{cases} \quad \text{Eq. (3)}$$

Where

$$\theta = \cos^{-1} \left\{ \frac{\frac{1}{2} [(R - G) + (R - B)]}{[(R - G)^2 + (R - B)(G - B)]^{1/2}} \right\} \quad \text{Eq. (4)}$$

The S component is

$$S = 1 - \frac{3}{(R + G + B)} [\min(R, G, B)] \quad \text{Eq. (5)}$$

And the intensity, I component is

$$I = \frac{1}{3}(R + G + B) \quad \text{Eq. (6)}$$

Where we can see that the intensity value of a pixel is the average value of all three R,G and B components.

The figure below show image in its respective RGB and HSI space:



Figure 4 : Image transformation a) Original. b) Red. c) Green. d) Blue. e) Hue. f) Saturation. g) Intensity

3.3 Color Vector Quantization

Color quantization reduces the number of colors used in an image thus reduce the processing complexity. Color quantization is usually done in the pre-processing step. In our method, we used vector quantization as discussed by Vural Gokmen [2] to reduce the number of color in our image.

User will be prompted to select four different regions that they are interested in and the region will be cropped using Matlab command 'imcrop'. In the example below, the two colors representing lesion (blue and red), the healthy skin and background is selected as the reference pixels.

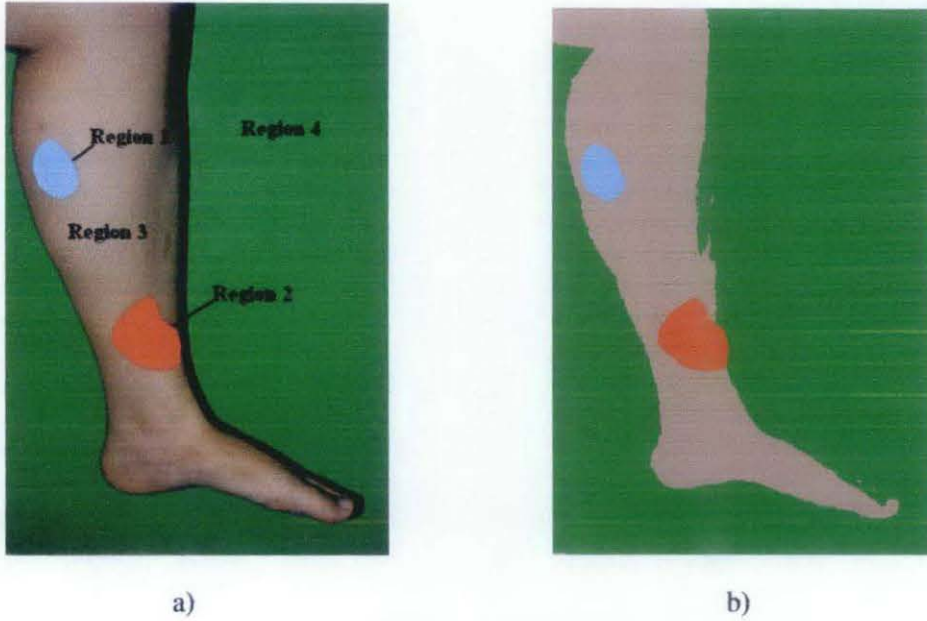


Figure 5: a) selected regions of original leg image. b) Quantized leg image

The mean of each vector component are calculated using Matlab where region 1, region 2, region 3 and region 4 has mean value [0.5007, 0.7002, 0.8112], [0.7509,0.1528,0.1643], [0.6099,0.5627,0.5471] and [0.1689,0.5482,0.3684] respectively. Pixels of the leg image in figure a) can be classified into four regions which are the blue region, the red region, the healthy skin region and the background. This can be obtained by calculating Euclidian distance of the image pixel by pixel and channel by channel.

The Euclidian distance of a pixel with respect to region 1 is given by :

$$D(n, m) = \sqrt{(x_r(n, m) - 0.5007)^2 + (x_g(n, m) - 0.7002)^2 + (x_b(n, m) - 0.8112)^2}$$

The value of $D(n,m)$ will decide whether the pixel belong to region 1 or not.

The scatter of the pixels in the R channel can be viewed from its histogram:

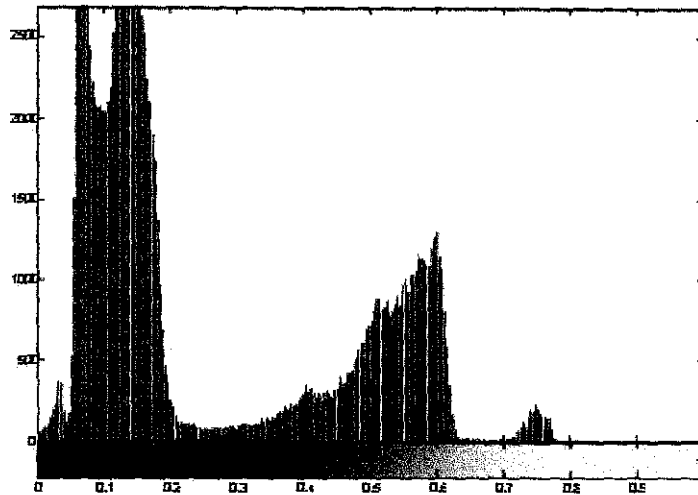


Figure 6 :Histogram of red channel before quantization

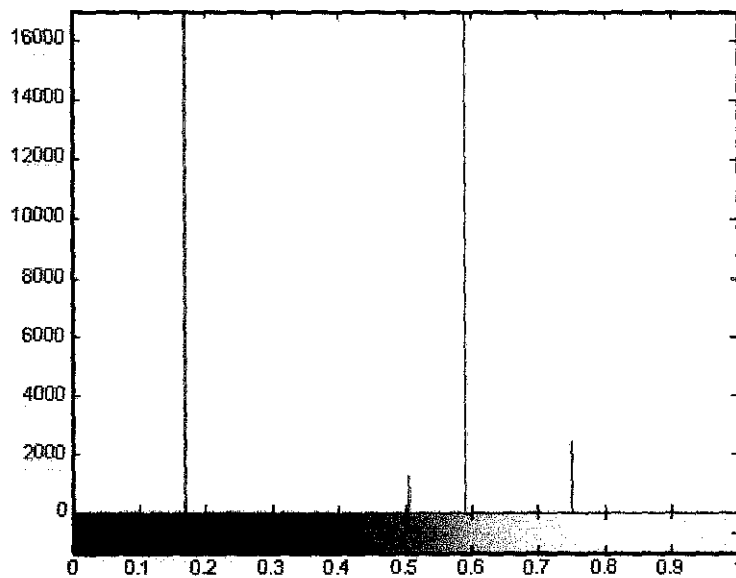


Figure 7: Histogram of red channel after quantization

Figure above show the scattered plot of the pixels in the red channel before quantization (figure 6) and figure 7the histogram after quantized. It is shown that after quantization the class pixel value is reduced.

3.4 Segmentation

3.4.1 Segmentation of Region of Interest (ROI)

In analysis of skin image, the three areas are considered; the healthy skin, the lesion and the background. Setting the background color as green enable us to extract the ROI since is clearly distinguishable from the skin when using the red channel of the RGB color space [6].

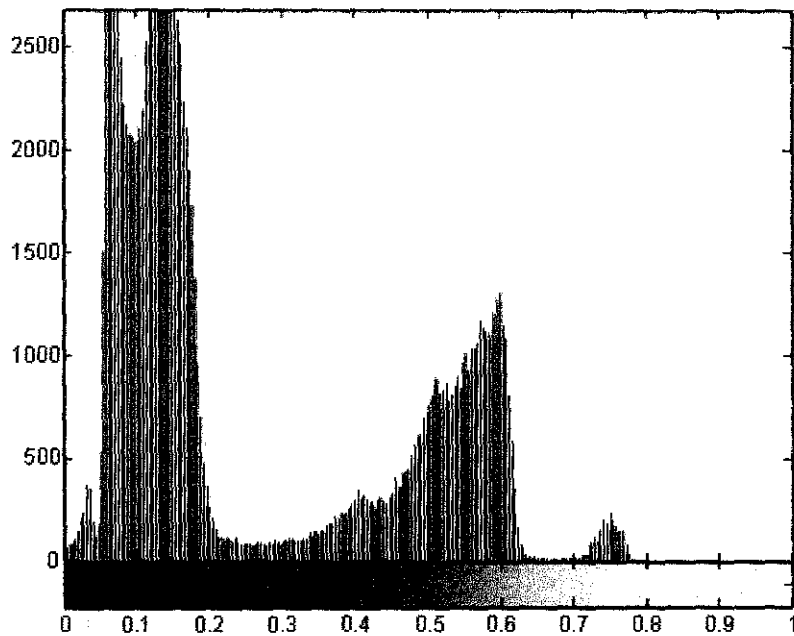


Figure 8: Histogram of the red band of image in figure 5 a).

From the histogram above, it is clearly seen that clear separation exist between three peaks and therefore a threshold value can be easily selected to separate the background from the image. User will be displayed with a histogram image, and will be prompted to enter a suitable threshold value. Selecting the threshold value for the red band as 0.3 yields the image:



Figure 9 : Region of interest of image in figure 5.

3.4.2 Segmentation of Lesion

The next important part of the module is to extract the lesion area from the image. Segmentation of lesion has to be highly accurate to yield good result. Segmentation is done in three conditions:

- i. HSI color space
- ii. RGB color space
- iii. Quantized RGB color space

3.4.2.1 Segmentation in HSI color space

Using Matlab, image is transformed into HSI color space using command 'im2hsv'. The three hue, saturation and intensity channel is then multiplied with ROI that we gained in part 3.4.1 using command 'immultiply' producing images :

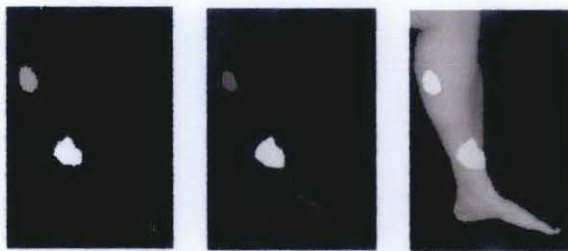


Figure 10 : Product of ROI and a) hue b) saturation and c) intensity channel.

The hue image is first selected as mask image, by thresholding it and gaining its binary image. The obtained mask is then multiply with the saturation and intensity image. Converting both products into black and white giving us the segmentation result where white represents lesion and black represent else.

Segmentation in HSI space is then carried out with saturation and intensity image as mask image following the same procedure. The corresponding Matlab code is attached in the appendix.

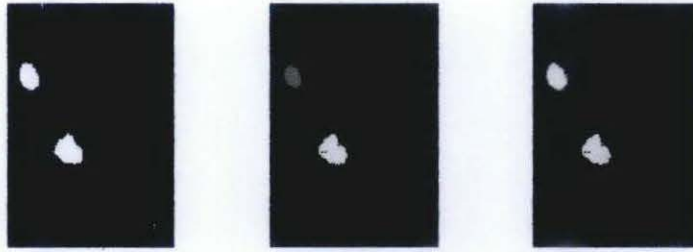


Figure 11 : a) Hue mask b) product of a) and saturation image

3.4.2.1 Segmentation in RGB color space

Just like segmentation in HSI, segmentation in color space also uses the same ROI image that we obtained in part 3.4.1. The obtained ROI image is multiplied with each red, green and blue color space. To segment the lesion, each of the channels are thresholded using where user will be prompted to enter suitable threshold value based on its histogram. The corresponding Matlab code is attached in Appendix B. The figure below show result of segmentation in RGB color space.

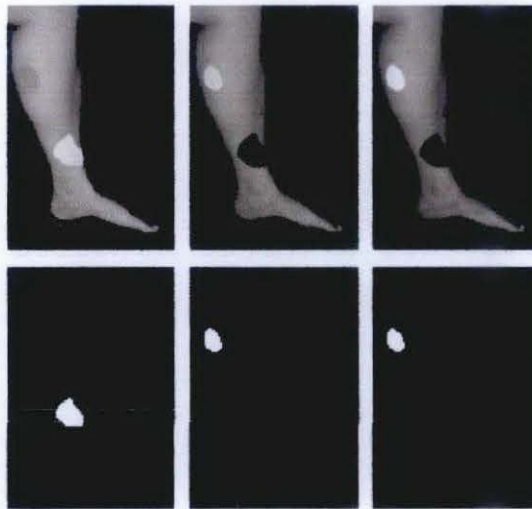


Figure 12 : a) Product of ROI and R b) product of ROI and G c) Product of ROI and B, d) thresholded R channel, e) thresholded G channel, f) thresholded B channel

Segmentation in quantized color space follow the same procedure as above however the difference is that the image undergone quantization process as shown in part 3.3.

3.5 Calculating percentage of lesion area

This part discusses how calculation of percentage of lesion area is carried out in this project. The outcome of the segmentation process is a binary (black & white image) with white represent lesion and black represent else. With this information gained it enables us to calculate the percentage of lesion area by assuming the total white pixel count in the segmented image divided by total white pixel in the ROI image is the ratio of lesion over the body part. Consider the leg image below :



Figure 13 : Region of interest

Using Matlab function 'nnz' the number of white pixel in the image is 30,752 pixels, we can now assume the area of the leg image is 30,752. Consider the segmented lesion image below :

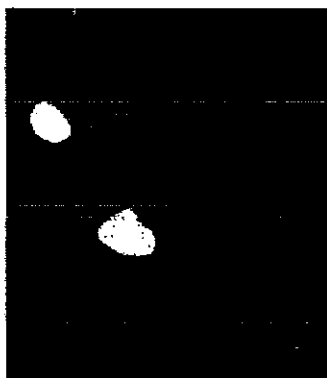


Figure 14 : Segmented lesion

The number of white pixels is 3,751, then dividing 3,751 with 30,752 yields 0.12 which means the lesion in 1/4 of the leg area (based on the Lund & Browder chart) is 0.42 percent.

However, directly calculating the lesion area by calculating the white pixels might be inaccurate because the white pixels may also come from noise. Therefore, in overcoming this situation, the noise in the segmented image has to be removed first using function 'bwareaopen'.

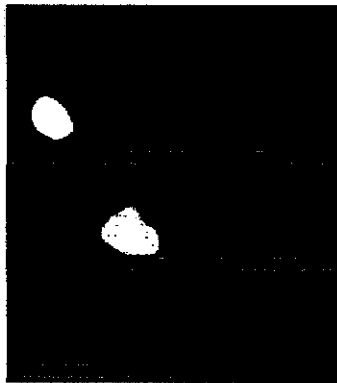


Figure 16 : Segmented figure with noise removed

After removing the noise, the percentage of lesion is calculated to be 9.9 percent.

Therefore , referring back to the Lund & Browder chart, the percentage of lesion over total whole body of an adult is :

Total affected area = percentage of lesion calculated x percentage of half of leg,C

$$= 9.9\% \times 3.5$$

$$= 0.345 \%$$

3.6 Result Justification

A ground truth image is obtained by manually segmenting the image using Adobe Photoshop. This ground truth image is assumed to be the perfect segmentation of the lesion. To justify the accuracy of our method, the image obtained is correlated with the ground truth image and the Root Mean Square Error is calculated.

The correlation function is given by :

$$f(x, y) * h(x, y) = \sum_{m=0}^{M-1} \sum_{n=0}^{N-1} f^*(m, n)h(x + m, y + n) \quad Eq. (7)$$

Where $f(x, y)$ is the ground truth image and $h(x, y)$ is the segmentation output. The output of the correlation function is a value ranging from 0 to 1.



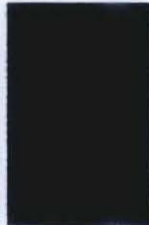



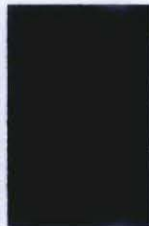









CHAPTER 4















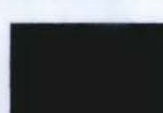



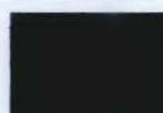



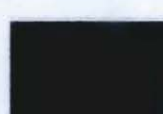
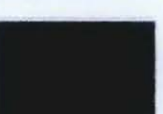





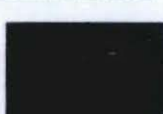
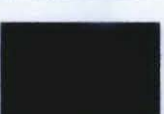



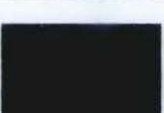

RESULTS AND DISCUSSION

4.1. Results of Segmentation in HSI Color Space

A set of image in appendix 9 are tested using the HSI segmentation as discussed in the earlier chapter. Segmentation is done with all three H, S and I channel as mask. The result is in the following tables







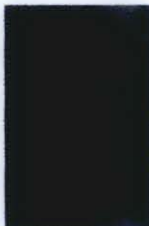





















Table 2 : Result of segmentation using hue mask



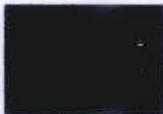


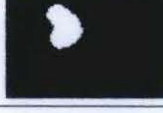
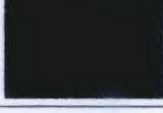
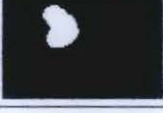


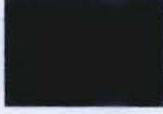













Sample	Original	Hue mask	Hue * sat	Hue * int
1				
2				
3				
4				

5				
6				
7				
8				
9				
10				
11				
12				
13				

The segmented images are then correlated with the ground truth images in appendix 9 to find the difference of the images with the ground truth and RMSE for each images are calculated and recorded in table 6.




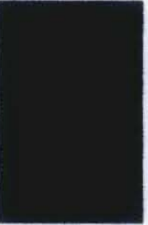











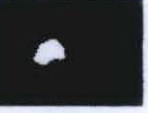



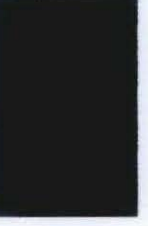







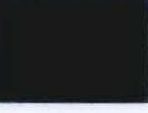
Table 3 : result of segmentation in using saturation mask







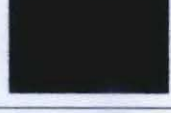
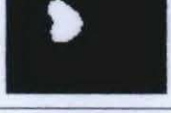

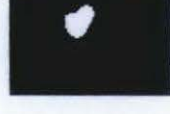








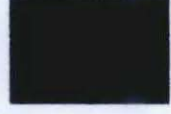
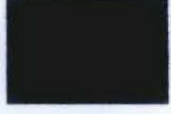



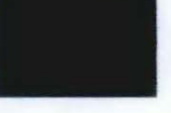
Sample	Original	Sat mask	Sat * hue	Sat * int
1				
2				
3				
4				
5				
6				
7				

8				
9				
10				
11				
12				
13				

The segmented images are then correlated with the ground truth images in appendix 9 to find the difference of the images with the ground truth and RMSE for each images are calculated and recorded in table 7.

Table 4: result of segmentation using intensity mask

Sample	Original	Int mask	Int * hue	Int * hue
1				
2				
3				
4				
5				
6				
7				



















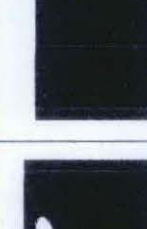





8				
9				
10				
11				
12				
13				

























The segmented images are then correlated with the ground truth images in appendix 9 to find the difference of the images with the ground truth and RMSE for each images are calculated and recorded in table 7.

4. 2 Results of Segmentation in RGB Color Space

The proposed segmentation using RGB color space is applied to the image in appendix 9. The results of the segmentation are in the following table.

Table 5: result of segmentation in RGB color space

Sample	original	Thresholded, R	Thresholded,G	Thresholded,B
1				
2				
3				
4				
5				
6				


























7				
8				
9				
10				
11				
12				






























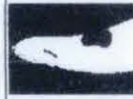





The segmented images are then correlated with the ground truth images in appendix 9 to find the difference of the images with the ground truth and RMSE for each images are calculated and recorded in table 8.

4. 3 Results of Segmentation in Quantized RGB Color Space

The proposed segmentation using RGB color space is applied to the image in appendix 9. The results of the segmentation are in the following table.

Table 6: Result of segmentation in quantized RGB color space

Sample	Original	Quantized	Thresholded, R	Thresholded,G	Thresholded,B
1					
2					
3					
4					
5					

6					
7					
8					
9					
10					
11					
12					

The segmented images are then correlated with the ground truth images in appendix 9 to find the difference of the images with the ground truth and RMSE for each images are calculated and recorded in table 9.

4.4 Result justification

Table 7: RMSE & correlation for HSI segmentation of result and Ground truth

Sample	Hue mask				Saturation mask				Intensity mask			
	saturation image		Intensity image		Saturation image		Intensity image		Hue image		Saturation image	
	RMSE	correlation	RMSE	correlation	RMSE	correlation	RMSE	correlation	RMSE	correlation	RMSE	correlation
1	0.0163	-	0.0018	0.9486	0.0163	-	0.0275	-0.0137	0.0163	-	0.0163	-
2	0.0153	-	0.001	0.09658	0.0153	-	0.0153	-	0.0010	0.9658	0.0153	-
3	0.0086	-	0.0057	0.7714	0.0086	-	0.0091	-0.0021	0.0003	0.9785	0.0086	-
4	0.0093	0.8414	0.0117	0.8005	0.0091	0.8449	0.0008	0.9864	0.0095	0.8362	0.0013	0.9787
5	0.0106	-0.0021	0.0019	0.9812	0.0005	0.9715	0.0067	0.7566	0.0007	0.9963	0.0102	-
6	0.0103	0.7719	0.0029	0.9436	0.0022	0.9559	0.0028	0.9853	0.002	0.9592	0.0105	0.768
7	0.0366	-	0.1587	0.1142	0.0363	-	0.1231	-0.0599	0.0366	-0.0029	0.0363	-
8	0.0627	-	0.0688	-0.0164	0.0627	-	0.0014	0.9880	0.0628	-0.0019	0.0009	0.992
9	0.0397	-0.0028	0.0397	-0.0024	0.0395	-	0.001	0.9826	0.0395	-	0.0012	0.9847
10	0.0191	0.6797	0.0197	0.6874	0.0196	0.6691	0.0020	0.9715	0.0192	0.6778	0.0019	0.973
11	0.0351	-	0.0357	0.0128	0.0351	-	0.0784	-0.0383	0.0351	-	0.0351	-
12	0.0361	-0.0012	0.0222	0.6121	0.036	-	0.0989	-0.0501	0.0335	0.2608	0.036	-
Average	0.024975	0.38115	0.030817	0.495798	0.023433	0.86035	0.030583	0.500573	0.021375	0.629978	0.014467	0.93928

Table 8 : RMSE and correlation of RGB thresholding and ground truth

Sample	R channel		G channel		B channel	
	RMSE	correlation	RMSE	correlation	RMSE	correlation
1	0.0043	0.8838	0.0008	0.9734	0.2602	0.208
2	0.0012	0.9619	0.0015	0.9505	0.0009	0.9692
3	0.0002	0.9830	0.0003	0.9821	0.0003	0.9781
4	0.0025	0.9608	0.0848	-0.043	0.0609	-0.0313
5	0.2871	0.1558	0.0003	0.9852	0.0006	0.9703
6	0.0105	0.768	0.171	0.5769	0.0171	0.5788
7	0.0008	0.9880	0.0011	0.9835	0.0011	0.9839
8	0.001	0.9914	0.0718	-0.0242	0.1049	-0.0541
9	0.0012	0.9846	0.0743	-0.0385	0.0462	-0.0166
10	0.0019	0.9726	0.0786	-0.0408	0.0613	-0.0311
11	0.1293	0.4265	0.0010	0.9847	0.1394	0.2927
12	0.0319	0.7781	0.0041	0.3990	0.0017	0.9760
Average	0.0393	0.8212	0.0408	0.5574	0.0578	0.4853

Table 9: RMSE and correlation of quantized RGB and ground truth

Sample	R channel		G channel		B channel	
	RMSE	correlation	RMSE	correlation	RMSE	correlation
1	0.0004	0.9860	0.0004	0.9860	0.3044	-0.0741
2	0.0203	0.6207	0.0222	0.6207	0.0222	0.6207
3	0.0004	0.9728	0.0004	0.9728	0.0004	0.9728
4	0.0016	0.9760	0.3203	-0.1165	0.2672	-0.1015
5	0.2648	-0.0592	0.0002	0.9869	0.0002	0.9869
6	0.0100	0.7795	0.0171	0.5801	0.0171	0.5801
7	0.0008	0.9880	0.0008	0.9880	0.0008	0.9880
8	0.0007	0.9936	0.3413	-0.1572	0.3370	-0.1554
9	0.0009	0.9879	0.1578	-0.0737	0.1578	-0.0737
10	0.0031	0.9581	0.2639	-0.1047	0.2290	-0.0923
11	0.0004	0.9938	0.0004	0.9938	0.3751	-0.1330
12	0.0030	0.9567	0.0030	0.9567	0.0030	0.9567
Average	0.0255	0.8461	0.0939	0.5527	0.1428	0.3729

4.5 Discussion

The root mean square error (RMSE) and correlation of the segmentation result with respect to their corresponding ground truth data are calculated to find the difference between them. As the RMSE value approaches zero, the segmented image more likely equal to the ground truth image. Correlation finds similarity of two correlated datas; therefore if the correlation result is equal to one, the two correlated data are equal.

Based on the RMSE and correlation values of the sample images and the ground truth image in table 7, segmentation in HSI color space gives minimum average RMSE and maximum correlation in segmentation of intensity mask and its saturation image.

Table 8 shows result of RMSE and correlating the segmentation results in RGB color space with their corresponding ground truth images. Segmentation in red channel gives minimum RMSE and maximum correlation.

The segmentation result of quantized RGB gives minimum RMSE and maximum correlation in red channel too. However, the RMSE value decreases and the correlation increases by some value compared to the results in table 7.

However, we should not only quantitatively evaluate the results; we should qualitatively verify them too.

Great segmentation results are highlighted with yellow color in table 7,8 and 9. From the results, it is seen that segmentation in RGB channel gives better results than segmentation in HSI. However, for image sample no.6 segmentation in RGB does not give great result but HSI does. Referring back to appendix 9, image sample no.6 composes of red and blue patches. Therefore thresholding in red channel, only segment red patch whereas blue and green channel detects the blue patch.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

From the experiment, we can see that, human skin has high values of red, therefore making the background as different as possible from the skin color is a good approach that will help in extracting the region of interest (ROI).

Segmenting lesion in RGB channel is only applicable if there's only one lesion in the given part, or if there are more than one lesion, provided that all lesion having the same color.

Segmentation in the hand part is quite challenging due to the nail image that is mistakenly classified as lesion.

There are many factors affecting the accuracy of segmentation; the color of the lesion itself, the surrounding pixels and its size.

In most cases, segmentation in RGB color space gives better result than segmentation in HSI color space.

Quantizing the image before segmentation does have effects on the result of segmentation. The accuracy of segmentation is increased compared to segmentation without quantizing the image first. It also seen that, with the number of color level decreased, the histogram show clear separation therefore it is easier to select the threshold value, T. Quantizing the image first before segmenting also reduces the effect of non-uniform illumination, thus giving better results.

From this research, we can conclude that segmentation of skin lesion based on its color properties is best done in RGB color space with the color being quantized first.

5.2 Recommendation

In this research, analysis is done toward lesion images which are represented by patches of colored papers. To improve the project, research and analysis could be done to real lesion images. We can see the effects and suitability of the module with real lesion images and does some modification on the program to suit the images.

In order to use this module user will be required to have some basic knowledge in image processing since this algorithm is semi-automated. User has to select the suitable threshold value to give good result, even though there is a built in threshold calculation function in the Matlab however when tested on the image the result is not so good. Therefore, combining the built in function with some modification might give good threshold value.

It is great too if the module has the function of evaluating the severity of the lesion. Given that the lesion is in form of burn, despite just giving the total percentage of the lesion per whole body, it could be a lot better if we could classify the degree of the burn based on the depth, the severity and the surface area.

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No	Details	Week															
		1	2	3	4	5	6	7		8	9	10	11	12	13	14	
1	Research on types of skin lesions	■	■							Mid semester break							
2	Research on methods to identify skin abnormality			■	■	■											
3	Research on method in lesion edge detection methods						■	■			■						
4.	Research on calculating lesion area.											■	■				
4	Research on 3D imaging (modeling chart)													■	■		
5	Developing algorithm using Matlab	■	■	■	■	■	■	■				■	■	■	■	■	■

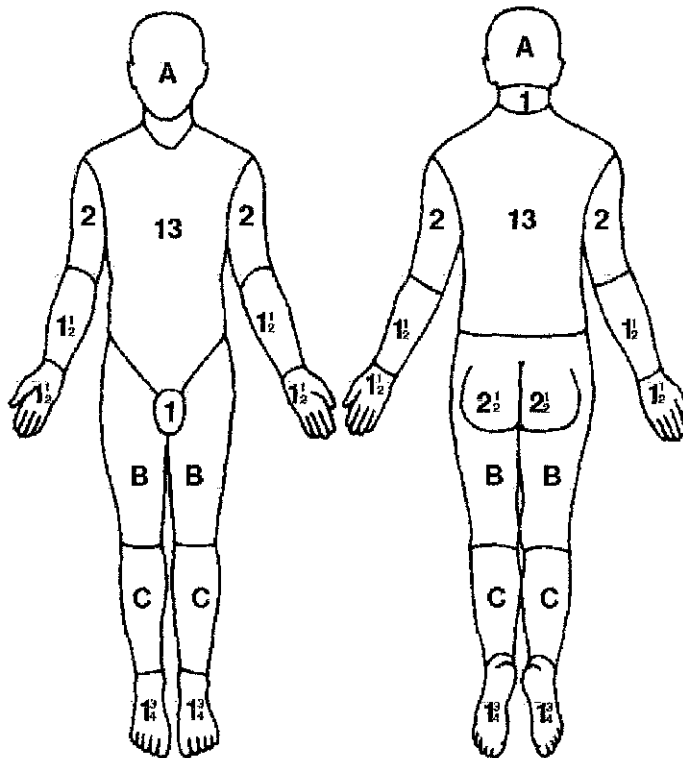
No.	Detail/ Week	1	2	3	4	5	6	7		8	9	10	11	12	13	14	15	
1	Project Work Continue								Mid semester break									
	i. Modelling burn chart using Matlab																	
	ii. Calculating percentage of affected area																	
	iii. Improving the lesion detection algorithm																	
	iv. Integrating and testing module																	
2	Submission of Progress Report																	
3	Pre-EDX																	
4	Draft report																	
5	Submission of technical report																	
6	Submission of final report																	
6	Seminar/viva/oral presentation																	
7	Submission of Dissertation (soft bound)																	

A BURN CHART

NAME _____ WARD _____ NUMBER _____ DATE _____

AGE _____

LUND AND BROWDER CHARTS



Ignore simple erythema.

 Superficial

 Deep

REGION	%
HEAD	
NECK	
ANT. TRUNK	
POST. TRUNK	
RIGHT ARM	
LEFT ARM	
BUTTOCKS	
GENITALIA	
RIGHT LEG	
LEFT LEG	
TOTAL BURN	

RELATIVE PERCENTAGE OF BODY SURFACE AREA AFFECTED BY AGE

AREA	AGE 0	1	5	10	15	ADULT
A = 1/2 OF HEAD	9 1/2	8 1/2	6 1/2	5 1/2	4 1/2	3 1/2
B = 1/2 OF THIGH	2 3/4	3 1/4	4	4 1/2	4 1/2	4 3/4
C = 1/2 OF ONE LOWER LEG	2 1/2	2 1/2	2 3/4	3	3 1/4	3 1/2

Source code for HSI segmentation using Hue mask

```

close all
clear all

image=imread('image');
im=im2double(image);
imtruth=imread('image');
imtruth=im2double(imtruth);
groundtruth=im2bw(imtruth);

r=im(:,:,1);
figure(1)
imhist(r);
level=input('Threshold value: ');
close(fgure(1))
roi=im2bw(r,level);

im2=rgb2hsv(im);
h=im2(:,:,1);
s=im2(:,:,2);
v=im2(:,:,3);

h=immultiply(h,roi);
s=immultiply(s,roi);
v=immultiply(v,roi);

figure(2);
subplot(1,4,1);
imshow(im);

%making hue mask
figure(1)
imhist(h);
level=input('threshold value = ');
close(fgure(1));
mask=im2bw(h,level);

subplot(142)
imshow(mask);
title('hue mask');

%product of hue mask and sat image
product1=immultiply(mask,s);
product1=im2bw(product1);
subplot(143)
imshow(product1);
title('hue mask vs sat');

%product of int hue and int image
product2=immultiply(mask,v);
product2=im2bw(product2);
subplot(144)
imshow(product2);
title('hue mask vs int');

```

```

%correlation
truthdata=reshape(groundtruth, [], 1);
data1=reshape(product1, [], 1);
data2=reshape(product2, [], 1);

%RMSE s
[m, n] = size (groundtruth);
Error = xor(product1,groundtruth);
Error2 = sum(Error);
Total = sum (Error2);
RMSEproduct1 = Total / (m*n)

correlation1 = corr(data1, truthdata)%product 1

%RMSE v
[m, n] = size (groundtruth);
Error = xor(product2,groundtruth);
Error2 = sum(Error);
Total = sum (Error2);
RMSEproduct2 = Total / (m*n)

correlation2 = corr(data2, truthdata)%product 2

```

Source code for HSI segmentation using Saturation mask

```

close all
clear all

image=imread('image');
im=im2double(image);
imtruth=imread('image');
imtruth=im2double(imtruth);
groundtruth=im2bw(imtruth);

%threshold to find ROI
r=im(:,:,1);
figure(1)
imhist(r);
level=input('Threshold value: ');
close(ffigure(1))
roi=im2bw(r,level);

im2=rgb2hsv(im);
h=im2(:,:,1);
s=im2(:,:,2);
v=im2(:,:,3);

h=immultiply(h,roi);
s=immultiply(s,roi);
v=immultiply(v,roi);

figure(2);
subplot(1,4,1);
imshow(im);

%making sat mask
figure(1)
imhist(s);
level=input('threshold value = ');
close(ffigure(1));
mask=im2bw(s,level);

subplot(142)
imshow(mask);
title('sat mask');

%product of sat mask and hue image
product1=immultiply(mask,h);
product1=im2bw(product1);
subplot(143)
imshow(product1);
title('sat mask vs hue');

%product of sat mask and int image
product2=immultiply(mask,v);
product2=im2bw(product2);
subplot(144)
imshow(product2);
title('sat mask vs int');

```

```

%correlation
truthdata=reshape(groundtruth,[],1);
data1=reshape(product1,[],1);
data2=reshape(product2,[],1);

%RMSE s
[m, n] = size (groundtruth);
Error = xor(product1,groundtruth);
Error2 = sum(Error);
Total = sum (Error2);
RMSEproduct1 = Total / (m*n)

correlation1 = corr(data1, truthdata)%product 1

%RMSE v
[m, n] = size (groundtruth);
Error = xor(product2,groundtruth);
Error2 = sum(Error);
Total = sum (Error2);
RMSEproduct2 = Total / (m*n)

correlation2 = corr(data2, truthdata)%product 2

```

Source code for HSI segmentation using Intensity mask

```

close all
clear all

image=imread('image1');
im=im2double('groundtruth');
imtruth=imread('groundtruth');
imtruth=im2double(imtruth);
groundtruth=im2bw(imtruth);

%threshold to find ROI
r=im(:,:,1);
figure(1)
imhist(r);
level=input('Threshold value: ');
close(fgure(1))
roi=im2bw(r,level);

im2=rgb2hsv(im);
h=im2(:,:,1);
s=im2(:,:,2);
v=im2(:,:,3);

h=immultiply(h,roi);
s=immultiply(s,roi);
v=immultiply(v,roi);

figure(2);
subplot(1,4,1);
imshow(im);

%making intensity mask
figure(1)
imhist(v);
level=input('threshold value = ');
close(fgure(1));
mask=im2bw(v,level);

figure(2)
subplot(142)
imshow(mask);
title('int mask');

%product of int mask and hue image

product1=immultiply(mask,h);
product1=im2bw(product1);
subplot(143)
imshow(product1);
title('int mask vs hue');

%product of int mask and sat image

product2=immultiply(mask,s);
product2=im2bw(product2);
subplot(144)

```

```

imshow(product2);
title('sat mask vs int');

%correlation
truthdata=reshape(groundtruth, [], 1);
data1=reshape(product1, [], 1);
data2=reshape(product2, [], 1);

%RMSE s
[m, n] = size (groundtruth);
Error = xor(product1,groundtruth);
Error2 = sum(Error);
Total = sum (Error2);
RMSEproduct1 = Total / (m*n)

correlation1 = corr(data1, truthdata)%product 1

%RMSE v
[m, n] = size (groundtruth);
Error = xor(product2,groundtruth);
Error2 = sum(Error);
Total = sum (Error2);
RMSEproduct2 = Total / (m*n)

correlation2 = corr(data2, truthdata)%product 2

```

Source code for RGB segmentation

```

close all
clear all

image=imread('image');
im=im2double(image);
imtruth=imread('image');
imtruth=im2double(imtruth);
groundtruth=im2bw(imtruth);

%threshold to find ROI
r=im(:,:,1);
figure(1)
imhist(r);
level=input('Threshold value: ');
close (figure(1))
roi=im2bw(r,level);

r=immultiply(roi,im(:,:,1));
g=immultiply(roi,im(:,:,2));
b=immultiply(roi,im(:,:,3));

%threshold in r channel

figure(1);
subplot(141);
imshow(im);
figure(2);
imhist(r);
level=input('threshold value: ');
close (figure(2));
rbw=im2bw(r,level);
figure(1);
subplot(142);
imshow(rbw);
title('thresholded r channel: ');

%thresholded in g channel

figure(2)
imhist(g);
level=input('threshold value : ');
close (figure(2));
gbw=im2bw(g,level);
figure(1);
subplot(143);
imshow(gbw);
title('thresholded g channel');

%thresholded in b channel

figure(2)
imhist(b);
level=input('threshold value : ');
close (figure(2));
bbw=im2bw(b,level);

```

```

figure(1);
subplot(144);
imshow(bbw);
title('thresholded b channel');

%correlation
truthdata=reshape(groundtruth, [],1);
data1=reshape(rbw, [],1);
data2=reshape(gbw, [],1);
data3=reshape(bbw, [],1);

%RMSE r
[m, n] = size (groundtruth);
Error = xor(rbw,groundtruth);
Error2 = sum(Error);
Total = sum (Error2);
RMSEproduct1 = Total / (m*n)
correlation1 = corr(data1, truthdata)%product 1

%RMSE g
[m, n] = size (groundtruth);
Error = xor(gbw,groundtruth);
Error2 = sum(Error);
Total = sum (Error2);
RMSEproduct2 = Total / (m*n)
correlation2 = corr(data2, truthdata)%product 2

%RMSE b
[m, n] = size (groundtruth);
Error = xor(bbw,groundtruth);
Error2 = sum(Error);
Total = sum (Error2);
RMSEproduct3 = Total / (m*n)
correlation3 = corr(data3, truthdata)%product 3

```


Source code for RGB quantized segmentation

```

close all
clear all
im_seg=imread('image');
im_seg=im2double(im_seg);
imtruth=imread('image');
imtruth=im2double(imtruth);
groundtruth=im2bw(imtruth);

%find ROI
r=im_seg(:,:,1);
figure(1)
imhist(r);
level=input('Threshold value: ');
close(ffigure(1))
roi=im2bw(r,level);
a=imcrop(im_seg);
b=imcrop(im_seg);
c=imcrop(im_seg);
d=imcrop(im_seg);
close figure 1
a=mean(a);
b=mean(b);
c=mean(c);
d=mean(d);
a=mean(a);
b=mean(b);
c=mean(c);
d=mean(d);
u=renklab(a,b,c,d,im_seg); %function renklab
seg_im=vectorquantize(u,seg_im); %function vectroquantized
%segmentation
r=immultiply(roi,seg_im(:,:,1));
g=immultiply(roi,seg_im(:,:,2));
b=immultiply(roi,seg_im(:,:,3));
figure(3);
subplot(131),imshow(r);
title('Red channel');
subplot(132),imshow(g);
title('Green channel');
subplot(133),imshow(b);
title('blue channel');
%threshold in r channel
figure(4);
imhist(r);
level=input('threshold value: ');
close(figure(4));
rbw=im2bw(r,level);
figure(5);
subplot(131);
imshow(rbw);
title('thresholded r channel: ');
%thresholded in g channel
figure(4)
imhist(g);
level=input('threshold value : ');
close(figure(4));
gbw=im2bw(g,level);

```

```

figure(5);
subplot(132);
imshow(gbw);
title('thresholded g channel');
%thresholded in b channel
figure(4)
imhist(b);
level=input('threshold value : ');
close.figure(4));
bbw=im2bw(b,level);
figure(5);
subplot(133);
imshow(bbw);
title('thresholded b channel');
%correlation
truthdata=reshape(groundtruth,[],1);
data1=reshape(rbw,[],1);
data2=reshape(gbw,[],1);
data3=reshape(bbw,[],1);
correlation1 = corr(data1, truthdata)
correlation2 = corr(data2, truthdata)
correlation3 = corr(data3, truthdata)
%RMSE r
[m, n] = size (groundtruth);
Error = xor(rbw,groundtruth);
Error2 = sum(Error);
Total1 = sum (Error2);
RMSEproduct1 = Total1 / (m*n)
%RMSE g
[m, n] = size (groundtruth);
Error = xor(gbw,groundtruth);
Error2 = sum(Error);
Total2 = sum (Error2);
RMSEproduct2 = Total2 / (m*n)
%RMSE b
[m, n] = size (groundtruth);
Error = xor(bbw,groundtruth);
Error2 = sum(Error);
Total3 = sum (Error2);
RMSEproduct3 = Total3 / (m*n)

figure(6)
subplot(151)
imshow(im_seg);
subplot(152);
imshow(seg_im);
subplot(153)
imshow(rbw);
subplot(154);
imshow(gbw);
subplot(155);
imshow(bbw);











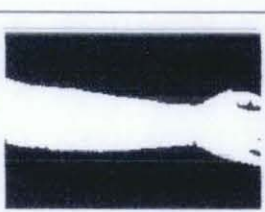




x = RMSEproduct1
p=correlation1



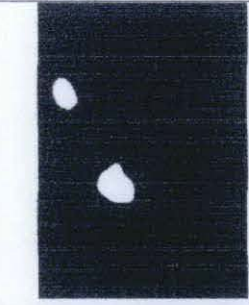

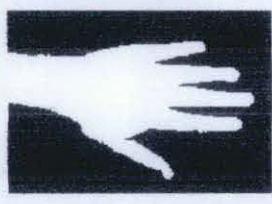

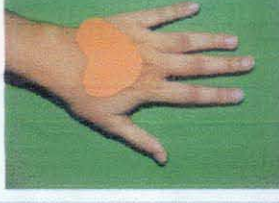



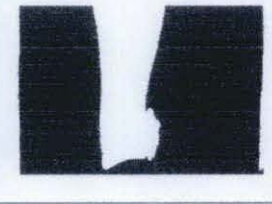


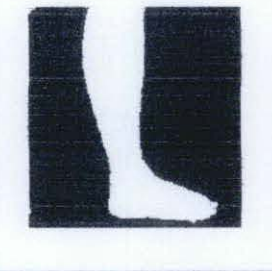
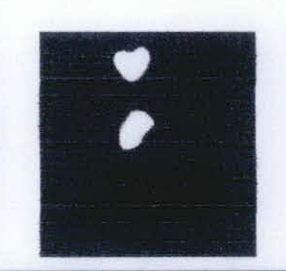

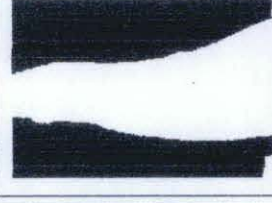

y= RMSEproduct2
q=correlation2

z= RMSEproduct3
r=correlation3

```

Samples of image , region of interest and ground truth image

Sample	original	Roi	Ground truth
1			
2			
3			
4			
5			

6			
7			
8			
9			
10			
11			
12	