

Chapter 1

Introduction

The problem addressed in this research is that of viewing all of the anatomy in the x-ray field in a single radiographic image. General radiography is a term that encompasses the capture of single projection radiographic images using film/screen (F/S) and computed radiography (CR) recording devices. Currently, general radiographic examinations are the most commonly performed diagnostic imaging examination in Australia. In the year from July 2005 to June 2006, general radiographic examinations constituted 49.0% of all diagnostic imaging examinations performed in Australia, including magnetic resonance imaging, nuclear medicine and ultrasound examinations. When x-rays were used as the energy source, general radiographic examinations constituted 74.1% of these diagnostic imaging examinations (Medicare Australia, 2007).

The viewing of certain anatomical regions in diagnostic radiographic images has been problematic since the advent of F/S radiography. Radiographic image display devices such as film or monitors have a major limitation of narrow latitude or dynamic range. A narrow latitude or dynamic range of an image recording device implies that all the energies used in the recording may not be captured correctly. In F/S radiography, a narrow latitude or dynamic range implies that all of the anatomy in the x-ray field may have to be visualised at a reduced or suboptimal contrast. As a result, viewers' ability to discern the anatomy is reduced.

X-ray photons as they exit the patient's anatomy constitute the image-forming beam. These x-ray intensities can be considered as having a high dynamic range; that is, there is a large range of x-ray intensities that exit from the patient's anatomy. However, x-ray film in its role as a recording device has a low dynamic range. X-ray film cannot always capture the full range of the x-ray intensities that reach it. Thus x-ray film cannot always record the full range of optical densities to allow visualisation of all the anatomical regions that have been irradiated (Bushong, 2001; Curry *et al*, 1990; Graham & Cloke, 2003; Thompson *et al*, 1994; Webb, 1988).

The techniques used by radiographers are designed so that the x-ray intensities of the anatomy of interest fall on the linear part of the film's characteristic curve. It is the role of the radiographer to select the appropriate x-ray tube voltage (kVp), x-ray tube current (mA), exposure time and focal-film distance (FFD) so that these x-ray intensities are best visualised (Ballinger, 1991).

Newer digital radiographic recording devices, such as CR, have a high dynamic range. These devices are capable of recording the full range of x-ray intensities that reach the recording medium. It is the display devices for viewing digital radiographic images, and the observers' eye, that limit the range of optical densities that can be visualised in a single image. Various digital image processing techniques allow the viewing of all recorded x-ray intensities, albeit within the limitations of the display device and the observers' eye. Again, it is the role of the radiographer to optimise the viewing of the digital radiographic image (Artz, 1997; Balter, 1990; Dowsett, Kenny & Johnston, 1998; Schaetzing *et al*, 1990; Weiser, 1997).

When viewing diagnostic radiographic images it is desirable to be able to visualise all of the irradiated anatomy in a single image. It is also desirable to be able to visualise the anatomy at the highest possible level of displayed contrast within the image. A high level of displayed contrast in an image allows the viewer to differentiate anatomical regions from each other to a greater extent than if the contrast level were low (Ballinger, 1991).

Methods to overcome the high dynamic range of the x-ray beam itself have been previously devised and are discussed in detail in this thesis. The use of shaped x-ray attenuating material placed in the x-ray beam is one such method. These *physical tissue compensation filters* (TCFs) effectively reduce the dynamic range of the x-ray beam prior to the recording of the information within the beam. Radiographers are responsible for the appropriate use of TCFs. The goal of the use of TCFs, along with the selection of kVp, mA, time and FFD, is to optimise the x-ray intensities within the characteristics of the F/S system (Ballinger, 1991).

Digital radiographic viewing techniques have, to a limited extent, further overcome the problem of viewing the anatomy in a single image. These methods are detailed in this thesis. One of the problems of these methods is that the spatial detail within the image is also altered. The problem of viewing digital radiographic images at a high level of image contrast without loss of spatial quality still exists.

This research was conducted in three distinct phases. In the first phase the characteristics of physical TCFs were examined. From this evaluation, characteristics of TCFs were identified that are relevant to the issue of dynamic range control within the x-ray image. These characteristics were used in the development of anatomically shaped *radiographic contrast-enhancement masks* (RCMs).

The development of RCMs was the second phase of the research. RCMs were developed to suit digital radiographic images of a variety of anatomical regions.

Various characteristics of TCFs that affect the dynamic range of the x-ray beam were modelled in the RCMs. These RCM characteristics are modifiable by the viewer of the image. It is expected that radiographers, who are typically the first viewer of radiographic images, will modify various characteristics of the RCM as well as using other image processing techniques to present an optimised image.

Anatomically shaped RCMs were then applied to the digital radiographic images. The effect of the RCM is to reduce the dynamic range of the displayed pixels in the digital radiographic image, rather than that of the x-ray beam. This facilitates visualisation of all of the anatomy within the image at a high level of image contrast.

The third phase of the research was to evaluate the effects of RCMs on digital radiograph images. RCMs were applied to a wide variety of digital radiographic images. Other dynamic range control methods alter spatial detail and introduce noise into the image. Quantitative comparisons of noise introduced into the image by RCMs were compared to other dynamic range reduction methods currently available.

Radiographers and other viewers of radiographic images subjectively assess image quality on a daily basis. Qualitative comparison of RCM modified images and the

original images was undertaken. A survey method was considered the most appropriate to compare subjective judgements of the two images. Survey questions were constructed. Images, with and without the application of a RCM, and the survey questionnaire were sent to radiographers and other imaging professionals for evaluation. The results of the survey were evaluated and reported. Conclusions from the survey were also drawn as to the value of RCMs in optimising digital radiographic images.