Digital Assessment of Facial Acne Vulgaris

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***Abstract*—** Acne affects 85% of adolescents at some time during their lives. Dermatologists use manual methods such as direct visual assessment and ordinary flash photography to assess the acne. However, these manual methods are time consuming and may result in intra-observer and inter-observer variations, even by experienced dermatologists. The objective of this research is to develop a computational imaging method for automated acne grading. The first step in the proposed method is pre-processing which involves lighting compensation. The CIE La*b* color space is used to measure any dissimilarity between skin colors. Acne segmentation has been performed using automated modified K-means clustering algorithm and support vector machines (SVM) classifier. Color and diameter are the main features extracted to classify acne blobs into different acne classes; papule, pustule, nodule or cyst. Finally, the severity level is determined such as mild, moderate, severe and very severe.

Keywords-K-means clustering, SVM Classifier, Feature Extraction, Acne Grading System

I. INTRODUCTION

Acne Vulgaris is the commonest form of acne, afflicting 99% of acne sufferers. Other less common types of acne include Acne Conglobata, Acne Excoriee, Acne Rosacea, Acne Cosmetica, Pomade Acne, Acne Fulminans, Acne KeloidalisNuchae, Acne Chloracne, Acne Mechanica and Acne Medicamentosa [1]. Acne type is differentiated mainly based on lesion type as well as the underlying cause, e.g., Acne Cosmetica is caused by cosmetics use, Mechanica in people who like to lean their face on the hands or pressure areas from helmets, Medicamentosa due to topical medicine applied on the skin, pomade acne due to use of talcum powder. In this paper, the main focus is on Acne Vulgaris only. The lesions in Acne Vulgaris comprise of comedones (whitehead and blackhead), papules, pustules, nodules, cysts and in some cases, scarring [2] as shown in Figure 1.

Figure I: Types of Acne Vulgaris Lesions

Various computational techniques have been proposed for acne analysis such as using fluorescence light photography [3], polarized light photography [4] and multispectral images [5]. The objective of these methods is to aid dermatologists so that they can clearly identify the acne lesion and its characteristics in order to monitor lesion growth. Although these methods can help dermatologist assess the acne clearly, there are limitations. Dermatologists still need to differentiate and count acne manually.

II. PROPOSED METHODOLOGY

Figure 2 shows the major steps of our methodology for the acne diagnosis system. The first step is image acquisition. In this step we acquire close-up photographs of five different regions of face which are forehead, nose, chin, right cheek and left cheek. A high resolution DSLR camera is used for image acquisition. The second step is pre-processing which involves lighting compensation and skin detection. Acne segmentation has been performed using K-means clustering algorithm for the third step. Traditional K-means clustering suffers from two problems; firstly it requires predefining the number of clusters required. Secondly, there is no automated way to select which clusters is acne among the retrieved clusters. In this work, we have developed a clustering method that automatically selects the suitable number of clusters (K-value) and identifies acne clusters in the image.

Next step is post-processing procedure which is done by correcting images from different errors such as removing the small holes and connecting the unconnected components. After that, the feature extraction is performed using color and size properties to classify acne blobs into different acne classes; papule, pustule, nodule or cyst. Once the types of acne has been detected, it will be calculated using modified standard grading system to determine the severity level such as mild, moderate, severe and very severe. This severity level is an indicator that dermatologist used to give the medication for treating the acne lesions.

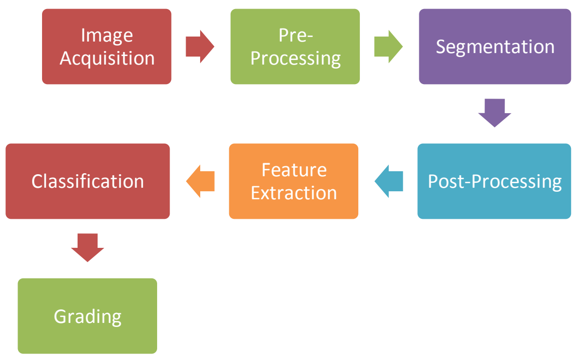

Figure 2: The process of acne assessment using image processing techniques

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A. Image Acquisition

Samples of acne images are collected from 50 patients with four different grades (mild, moderate, severe and very severe). These samples are taken at Department of Dermatology, Hospital Kuala Lumpur (HKL) using Digital Single Lens Reflex (DSLR) camera. Images of right cheek, left cheek, nose, forehead, chin, chest and back are digitally photographed from each patient as shown in Figure 3.

Figure 3: Close up images of forehead, nose, chin, left and right cheek

B. Pre-Processing

(i) Lighting Compensation

After the illumination (Y) is extracted from the RGB image, the Y component is normalized and averaged as shown in Figure 4. The objective of computing the illumination is to determine either the image is balanced exposed, over exposed or under exposed. Consequently, Ymax is the maximum Y value for a normally (balanced) exposed image. While Ymin is the minimum value for normally (balanced) exposed image.

The Yfactor is a correction factor that is computed based on the difference between the average luminance of the current image and Ymax and Ymin. Yfactor is set according the difference; if Yavg is greater than Ymax then Yfactor is set to less than 1 in order to reduce the illumination of the image. If the difference is very large, this fraction will be smaller. The same concept is applied when Yavg is less than Ymin then Yfactor is set greater than 1. Then, the new value of global Y factor is multiplied with Red, Green and Blue channels.

(ii) Skin Detection

After lighting compensation, the image is ready for detecting the skin based on the statistical distribution of its color components. According to Inseong *et al* [6], human skin has a specific color range in the Cb-Cr space. Since Malaysian skin types are type III to V [7], therefore according to [6], skin pixels are in the range of 10 to 35 for Cr components and -20 to 0 for Cb components.

Figure 5(a) shows the image after lighting compensation process. Figure 5(b) shows the binary image with white region referring to skin pixels, while black pixels are for non-skin region. Finally skin detection is achieved using mask shown in Figure 5(c).

C. Acne Vulgaris Segmentation

There are major colors in the human image such as red, pink, yellow, white and black. Therefore, it is easy to see the difference between these colors from one another. The L*a*b* color space (also known as CIELAB or CIE L*a*b*) is used to quantify these visual differences.

The background color is chosen based on high contrast colour to the human skin. Hence, background can be easily differentiated from the image. Red is known as the most dominant color of human skin [8]. Using green color for the background is expected to highlight the pixels belonging to the human skin. Skin pixels will have positive values and pixels belonging to the background will have negative values for the CIE a* band.

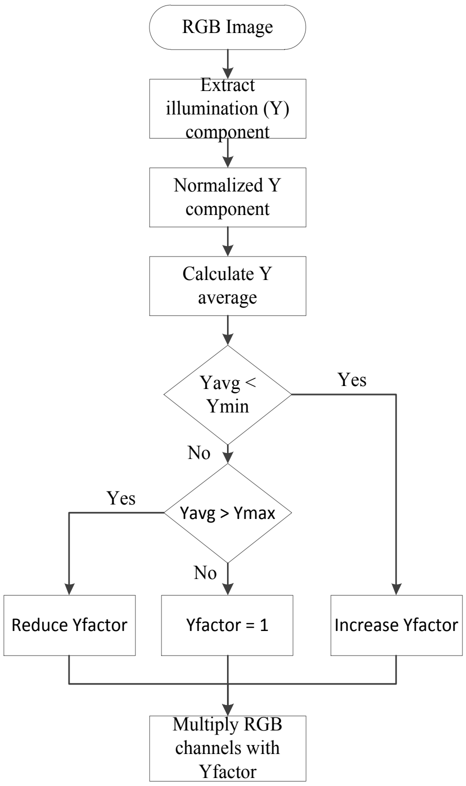

Figure 4: The process of lighting compensation

(a) (b) (c)

Figure 5: Skin Detection

K-means is suitable for biomedical image segmentation since the number of clustering (K-value) is usually known for images of particular region of human anatomy [9]. However, there are two major problems with the existing K-means clustering. First is that K-means requires predefining the number of clusters that we want to segment the image to.

Usually the number of clusters is not fixed and it can vary from image to image. The second problem with K-means clustering is how to choose the cluster that represents the acne.

Due to these problems, this work focuses on producing an automated method for selecting the number of clusters and the optimal clusters index for K-mean cluster of acne images. Figure 6 shows the flow of the proposed automated K-means clustering.

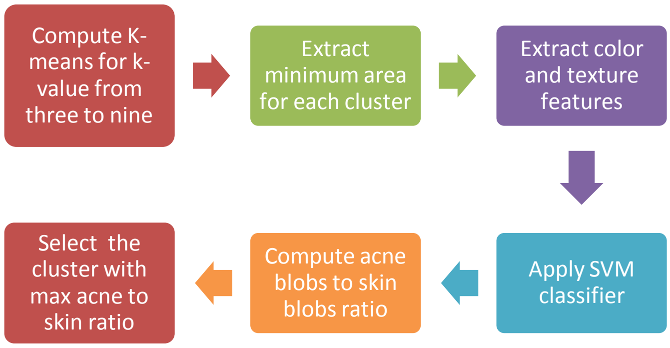

Figure 6: Flow of automated K-means clustering

D. Classifying Acne and non-Acne Pixels

In order to discriminate acne and non-acne, several features were used including mean, variance, energy and entropy. 520 samples of skin and 520 samples of acne were tested using colors and textures properties. Using the four features (Mean, Variance, Entropy, Energy), we build a support vector machine classifier that classify the cluster content into acne/skin.

In our SVM implementation we have chosen 70% of the data for training and 30% for cross validation and testing. Linear SVM kernel was used for the separation between the acne/skin groups. Next step is post-processing which is done by correcting images from errors such as removing the small holes and connecting the unconnected components.

E. Feature Extraction

After segmentation and classification into acne and non-acne regions, discriminative features are extracted from the lesion. Firstly, the reference blob is identified. The reference blob which is the 5mm circle is pasted into patient's face as ruler sticker or indicator. Then, the pixel size of diameter of reference blob is calculated. After that, the pixel size of the blob of each lesion is identified and calculated. If pixel size of diameter blob for lesion is bigger than the pixel size of reference blob, the blob is automatically labeled as nodule and cysts because they are larger than 5mm.

However, when the pixel size of lesion blob is less than pixel size of reference blob, the area of each blob and area of filled blob are calculated. After that, if the size of filled area is bigger than area of that blob, the blob automatically is labeled as pustule. This indicates that there is hole inside the blob corresponding to the characteristics of pustule.

F. Grading

Modified Global Acne Grading System (mGAGS) is used for grading which divides the face into five locations (forehead, nose, chin, right and left cheek). The five locations are graded separately on a 0 to 4 scale depending on the most severe lesion within that location (0 = no lesions, 1 = comedones, 2 = papules, 3 = pustules and 4= nodules). The score for each area is the product of the most severe lesion, multiplied by the area factor. These individual scores are then added to obtain the total score. For total score in between 1 to 13, the patient is classified as mild while for total score in between 14 to 22, patient is classified as moderate. If total score is in between 23 to 28 then grade is severe and if more than 29 then it is very severe as shown as in Table 1.

Table 1: Modified Global Acne Grading System (mGAGS)

Location	Factor (F)	Severity (S)		Local Score (FxS)	Acne Severity	
Forehead	2	0	Nil		Mild	1-13
Right Cheek	2	1	Comedone		Moderate	14-22
Left Check	2	2	Papule		Severe	23-28
Nose	1	3	Pustule		Very severe	>29
Chin	1	4	Nodule			
		Total Score				

III. RESULTS

The images are visualized using Graphical User Interface (GUI) as shown in Figure 7. In order to validate the accuracy of our automated segmentation method, we have tested this method on 50 images of different acne types and skin color types. The results of segmenting these 50 images have been compared with their respective ground truth images and for each image the sensitivity, specificity and accuracy have been computed. The receiver operating characteristic (ROC) analysis is used as an indicator of the performance.

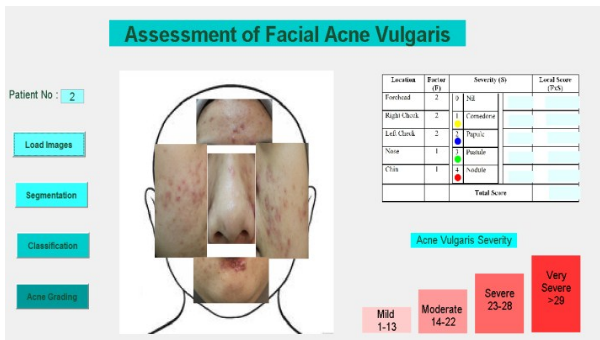

Figure 7: Original Images

Sensitivity measures the proportion of actual positives which are correctly identified and specificity measures the proportion of negatives which are correctly identified. In addition, accuracy gives overall performance of the classifier. Table 2 shows the average sensitivity, specificity and accuracy computed for segmentation process. Post processing step means applying morphological filters to fill holes and remove small isolated blobs.

Table 2: Average sensitivity, sensitivity and accuracy for segmented images

`	Sensitivity	Specificity	Accuracy
Without post-processing	83.6%	98.3%	91%
With post-processing	90%	97.2%	93.6%

Figure 8 shows the receiver operating characteristics (ROC) curve for the 50 images tested. The ROC curve shows the sensitivity plotting against 1-specificity. As the figure shows the minimum sensitivity value is 63% and the maximum is 98%. Also the figure shows that the minimum specificity value is 88% while the maximum value is 99.98%.

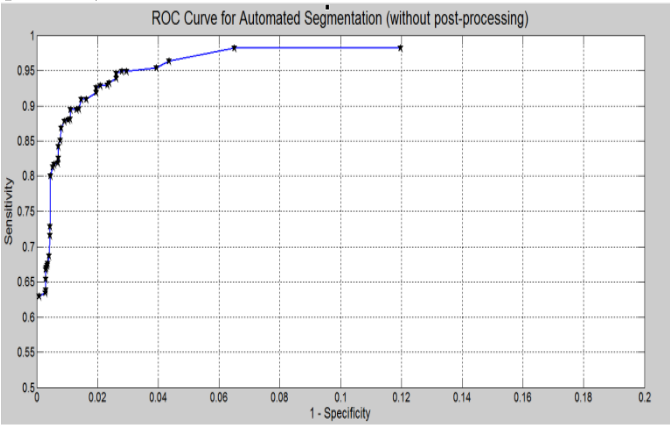

Figure 8: ROC Curve for Automated Segmentation (without post-processing)

The intent of the classification process is to categorize all pixels in a digital image into one of several types of acne lesion. Feature extraction based on color and size. The 5mm blue ruler sticker is used as an indicator to measure the pixel sizes of 5mm in every image. Nodule cysts is more than 5mm and the papule, pustule and comedone are less than 5mm. Therefore, once the system detected the nodule cysts, it automatically gives the severity 4 even though they also have other types of acne. It is because the nodule cysts is the most severe compared to others acne lesions [10].

Figure 9 shows the classification results for forehead, nose, chin, right and left cheek. The red circle indicates nodule with its severity as four, green circle indicates pustule and its severity is three. The blue circle indicates papule with its severity which is two and yellow circle indicates comedone with its severity which is one.

Then, the score for each area is the product of the most severe lesion, multiplied by the area factor. These individual scores are then added to obtain the total score. For total score in between 1 to 13, the patient is classified as mild while for total score in between 14 to 22, the patient is classified as moderate. If total score is in between 23 to 28 then grade is severe and if more than 29 then it is very severe [11].

IV. CONCLUSION

In this paper, we have proposed a method for the objective assessment of acne grading. The proposed method is based on modified K-means clustering and SVM classifier for separating acne regions from non-acne regions. After that, a set of features are extracted for the classification of various types of acne lesions. Based on that classification, acne grade is determined. Hence, the proposed method can reduce the inter- and intra-observer variability. The proposed method has the potential to assess acne objectively and consistently.

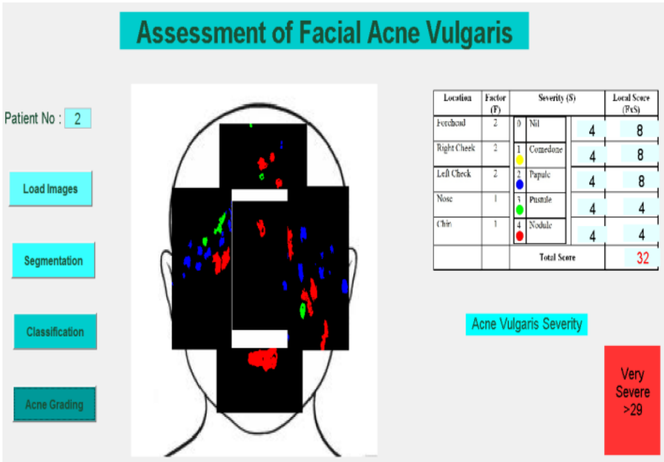

Figure 9: mGAGS classification result

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