Chapter 1

Overview

1.1 Computer aided long-bone fracture detection

To provide an accurate diagnosis, a medical imaging examination depends on a high quality image, and also an accurate interpretation of that image by a skilled reader. Over the last hundred years, the field of radiology has grown as a result of advances in imaging technology, so that today, extremely high-quality images are produced for examination. However, the methods of interpretation have only recently begun to benefit from advances in computer technology [41]. The term computer-aided diagnosis (CAD) includes a diagnosis that is made by a radiologist who utilises the output of a computerised analysis of the medical images as a second opinion when making the diagnosis. This assists the radiologists' image interpretation by improving the accuracy and consistency of radiological diagnosis and also by reducing the image reading time [36]. In this situation, CAD can be thought of as a "second pair of eyes for the radiologist", or the equivalent of a "spell checker".

As a result of their non-systematic search patterns, and the camouflaging effect of the normal anatomical background, humans have a limited ability to detect and diagnose disease when interpreting medical images. In addition, some normal and abnormal lesions can have similar characteristics, resulting in possible interpretational errors [41]. Fortunately, developments in computer vision have demonstrated the potential for computers to provide a second opinion when interpreting medical images. Good algorithms will search in a systematic manner, and may one day be capable of differentiating between normal and abnormal lesions, despite their similar characteristics. This type of computer technology is a promising and efficient source of assistance for radiologists, and should help improve diagnostic performance [108].

This thesis presents algorithms pertaining to a CAD system for semi-automated segmentation of long-bones from x-ray images, and semi-automated detection of fractures within the segmented regions.

1.2 Thesis structure

While a few bone segmentation and fracture detection algorithms have been developed in the past, they are generally for specific anatomic regions, and do not necessarily produce good results. The aim of this thesis is therefore to explore how to semi-automatically detect midshaft fractures in long-bones, using plain diagnostic x-rays.

The following chapter examines the anatomy of bones, the types of fractures that can occur within them, and how they are visualised using plain diagnostic x-rays. The reasons why fractures can be missed during the manual reading of x-ray films are suggested, and a solution to the identified problem is proposed. The creation of a library of x-ray images for development and testing is also described. Chapter 2 therefore provides the relevant physiological, epidemiological and treatment knowledge that is required before a biomedical engineering approach to the problem of computer aided fracture detection is examined. Chapter 3 reviews the areas of computer aided diagnosis and automatic image segmentation, focusing specifically on the detection of fractures and the segmentation of bones from x-ray images. After identifying what has already been achieved in this area, as well as specifying what is still required, the aims of this thesis are outlined in detail.

In Chapter 4, edge detection is used as a low-level image analysis tool to extract shape information about the bones and fractures within the image. A scale-space approach is used for the edge detection, requiring smoothing of the image. Various smoothing methods are examined, their advantages and disadvantages discussed, and one method chosen for implementation. Finally, the problem of scale selection is identified, and a solution proposed. After edges are extracted, Chapter 5 explains how the bones can be approximated by a set of parameters, using a modified Hough Transform. A method of detecting peaks in the Hough accumulator is outlined and results are presented. Chapter 6 uses the calculated parameters to segment the diaphysis from the rest of the bone. A bone centre-line determination algorithm is described, along with two novel diaphysis segmentation algorithms. Results are again presented to show that one segmentation method is much more accurate than the other, and is therefore the method of choice. In Chapter 7, a unique method of detecting long-bone fractures using gradient analysis is described. This involves the creation of a gradient composite measure that is used to identify abnormal gradients, which are then highlighted for a radiologist to manually inspect. Threshold selection is examined, and the fracture detection performance is evaluated.

Some parts of the complete algorithm are slow to compute, specifically the smoothing and Hough Transform. Although the algorithm implementations are for proof of concept purposes only, Chapter 8 examines ways of decreasing the calculation time—to allow a more rapid diagnosis to be made—through the use of algorithm parallelisation. The parallelisation methods and their effectiveness are discussed. The final chapter draws together the findings of this research and discusses recommendations for future research.