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Automatic Detection and Severity Measurement of Eczema Using Image Processing

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***Abstract*— Chronic skin diseases like eczema may lead to severe health and financial consequences for patients if not detected and controlled early. Early measurement of disease severity, combined with a recommendation for skin protection and use of appropriate medication can prevent the disease from worsening. Current diagnosis can be costly and time-consuming. In this paper, an automatic eczema detection and severity measurement model are presented using modern image processing and computer algorithm. The system can successfully detect regions of eczema and classify the identified region as mild or severe based on image color and texture feature. Then the model automatically measures skin parameters used in the most common assessment tool called "Eczema Area and Severity Index (EASI)," by computing eczema affected area score, eczema intensity score, and body region score of eczema allowing both patients and physicians to accurately assess the affected skin.**

I. Introduction

Eczema is one of the most widely known skin diseases, affecting about 10-20% of infants and 3% of adults and children [1]. It is defined by itchiness combined with crusting, scaling and lichenification of skin often in reddish patches. Infection due to eczema can occur on any part of the body like face, elbow, neck, arm, legs, etc. By using modern imaging technology and a computer algorithm, the presence of eczema can be efficiently detected and monitored. Application of image processing for skin disease detection and analysis has been garnering significant attention recently. To date, considerable work has been done by using image processing for detection and measurement of severity of skin cancer (melanoma) [2]. Several researchers have also applied image processing techniques to detect and analyze psoriasis, (a common skin disease involving rapid proliferation of epidermal skin cells) [3]. But not enough work has been accomplished deliberately for eczema only. Suter et al. proposed a texture characteristic (texton) based prototype for detection of hand eczema [4]. However, the developed system is limited to detection of hand eczema only. Also, it works with grayscale images and omit important color features of eczema like redness from the system. The eczema affected region of skin is usually small during the initial stage, but, if not treated in a timely way can lead to graver consequences like impairment. The dermatological cost and cure time are also directly proportional to the severity of eczema. During the preliminary stage of disease, most patients don't understand the nature and severity. They usually rely on their own judgment to measure the severity of the affected region. They therefore often misjudge whether the affected part is a form of skin disease. Consequently, they miss the time point when a simple treatment would be enough to cure their eczema successfully. So, early identification and detection of severity are the keys to efficient management of the disease.

Here, we are proposing an automatic eczema detection, monitoring and severity measurement methodology where patients can just take an image of their affected area and identify and determine the severity of eczema. We have applied several techniques including image segmentation, feature extraction, and statistical classification to identify and differentiate between mild and severe eczema. Once the affected area is identified and delineated, a severity index was generated for each image.

The following parts of this paper are arranged as follows: Section II discusses algorithm architecture and methodology with a detailed explanation of image segmentation procedures, feature extraction, classification techniques, and severity indexing criterion. Section III presents the results of the proposed prototype, and conclusions are presented in section IV.

II. Architecture and Methodology

In this section, the methodology of the proposed system for automatic detection and measurement of eczema severity are discussed. The whole architecture can be subdivided into several important modules comprising segmentation, feature extraction, classification, and severity measurement. These discrete modules are interconnected.

Two segmentation algorithms were used for this prototype; first, a skin detection segmentation algorithm was applied to produce a mask to separate the skin region of the image from the remainder of the image. Once the skin area was separated, we used a second segmentation algorithm to find the eczema region within the skin region.

In Section A, B, C, D, E below, the details of the proposed skin region detection, eczema segmentation, feature extraction, classification technique, and severity index measurement are presented. These discrete modules are interconnected, as shown in Fig. 1.

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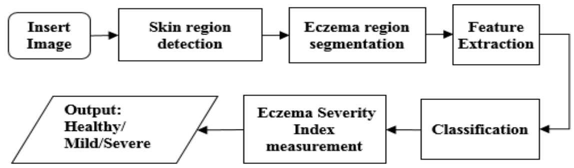

Figure 1. Brief flowchart to show how different sections are interconnected in the proposed eczema detection and severity measurement prototype.

A. *Skin Region Detection:*

Skin detection and segmentation was applied to simplify the image for the next stage of processing by discarding the non-skin pixels. To detect skin pixels, a skin color-based method described in [5] was applied. The eczema images were converted from RGB to the YCbCr color space. According to [6], skin color follows an elliptical distribution, so applying this elliptical distribution to the blue-difference (Cb) and red-difference (Cr) chroma components, the skin region of all the image were detected. In some images, the eczema region color was quite different from the skin color. All holes were filled by using image dilation and erosion techniques to ensure proper skin region detection. Fig.2 shows an example of a skin detection performance. After successfully detecting skin areas for all of our images encompassing various skin colors ranging from darker brown to light skin, we moved to the next step of segmentation.

B. *Segmentation of Eczema Region:*

The aim of this segmentation module is to distinguish the eczema region from the skin area. Conventional methods employed in segmentation are thresholding, compression-based methods, clustering, region growing, watershed transformation, etc. [7]. To correctly identify the eczema areas, we were looking for a segmentation method with high accuracy. Several basic segmentation techniques such as otsu, region growing and watershed segmentation were tried first. Since the eczema-affected region can be both concentrated and/or scattered, none of these methods could give accurate results. Then the color-based segmentation method based on k-means clustering, combined with morphological image processing techniques were chosen to segment more accurately the affected region. Clustering is a technique of partitioning the image into k groups or clusters based on the Euclidean distance of an image pixel from a selected cluster centroid. The algorithm first initializes k numbers for the centroid for each of the k numbers of clusters by computing the histogram of the image. Then each pixel is added to that cluster if the difference in the pixel value and centroid value is a minimum. Clustering can be applied spatially or in color space. The clustering method is very sensitive to objects in the image since objects tend to have similar properties. The RGB image was converted to L*a*b* color-space to describe more precisely the color intensity. Then the eczema region was segmented using the clustering algorithm. The whole clustering method was replicated three times to reduce the local minima. After that, several morphological image processing techniques, like erosion and dilation, were applied in the segmented eczema cluster. All the tiny holes were removed, and a continuous region of the affected area was separated. Fig. 3 shows the result of segmentation and morphological image processing.

Figure 2. The output of our proposed skin detection scheme. Image (a) shows the original uploaded image. Image (b) shows the detected skin region according to the algorithm we have used.

C. *Feature Extraction:*

The aim of the feature extraction method was to extract biologically meaningful features of the eczema region that can aid in identification and evaluation or disease state. There are many feature extraction methods described in the literature like pattern analysis. For mole analysis, the American Academy of Dermatology uses image features, in the 'ABCDE' technique for skin cancer detection. The features these letters stand for are Asymmetry, Border irregularity, Color variation, Diameter of region and Evolving (changing over time). There are many potential features that can be extracted, but it is important to avoid features that are noisy or redundant to reduce the number of features to be evaluated in order to limit complexity and computation time. We selected 16 features of color, border, and texture as follows:

i) Color Features: We used one of the most common color features from literature, which is the mean value of color in several color channels. Color channels used to capture color variations were grayscale, Red, Green, Blue (from RGB color-space), Luminance and Chrominance (from YCbCr color space), and Hue and Value (from HSV color-space). In total, ten features were extracted to describe the color properties of the affected region.

ii) Texture Features: Texture features of the eczema-affected region were quantified using a Gray Level Co-occurrence Matrix (GLCM) of a grayscale image. GLCM-based texture analysis is one of the widely known methods to quantify texture features. GLCM describes the texture of an image by tabulating how often a combination of pixels with a specific brightness level occurs in an image in a particular spatial direction. The horizontal direction of each

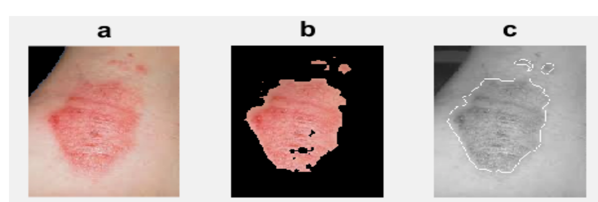

Figure 3. The output of proposed eczema segmentation scheme. Image (a) shows the skin region of original eczema image. Image (b) shows the segmented eczema region and image (c) shows the outlined eczema region after applying morphological image processing techniques.
Image Courtesy: skincarebylouisa [11]

pair of pixels was used to calculate the texture feature. Features extracted from the GLCM matrix to describe the region are contrast, correlation, energy, and homogeneity. According to [6], for a precise estimation of texture features, the GLCM needs to be dense. Therefore, as shown by Hanh-Toan Do *et al.* in [2], we quantized the gray level image pixel values to 64 bits before calculating the GLCM features.

iii) Border Features: The border features were also measured to determine the irregularity of the segmented eczema shapes. The distance from the centroid to the border of each eczema region was measured. The features derived from this measurement were distance variance and the solidity of the region.

Among these 16 features, 14 features were selected to be used for feature selection and two border features were excluded as they created false positive classifications.

D. Classifications:

Total image database included 85 images of healthy skin, and skin with mild eczema and severe eczema collected from several websites [1], [10-14]. The images were classified as healthy skin (31), mild eczema (24), or severe eczema (30) images according to the advice of a practicing dermatologist. The whole classification process was divided into two parts as follows:

i) Healthy and eczema image classification: In this step, all the healthy skin images were separated from eczema images. The training image set (16 healthy image and 29 eczema images) was passed through the skin detection process. After the skin region had been segmented, we extracted all 14 features described in C for each segmented skin region. Then the features were used as a training dataset for a Support Vector Machine (SVM) classifier [8]. When a test image was given as input to the classifier, it classified the healthy skin images in group 1 and eczema images in group 2. Thus, if the entered image was a healthy image, the classifier identified it as a healthy skin image and suggested that no further analysis was required for this image. When an eczema image was identified, the classifier assigned the image to group 2 and passed it to the next step for mild or severe eczema classification.

ii) Mild or severe eczema classification: Here the prototype classified the eczema into mild or severe. The eczema regions of training images were segmented using step B, and then the 14 features were calculated using the feature extraction method described above. Then the feature matrix was given as a training set to the SVM classifier. When the test image was mild eczema, it was classified into group 1. Severe eczema was classified into group 2. The SVM classifier was primarily responding to the color and texture of the eczema region.

E. Severity Index Measurement:

After classifying the eczema image data into the mild or severe group, a severity index was determined for all the test images. The widely accepted eczema severity measurement tool EASI, described in [9], was used as a base for severity measurement. However, we modified the EASI method slightly to make it less complex and more system friendly. The final severity index was found as a combination of area score, eczema intensity score, and body region score.

i) Area Score:

The area score was calculated by taking the percentage of pixel values affected by eczema compared to the total skin region area. The area score for different percentages was calculated as specified in the EASI method described in Hanifin *et al*. [9] and as shown in Table I.

TABLE I. AREA SCORE

Percentage of Eczema Region	Area Score
0: No eczema	0
1-9%	1
10-29%	2
30-49%	3
50-69%	4
70-89%	5
90-100%	6

ii) Eczema Intensity Score:

Eczema intensity depends mainly on the redness, thickness, amount of scratching, and/or lichenification of the affected region. Since it is not possible to infer properties like lichenification and amount of scratching from image only, we modified the intensity score and assign a certain value according to the system output for mild and severe eczema. The classifier classified the images as mild or severe based on color and texture features and assuming the presence of all properties. As per [9], we assigned 1 for each of the four properties for mild eczema and 3 for the properties for severe eczema. Thus, the eczema intensity score for mild eczema was 4 (redness=1, thickness=1, scratching=1, and lichenification=1). For severe eczema, the intensity score was 12 (redness=3, thickness=3, scratching=3, and lichenification=3).

iii) Body Region Score:

The EASI scoring system specified a certain multiplier for different body site. The multiplier or body region score for each of the four body parts was as follows [9]: Head and neck: Multiplier = 0.1, Upper Limbs: Multiplier = 0.2, Trunk: Multiplier = 0.3, and Lower Limb: Multiplier = 0.4. Finally the severity index of the eczema region was calculated using (1).

$$\textit{Severity Index} = \textit{Area Score} \times \textit{Intensity Score} \times \textit{Region Score} \quad (1)$$

III. RESULTS AND ANALYSIS

Skin detection was the first stage of the eczema detection and severity index measurement system. All of our training and test images were passed through the skin detection algorithm. We also tested the algorithm with nearly 20 non-skin images collected from the internet. The algorithm worked with 100% accuracy to detect skin pixels. The whole image database of 85 images was divided into a training set and a test set. 45 images were used as the training set for the classifier (Healthy: 16, Mild: 14, Severe: 15). The remaining

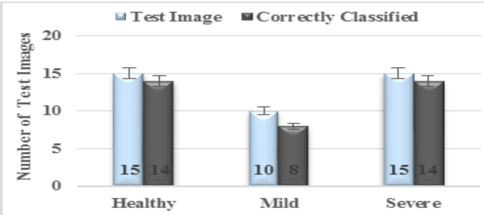

Figure 4. Classification result for healthy skin, mild eczema, and severe eczema test images. 36 out of 40 test images were classified correctly showing 90% overall classification accuracy.

40 images (Healthy: 15, Mild: 10, Severe: 15) were used as a test set to evaluate the efficiency of the system. The training and test images were selected randomly. In the testing phase, a binary SVM classifier successfully classified 93% of healthy images, 80% of mild eczemas, and 93% of severe eczema images. The classifier performance is shown in Fig. 3. The classification accuracy calculated using (2) resulted in a 90% accuracy.

$$Accuracy\ \% = (Ns/Nf) \times 100 \qquad (2)$$

where Ns = number of correctly classified images and
Nf = total number of test images.

The severity index was determined by using the percentage area of the skin with eczema, the eczema intensity, and the affected body region. Based on these properties the range of severity index for mild eczema can be 0.4 to 9.6. For severe eczema, the range can vary from 1.2 to 28.8. For mild and severe eczema images with higher severity index values, a clinic visit recommendation was also added. Fig. 4 shows a sample input with the final output of the proposed eczema monitoring and severity measurement prototype.

IV. Discussion

In this study, we proposed: (i) an efficient segmentation system by merging skin detection, color segmentation, and morphological imaging; (ii) a set of features which can efficiently presents the color and texture variation for healthy skin, mild eczema and severe eczema; and (iii) a severity measurement technique of eczema to calculate the risk score easily. Our assessment confirms the efficacy of the proposed system. Eczema can spread very easily and turn into an infection if proper action is not taken during the first stage. Therefore, early detection and treatment is key.

This proposed system is a first prototype which shows that a reliable, automatic eczema detection and severity measurement system is possible. Though system accuracy was high, it could be more accurate if we used an image database with a large number of calibrated images. However, the severity index measurement is not without limitations. The system did not include lichenification and scratching while calculating eczema intensity score. Also, the area score largely depends upon the image used. Nevertheless, this scoring system can be used more successfully and more meaningfully for relative severity

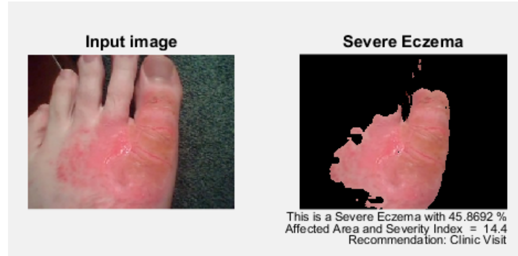

Figure 4. Sample Output Result for a Severe Eczema Image. The left part of the image shows the Input Original Image, where the Right Part shows the Output of the System with Eczema Intensity, (mild or severe), affected area percentage and Severity Index.
Image Curtesy: Eczema-Ltd III [12]

measurement if the eczema images are taken from same distance.

At present, the whole automatic system runs on desktop computers. Our future goal is to develop a smartphone-based application for automatic detection and severity measurement of eczema so that the patients can react quickly.

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