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Computation of Wound Healing Score for Patients with Diabetic Foot Ulcer

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Abstract: Diabetic Foot Ulcer (DFU) is a serious health issue for a patient with diabetes. The death risk is greater for a patient suffering from Diabetic Foot ulcer when compared with a patient without the history of Diabetic Foot ulcer. Normally the healing status of the wound is determined based on the visual examination done by the clinicians. The conclusions made about the wound and its healing status by this procedure is not accurate. A simple methodology for the assessment of the wound and its healing status is proposed. Here the foot images of the patients are taken on regular basis and these images are analyzed using various image processing tools. The foot image is filtered, preprocessed and then the wound and foot regions are determined. After this the color tracing of the wound is performed. Finally, the healing score is determined by comparing the two foot images taken on regular time intervals.

Keywords: Diabetic Foot Ulcer, Wound Tracing, Color Tracing, Healing Score.

I. INTRODUCTION

One of the dangerous and serious complications of diabetes is the Diabetic Foot ulcer. The Diabetic Foot ulcers are very painful in nature and it makes the patient's life physically more difficult. Moreover, the foot ulcers are susceptible to infections and the wound healing process is very slow. The high level of glucose in the blood results in the nerve injury. This nerve injury is indicated by the lack of sensation and hardening of the foot. Consequently, diabetic patient could not sense a wound or inflammation on the foot.

The diabetes can also affect the blood vessels. When the blood vessels are tapering then very less amount of oxygen and blood reaches the foot and as a result of this the wound healing is delayed. Due to the lack of proper blood supply the diabetic patients may also get affected by gangrene. The insufficient treatment and care may lead to amputation of the leg.

There exist some major problems related with the treatment of Diabetic Foot Ulcers. Firstly, the patient suffering from Diabetic Foot Ulcers must go to the clinic on a regular basis. This type of regular checkup is not only inconvenient to the patient and the clinicians, but also time consuming too. Secondly, the wound assessment procedures conducted by the clinicians are mainly based on the visual examination. The physical dimension and the color of the tissues are considered in order to describe the wound type and the current status of the wound. The visual examinations conducted on a regular timely basis is a very difficult task to track the healing status of the wound.

The wound boundary computations are usually carried out with a particular implementation of the level set algorithm. The major drawback of level set algorithm is that the iteration of the global level set functions is computationally intensive to implement. Moreover, the level set evolution purely depends on the initial curve which has to be pre-delineated either manually or by the usage of a well-designed algorithm. Eventually the false edges may interfere with the evolution when the skin color is not uniform enough which occurs frequently in almost all biomedical images. Hence a better methodology is required to solve this problem. So in order to eradicate these problems the level set algorithm is replaced by using efficient image processing tools.

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II. PROPOSED METHODOLOGY

The determination of the wound and foot regions from the foot images and the computation of the healing score requires various image processing techniques. The various techniques used here are described in this section. The figure 2(a) shows the proposed block diagram for the wound assessment.

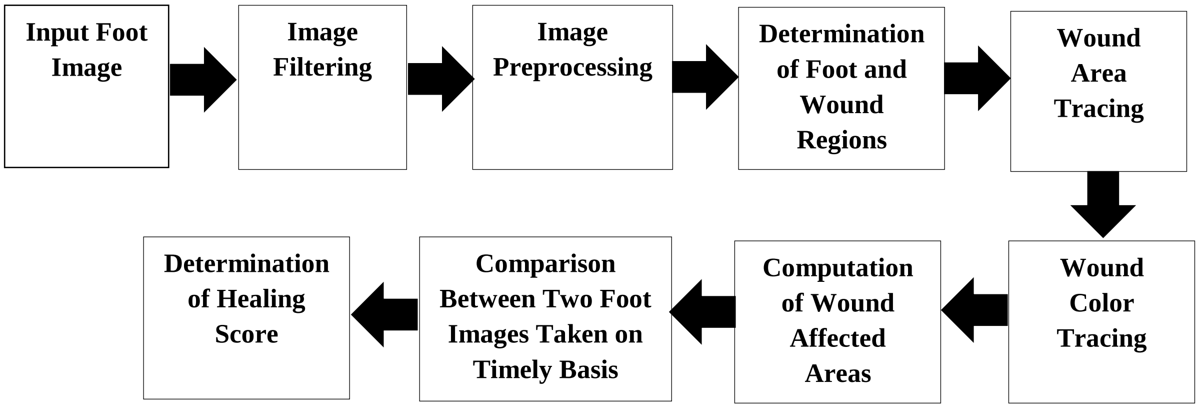

Figure 2(a) Proposed Block Diagram for Wound Assessment

1) Image Filtering: The input image is the foot image of the patient suffering from the Diabetic Foot ulcer. The foot image can be Captured with the help of a high resolution digital camera or a smart phone. During the image capturing there are possibilities for the occurrence of the noises in the image. These image noises are basically the random variations of the brightness or color information in the image. The image noises arise as an undesirable byproduct of image capture that adds spurious and extraneous information. The presence of the gaussian noise in the image is removed by the usage of a gaussian filter. In noise filtering process each pixel intensity vale is replaced with a new value taken over a neighborhood of fixed size. Gaussian filtering is a very effective method for the removal of gaussian noise. In gaussian filtering the weights are calculated according to the gaussian function and the gaussian width (σ) is user defined. The weights give high significance to the pixels near the edge and this consequently reduces the chances for blurring of edges. The degree of smoothing is controlled by the gaussian width (σ). Moreover, the gaussian filtering is computationally efficient and rotationally symmetric in nature.

2) Image Preprocessing: Image preprocessing consist of some operations which are performed at the lowest level of abstraction. The main objective of the image preprocessing is the improvement of the image data which involves the suppression of the undesirable distortions from the image and then to enhance some of the essential features for further processing of the image. The morphological operations include a wide set of image processing operations that processes the images based on shapes. In structuring element is applied to an input image and creates an output image of the same size. Here the value of each pixel in the output image is based on comparing the corresponding pixel n the input image with its neighbors. The two basic types of morphological operations are dilation and erosion. Morphological dilation operation adds pixels to the boundaries of the objects in an image whereas the morphological erosion operation removes pixels on the object boundaries. the shape and size of the structuring element determines the number of pixels to be added or removed from the objects in an image. In both these morphological operations the state of the pixels in the output image is computed based on a rule which is applied to the corresponding pixels and its neighbors in the input image. The basic criterion for the selection of the morphological operation whether erosion or dilation depends on the rule applied to process the pixels. The rule followed for morphological erosion is that the value of the output pixel in the input pixel's neighborhood. The rule followed for morphological dilation is that the value of the output pixel is the maximum value of all the pixels in the input pixel's neighborhood. Here morphological close operation is performed after gaussian filtering of the input foot image. The morphological close operation is an operation which includes a morphological dilation operation followed by a morphological erosion and the same structuring element is used for both the operations. Here disk-shaped structuring element is used for morphological close operation. The morphological closing of the image using disk approximations are much faster than when the structuring element uses approximations. After the morphological closing process, the very next step is to find the regional maxima in the image. Regional maxima are actually the connected components of pixels which possess a constant intensity value and whose external boundary pixels all will possess a value less than the constant intensity value. After the determination of the regional

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maxima dilation of the image is done. The very next step after the dilation is the conversion of the dilated image into gray scale image. Thus the complete preprocessed image s obtained. The preprocessed image is actually the result of morphological closing operation, determination of the regional maxima and image dilation. Now from the preprocessed image the foot region and the wound region are determined.

3) Foot and Wound Regions Determination: The foot region must be determined in order to calculate how much percentage of wound is affected within the foot. Thus from this the foot count can be calculated. The wound region is the area which denotes the region of the foot which is affected by the wound. Thus from this the wound count can be calculated. Eventually the wound affected area in the foot is assessed and it is represented in a pie chart. The wound region and the foot region are expressed in percentage within the pie chart. The pie chart representation makes easy visualization of the wound affected in the foot. During the foot and wound area computation process, some of the important and useful image processing tools used here are imadjust, imb2bw and regionprops. The imadjust image processing tool will adjust the image intensity values. The image processing tool im2bw will produces binary images from indexed, intensity or RGB images. For performing this task, suppose if the image is not already an intensity image then it is first converted into gray scale format and then converts this obtained gray scale image into binary image by thresholding process. The processing tool regionprops is a useful tool that measures a variety of image features and quantities.

4) Tracing the Wound Area: After finding the wound area, the wound area is traced by using bwtraceboundary image processing tool. The objects are marked as binary ones and the background is marked as binary zeros.

5) Wound Color Tracing: The healing status of the wound here is assessed based on the red-yellow-black color evaluation model. The RYB (red-yellow-black) model is a simple and consistent wound classification model. It classifies the wound tissues within a wound as red, yellow, black or mixed tissues which indicates the different phases of the wound healing process. According to this model the wound area with red tissues indicates the regeneration, maturation or inflammatory phase. The wound area having yellow tissues indicates the tissues containing slough that are not ready to healed the black tissues imply the necrotic state of tissues that are not ready to heal.

6) Comparison between the foot images: The comparison between the two images of the wound taken on weekly basis is done on two factors namely wound area and healing rate. Here for images are taken on weekly basis as shown in the figure 2(b). Image 1 is the initial image which indicates the condition of the patient. Image 2 is taken on the next week. Images 3 and 4 are taken on every successive week. If the wound area is greater in the previous image when compared with the present image (which is taken on the successive week) then the wound will be reduced. This will be displayed here in the command window. The corresponding healing status will also be displayed. The healing score is expressed in percentage and it is represented in a pie chart.

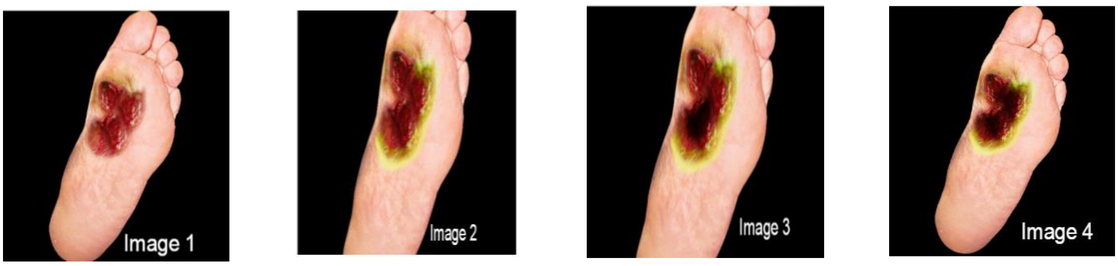

Figure 2(b) Images taken on weekly basis

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III. EXPIREMENTAL RESULTS

This section deals with the results obtained for the various processes. The healing status of the wound is computed using different processes that are mentioned in the above section using MATLAB software.

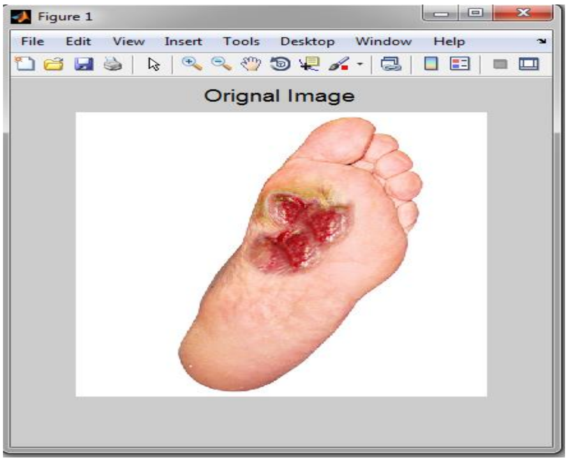

Figure 3(a) Input Foot Image (Image 1)

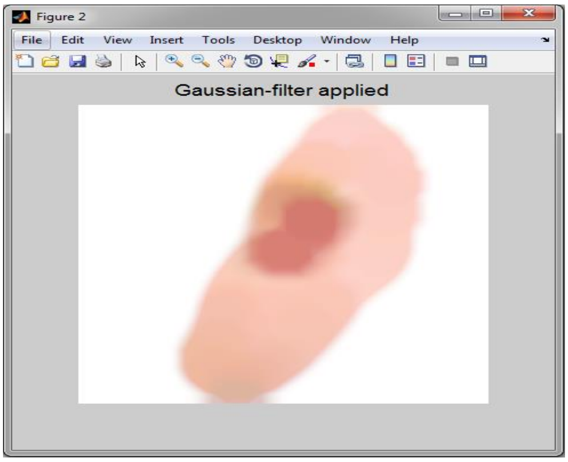

Figure 3(b) Gaussian Filtered Image

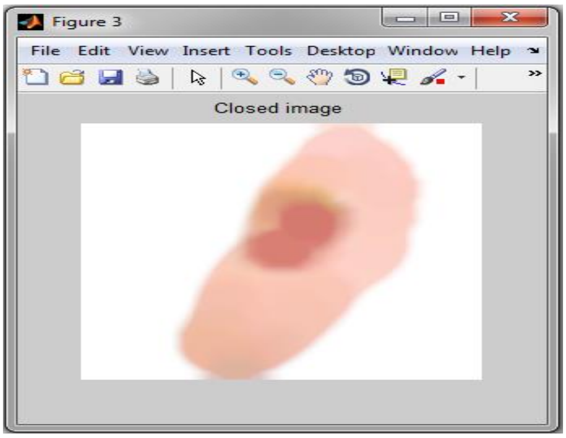

Figure 3(c) Morphologically Closed Image

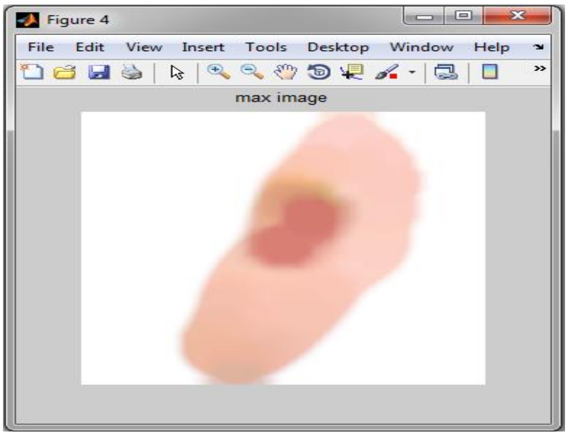

Figure 3(d) Region maxima of the Image

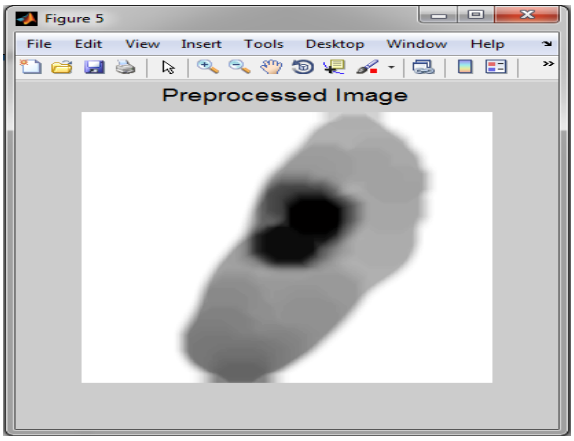

Figure 3(e) Preprocessed Foot Image

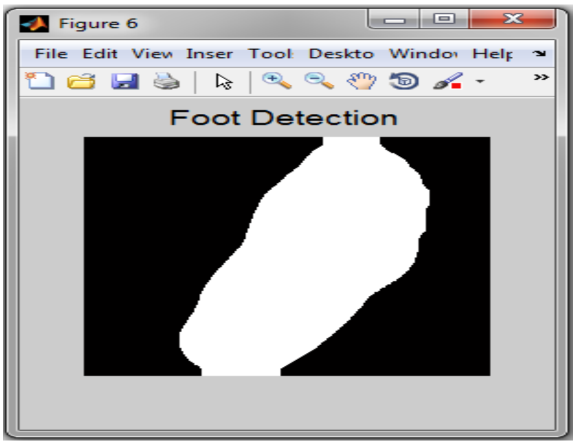

Figure 3(f) Foot Region Detected

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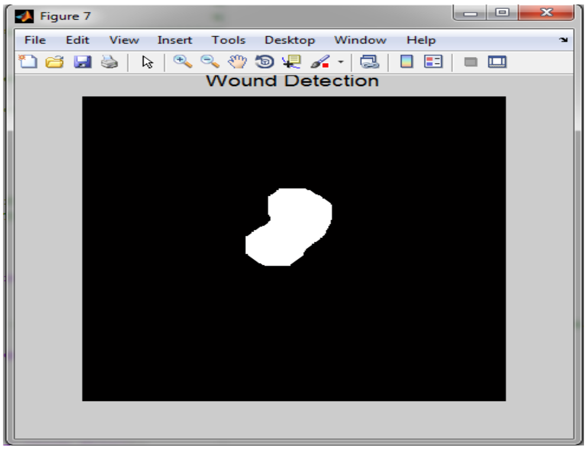

Figure 3(g) Wound Region Detected

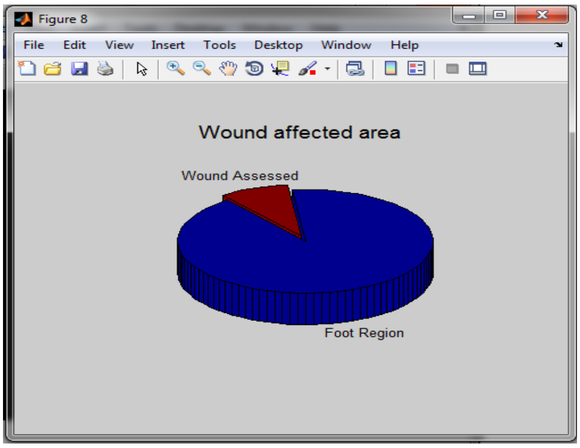

Figure 3(h) Determined Wound Affected Area

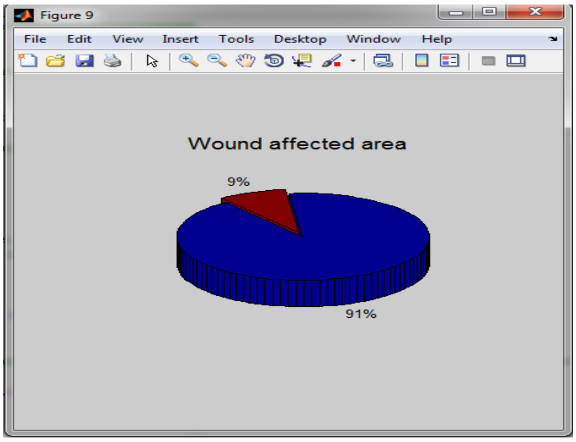

Figure 3(i) Wound Affected Area in Percentage

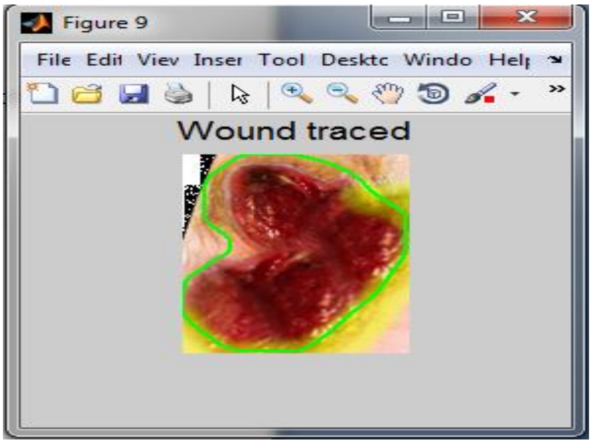

Figure 3(j) Traced Wound Affected Area

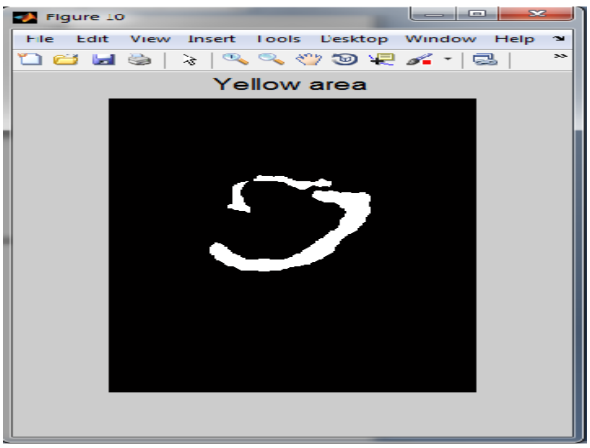

Figure 3(k) Yellow Area Detected (Image 2)

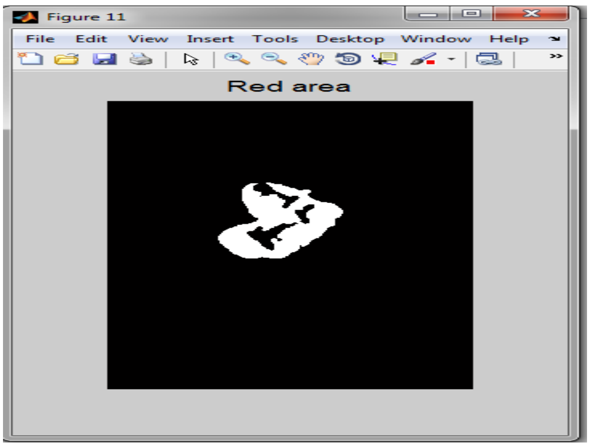

Figure 3(l) Red Area Detected (Image 2)

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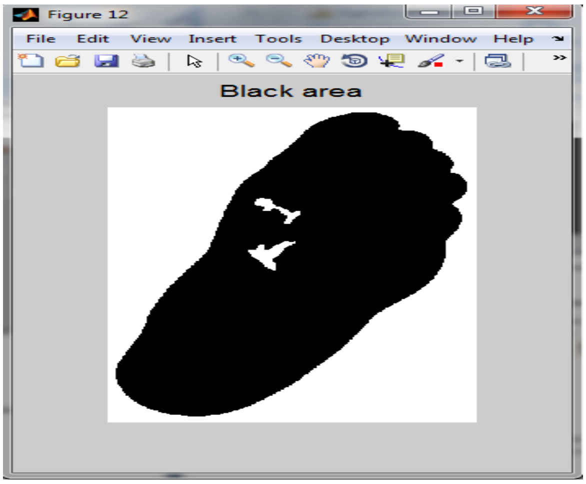

Figure 3(m) Black Area Detected (Image 2)

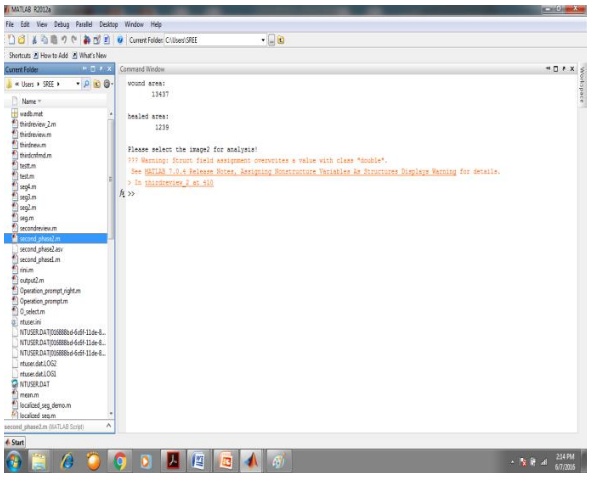

Figure 3(n) Command Window Showing Wound Area and Healed Area (Image 1)

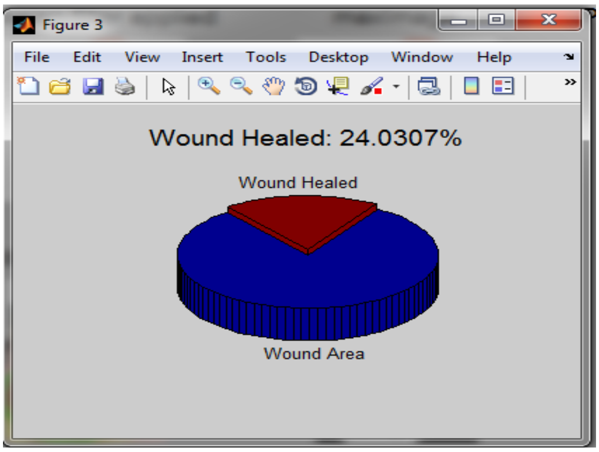

Figure 3(o) Wound Healing Score

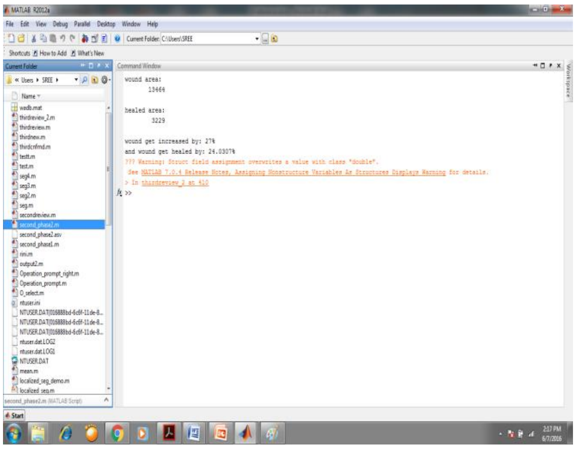

Figure 3(p) Command Window Showing the Wound Healed in Percentage

IV.CONCLUSION

The proposed method is very effective for the wound healing status. Wound assessment provides useful information for the doctors to understand the present situation of the wound and can prescribe the medicines based on the healing status. This can reduce the death risk caused by Diabetic Foot Ulcers. By using the various image processing tools the doctors can analyze the complications regarding the wound very easily. Here the wound area is computed and its value is expressed in percentage and is represented in a pie chart. This makes easy visualization of the wound affected area in the foot. Moreover, here the healing score of the wound is computed which is an accurate diagnosis tool for doctors in order to reduce or increase the dosage of the medicines.

V. ACKNOWLEDGEMENT

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BIOGRAPHY

Sree Sankar.J received his B.E. in Electronics and Communication Engineering from Sivaji College of Engineering and Technology in the year 2013. He completed his M.E. in Communication Systems from Sivaji College of Engineering and Technology in the year 2016. He has authored seven publications in reputed Journals. His area of interest includes Antennas and Wave Propagation, Medical Electronics, Bio-Medical Imaging and Optical Communication. He is currently working as an Assistant Professor in the Department of Electronics and Communication Engineering, James College of Engineering and Technology, Kanyakumari.

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