CHAPTER 1

Chapter - 1. Introduction

<table>
<thead>
<tr>
<th>S. No</th>
<th>Name of the Sub-Title</th>
<th>Page No</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>Introduction</td>
<td>2-5</td>
</tr>
<tr>
<td>1.2</td>
<td>Analysis and Classification of Wound</td>
<td>5-7</td>
</tr>
<tr>
<td>1.3</td>
<td>Objectives of the Present Study</td>
<td>8-9</td>
</tr>
<tr>
<td>1.4</td>
<td>Brief Outline of the Thesis</td>
<td>9-13</td>
</tr>
<tr>
<td>1.5</td>
<td>Image Databases</td>
<td>13-17</td>
</tr>
<tr>
<td>1.6</td>
<td>Summary</td>
<td>18</td>
</tr>
</tbody>
</table>
CHAPTER 1

INTRODUCTION

Generally, it is common that mammals especially human being are affected by wounds. The wound is resulted due to injury out of cut or burn etc., and most of the time occurs accidentally. The formation of the wound is generally due to the dead tissue which gets formed at the location where injury occurs. Hence it becomes inevitable to devise a method to heal the wound at the earliest and for achieving this it is required to assess the wound based on its type and the severity level.

This present work finds different techniques to capture the image of the wound, for performing the wound assessment. The wound assessment is carried out after filtering the wound image by removing the air bubbles and hair around the wound in order to clean and segment the wound image to estimate the healing time required. Keeping the patient’s condition and the availability of an expert doctor sitting at a far off location the concept of telemedicine is also explored in the present work.

A detailed case study on the formation of a wound and stages involved in the healing process of the same along with the types of tissues and its colour intensity has been discussed by eminent personalities in the past. The present work details various techniques involved in the analysis and healing status of wounds by using colour image processing. One such technique, novel classifier which classifies the wound based on the severity and applying overlay
segmentation to reduce the severity and changing the severity level as classified labels is discussed here in detail.

1.1 Introduction

The wound healing status is monitored by analysing and classifying the wound based on its severity level. A wound can be defined as an injury to living tissue caused by cut, burn etc., where skin is the major part to get affected. The layer of tissues which are very soft in nature and covering the outer part of the body is called the skin. The tissues of a particular location or the body get badly damaged when a wound occurs in any part of the body. Then the process of converting unhealthy tissues into healthy tissues are called as wound healing process has to be taken up. The assessment of the wound in a pre determined periods of time is essential to estimate the recovery time of a wound.

Considering the tissue classification as the fundamental criteria, the assessment of the wound healing process is performed. Wound healing process undergoes various phases and mostly depends on several factors like age, gender, health conditions etc., of the patient. By assessing wound healing process, it is always possible to estimate the efficacy of the drug to be administrated to the patient under medication. A new classifier Wound Image Analysis Classifier (WIAC) is developed which classifies the wound as superficial, deep dermal and fullthickness based on the severity of the wound. This classifier classifies them into any one of the severity level as ‘0’ or ‘1’ or ‘2’. The utmost goal of the wound healing analysis is the estimation
of drug level to be given. A novel classifier which uses transparent overlay as drug and it is applied on the segmented wound classifies the wound based on its severity level as metric. Different segmentation techniques were used to analyse and choose the best segmented image based on the quality, area, size and shape of the wound. Classifier classifies the wound based on various characteristic features like intensity of the various colours present in wound image.

A linear model (classifier) which distinguishes background and cellular local patches known as patch classifier is part of the segmentation algorithm in the wound image analysis classifier techniques. Second level classification of cellular regions which are tagged as background by the patch classifier is carried out by an additional classifier trained on spatial clusters of local patches (regions). When a wound image is under test, a grid of textures are overlaid on it. The severity level of the segmented wound is produced by each texture is assigned to the overlay classifier and further the regions marked as background are further classified by the regions classifier.

By applying the Kernel Graph Cut segmentation process the redefinition of the contours of the wound image are carried out. Support Vector Machines (SVM), K-Nearest Neighbor (K-NN) classifier and WIAC are trained for classifying various set of wound images by their own set of features. The output of each classifier is an overlap score for every transparent overlay overlaid on segmented wound image, which measures the severity level of the wound for every
texture covering on the segmented wound image while classifying the wound.

As defined by the linear model the overlap score of any given overlay is termed as the Euclidian distance of its feature-vector represented in the hyper plane. The three overlap scores for each overlay, one from each classifier, are further fed as a vector, into an additional training session that calculates the final classification, which is used to put weights on the output of the three classifiers to achieve the final classification known as classification stacking.

### 1.2 Analysis and Classification of Wound

The segmented wound images are partitioned into a grid of non-overlapping textures of 20X20 pixels. An expert visual inspection is carried out to mark the wound images and their corresponding pixel-wise cell-background baseline markings are used as input for the training set. From each overlay, either sets of features or combination of features are extracted each one describing the texture’s statistics to be used for separating wound textures from background textures, as follows:

- Wound Image and overlay gray-level mean and standard deviation.
- Histogram of Gray level overlaying.
- Histogram of overlays gradient intensity, a measure for the amount of details in the overlay.
The spatial smoothness of the overlays is the only difference which can be observed between each pixel intensity and its neighbors surrounding pixel.

The features of a broader area surrounding the texture, including mean and standard deviation of gray-level, gradient intensity and smoothness, as well as gray-level histogram are concatenated.

The following listed analyses were performed to evaluate the contribution of each feature set to estimate the performance of the overall patch classifier.

- Each of the feature vectors were evaluated separately in comparison to the combined overlay classifier i.e., using a single feature vector and the corresponding classifiers (SVM, K-NN, WIAC) as the overlay classifier on every data set.
- The results obtained using the intensity histogram were inferior and other feature sets were significantly marginal.
- Discarding the intensity histogram feature set and training a overlay classifier based on the remaining feature sets resulted with inferior performance compared to the classifier that was trained using all feature sets.

After the classification of local overlays, an additional classification of each spatially-connected component of the background textures are performed to decide whether it is actually a part of the background or not.
The task of global regional classification is performed by a trained additional classifier event. The original image and the overlay map are used to extract the following features from a segmented wound image such as the region's size (number of pixels), a histogram based on the original image intensities and another based on the textures overlap scores. The following are the steps followed in any classifier:

- First step of this classifier is to pick a wound from wound database.
- Various segmentation techniques are applied to segment the wound from the wound image and selecting the best wound image by considering various factors like quality, area of the wound etc.,
- The quality of the wound is improved by preprocessing the segmented wound image using filtering / denoising techniques.
- The severity level ‘0’ or ‘1’ or ‘2’ is determined by classifying the filtered, denoised, segmented wound images into various levels.
- The three most efficient classifiers namely SVM, K-NN, WIAC are used in the classification of the wound images.
- After getting the severity level from various classifiers individually the transparent overlay technology is applied to transform the high severity level to low severity level and to extract the healed wound image.
1.3 Objectives of the Present Study

The estimation of the duration of the wound healing is done by analysing and classifying the wounds and this is the main objective of this research work. The prediction of the healing of a wound is difficult as it needs to be monitored on timely basis and measuring the area of the wound daily which is a difficult process in the present traditional approaches. This research work aims at developing an efficient technique for monitoring the wound healing status in which the wound image is considered as input. The status of the wound is analysed by measuring the intensities of various colours present in wound, by extracting the area of the wound using an efficient segmenting technique. The extraction of the wound area is carried out by developing various transparent overlays and applying iteratively on the wound image using overlapping technique, thus analysing the healing status of the wound by decreasing effect of colours on area of the wound.

The main aim of the present thesis are

1. Analysing various multiscale transformation techniques like wavelet, curvelet, ridglet for denoising of wound images and derive a novel technique called colourlet transformation technique.
2. Analysation of a very efficient filtering technique for performing partitioning the wound image.
3. Integration of the performance analysis of various classifiers like K-NN and fuzzy in classifying the wound based on its labels.
4. Understanding thoroughly about various SVM classifiers used to classify the wound images based on tissues present in the wound and their level of severity.

5. Devising a novel classifier which classifies the wound based on its severity condition and comparing the performance with the existing classifiers like SVM, K-NN.

6. Understanding the functioning of WIAC a wound monitoring technique for efficient denoising, segmentation and classification techniques for monitoring the wound healing status.

1.4. **Brief Outline of the Thesis**

The present thesis focuses on automation of wound monitoring remotely by uploading wound images and making it available to the doctors and get treatment for the wound by analysing the status of the wound using automation methods of various image processing techniques. In this report different filtering, segmentating, clustering and classifying techniques have been applied effectively to analyse and classify the wound for obtaining wound healing assessment. An efficient classifier called ‘WIAC’ has been developed which uses segmentation and classification, filtering method as a denoising element and applying iteratively transformation overlay technique using image overlap for efficient tracking of wound healing status.

The chapter 2, “Literature Survey” throws light in the different phases of wounds and its assessment by observing the intensity of the colours of the tissues to estimate the severity level as ‘0’ or ‘1’ or ‘2’.
This chapter also discusses the assessment of the wound by contact and non contact method of either calculated or remotely available patient.

In Chapter 3, “Denoising of Wounds Using Colourlet Transformation”, a new transformation technique has been introduced to transform the wound image based on the intensities of the colours present in wound images. An efficient denoising mechanism is introduced in this chapter to remove noise from an image in spatial and transform domains. The filters used in spatial domain are Lee, forst, SRAD etc., the proposed technique Colourlet Transformation is more effective than existing filtering techniques like Wavelets, Curvlets, Ridglets. As colour is a perception and not a characteristic inherent to objects extensive use of the colour components like chromatic and the luminance components, which is computationally more efficient than the spatial domain based methods.

In Chapter 4, “Unsupervised Wound Image Segmentation”, an unsupervised segmentation technique has been applied for identification of region of interest in the wound images by removing unwanted regions of the wounds and to filter the edges of the wound, Gabor filtering technique is incorporated. In the present study two methods namely Gabor Filters and Kernel Graph Cut are adopted for segmenting wound image. The various textures in the wound image are used for the segmentation of the image in the Gabor Filter method which entails the generation of a large number of two dimensional Gabor Filters called a Filter Bank to filter the concerned image. Once
the filtration of the image under consideration is performed the process of feature extraction is assured. The optimized value of features extracted from the image under consideration enhances the performance of the clustering and segmentation of image processing. The second method adapts the multiregion graph cut in a Kernel induced space uses a variety of features such as colour, intensity, pixel relationships, texture vectors and spatial location of pixels for the segmentation of the wound image. This method involves in minimization of a function containing the original data term which allusions the wound image data transformed by means of a Kernel function. The two consecutive optimization algorithms repeated are Graph cut and iterative fixed point calculations for revising the parameters of the regions.

In Chapter 5, “Digital Analysis of Changes in Chronic Wounds through Image Processing”, K-NN and Fuzzy classifiers have been introduced to analyse the changes involved in digital wound images. In this research work, usage of certain classifiers like K-NN and Fuzzy are explored. It is clearly seen that K-NN is most suitable for all types of wounds and fuzzy is very much suitable for Diabetic and Venous ulcers only, since their mean values are denoted in higher range because of which the wounds may take more time to heal.

In Chapter 6, “Assessment of the Wound-Healing Process by Tissue Classification”, a novel method has been proposed to assess wound healing process by performing tissue classification. Wound tissues have been classified as granular, slough, necrosis and these
can be identified based on the intensity of their colours. In this work the wound is preprocessed by a filtering technique to remove noise of the wound present in the form of hair at boundaries of the wound. The segmentation of wound image is carried out by using K-Means clustering technique and classification of the wound using SVM technique based on tissues present in the wound and their severity level. In this work wound healing assessment by a single tissue classification taken on a timely fashion and analysis of the healing stage by applying tissue classification technique.

In Chapter 7, “Wound Image Analysis Classifier for efficient tracking of Wound Healing Status” an effective classifier has been developed for tracking wound healing status using image overlap of overlays of wound area by segmenting effectively using various segmentation techniques and filtering the segmented wound using efficient filtering technique. Wounds are evolved by increase in number of damage tissues. The measurement of the area covered by the wound periodically is the age old way of assessing the wound healing status which is tedious and cumbersome. The fundamental major classifications of the wound healing status are contact and non-contact methods. The aim of this thesis is to precisely assess the wound and this can be done by capturing the wound images. The photographic wound assessment tool (PWAT) is one of the various tools available to record perfect wound images for both chronic pressure ulcers and leg ulcers occurring due to vascular deficiency. Generally, the characteristics like venous, pressure, diabetic and
arterial ulcers of various types of wounds differ from one another, and the determination of reliability and validity using the PWAT to assess the appearance of the wound is very important. The area of the wound is segmented from the image of wound by employing an advanced technique of segmentation and the wound thus segmented is initially processed to bring down the noise using advanced filters and denoising techniques. To classify the wound images error free classifiers are required and the Wound Image Analysis Classifier (WIAC) is one among them which is compared with the available classifiers like SVM and K-NN for experimental evaluation.

1.5. Image Databases

In the present research work, wound images play an important role in testing, capturing of wound images and developing a database of wounds is an important activity in data collection. Various wounds [35] have been collected from different sources which are available on free of cost and used for this research work. As wounds have been classified based on severity level of the wound as Superficial dermal wounds is shown in figure 1.1, Deep dermal wounds is shown in figure 1.2, Full-thickness under skin burn injuries wounds is shown in figure 1.3 and Miscellaneous of wound images is shown in figure 1.4. Ulcers which are internal wounds increase the difficulty in segmenting them. The process of extracting wound images digitally is cumbersome because of the wound location which determines its area and the different wounds based on their severity are furnished as follows.
Figure: 1.1 Superficial Dermal Wounds having less severity level: wound_sd.001, wound_sd.002, wound_sd.003, wound_sd.004, wound_sd.005, wound_sd.006, wound_sd.007, wound_sd.008, wound_sd.009, wound_sd.0010, wound_sd.0011, wound_sd.0012, wound_sd.0013, wound_sd.0014, wound_sd.0015, wound_sd.0016, wound_sd.0017, wound_sd.0018, wound_sd.0019, wound_sd.0020, wound_sd.0021, wound_sd.0022, wound_sd.0023, wound_sd.0024, wound_sd.0025.
Figure 1.2: Deep dermal wound with high severity level: wound_dd.001, wound_dd.002, wound_dd.003, wound_dd.004, wound_dd.005, wound_dd.006, wound_dd.007, wound_dd.008, wound_dd.009, wound_dd.0010, wound_dd.0011, wound_dd.0012, wound_dd.0013, wound_dd.0014, wound_dd.0015, wound_dd.0016, wound_dd.0017, wound_dd.0018, wound_dd.0019, wound_dd.0020, wound_dd.0021, wound_dd.0022, wound_dd.0023, wound_dd.0024, wound_dd.0025.
Figure 1.3: Fullthickness wounds: wound_ft.001, wound_ft.002, wound_ft.003, wound_ft.004, wound_ft.005, wound_ft.006, wound_ft.007, wound_ft.008, wound_ft.009, wound_ft.0010, wound_ft.0011, wound_ft.0012, wound_ft.0013, wound_ft.0014, wound_ft.0015, wound_ft.0016, wound_ft.0017, wound_ft.0018, wound_ft.0019, wound_ft.0020, wound_ft.0021, wound_ft.0022, wound_ft.0023, wound_ft.0024, wound_ft.0025, wound_ft.0026, wound_ft.0027, wound_ft.0028, wound_ft.0029, wound_ft.0030.
Figure 1.4: Miscellaneous collection of wound images (Superficial Dermal, Deep Dermal, Full Thickness): wound_mc.001, wound_mc.002, wound_mc.003, wound_mc.004, wound_mc.005, wound_mc.006, wound_mc.007, wound_mc.008, wound_mc.009, wound_m.0010, wound_mc.0011, wound_mc.0012, wound_mc.0013, wound_mc.0014, wound_mc.0015, wound_mc.0016, wound_mc.0017, wound_mc.0018, wound_mc.0019, wound_mc.0020, wound_mc.0021, wound_mc.0022, wound_mc.0023, wound_mc.0024, wound_mc.0025, wound_mc.0026, wound_mc.0027, wound_mc.0028, wound_mc.0029, wound_mc.0030.
1.6. Summary

In this chapter a brief introduction to a novel classifier which classifies various types of wounds based on severity of the wound called as Wound Image Analysis Classifier (WIAC) is studied. The next section deals about steps involved in analysis and classification wounds. The next section discusses the objective of this research which is divided into various chapters like denoising of wound images based on colour, segmenting the region of interest of a wound image, classifying the wound based on severity level which can be computed by extracting intensity of the colour of a wound. The subsequent section gives a brief explanation regarding various techniques involved in filtering, segmenting, classifying. The sections that are subsequently placed details the steps involved in the process of image database collection.

The following chapter discusses theoretical background needed to understand the present thesis work like wounds, wound terminology, tissue classification based on colour etc. The present work focuses on the wound healing analysis by measuring area of the wound on timely fashion and using colour as a metric. As analysis of the wound healing status by measuring the wound is a tedious process the analysis is done by measuring intensity of the colour in wound which indicates healing status more predominantly than area of the wound.