Edge Detection of Femur Bones in X-ray images – A comparative study of Edge Detectors

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ABSTRACT
Medical images carry huge amount of information for the analysis of various diseases in the human body. The X-ray images are used for examining bone structure and other tissues. Also, the clear conclusion about disease diagnosis and treatment can be drafted out from the medical experts based on the X-ray images. The objective of this paper is to compare the performance of edge detectors used for edge detection of the human femur bone in X-ray images. The experimentation has been done with various edge detectors, namely, Roberts, Sobel, Prewitt, Canny's and Laplace operators. The results show that the Laplace operator performs better than other methods in its application to X-ray images of femur bones, which has significance to medical and forensic experts.

Keywords
Femur bone, Edge detection, X-ray images.

1 INTRODUCTION

The most popular modes of image acquisition in medical science are X-rays, MRI, Ultrasound imaging, Computer tomography etc. These techniques tend to be very economic, efficient, and easily accessible [1]. These images are used to fetch the symptoms of various diseases of patients in order to treat them and also make some clear prediction on the health of the patient suffering from particular diseases. The medical experts having good knowledge about these images are laboured to examine them [12]. Among these images, the most familiar, uncomplicated and prominent quality images are the X-Ray images [11]. The image processing methods are used for better understanding of the image for medical diagnoses [2]. The X-ray films are converted into digital images by scanning the images by 72X72 Dpi scanner. The scanned X-ray images of human femur bone of various normal, diseases, and fracture cases are considered for image analysis [13]. The challenging issues relate to finding the edges of decayed and swollen bones [3], because the infected part of the bone remains blurred or unseen in X-ray films when it is shot.Femur bone can be said as the thigh bone, and it is the longest bone [14] of the human skeleton located in between the hip bone and the knee [4]. The study consists of normal bone, diseased bone and fractured bone. The diseased bone has symptoms of swelling and decaying on some parts whereas the fractured bone consists of oblique, comminuted, and linear fracture. The femur bone is examined in the context of medical diagnosis as well as forensic investigation [5] [10].

2. EDGE DETECTION

2.1 Proposed edge detection based on Laplace second order differences operator:

The Laplacian operator is a second order derivative which is obtained by considering difference of differences, which is also called central differences. Prior to applying Laplacian algorithm the image has to be smoothed using Gaussian smoothing filter which reduces noise in an image. The calculation of forward difference and backward difference [15] are performed as it is shown below:

$$\delta^2{}_x = \nabla\Delta f(x, y)$$

$$= \Delta (f(x+1, y) - f(x, y))$$

$$= (f(x+1, y) - f(x, y)) – f(x, y) – (f(x, y) – f(x-1, y))$$

$$= f(x+1, y) – 2f(x, y) +f(x-1, y)$$

The matrix filter used to implement is:

$$\begin{bmatrix} 0 & 0 & 0 \\ 1 & -2 & 1 \\ 0 & 0 & 0 \end{bmatrix}$$

The corresponding matrix filter to calculate second differences $\delta^2{}_y$ in the y direction is:

$$\begin{bmatrix} 0 & 1 & 0 \\ 0 & -2 & 0 \\ 0 & 1 & 0 \end{bmatrix}$$

T he sum of these two can be written as

$$\nabla^2 = \delta_x^2 + \delta_y^2$$

and the final matrix filter is:

$$\begin{bmatrix} 0 & 1 & 0 \\ 1 & -4 & 1 \\ 0 & 1 & 0 \end{bmatrix}$$

This is known as a discrete Laplacian.

The Laplacian operator is very sensitive to noisy images and it is advantageous to use because the edge detection is uniform on an image.

2.2 Other edge detection methods

2.2.1 Roberts Operator: The Roberts cross gradient operator performs the discrete differentiation. The spatial gradient of an input image can be calculated absolute by computing the sum of squares of the differences between diagonally neighbouring pixels [16]. The convolution kernel has 3x3 pair, one is normal and the other is rotated by 90^0, as shown in Fig.3(a) and (b), respectively.

2.2.2 Sobel Operator: The Sobel operator calculates the opposite of the gradient of the input image. The basic behind edge detection is to find opposite gradient in horizontal and vertical direction of an image grid by introducing a very small value of filter [17]. The Fig.3(c) and (d) shows that one kernel is normal and the other rotated by 90^0.

2.2.3 Prewitt Operator: The properties of Prewitt operator are similar to Sobel operator, hence edge detection can be performed in both horizontal and vertical direction of an image [18]. The masks are as shown in Fig. 3(e) and (f).

2.2.4 Canny Operator: Canny operator is one of the optimal edge detector and edge detection is done in multiple stages. Noise reduction is one of the primary step to smooth the image .Then the edge gradient can be determined by returning the value of first derivative in horizontal, vertical and diagonal directions of a particular image [19]. The algorithm then finds the pixels which are at the maximum and suppresses the non-maximum pixels. To track down the remaining pixel algorithm uses hysteresis with proper threshold.

$$\begin{bmatrix} 1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} 0 & 1 & 0 \\ -1 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix}$$

(a) (b) (c)

$$\begin{bmatrix} -1 & -2 & 1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix} \begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix} \begin{bmatrix} -1 & -1 & -1 \\ 0 & 0 & 0 \\ 1 & 1 & 1 \end{bmatrix}$$

(d) (e) (f)

Fig. 3: Masks of (a & b) Robert's, (c & d) Sobel, and (e & f) Prewitt Operators.

3. EXPERIMENTAL RESULTS

The experimentation has been done using 100 digital X-ray images of femur bones, which are scanned images of X-ray films with 72X72 Dpi and image size is 256X256. The implementation of the edge detection algorithms is carried out using Intel core i5 system at 2.30GHz and Matlab 7.0. The proposed Laplace second order difference operator has been applied to the different images. The Fig.4 (a) show the sample original X-ray images of femur bones and Fig.4(b) shows the corresponding resultant edge detected images by using Laplace second order difference operator. The results of Laplace operator can be compared with the results of other edge detection methods, namely, Roberts, Sobel, Prewitt and Canny operators. The Fig.5 shows the comparison of the results of these methods for one sample image.

Fig.4 (a): Sample Original X-Ray images of femur bones

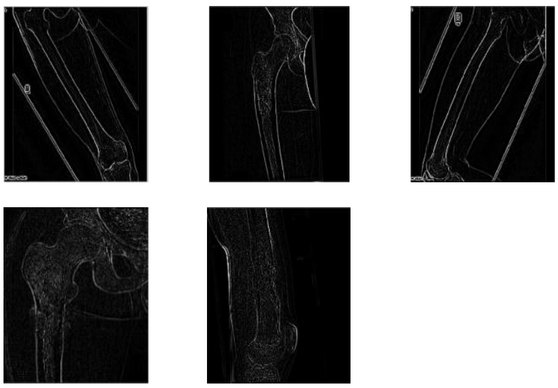

Fig. 4 (b): Edge detected images by using Laplacian Second order Differences, Corresponding to the X-ray images of femur bones in Fig.4(a).

We observe that Robert cross gradient operator is very quick to compute. The resultant image is very similar to the one obtained by Sobel operator but quality of edge pixels are found to be degraded due to lot of jerky effect on edges (Fig. 5(b)).

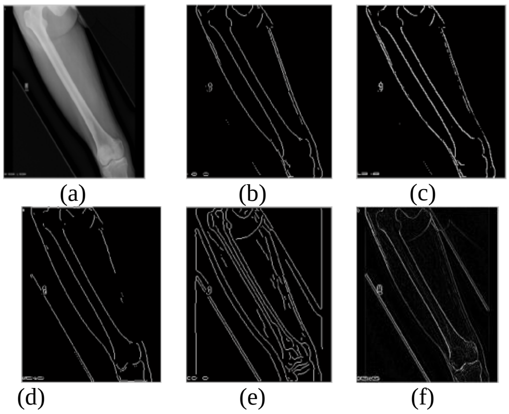

Fig. 5: (a) Original X-Ray input image and corresponding resultant edge detected images by using (b) Roberts, (c) Sobel, (d) Prewitt, (e) Canny, and (f) Laplace second order difference operators.

The Sobel operator is slower than the Roberts operator. It's larger convolution kernel smoothes the input image to a greater extent and hence makes the operator less sensitive to noise. From the Fig. 5(c), we observe that lower head of the femur is not clear as compared to that obtained by Prewitt operator (Fig. 5(d)). Thus, performance of the Sobel operator is poorer than Prewitt operator. Prewitt edge detection operator gives better result for less noisy images. But it fails to give good results for poor quality and more noisy images, which makes it difficult to detect the edges of the bone in normal bone structure and the fractured bone. In the resultant image of the Canny edge detection operator (Fig. 5(e)) spurious edges also occur, which makes clear differentiation between bones, muscles and other structures difficult. The experimental results show that the edges of the femur bone are more clearly detected without any discontinuity by using Laplace second order difference operator as compared to the other methods. These results gain significance in view of the forensic investigation of fractured bones, in which the fracture type and extent give clues about the possible cause of the fracture.

4 CONCLUSION

In this paper, we have examined the performance of Laplace operator in comparison with other edge detection methods in the literature, namely, Roberts, Sobel, Prewitt, and Canny's operators, which are applied to the X-ray images of femur bones. From the experimental results, it is observed that the Laplace operator gives better edge detection results than the other methods in the investigation of X-ray images of femur bones, which has significance to medical and forensic experts.

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