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Leg Ulcer Wound Image Analysis of Sickle cell Anemia- a fuzzy thresholding based Approach

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ABSTRACT: Wounds or Leg Ulcers caused by sickle cell anemia(SCA) is a serious clinical problem in front of medical professionals and biomedical researchers. These types of wounds will not heal quickly and takes more time for healing. If sufficient attention and care is not given to such patients a leg ulcer become chronic and leads to complications. Analysis of such leg ulcer images based on tissue characteristics is necessary to know the success or failure in treatment strategy or to know the progression of wound. In the present work a method is developed for the analysis of leg ulcer images due to sickle cell anemia based on fuzzy thresholding.

KEYWORDS: Wound image analysis, Sickle cell anemia, leg ulcer, Image segmentation, Thresholding, Fuzzy thresholding.

I. INTRODUCTION

Leg ulcers are commonly found in sickle cell anemiapatients which cause severe pain and frequent hospitalization. If not treated carefully, they develop into chronic wounds and make more complications. In order to avoid such situations, computer based wound image analysis techniques using image processing are developed, for the diagnosis of the diseases and treatment planning. Such systems are not only very much useful for physicians in their diagnosis but also help the patients for faster healing of ulcer wounds. Fuzzy image processing can provide sufficient and necessary help for diagnostic decision making, thereby reducing the time for wound healing. Many characteristics of the wound such as area, tissue, temperature and smell can be observed in order to do the diagnosis of the wound. Three kinds of tissues are monitored (a) Granulation tissue, which has a reddish hue, shows the growing of new tissue ;(b) slough with a yellowish colour is a result of infection; (c) necrotic tissue with a dark colour, represents the area of dead tissue.

Among the computer based image analysis techniques image processing techniques are relatively simple and faster. The tremendous amount of information contained in the images can be brought out clearly if suitable algorithms are applied. In medical image analysis, image segmentation provides a vital role in identifying an object. Image segmentation is a method of analyzing an image. Image segmentation sub divides an image into its constituent parts and hence simplifies the analysis process. The classical image segmentation process includes region growing, thresholding, splitting and merging etc. Application of fuzzy set theory in the field of image processing is one of the latest developments in image analysis.

Fuzzy set theory is not new now and is already applied in several areas of medicine, biology, biomedical engineering etc., even after its introduction by Zadeh[1]. Zadeh has revealed the truth that, disease diagnosis would be the most likely application domain of his theory. Leg ulcers are common among people with certain diseases such as sickle cell anemia and diabetes etc. Wound image analysis is very much essential for physicians to know healing rate of several type of ulcers. Fuzzy image processing technique is relatively simple and they give valuable information about wound healing process in different type of leg ulcer tissues.

The remaining part of the paper is organized as follows. Section II describes classical thresholding technique in non - fuzzy platform. In section III fuzzy thresholding strategies are explained. Section IV the proposed method is explained. In section V result and discussion are given. End section VI presents final conclusions.

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II. THRESHOLDING

Among the classical segmentation techniques, thresholding is one of the most simple, easy to implement and very effective image analysis strategy. Researchers have applied thresholding techniques in various fields such as document processing, scene analysis, satellite imaging, material inspection, quality control etc. Medical image processing is another important area that has extensively used image thresholding to help the experts for the interpretation of digital images. Segmentation based on gray level histogram thresholding divide the image containing two regions of interest namely the object and background. Applying this threshold to the images, pixels whose gray level is under this value are assigned to a region and the reminder to the other. When the histogram doesn't exhibit a clear separation, ordinary thresholding fail or perform poor. Fuzzy set theory provides an excellent tool to deal with multi model histograms. Due to the introduction of fuzzy set theory in image processing several image analysis techniques were introduced by computer professionals and biomedical engineers. As a result of this, scientists have developed fuzzy thresholding based algorithms for image analysis [2-8].

For the purpose of image analysis, several segmentation algorithms are now available. Among the classical segmentation techniques, one of the most simple and effective method is thresholding. Gray level thresholding is the process of partitioning pixels in a digital image into two mutually exclusive and exhaustive regions. Thresholding is a most commonly used method of segmentation when objects and background are distinguishable using grey values. Because of the uncertainties associated with the real life situations, identification of such a unique threshold is quite difficult. This has persuaded the researchers for the development of a number of algorithms based on objective functions whose maxima or minima correspond to the threshold T. When the regions are separable by grey values alone, thresholding can be defined as the process of identification of an optimal discriminant grey value and there after partitioning the scene to minimize the error in pixel classification. Therefore the problem of thresholding should be attempted with the robust pattern classification tools.

Thresholding algorithms can be classified into two major categories mainly boundary based algorithms and region based algorithms. In boundary based algorithms the boundary based pixels of the objects are located to separate it from the scene. In region based algorithms all similar pixels belong to the objects that are separated from the rest of the image. Among the classical thresholding techniques, the one proposed by Otsu [9] stand first in the field. Another thresholding technique proposed by Kapuret.al [10] provides considerable interest in thresholding based segmentation. Type II fuzzy is used for thresholding in association with human visual non-linearity characteristics by Yang Xiao et.al [12]. Thresholding techniques have been used for image analysis purpose as back as 1980's. Researcher like N Otsu [9], Kapur [10], T.Pun [11] etc made their own algorithms for thresholding. These types of ordinary thresholding techniques provide poor performance where non uniform illuminations corrupt object characteristics and inherent image vagueness is present. Fuzzy based image thresholding methods are introduced to overcome these problems.

III. FUZZY THRESHOLDING

Fuzzy set theory has been implemented in image segmentation applications to describe the vague concepts in the modern mathematical framework. The crisp set theoretic concepts can be considered as a special case of fuzzy sets when the membership function reduces to a bi-valent one. The application of fuzzy set theoretic concepts to pattern recognition problems resulted in a number of elegant strategies to incorporate the ambiguity in measurement and classification. The concept of fuzzy partitioning can be extended for digital image thresholding by visualizing the object and background regions as fuzzy sets. A fuzzy thresholded description of an image can be characterized by two membership functions in such a way that they reflect the nature of the object and background grey distribution even after thresholding. Pal has extended the definition of classical thresholding to fuzzy setting by defining a membership function. The image can be viewed as a single fuzzy set where the membership distribution reflects the compatibility of pixels to the region to which it belong. Pal's method reflects the ambiguity in the transition region between object and background classes.

Fuzzy thresholding based image analysis techniques are now available in the literature [1-6]. C .V Jawahar's investigation on fuzzy thresholding remains as a shining star in the world of segmentation research [4]. One of the main approaches in this direction is fuzzy clustering. This has led to the development of two important algorithms namely fuzzy C-mean clustering algorithm and fuzzy K-mean clustering algorithm [13]. Detailed study on fuzzy thresholding algorithm has been performed on database by S. R. Kannanet.al [14] and M SeetharamaPrasedet.al [15]. M

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SeetharamaPrased et.al have conducted detailed studies on various non-fuzzy and fuzzy thresholding algorithms and proposed a new algorithm for thresholding based on fuzzy set theory.

A method for the automatic histogram thresholding using fuzzy measures has been proposed by K. Srinivaset.al [16]. Type –II fuzzy is used for thresholding by Yang Xiao et.al [17]. In this work an improvement of multilevel thresholding technique, Yang Xiao used type –II fuzzy sets. U Sesadri, B. Sivasankar and C. Nagaraju found optimal threshold values by three thresholding techniques of bi-level multi-level and fuzzy entropy [18]. Mohammed A.N and AL-Azawi use image thresholding using histogram fuzzy approximation [19]. Sweta R. Parkhedkar and Yogita K Dubey [20]developed a method for brain tumour detection of MR images.

IV. PROPOSED ALGORITHM

Wound images of leg ulcers are collected from the hospitals where sickle cell anemia (SCA) patients are undergoing treatment. Photographs of wounds are taken while the physicians are cleaning and applying medicines. First of all colour images are grey scaled. A suitable filter (Median filter in this work) is then applied and the noise present in the images is removed. Thresholding is performed on the filtered images and the output 1 is taken, using the grey level thresholding. Fuzzy thresholding is performed on the filtered images and the output 2 is taken. Colour thresholding is done on the input images and the corresponding output 3 is taken. This is an unavoidable operation because we have to know the different types of tissues in the wound image. All the outputs are then given to the radiologists and physicians for interpretation.

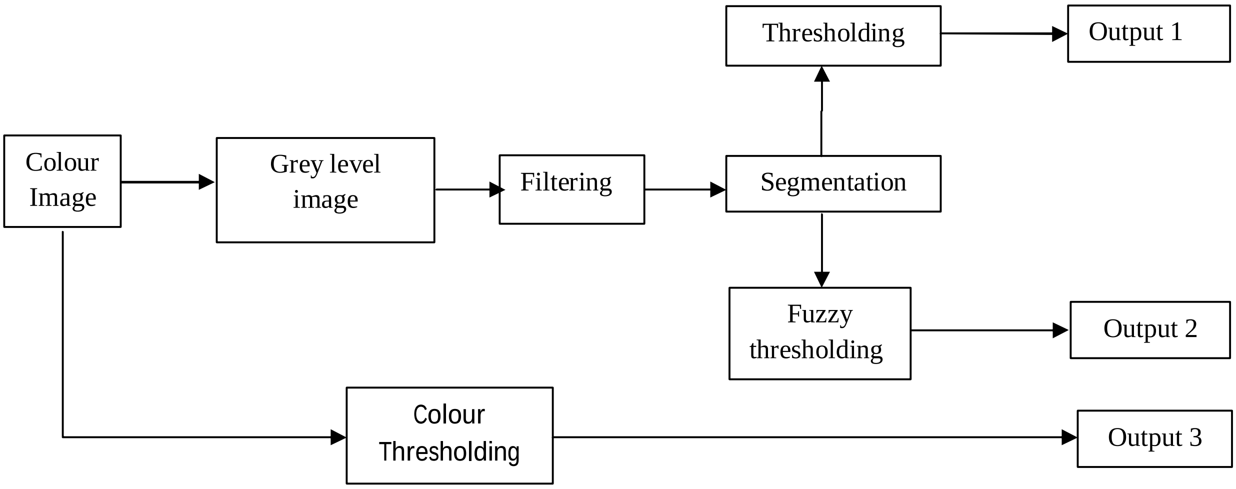

Fig.1.Block schematic of leg ulcer image analysis system

For each region of interest, RGB histograms are plotted and used as features for classification. We define the vectors

L= $[l_r \quad l_g \quad l_b]$.. (1)

Where $l_r, \ l_g, \ l_b$ are the vectors of the RGB.

$$l_i = \begin{bmatrix} l_0 \\ l_1 \\ . \\ . \\ l_n \end{bmatrix}, \text{ i= r, g, b, N} \qquad \text{.................................} (2)$$

STAGE 1:

For each region of interest define a matrix S representing class of tissue types

S= $[S_r, \ S_g, \ S_b, class]$ .... (3)

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Where $S_r, \; S_g, \; S_b$ are the features of RGB histograms.

$$S_i = \begin{bmatrix} S_0 \\ S_1 \\ \cdot \\ \cdot \\ S_n \end{bmatrix}, \text{ i= r, g, n,N =255} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(4)$$

STAGE 2:

Knowledge is prepared using pre classified region of interests. for region of interest of known types we define a feature 'P' representing the class of tissue types, we define a feature 'P' representing the class of tissue type

$$P = \{[P_r, \; P_g, \; P_b\;], C\} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(5)}$$

where C is the class of tissue (unknown tissue) $P_r, \; P_g, \; P_b$ gives the feature vectors of RGB histograms, and C represents the unknown tissue class.

Distance (S, P) $\sum_{i=r,g,b} dist\,(S_i, P_i\;)$ ……………………………………………….(6)
The majority class represented by the k most similar cases ($S_1, \; S_2, \; S_3$ ……..S_k) was used to predict the tissue (ROI) classification.

V. RESULT AND DISCUSSIONS

In the present work, fuzzy thresholding based segmentation has been performed on sickle cell disease affected wound images of leg ulcer. The ultimate aim of this work is to find the wound area and perimeter. Physicians involved in the treatments and patients who are undergoing treatments are always interested to see that how far the wound is healing. Hence it is necessary to conform and quantify the wound area with mathematical support.

Another approach in the present work is that grey level based thresholding and colour thresholding have been performed for visual identification. The healing wound has different types of tissues such as necrotic tissues, granular tissues; slough etc. through colour image processing of above tissues can be distinguished clearly.

The results are verified with the help of experienced medical experts manually to check whether the wound is healing or not. An experiment is conducted to find out the reduction in area of the wound of leg ulcer. The wound area is measured during the treatment on a regular basis for one month each time and when the patient came to the hospital for his/her treatment.

There are three outputs for the proposed system.

1. Colour image is first converted into grey level image. It is then filtered with a median filter. Fuzzy thresholding have been performed after this and the outputs are taken.
2. Thresholding have been performed on grey level images to segment the wound area specifically and clearly.
3. Thresholding is performed on colour image and the output is taken for visual inspection and interpretation.

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Table 1. Wound area measurement of different patients during their visit

Patients	Area of wound in mm^2			
	First visit	Second visit	Third visit	Fourth visit
1	754.01	750.00	670.64	510.26
2	786.72	780.32	792.23	687.32
3	720.16	648.18	630.55	629.84
4	888.71	880.20	800.41	694.32
5	422.25	402.60	390.76	285.41
6	710.88	700.32	630.20	510.52
7	781.69	710.55	610.16	553.73
8	760.36	699.41	597.14	460.86
9	758.18	799.33	719.82	687.69
10	802.68	718.36	642.73	593.24

It is possible to observe so many things from the above table 1. The ultimate aim was to see the reduction in area of wound as the time progress. Most of the patients were shown interest in the beginning for observing the wound and allowed for taking photographs. However in the later stages they are least interested in showing their wounds. Some physicians could not have control over the patients in some cases and they did not turn up in the time of appointment.

After the first two visits some of the patients did not show interest even for consulting with the physicians, under the impression that wound healing is natural and physician also has got no role on it. In the later stages they allowed us to see the wounds only during dressing and cleaning of wound. Even after meeting them in their residence along with the physicians some patients are not bothered to show the wounds. This has led to so many difficulties in getting the readings.

At the beginning we have started with (30 persons) but we could get the reading of only 10 people at the end. Several times planning was forced to change in order to follow-up the patients. Perimeter of the wounds measured in all cases also found to be reduced considerable as the time progressed. The results which we got are found to be very much encouraging but we have wasted quite long time to get the readings due to the noncooperation of patients. We have planned to do the analysis in two different ways. One is a global approach. The area is measured from the original image of the wound. In the second case the wound is segmented and subsequently it is measured. The local areas of few wounds are segmented and are shown separately in table 2.

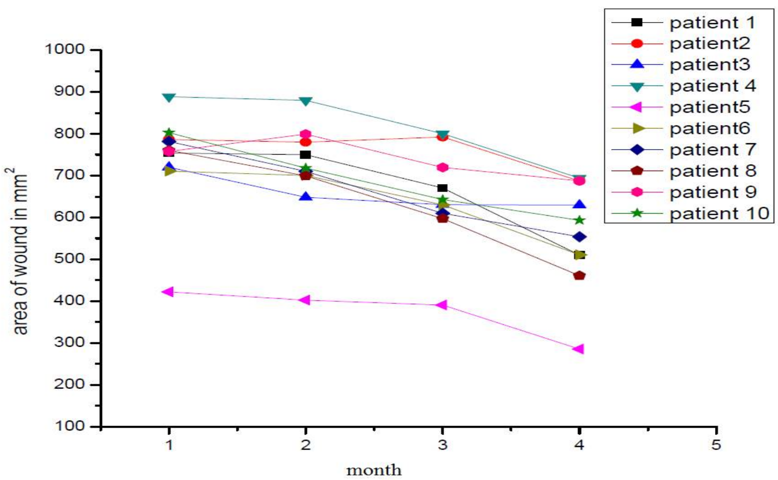

Fig. 2 Plot of the wound healing processing verses time

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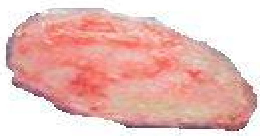
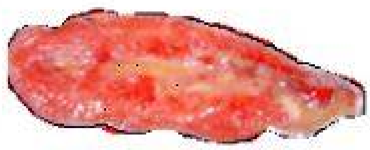
The above figure is the plot of area of wound verses monthly observation of the patients having leg ulcer from table 1. The plot makes it easier for the physicians to understand the wound healing process. The physician will have the access to the initial area and final area of the wound of the same patient. By comparing the initial and final values it is possible to make sure that the wound is exactly healing.

Table 2 Wound area and perimeter measurement after segmentation

Sl no	Area in pixels	Perimeter in pixels	Figure no	Figure
1	41867	888	3(a)	
2	36530	786	4(a)	
3	22868	754	5(a)	

In table 2 the area and perimeter of the wound is measured. The wound area are segmented separately and shown in figures in respective columns. The area of wound at different interval of time is given in table 1 and table 2 shows the segmented wound of different patients at the same month. The area and perimeter are measured in order to record the measurement of wound at different visit of patient. During their visit the photograph of the wound is taken. Theses photographs (images) are taken for processing with different techniques available with image processing toolbox.

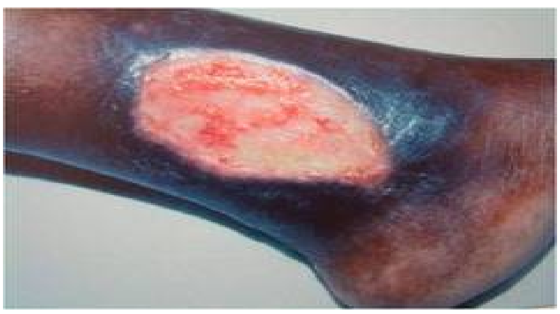


Fig. 3(a) Original Image

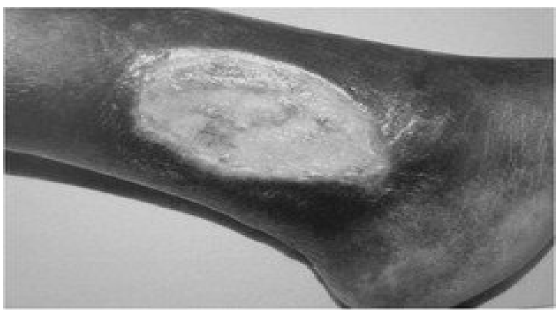


Fig. 3(b) Grey Scaled Image

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Fig. 3(c) Thresholded Images

Fig. 3(d) Colour Thresholded Image

Figure 3(a) is the original image of patient-1 used for the analysis. From the image itself we can understand that the wound is so serious and the patient came for doctor’s consultation when the wound became very large. This is very chronic condition of leg ulcer. This image is processed by converting it to grayscale with 32 bit image and shown in figure 3(b). Thresholding is performed on the above image and shown in fig 3(c). Colour thresholding have been performed. For the sake of simplicity only one colour (red) is being shown in fig 3(d).

Fig. 4(a) Original Image

Fig. 4(b) Grey Scaled Image

Fig. 4(c) Thresholded Images

Fig 4(d) Colour Thresholded Image

Fig 4(a) is the original image of sickle cell anemia infected wound image of patient 5 from table 1. This has been converted to 32bit grayscale image and shown in fig 4(b). The wound image itself mentions that the wound is very small and may need less medical care. The wound analysis through image processing especially colour thresholding will mention depth of wound care required. Thresholding has been done for identifying the position of the wound in leg. Colour thresholding also has been performed to identify the characteristics of the tissues as shown in fig 4(d). The above procedure has been performed in image 5(a). This is the image of a patient 10 in table 1.

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Fig. 5(a) Original Image

Fig. 5(b) Grey Scaled Image

Fig. 5(c) Thresholded Images

Fig. 5(d) Colour Thresholded Image

<u>Leg Ulcer Fuzzy Thresholding:</u>

Fig. 6 (a)

Fig. 6(b)

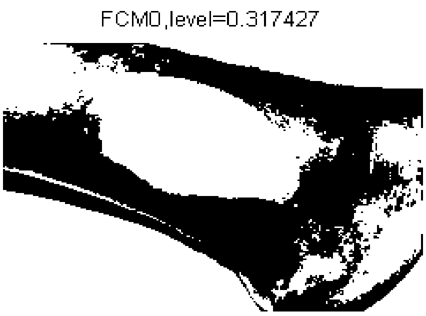

Fig. 6(c)

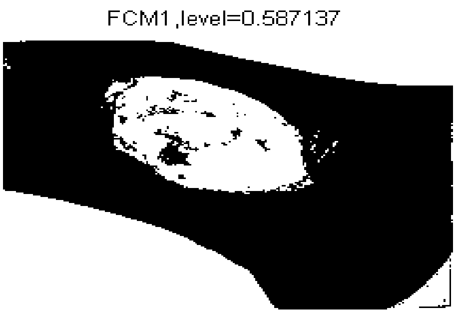

Fig. 6(d)

Fig 6(a) is the original image of the patient-1. Now we are using fuzzy thresholding method to segment the wound with different level of Fuzzy C-means (FCM). These different levels are used to get the correct segmentation of wound. The segmentation is done to measure the area and perimeter of the wound and hence to check whether the wound area is reducing or not. Otsu thresholding and FCM at different levels are processed in order to differentiate the wound during

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different stages of healing. The images that are taken at different intervals of time are processed for measuring area of the wound. This is recorded and kept as database to check whether the wound is healing. This can help the doctors to realize the depth of leg ulcer affected due to sickle cell anemia. Hence the physicians can follow correct treatment options. The same procedure is repeated with the fig 7(a) and 8(a) and those are the images of patients 5 and 10 in table 1.

Fig.7 (a)

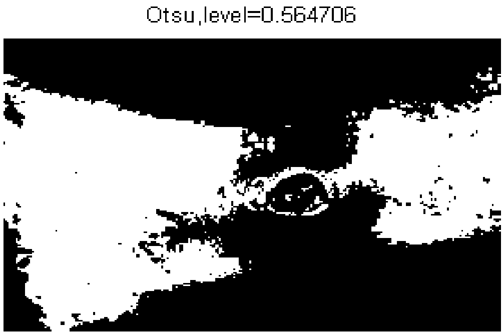

Fig. 7(b)

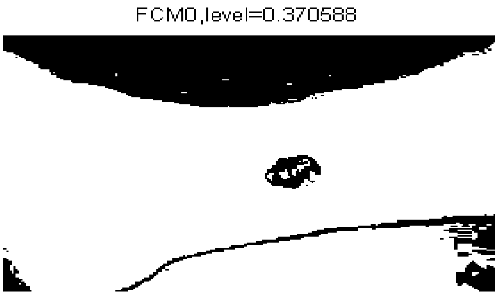

Fig.7(c)

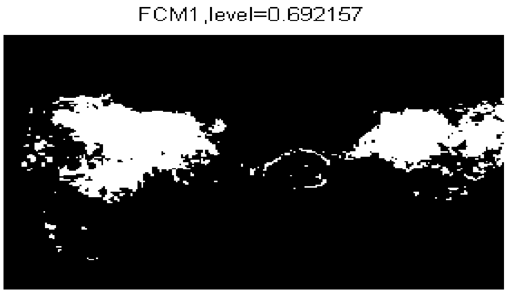

Fig. 7(d)

Fig.8(a) Fig.8(b)

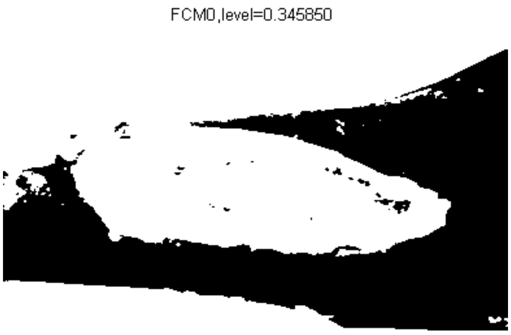

Fig.8(c)

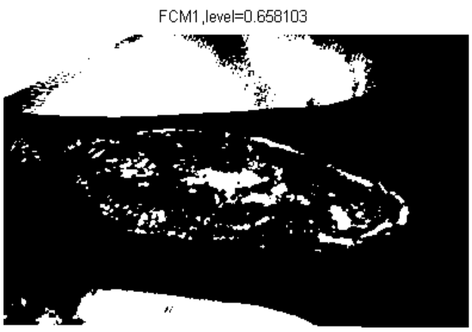

Fig. 8(d)

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VI. CONCLUSION

Wound image analysis is important in some diseases such as sickle cell anemia and diabetes. These wounds provide severe pain episode to patients and should be treated properly and carefully. If not they become chronic and leads to patients death. The physicians involved in the treatment are also anxious to see that their treatment methodology is effective or not. In the present paper various image thresholding strategies are investigated which are useful for the analysis of SCA affected wound images. Both crisp as well as fuzzy based thresholding techniques have been studied. In the present paper grayscale images and colour images are used for the purpose of analysis. An algorithm is proposed which is turned specifically for wound image analysis of leg ulcers of sickle cell anemia.

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