ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 2, Issue 5, November 2012

A Comparative Study on Edge Detection Algorithms for Computer Aided Fracture Detection Systems

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*Abstract— **X-Ray is one the oldest and frequently used devices, as they are non-invasive, painless and economical. A bone x-ray makes images of any bone in the body and a typical bone ailment is the fracture, which are cracks in bones. Detection and correct treatment of fractures are considered important, as a wrong diagnosis often lead to ineffective patient management, increased dissatisfaction and expensive litigation. An automatic fracture detection system consists of three main steps, namely, preprocessing, segmentation and fracture detection. During segmentation and fracture detection, one important algorithm used is an edge detector to identify edges, which are the boundary between an object and the background, and indicates the boundary between overlapping objects. Owing to the important role played by edge detectors, this paper compares the various traditional edge detectors available, namely, canny, sobel, prewit, Log and Roberts. Experiments were carried out to analyze their performance and suitability for detecting edges in x-ray images**.*

***Index Terms*— X-Ray Images, Preprocessing, Fracture Detection, Edge Detection Algorithm.**

I. INTRODUCTION

Medical image processing is a field of science that is gaining wide acceptance in healthcare industry due to its technological advances and software breakthroughs. It plays a vital role in disease diagnosis and improved patient care and helps medical practitioners during decision making with regard to the type of treatment. Several state-of-the-art equipments produce human organs in digital form. Examples of such devices include X-Ray, Computed Tomography (CT), Magnetic Resonance Imaging (MRI), Ultrasound (US), Positron Emission Tomography (PET) and Single Photon Emission Computed Tomography (SPECT). Out of these, X-Ray is one the oldest and frequently used devices, as they are non-invasive, painless and economical. A bone x-ray makes images of any bone in the body, including the hand, wrist, arm, elbow, shoulder, foot, ankle, leg (shin), knee, thigh, hip, pelvis or spine [8]. A typical bone ailment is the fracture, which occurs when bone cannot withstand outside force like direct blows, twisting injuries and falls. Fractures are cracks in bones and are defined as a medical condition in which there is a break in the continuity of the bone. Detection and correct treatment of fractures are considered important, as a wrong diagnosis often lead to ineffective patient management, increased dissatisfaction and expensive litigation. The importance of fracture detection comes from the fact that in clinical practice, a tired radiologist has been found to miss fracture cases after looking through many images containing healthy bones [1]. Computer detection of fractures can assist the doctors by flagging suspicious cases for closer examinations and thus improve the timeliness and accuracy of their diagnosis. Moreover, tibia fractures are the subject of ongoing controversy and discussion. Despite newer innovations, automatic detection of tibial fractures essentially remains unresolved as these injuries are different and variable in presentation and their outcomes are unpredictable [2]. An automatic fracture detection system consists of three main steps, namely, preprocessing, segmentation and fracture detection. Preprocessing consists of procedures that enhance the x-ray input image in a way that its result improves the fracture detection process. The segmentation process consists of two steps. The first step separates the bone structure from the x-ray image and the second step identifies the diaphysis region from the segmented bone structure. The third step, that is, Fracture Detection determines the presence or absence of fracture in the segmented image. In fracture detection applications, detecting a fracture accurately is often a difficult and challenging task. Today, a large number of X-Ray images are interpreted in hospital and computer aided system that can perform some intelligent task and analysis is needed in order to raise the accuracy and bring down the miss rate in hospital. During segmentation and fracture detection, one important algorithm used is an edge detector to identify edges, which are the boundary between an object and the background, and indicates the boundary between overlapping objects [6]. In fracture identification systems, using the edge details, the bone region can be extracted efficiently during segmentation process and fractures can be identified efficiently during detection process. Usage of edge detection reduces the amount of data to be processed and filters out non-relevant information, while preserving the important structural properties of an image. If the edge detection step is successful, the subsequent tasks of fracture detection may be substantially simplified. Owing to the important role played by edge detectors, this paper compares the various edge detectors available and analyzes their suitability for x-ray images. The rest of the paper is organized as follows. Section II presents the edge detecting algorithms considered for comparison in this study. Section III presents the results of

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 2, Issue 5, November 2012

the edge detectors when used with x-ray images. Section 4 concludes the work with future research directions.

II. EDGE DETECTION ALGORITHMS

Edges form the outline of an object and when efficiently identified can locate all the objects in an image. Moreover, basic properties such as area, perimeter can be measured easily. The edge of a bone structure is one of the most meaningful parts used during extraction from background. The frequently used edge detectors are Sobel, Prewitt, Roberts, Canny and Laplacian of Guassian (LoG) algorithms. These are implemented as a series of image convolutions by using variable weight in the convolution kernel. The performance of these detectors depends upon the application being proposed. Another fact is that before edge detection, the proposed preprocessing phase performs a smoothening step and enhances the edges. In this work, the CLAHE algorithm [3] is used for this purpose. Edge detection process involves small kernels to convolve with an image to estimate the first-order directional derivatives of the image brightness distribution. Kernels are pre-defined group of edge patterns to match each image segments of a fixed size. The edge value is calculated by forming a matrix centered on each pixel. If the value is larger than a given threshold, then the pixel is classified as an edge. All the gradient-based algorithms have kernel operators that calculate the edge strength in directions which are orthogonal to each other, commonly vertically and horizontally. The contributions of the both components are combined to give the total value of the edge strength. The kernel used by different classical edge detectors are given below. Edge detection algorithms are grouped into two categories, namely, Gradient operator and Laplacian operator [4]. Gradient operator detects edge pixel by obtaining the maximum and minimum value at first derivative level on the image. Equation (1) calculates the gradient operator, Δ, and its application on vector I.

$$\Delta = \left(\frac{\partial}{\partial r}, \frac{\partial}{\partial c}\right) \quad \Delta I = \left(\frac{\partial I}{\partial r}, \frac{\partial I}{\partial c}\right) \qquad (1)$$

The ΔI can then be used to find the value of the gradient magnitude |ΔI| and orientation ϕ of the image. The gradient magnitude shows the strength of an image edge and gradient orientation shows the edge pixel orientation. The classical gradient operators selected in this work are Sobel, prewitt, Robert, Canny [5][9]. Laplacian Operator is a second order derivative, where the value of edge pixel at the first derivative is referred to as zero-crossing at second order derivative. The disadvantage of this operator is its sensitive feature towards noise effect. In solving this problem, Gaussian function is being applied on the image. This is terms are Laplacian of Gaussian (LoG). The operators are explained below.

A. Sobel Operator

Sobel Operator was discovered by Irwin Sobel. It uses a 3x3 convolution mask which is the x and y direction on the image. It is discovered at first derivative level. The horizontal and vertical pixel masks for Sobel Operator are shown in Figure 1

-1	0	1
-2	0	2
-1	0	1

g^1

(a)

1	2	1
0	0	0
-1	-2	-1

g^2

(b)

Fig 1: Sobel Operator

The mask will be moved until all the images and each value, R, will be kept into an output array, which is located at the mask centre. The formula to find the gradient magnitude is Equation (2).

$$|G| = |G_x|\,|G_y| \qquad (2)$$

Where G_x and G_y are given by the formulae (3) and (4).

$$G_x = (a_2 + ca_3 + a_4) - (a_0 + ca_7 + a_6) \qquad (3)$$

$$G_y = (a_0 + ca_1 + a_2) - (a_6 + ca_5 + a_4) \qquad (4)$$

Where c is a constant with a value 2.

Fig 2 shows the neighborhood pixels that describe sobel operator concept.

a_0	a_1	a_2
a_7	i, j	a_3
a_6	a_5	A_4

Fig 2: Neighborhood Pixel Describe Sobel Operator Concept

B. Prewitt operator

Prewitt Operator is pioneered by Judy Prewitt [7] and is based on the central difference concept and is given by

$$\frac{\partial_I}{\partial x} \approx [I(x+1, y) - I(x-1, y)/2] \qquad (5)$$

This will produce a convolution mask (Figure 3),

-1	0	1

Fig 3: Convolution Mask

Prewitt Operator is much more sensitive to noise effect. Thus, averaging process will be used to solve the noise problem. The convolution mask for Prewitt Operator have been implemented after averaging process at x and y axis for δ/δx and δ/δy. The equation for Prewitt Operator and Sobel Operator is quite similar except for the value of constant c=1.

ISSN: 2277-3754
ISO 9001:2008 Certified
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C. Robert Operator

Robert Cross Operator uses 2x2 convolution masks. It uses {+1,–1} operator that will calculate the value

$$I(\bar{x}_i) - I(\bar{x}_j) \qquad (6)$$

for (i,j) pixel at environs pixel. Mathematically, this equation is known as "forward differences".

$$\frac{\partial I}{\partial x} \approx I(x+1, y) - I(x, y) \qquad (7)$$

Convolution mask of Robert Cross Operator is illustrated in Figure 4.

+1	
	-1

g^1

	+1
-1	

g^2

Fig 4: Convolution Mask Using Robert Cross Operator

Calculation for gradient magnitude is given as:

$$G = \sqrt{(g_1 * f)^2 + (g_2 * f)^2} \qquad (8)$$

D. LoG Operator

The Laplacian L(x,y) of an image with pixel intensity values I(x,y) is given by:

$$L(x, y) = \frac{\partial^2 I}{\partial x^2} + \frac{\partial^2 I}{\partial y^2} \qquad (9)$$

Since the input image is represented as a set of discrete pixels, the discrete convolution kernel can approximate the second derivatives in the definition of the Laplacian. Three commonly used small kernels are shown in Fig 5.

0	1	0
1	−4	1
0	1	0

1	1	1
1	−8	1
1	1	1

−1	2	−1
2	−4	2
−1	2	−1

Fig 5 Discrete Approximations to the Laplacian Filter

The application of Gaussian smoothening as a pre-processing step reduces the high frequency noise components prior to the differentiation step. The 2-D LoG function centered on zero and with Gaussian standard deviation σ has the form:

$$LoG(x, y) = -\frac{1}{\pi\sigma^4}\left[1 - \frac{x^2 + y^2}{2\sigma^2}\right] e^{-\frac{x^2+y^2}{2\sigma^2}} \qquad (10)$$

E. Canny Operator

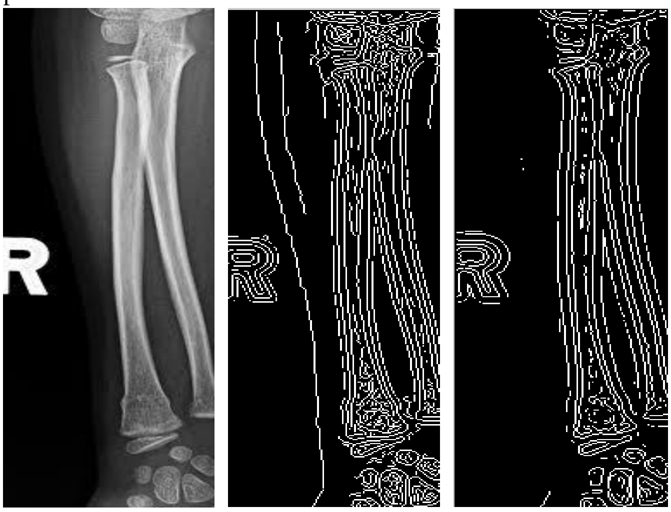
The Canny technique is implemented as five separate steps, as given below.

1. Smoothing: Blurring of the image to remove noise.
2. Finding gradients: The edges should be marked where the gradients of the image has large magnitudes.
3. Non-maximum suppression: Only local maxima should be marked as edges.
4. Double thresholding: Potential edges are determined by thresholding.
5. Edge tracking by hysteresis: Final edges are determined by suppressing all edges that are not connected to a very certain (strong) edge.

The canny edge detector first smoothes the image, to eliminate noise and then finds the image gradient to highlight regions with high spatial derivatives. The algorithm then tracks along these regions and suppresses any pixel that is not at the maximum (non maximum suppression). The gradient array is then further reduced by hysteresis. Hysteresis is used to track along the remaining pixels that have not been suppressed. Hysteresis uses two thresholds and if the magnitude is below the first threshold, it is set to zero (made a non-edge), else it is made an edge. And if the magnitude is between the 2 thresholds, then it is set to zero unless there is a path from this pixel to a pixel with a gradient above T2.

III. EXPERIMENTAL RESULTS

The proposed edge detector was tested with various test images. All the images were 256 x 256 gray scale images. The system was implemented using MATLAB 7.3 and was executed on Pentium IV machine with 512MB RAM. The results obtained are shown in Figure 6 Further, the speed of detecting the edges was also analyzed and results are presented in Table 1.



Original **Canny** **Sobel**

ISSN: 2277-3754
ISO 9001:2008 Certified
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Prewit **LoG** **Roberts**

Fig 6 : Edge Detection Results

From the visual inspection of the images obtained it can be seen that the Canny edge detector is the efficient algorithm in identifying the edges clearly. This was followed by Sobel edge detector. From Table 1, the Roberts method is identified as the fastest algorithm. However while taking into consideration both visual results and speed, Sobel is identified as a suitable algorithm for detecting edges from the x-ray images. Eventhough Canny produced better visual results, the time complexity is high when compared with Sobel. The Sobel edge detector has 69% speed efficiency gain when compared with Canny. This indicates that the Sobel method is more efficient and can enhance other processes, like segmentation, classification, in fracture detection system.

Technique	Time (Seconds)
Canny	4.21
Sobel	1.27
Prewit	1.32
LoG	1.16
Roberts	1.05

Table 1: Speed of Detection (Seconds)

IV. CONCLUSION

This paper analyzed the applicability of five different edge detection algorithms for detecting the edges of X-ray images. The five algorithms considered are the Canny, Sobel, Prewit, Log and Roberts. These algorithms were selected because of their popularity in image analysis systems. Various experiments proved that the Sobel edge detection algorithm is fast and efficient in identifying the edges. In future, methods to speed up the Canny edge detector by combining them with wavelets will be probed. Further, the effect of sobel edge detector on segmentation of bone images from x-ray images will also be taken up.

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