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Wound Image Analysis System for Patients with Diabetes using two Level Segmentation

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Abstract – Foot ulcer for diabetic patients is a major problem. In today's healthcare systems Medical image processing plays an important role. The results of Medical Imaging procedures can be used for surgical planning and simulation, radiotherapy planning and to find the healing status of the disease. Visual assessment of diabetic wound images by physicians suffer with time consumption and also do not produce objective measurements and quantifiable parameters of the healing status. But the above mentioned problems can be solved by doing the medical image analyzes automatically using computer by applying various image segmentation methods. In this paper, Wound Image Analysis System partitions the wound image into meaningful segments using image segmentation technique in order to analyze the wound status. The aim is to accurately segment the wound region and to perform color analysis to find the healing status of wound. The image is captured and then the wound healing status is determined by applying Adaptive Mean Shift Image Segmentation followed by wound boundary determination. Experimental results show that the proposed Wound Image Analysis System minimize the frequency of health centre visit by the diabetic patients and also help to find the healing status of wound by referring the history of recently stored wound images.

Index Terms – Medical Images, Image Segmentation, Mean-shift Algorithm, Wound analysis.

1. INTRODUCTION

Monitoring the wound healing process is a heavy task for clinicians and nurses as it is necessary to assess the wound. All types of wounds need assessment; not only routine wounds but also ulcers, burns, traumatic or surgical wounds. For individuals with type 2 diabetes, foot ulcers constitute a significant health issue affecting 5–6 million individuals in the US [1]. Foot ulcers are painful, susceptible to infection and very slow to heal [2], [3].

Moreover, wound care is expensive, cost effective about 8 billion Euros per year, as the healing process can take several months to heal, and with the aging of the population this will necessarily increase by 25% over the next 10 years. Solution for this task consists of the following steps

1) Patients can capture their wound image comfortably by placing their foot on any angle.

2) Wound image analysis is implemented by using a proposed system which consists of the mean shift algorithm, wound boundary determination method and color segmentation method to detect the wound healing status. Previous methods like level set method [4], SVM have many disadvantages i.e. it is too cost effective. When the skin color is not uniform enough it gives false edges and missing boundaries. So in order to solve these issues a better method is required like adaptive mean-shift segmentation algorithm.

This paper is formulated as follows: Section 1- brings an overview of wound image assessment method to analyze the wound and set forth the mean-shift algorithm to segment the image. Section 2-introduces the foot outline and wound boundary analysis method to detect the foot outline and wound boundary of an image. Section 3-gives the experimental results of the techniques used above.Section-4-gives the conclusion of the entire wound Image analysis system.

2. WOUND EVALUATION METHOD

2.1. *Wound evaluation system overview:*

Wound image assessment system consists of several processes including image capture, wound image storage in database, wound image pre-processing, wound edge determination, wound color segmentation and wound trend detection. The wound image is captured by a Smartphone and then it is stored in the image storage database. Image preprocessing is the first task after Image capturing. Image pre-processing step minimizes the high resolution image in order to increase the speed and to eliminate the unwanted details. The original image pixel dimension is divided by 4 in both horizontal and vertical direction to get 816*612. It gives a good balance between wound resolution and efficiency [5][6].

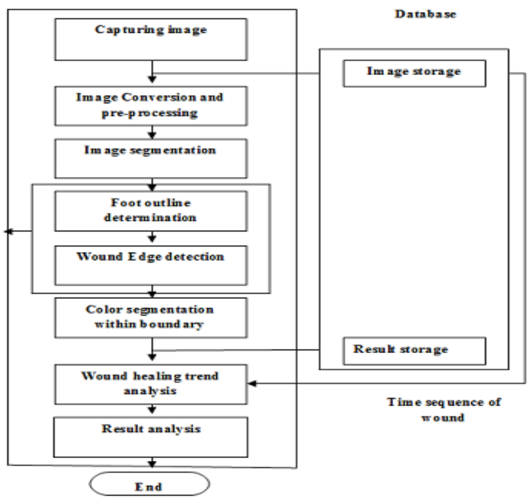

Figure 1 show the flow of wound image analysis system which consists of several tasks.

Image pre-processing: In this step, the original image (pixel dimensions of 3264X2248) is divided by “4” both in vertical and horizontal direction and reduced to pixel dimension 816 X612 which has proven to provide a good between the wound evaluation and preprocessing efficiency. After that Gaussian noise present in the image is removed using Gaussian Blur method.

Foot outline detection: The preprocessed image is converted to grayscale image and then the Otsu Binary thresholding is applied to detect foot outline. According to foot outline detection result and if the foot detection result is regarded as binary image, at that time infected area is detected by “White”and rest part marked as “black“ and this help to locate the wound boundary within the foot region .When the foot boundary not closed at that time problem become more complicated.

Wound boundary Detection: To determine the actual wound boundary, the system locates the black part labeled as ―0‖ within the white foot area (Hollow region detection in the foot area).Then line based scanning algorithm is employed to process each row of image. In this wound boundary determination algorithm, each row in the binary image matrix is regarded as the basic scanning unit. In each row, the part labeled as ―0‖ in the detected foot region is regarded as the wound part. After every row is scanned, the wound boundary is determined accordingly. Because some small outlier regions may also be generated due to the local color variation of the skin, a Small region filtering procedure is needed to identify only the largest black region as the wound.

Color Segmentation: Each pixel in the wound boundary is labeled into certain classes as granulation, slough and necrosis. The classical self-organized clustering method called K-mean with high computational efficiency is used for wound region color segmentation. After the color based segmentation feature vector like wound area size and dimensions of different wound tissues are used to find the healing state of wound. This feature vector, along with both the original and analyzed images, is saved in the result database.

Wound healing trend: The Wound healing trend analysis is performed on a time sequence of images belonging to a given patient to monitor the wound healing status. The current trend is obtained by comparing the wound feature vectors between the current wound record and the one that is just one standard time interval earlier (typically one or two weeks). Alternatively, a longer term healing trend is obtained by comparing the feature vectors between the current wound and the base record which is the earliest record for this patient.

2.2. *Mean-Shift filtering algorithm:*

The mean-shift algorithm belongs to the density estimation based nonparametric clustering methods, in which the feature space can be considered as the empirical probability density function of the represented parameter. This type of algorithms adequately analyzes the image feature space (color space, spatial space or the combination of the two spaces) to cluster and can provide a reliable solution for many vision tasks. In general, the mean-shift algorithm models the feature vectors associated with each pixel (e.g., color and position in the image grid) as samples from an unknown probability density function f(x) and then finds clusters in this distribution. When the mean shift procedure is applied to every point in the feature space, the points of convergence aggregate in groups which can be merged. These are the detected modes, and the associated data points define their basin of attraction. The clusters are delineated by the boundaries of the basins, and thus can have arbitrary shapes. The number of significant clusters present in the feature space is automatically determined by the number of significant modes detected.

The segmentation algorithm can be adjusted to provide sufficient space for skin color smoothness by changing the resolution parameters. This mean-shift algorithm analyzes the image feature space to cluster. This algorithm demonstrate the element vectors associated with every pixel as samples from an unknown probability density function f(x) and then find clusters. The mode is known as the centre for each cluster[6].Specified n data points x_i ,i=1..n in the dimensional space R^d ,the estimator is shown [7]:

$$f_{h,k(x)} = \frac{C_{k,d}}{n,h^d} \sum_{i=1}^{n} k\left(\left\|\frac{x-x_i}{h}\right\|^2\right) \quad (1)$$

where h is a bandwidth parameter satisfying $h > 0$ and $C_{k,d}$ is a normalized constant [7].The profile of the kernel function is k(x) defined for x>=0 and $\|.\|$ it represents the vector normal. By applying mean-shift algorithm starting from a local maximum ,which can be a random input data ,it calculate the density estimate f(x) at y_k and also using the gradient descent method it takes an upward step. The angle of f(x) is,

$$\nabla f(x) = \frac{2C_{k,d}}{nh^{d+2}} \left[\sum_{i=1}^{n} g\left(\left\|\frac{x-x_i}{h}\right\|^2\right)\right].m(x) \quad (2)$$

$$m(x) = \frac{\sum_{i=1}^{n} x_i g\left(\left\|\frac{x-x_i}{h}\right\|^2\right)}{\sum_{i=1}^{n} g\left(\left\|\frac{x-x_i}{h}\right\|^2\right)} - x \quad (3)$$

Where $g(r) = -k'(r)$ and n is the number of neighbours taken. In this procedure the current measure of the mode at iteration k is replaced by its weighted mean is shown[7]:

$$y_{k+1} = y_k + m(y_k) \quad (4)$$

$$K_{hs,hr}(x) = \frac{C}{h_s^2 h_r^p} k\left(\left\|\frac{x^s}{h_s}\right\|^2\right) k\left(\left\|\frac{x^r}{h_r}\right\|^2\right) \quad (5)$$

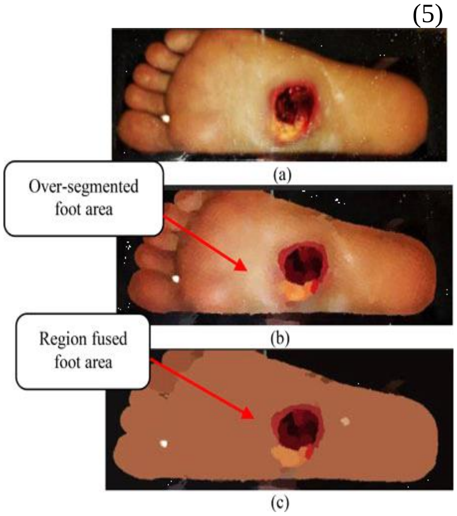

Figure 2:Mean Shift Based Segmentation result.(a) Original image.(b) Mean-shift-filtered image. (c) Region fused image.

This iterative update of the local maxima estimation will be continued until the convergence condition is met. After the filtering procedure above, the image is usually over segmented. Figure 2 shows the result of mean shift segmentation which is used by wound boundary detection process.

2.3. *Wound Edge Detection and Analysis Algorithm:*

The wound edge detection method is based on some three assumptions. First, the image of the foot contains some irrelevant background information. Second, the sole of the foot healthy skin contains nearly uniform color feature. Third, foot ulcer is not located at the edge of the foot outline.

The fast largest connected component determination method is used on the segmented image [8].In color thresholding the color features extracted from the mean-shift filtering algorithm is compared with an emprical skin color feature[9].Then generate a binary image with pixels that are part of the foot labelled “1” (white) and the rest part of the image labelled “0” (black).

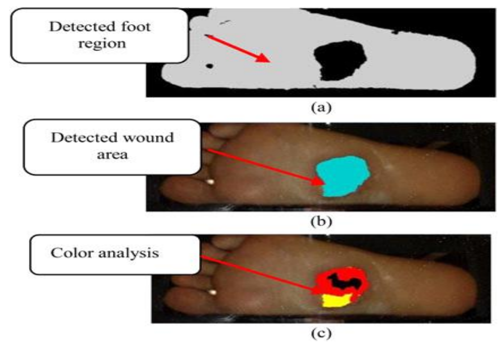

Figure 3. Wound Edge detection and analysis result. (a) Foot boundary detection result. (b) Wound Edge determination result. (c) Color segmentation result within the wound boundary.

The result of the foot area determination is executed on the region fusion image shown in Figure 2 is presented in Figure 3(a).A Small region filtering procedure is used to identify only the largest black region as the wound. A sample of the wound boundary determination result is shown in Figure 3(b).

The RYB (red–yellow–black) wound classification model, classifies wound tissues within a wound as red, yellow, black which represent the different phases on the continues of the wound healing process[10]. Red tissues are viewed as the inflammatory (reaction) phase, yellow tissues imply tissue containing slough that are not ready to heal; and black tissues indicate necrotic tissue state [10], [11].Based on this the wound analysis task classify all the pixels within the wound boundary into the RYB color categories and cluster them.

A fast clustering algorithm called K-mean is also applied to the wound image analysis [12]. This algorithm solves the clustering problem. A sample of the color-based wound analysis result is shown in Figure 3(c).

3. EXPERIMENTAL RESULTS

MATLAB is a high performance language from technical computing. It integrates computation, visualization, programming in an easy to use environment where problems and solutions are expressed in familiar mathematical notation. The experiment is conducted using MATLAB 2013a in the system with the specification of Window 7, RAM 2GB, Hard disk 500GB. The wound images of 10 Diabetic patients are taken with 15 days interval for three month duration and stored in the database. Then the result of processed images is stored in the same database. Wound Trend detection process analyze the time sequence of wound images belong to the same person in order to find the healing status of wound. Figure 4 shows the result of Wound image analysis system.

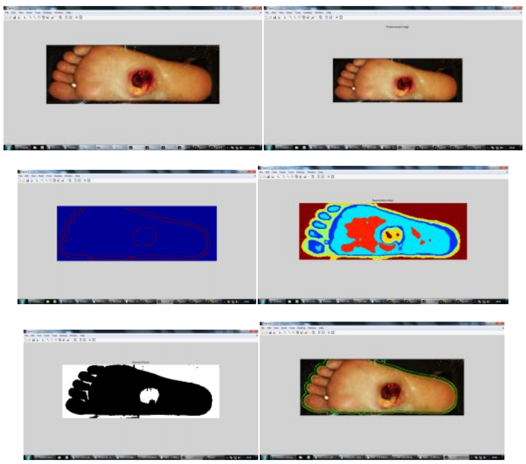

Figure 4.Result of Wound analysis system a) Original image b) Preprocessed image c) Segmentation initialization d) Segmentation map e) Detected wound g) foot and wound boundary

Figure 4(a) is an original image. In Figure 4(b) shows the result of preprocessing step which transforms a source image into a new image which is fundamentally similar to the source image, but differs in certain aspects. Gaussian blur method is used to eliminate the noise. Figure 4(c) is an initialization map to segment the image and gives Figure 4(d) using image segmentation method. It is the process of partitioning a digital image into multiple segments. Figure 4(e) is the detected wound This method is to detect the outline of the foot based on the skin color. Commission Internationale d'e clairage (CIE) lab is used as a standard color checkers for both light and dark skin. Fig g) is the detected foot and wound boundary, wound boundary result is based on the foot outline detection result.A simple connected region detection method is used to find a wound boundary. The file format used here is JPEG.

4. CONCLUSION

A novel wound image evaluation system for patients with type2 diabetes suffering from foot ulcers. The wound images are captured by the smart-phone camera. The adaptive mean-shift based wound edge detection algorithm is applied to the given foot image of the real patients. This method efficiently provides accurate wound boundary detection results on the wound images.

This application is intended for the home-environment for each individual patient. Based on the experimental results it is determined that any noise level encountered during the image captured process can be effectively removed by applying Gaussian blurring filters before wound analysis. The primary application of our wound analysis system is Home-Based self management by patients. The result of wound image analysis obtained at each assessment is stored in the database for doing wound trend analysis in future. Wound image trend analysis system analyzes the time sequence of images in the database to find the healing status of wound. The algorithm running time analysis reveals that the fast implementation on a wound image analysis only takes few seconds. With this implementation, the wound analysis system made assumption about location of wound images in the foot and also the algorithm is too complex. In future work, apply machine learning methods can be applied to train the wound analysis system based on clinical input and hopefully thereby achieve better boundary determination results with less restrictive assumptions.

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