International Journal of Scientific Research in Computer Science, Engineering and Information Technology

Smartphone-Based Wound Assessment System for Patients with Diabetes

Karthik K, Prof. K. M Sowmyashree

Department of MCA, P.E.S. College of Engineering, Mandya, India

ABSTRACT

Diabetic foot ulcers represent a significant health issue. Currently, clinicians and nurses mainly base their wound assessment on visual examination of wound size and healing status, while the patients themselves seldom have an opportunity to play an active role. Hence, amore quantitative and cost-effective examination method that enables the patients and their caregivers to take a more active role in daily wound care potentially can accelerate wound healing, save travel cost and reduce healthcare expenses. Considering the prevalence of smartphones with a high-resolution digital camera, assessing wounds by analyzing images of chronic foot ulcers is an attractive option. In this paper, we propose a novel wound image analysis system implemented solely on the Android smartphone. The wound image is captured by the camera on the smartphone with the assistance of an image capture box. After that, the smartphone performs wound segmentation by applying the accelerated mean-shift algorithm. Specifically, the outline of the foot is determined based on skin color, and the wound boundary is found using a simple connected region detection method. Within the wound boundary, the healing status is next assessed based on red–yellow–black color evaluation model. Moreover, the healing status is quantitatively assessed, based on trend analysis of time records for a given patient. Experimental results on wound images collected in UMASS—Memorial Health CenterWound Clinic (Worcester,MA)following an InstitutionalReviewBoard approved protocol show that our system can be efficiently used to analyze the wound healing status with promising accuracy.

Keywords : Android-Based Smartphone, Mean Shift, Patients With Diabetes, Wound Analysis

I. INTRODUCTION

For individuals with type 2 diabetes, foot ulcers constitute a significant health issue affecting 5–6 million individuals in the US. Foot ulcers are painful, susceptible to infection and very slow to heal. According to published statistics, diabetes-related wounds are the primary cause of nontraumatic lower limb amputations with approximately 71 000 such amputations in the US in 2004. Moreover, the cost oftreating diabetic foot ulcers is estimated at $15 000 per year per individual. Overall diabetes healthcare cost was estimated at $245 billion in 2012 and is expected to increase in the coming years.

There are several problems with current practices for treating diabetic foot ulcers. First, patients must go to their wound clinic on a regular basis to have their wounds checked by their clinicians. This need for frequent clinical evaluation is not only inconvenient and time consuming for patients and clinicians, but also represents a significant health care cost because patients may require special transportation, e.g., ambulances. Second, a clinician's wound assessment process is based on visual examination. He/she describes the wound by its physical dimensions and the color of its tissues, providing important indications of the wound type and the stage of healing. Because the visual assessment does not produce objective measurements and quantifiable parameters of the healing status, tracking a wound's healing process across consecutive visits is a difficult task for both clinicians and patients.

Technology employing image analysis techniques is a potential solution to both these problems. Several attempts have been made to use image processing techniques for such tasks, including the measurement of area, or alternatively using a volume instrument system (MAVIS) or a medical digital photogrammetric system (MEDPHOS). These approaches suffer from several drawbacks including high cost, complexity, and lack of tissue classification.

To better determine the wound boundary and classify wound tissues, researchers have applied image segmentation and supervised machine learning algorithm for wound analysis. A French research group proposed a method of using a support vector machine (SVM)-based wound classification method. The same idea has also been employed in for the detection of melanoma at a curable stage. Although the SVM classifier method led to good results on typical wound images. it is not feasible to implement the training process and the feature extraction on current smartphones due to its computational demands. Furthermore, the supervised learning algorithm requires a large number of training image samples and experienced clinical input, which is difficult and costly.

Our solution provides image analysis algorithms that run on a smartphone, and thus provide a low cost and easy-to-use device for self management of foot ulcers for patients with type 2 diabetes. Our solution engages patients as active participants in their own care, meeting the recommendation of the Committee on Quality of Health Care in America to provide more information technology solutions. The widely used commodity smartphone containing a high-resolution camera is a viable candidate for image capture and image processing provided that the processing algorithms are both accurate and well suited for the available hardware and computational resources. To convert an ordinary smartphone into a practical device for self management of diabetic wounds, we need to address two tasks: 1) develop a simple method for patients to capture an image of their foot ulcers; and 2) design a highly efficient and accurate algorithm for real-time wound analysis that is able to operate within the computational constraints of the smartphone.

Our solution for task 1) was specifically designed to aid patients with type 2 diabetes in photographing ulcers occurring on the sole of their feet. This is particularly challenging due to mobility limitations, common for individuals with advanced diabetes. To this end, we designed and built an image capture box with an optical system containing a dual set of front surface mirrors, integrated LED lighting and a comfortable, slanted surface for the patients to place their foot. The design ensures consistent illumination and a fixed optical path length between the sole of the foot and the camera, so that pictures captured at different times would be taken from the same camera angles and under the same lighting conditions. Task 2) was implemented by utilizing an accurate, yet computationally efficient algorithm, i.e., the mean-shift algorithm, for wound boundary determination, followed by color segmentation within the wound area for assessing healing status.

In our previous work, the wound boundary determination was done with a particular implementation of the level set algorithm, specifically the distance regularized level set evolution method. The principal disadvantage of the level set algorithm is that the iteration of global level set function is too computationally intensive to be implemented on smartphones, even with the narrow band confined implementation based on GPU. In addition, the level set evolution completely depends on the initial curve which has to be predelineated either manually or by a well-designed algorithm. Finally, false edges may interfere with the evolution when the skin color is not uniform enough and when missing boundaries, as frequently occurring in medical images, results in evolution leakage (the level set evolution does not stop properly on the actual wound boundary). Hence, a better method was required to solve these problems.

II. MODULE SPECIFICATION

1. Wound Image Analysis System overview

In this module, we carry out a *Wound boundary determination* based on the foot outline detection result. If the foot detection result is regarded as a binary image with the foot area marked as “white” and rest part marked as “black,” it is easy to locate the wound boundary within the foot region boundary by detecting the largest connected black” component within the “white” part. If the wound is located at the foot region boundary, then the foot boundary is not closed, and hence the problem becomes more complicated, i.e., we might need to first form a closed boundary. When the wound boundary has been successfully determined and the wound area calculated, we next evaluate the healing state of the wound by performing *Color segmentation*, with the goal of categorizing each pixel in the wound boundary into certain classes labeled as granulation, slough and necrosis. The classical self-organized clustering method called K-mean with high computational efficiency is used. After the color segmentation, a feature vector including the wound area size and dimensions for different types of wound tissues is formed to describe the wound quantitatively. This feature vector, along with both the original and analyzed images, is saved in the result database. 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. **Mean-Shift-Based Segmentation Algorithm:**

In this module we implement mean-shift-based segmentation, 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.

3. **Wound Boundary Determination and Analysis Algorithms:**

In this module we implement wound boundary determination, because the mean-shift algorithm only manages to segment the original image into homogeneous regions with similar color features, an object recognition method is needed to interpret the segmentation result into a meaningful wound boundary determination that can be easily understood by the users of the wound analysis system. As noted, a standard recognition method relies on known model information to develop a hypothesis, based on which a decision is made whether a region should be regarded as a candidate object, i.e., a wound. A verification step is also needed for further confirmation. Because our wound determination algorithm is designed for real time implementation on the smart phones with limited computational resources, we simplify the object recognition process while ensuring that recognition accuracy is acceptable.

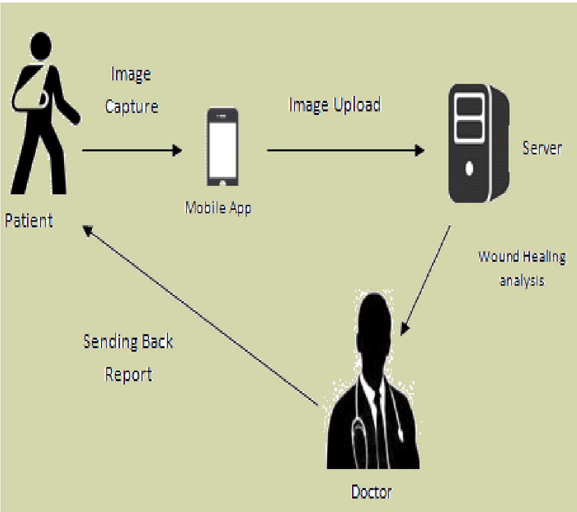
III. BACKGROUND WORK

- There are several problems with current practices for treating diabetic foot ulcers.
- First, patients must go to their wound clinic on a regular basis to have their wounds checked by their clinicians. This need for frequent clinical evaluation is not only inconvenient and time consuming for patients and clinicians, but also represents a significant health care cost because patients may require special transportation, e.g., ambulances.
- Second, a clinician's wound assessment process is based on visual examination. He/she describes the wound by its physical dimensions and the color of its tissues, providing important indications of the wound type and the stage of healing. Because the visual assessment does not produce objective measurements and quantifiable parameters of the healing status, tracking a wound's healing process across consecutive visits is a difficult task for both clinicians and patients.
- The wound boundary determination was done with a particular implementation of the level set algorithm; specifically the *distance regularized level set evolution* method. The principal disadvantage of the level set algorithm is that the iteration of global level set function is too computationally intensive to be implemented on smart phones, even with the narrow band confined implementation based on GPUs.
- In addition, the level set evolution completely depends on the initial curve which has to be pre-delineated either manually or by a well-designed algorithm. Finally, false edges may interfere with the evolution when the skin color is not uniform enough and when missing boundaries, as frequently occurring in medical images, results in evolution leakage (the level set evolution does not stop properly on the actual wound boundary). Hence, a better method was required to solve these problems.

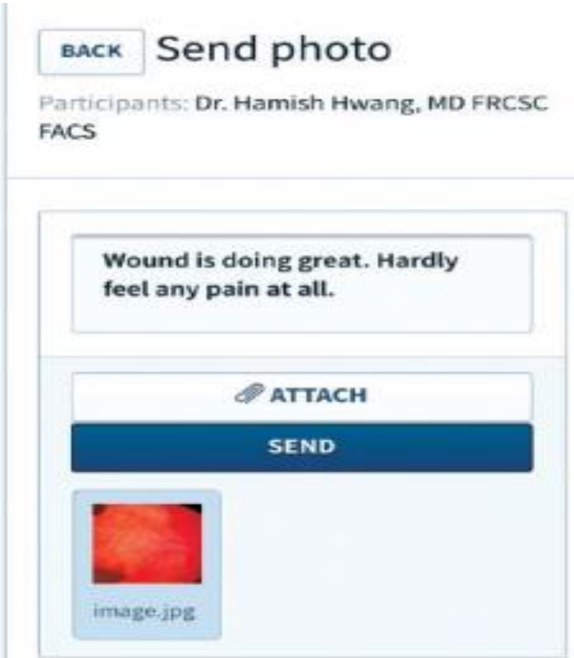
IV.METHODOLOGY

- In this paper, we replaced the level set algorithms with the efficient mean-shift segmentation algorithm.
- While it addresses the previous problems, it also creates additional challenges, such as over-segmentation, which we solved using the region adjacency graph (RAG)-based region merge algorithm.
- In this paper, we present the entire process of recording and analyzing a wound image, using algorithms that are executable on a smart phone, and provide evidence of the efficiency and accuracy of these algorithms for analyzing diabetic foot ulcers.

1. **Architecture Diagram**



2. SNAPSHOT



V. CONCLUSION

We have designed and implemented a novel wound image analysis system for patients with type 2 diabetes suffering from foot ulcers. The wound images are captured by the smartphone camera placed on an image capture box. The wound analysis algorithm is implemented on a Nexus 4 Android smartphone, utilizing both the CPU and GPU.

We have applied our mean-shift-based wound boundary determination algorithm to 30 images of moulage wound simulation and additional 34 images of real patients. Analysis of these experimental results shows that this method efficiently provides accurate wound boundary detection results on all wound images with an appropriate parameter setting. Considering that the application is intended for the home environment, we can for each individual patient manually find an optimal parameter setting based on a single sample image taken from the patient before the practical application. Experimental results show that a fixed parameter setting works consistently well for a given patient (the same foot and skin condition). In the future, we may consider applying machine learning approaches to enable self-adaptive parameter setting based on different image conditions. The algorithm running time analysis reveals that the fast implementation of the wound image analysis only takes 15 s on average on the smartphone for images with pixel dimensions of 816 × 612.

Accuracy is enhanced by the image capture box, which is designed so that consistent image capture conditions are achieved in terms of the illumination and distance from camera to object. While different smartphone cameras do have slightly different color space characteristics, we have not included color calibration mainly because the most important aspect of the wound assessment system is the tracking of *changes* to the wound, both in size and color, over consecutive images captures.

Given the high resolution, in terms of pixel size, of allmodern smartphone cameras, the performance of our wound analysis system is not expected to be affected by resolution differences across smartphone cameras. In fact, the original large resolution images are downsampled to a fixed spatial resolution of 816 × 612 pixels.

While different image noise levels for different smartphone cameras are a potential concern, we have determined, based on the experimental results, that any noise level encountered during the image capture process can be effectively removed by applying a Gaussian blurring filter before wound analysis.

The primary application of our wound analysis system is home-based self-management by patients or their caregivers, with the expectation that regular use of the system will reduce both the frequency and the number of wound clinic visits. One concern is that some elderly patients may not be comfortable with operating a smartphone, but this concern could be addressed by further simplifying the image capture process to a simple voice command.

An alternative deployment strategy is placing the system in wound clinics, where a nurse can perform the wound image capture and data analysis. With this implementation, the wound analysis can be moved from the smartphone to a server, which will allow more complex and computationally demanding wound boundary detection algorithms to be used. While this will allow easier and more objective wound tracking and may lead to better wound care, this implementation of the wound analysis system is not likely to reduce the number of visits to the wound clinic. In either implementation, telehealth is an obvious extension to the wound analysis system whereby clinicians can remotely access the wound image and the analysis results. Hence, a database will be constructed on a possibly cloud-based server to store the wound data for patients. The possibility of microbial contamination of the image capture box by the users or the environment has so far only been addressed by wiping the surface of the box with an antimicrobial wipe after each use. A better solution may be a disposable contamination barrier, which will cover the slanted surface of the box except the openings. This will avoid the patient's foot directly touching the surface of the image capture box.

The entire system is currently being used for wound tracking in the UMass-Memorial Health Center Wound Clinic in Worcester, MA. This testing at the Wound Clinic is a first step toward usability testing of the system by patients in their homes.

In future work, we plan to apply machine learning methods to train the wound analysis system based on clinical input and hopefully thereby achieve better boundary determination results with less restrictive assumptions. Furthermore, we plan to compute a healing score to be assigned to each wound image to support trend analysis of a wound's healing status.

VI. REFERENCES

[1]. K. M. Buckley, L. K. Adelson, and J. G. Agazio, "Reducing the risks of wound consultation: Adding digital images to verbal reports," Wound Ostomy Continence Nurs., vol. 36, no. 2, pp. 163-170, Mar. 2009.

[2]. V. Falanga, "The chronic wound: Impaired healing and solutions in the context of wound bed preparation," Blood Cells Mol. Dis., vol. 32, no. 1, pp. 88-94, Jan. 2004.

[3]. C. T. Hess and R. S. Kirsner, "Orchestrating wound healing: Assessing and preparing the wound bed," J. Adv. Skin Wound Care, vol. 16, no. 5, pp. 246-257, Sep. 2006.

[4]. R. S. Rees and N. Bashshur, "The effects of tele wound management on use of service and financial outcomes," Telemed. J. E. Health, vol. 13, no. 6, pp. 663-674, Dec. 2007.

[5]. NIH's National Diabetes Information Clearing House, National Institute of Health. (2011). Online]. Available: www.diabetes.niddk.nih.gov

[6]. H. Wannous, Y. Lucas, and S. Treuillet, "Combined machine learning with multi-view modeling for robust wound tissue assessment," in Proc. 5th Int. Conf. Comp. Vis. Theory Appl., May 2010, pp. 98-104.

[7]. H.Wannous,Y. Lucas, S. Treuillet, andB.Albouy, "A complete 3Dwound assessment tool for accurate tissue classification and measurement," in Proc. IEEE 15th Conf. Image Process., Oct. 2008, pp. 2928-2931.

[8]. P. Plassman and T. D. Jones, "MAVIS: A non-invasive instrument to measure area and volume of wounds," Med. Eng. Phys., vol. 20, no. 5, pp. 332-338, Jul. 1998.

[9]. A. Malian, A. Azizi, F. A. Van den Heuvel, and M. Zolfaghari, "Development of a robust photogrammetric metrology system for monitoring the healing of bedscores," Photogrammetric Rec., vol. 20, no. 111, pp. 241-273, Jan. 2005.