Image Analysis Software to the Early Detection of Pressure Ulcers
— Individual Project Background Report —

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Chapter 1

Introduction

Pressure ulcers (PU) have been defined as an area of localised damage to the skin and underlying tissue caused by pressure, shear, friction or a combination of these factors (European Pressure Ulcer Advisory Panel). Pressure ulcers are not only costly affecting a significant proportion of the population, but are associated with increased mortality.

They occur when unrelieved pressure, typically over a bony protrusion, initially causes blood to pool at the site. Blood vessels are constricted and the skin is starved of oxygen and other nutrients. If not diagnosed and relieved of pressure early, the skin or even underlying tissue and bone may ulcerate. Early detection is thus key to avoiding pressure ulcers and the subsequent treatment costs, with several non-invasive techniques, including image processing and analysis, recently being developed for this purpose.

In pressure ulcer stage I, Skin is not broken but is red or discolored or may show changes in hardness or temperature compared to surrounding areas. When you press on it, it stays red and does not lighten or turn white. The redness or change in color does not fade within 30 minutes after pressure is removed. And the most importantly, A pressure sore at this stage can be reversed in about three days if all pressure is taken off the site.

The aim of this project is to explore the feasibility of using non-invasive techniques for the early detection of pressure ulcers. Emphasis will be placed on exploring a range of image processing and image analysis techniques and develop an practical pressure ulcers image process analysis software.

Chapter 2

Background

2.1 Pressure Ulcers

A pressure ulcer (PU) is any lesion caused by unrelieved pressure resulting in damage of underlying tissue [24]. Pressure ulcers are areas of localized tissue destruction caused by compression of soft tissue between a bony prominence and an external surface for a prolonged period of time [3]. Unrelieved pressure and shear are the most important contributing factors in the pathogenesis.

In UK, nearly 700,000 people are affected by pressure ulcers each year, across all care settings, including patients in their own homes, with the most vulnerable of patients aged over 75. Around 186,617 patients develop a pressure ulcer in hospital each year [6]. Given the aging of the population, PU are likely to become a problem of increasing proportion in the near future [1].

Pressure Ulcers are associated with significant economic burden, and costs continue to rise [12]. The cost of treating a pressure ulcer varies from £1,064 to £10,551. Costs increase with ulcer grade because the time to heal is longer and because the incidence of complications is higher in more severe cases. The total cost in the UK is £1.4 £2.1 billion annually (4% of total NHS expenditure) [2]. Pressure ulcers cost $9.1 -$11.6 billion per year with 2.5 million patients in the US. Cost of individual patient care ranges from $20,900 to $151,700 per pressure ulcer [15]. Pressure ulcers are not only costly, but are associated with increased mortality.

Therefore, these consequences highlight the value of the early detection of pressure ulcers. If pressure ulcers are detected in the early stage, simple care of the tissue can allow the skin to remain intact and heal without scarring or the need for surgical intervention.

According to the staging description of PU revised by International NPUAP- EPUAP Pressure Ulcer [7], stage I PU presents as Intact skin with non-blanchable erythema of a localized area usually over a bony prominence. Discoloration of the skin, warmth, edema, hardness or pain may also be present. Darkly pigmented skin may not have visible blanching. And Stage I may be difficult to detect in individuals with dark skin tones due to increased melanin content.

2.2 Related Research

Main issues regarding proper characterization of skin lesions consists of image acquisition, the image processing and analysis, the feature extraction, and the classification methodology [16]. Major advantage of using computer is that patients do not have to undergo many painful diagnosing techniques. Moreover it speeds up the procedure of diagnosis of the disease according to the processed images of skin. There are several previous studies to show what techniques are used to improve the early detection of pressure ulcers.

Image processing and computational techniques have been applied in different aspects of wound diagnosis. Some aspects involve wound-area identification, which has been tackled with different techniques such as contour detection with histogram segmentation, active contours modelling, region growing, clustering approaches or skin texture models [4] [8] [9]. Some approaches focus on detecting the different tissues existing in the wound, by using diverse segmentation methodssuch as histogram thresholding, watersheds, mean-shift smoothing, region growing, classification or graphs-

sometimes combined with machine learning strategies [10] [21] [23] [22].

Erythema can be detected with relatively simple and low-cost imaging and image enhancement techniques at pressure ulcers stage I, which was suggested by Prabhu Jude Rajendran. They used CLAHE algorithm and the preliminary results clearly indicate that the enhanced images exhibit higher contrast and make the pressure ulcer site more conspicuous to the examiner [18].

Jon Leachtenauer research group used a non-contact imaging-based method to detect Stage I pressure ulcers over a wide range of melanin levels. Two approaches were explored: the first used broad and narrow band visible spectrum imaging, and the second used near infrared (NIR) imaging. The results are presented together with results of numerical analysis of different erythema indices derived from the visible spectrum images [11].

A study at the University Hospital of University of Sao Paulo revealed a pressure ulcers incidence of 39.8% [19], and the evolution of healing process is followed by measuring PU using simple measures, tracing, photographs or image analysis by a computational system, which is sup ported by softwares Motic and AutoCAD [13].

R.Guadagnin, R. de S. Neves et al initially captured images by digital camera. Each image was separated in the images that correspond to blue, green and red bands. They then performed convolution on each image with a 9x9 mean mask with Idrisi Software to remove distortion due to texture peculiarities as it may happen that due to texture peculiarities isolated points distort parts of the images that belong to healthy skin, pressure border or pressure core [20].

Hairong Qi et al. describe a custom geometric correction method to restore the image from the misalignment distortion and present a binary tree-based generic demosaicking algorithm to efficiently estimate the missing special components and reconstruct a high-resolution full-spectral image. They used this new method for early detection of pressure ulcers, particularly so for dark pigmented skin to show how the geometric correction and demosaicking algorithms successfully reconstruct a full-spectral image from which apparent contrast enhancement between damaged skin and the normal skin is observed [17].

Jean-Franois Deprez proposed a 2D ultrasound elastography based on ultrasound imaging to address the challenging problem of pressure ulcer early detection. This was able to detect a subepidermal layer, helping to differentiate between pathological and healthy regions [5].

Chapter 3

Progress

I have already broken the project down into three main parts: modelling, implementation and evaluation. Modelling will focus on image process algorithms. In the implementation phase, the model is transformed in computer code and implemented into the software. During modelling and implementation are sufficiently far along that the code is producing results, then the evaluation stage can begin and results can be analysed. Although separate they are not independent. For example, difficulties in implementation may require a rethink in the model, the implementation must include code that stores results for evaluation and evaluation of results may lead to changes in the model. Most of the progress so far has been on modelling and so I shall focus on it for this chapter.

3.1 Progress summary

A Medical Bsc student used linear normalisation, global histogram equalisation and contrast limited adaptive histogram equalisation to enhance image, and the videos were processed through eularian colour magnification. The findings in that report have confirmed that image processing can be used to improve image contrast and subsequently aid in the detection of erythema. This applies to all skin colours [14]. This report will using his findings and test more image process algorithms and implement them to the software.

3.2 Plan

3.2.1 Implementation

The process of implementing the image process methods into computer code must be broken down into smaller tasks. This will also include basic windows menu design, image adjustment methods, database setting, are appropriate to use. I have also given a brief description of the manner in which I plan to work in the Appendix A

3.2.2 Evaluation

In order to evaluate all the image process methods, it is necessary to decide first what should be considered as successful outcomes and then how these should be measured. For example, different images taken from nurses gains better effect results using different algorithm and why, and as a whole, which might be measured as the best solution for analysis, setting it as default.

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Appendix A

Software Engineering Methodology

This project is more than producing a software but I consider it as a significant portion to be software engineering. As such I will layout briefly how I plan to follow good practices.

Version Control I will keep my code (including all the reports) under version control using Git. Git is very useful to use on individual projects since it does not require setting up a server for repositories unlike centralized version control systems such as Subversion. Using Git also allows me to backup my code on Github where anyone can follow my progress if they want, `https://github.com/Shanshan-IC/MscProject`. For instance the source for this Latex document can be found at `https://github.com/Shanshan-IC/MscProject/Backgroundreport`.

MATLAB The software will be implemented image processing algorithms based on data test results on MATLAB image process toolbox.

OpenCV The software will be developed by Visual Studio 2012 with OpenCV. OpenCV (Open Source Computer Vision Library) is an open source computer vision and machine learning software library. OpenCV was built to provide a common infrastructure for computer vision applications and to accelerate the use of machine perception in the commercial products.

Database In the middle of stage, the software will be implemented the database to help nurses and doctors to store patients' skin analysis data and monitor the progress during the detection stage.

Test Driven Developement Test-driven development is an advanced technique that uses unit tests to drive the design of software. The suite of unit tests provides constant feedback that each component is still working and act as documentation that cannot go out-of-date.