Performance Analysis of Various Edge Detection Techniques in X-Ray Imaging

R Sathish Kumar¹, R Karthikamani²

1 Assistant Professor, Department of Mathematics, Sri Ramakrishna Mission Vidyalaya College of Arts and Science, Coimbatore, Tamilnadu, India.
2 Assistant Professor, Department of Electronics and Instrumentation, Bannari Amman Institute of Technology, Sathyamangalam, Erode, Tamilnadu, India.
rsksrmv@gmail.com, karthikamani@bitsathy.ac.in

Abstract. Edge detection is an image processing method used for discover the limitations of objects within the image. It works by sensing incoherence in illumination. Edge detection is used for image segmentation and data extraction in areas such as image processing, computer vision and machine vision. In these four techniques such as Sobel Operator, Robert Operator, Prewitt Operator, and Canny Operator are used for detection of edge detection in which the canny operator is the most effective manner of finding the edge detection using X-rays. The key aim of this task is to sense human minor leg bone fracture from X-Ray imageries. The suggested structure has two steps namely pre-processing segmentation and fracture detection. Canny method produces very effective image. This paper compares the various edge detection techniques for detecting the bone fracture of lower leg bone and finds effective. The performance of the four segmentation techniques are compared based on the execution time and accuracy. The execution speed of Canny operator is 32.5 seconds and accuracy is 88.7%.

Keywords: X-ray, Sobel Operator, Robert Operator, Prewitt Operator, and Canny Operator.

Introduction

Image processing became a part of this world in every field like medical, etc. It also developed in medical applications to provide analysis of human body. Many digital images has been taken from the patients like X-ray, Computerized Tomography (CT), Ultra Sonography (US), Magnetic Resonance Imaging (MRI). These images are helpful for the diagnosis for physicians and research in medical. It is the very easiest way to know the problem of patient’s body parts and location. Human body consists of 206 bones[1]. The bone fracture is usually detected using X-ray. It is commonly problem in human beings and classified in various ways. They are: prosthetic fracture: weakness of bone, traumatic fracture: due to sustained trauma caused by road accident, fall; pathologic fracture: due to disease, weak the bones caused by osteoporosis[2]. This paper analyse the natural leg bone and fractured leg bone. Edge detection algorithm is used in this paper to detect fracture of leg by using MATLAB software. Classifications of edges based on behaviour are: edge structure, edge orientation and noise environment. To perform edge detection, gradient method and laplacian method are used. Gradient method will detect the edge of image in maximum and minimum at first derivative. It will specify the threshold and finds magnitude of greater intensity in first derivative. Other method is laplacian method, which finds edge in zero crossing at
second derivative. It has one dimensional ramp shape. Common operators used in gradient method are Robert operator, Sobel operator, Prewitt operator, Canny operator and others. These operators are helpful to analyse crack in bone by medical images[3].

1. Block diagram

The figure 1 shows the system flow diagram that has been implemented to get results of fractured bone and normal bone of leg using different algorithms. It is done using MATLAB software for better results. Input image is pre-processed using required filter to remove noise and image segmentation is applied using edge detection operators. Therefore final result is obtained using different operators of non-fractured bone and fractured bone.

![System Flow Diagram](image)

**Figure 1.** System Flow Diagram

2. EDGE DETECTION TECHNIQUES

2.1. SOBEL OPERATOR

This operator has pair of 3x3 matrix convolution and rotated by 90. Based on pixels, it will responds in maximum to edges in vertical and horizontal directions. In each orientation of input image produces separate measurements from each kernels. This will helpful to combine each orientation in magnitude. Device the Sobel method for edges detection, which is created on a 3 by 3 array that is stirred over the main image[4]

\[
\begin{matrix}
-1 & 0 & 1 \\
-2 & 0 & 2 \\
-1 & 0 & 1 \\
\end{matrix}
\]

Gradient magnitude is given by:

\[
|G| = \sqrt{G_x^2 + G_y^2} \tag{1}
\]
Approximate magnitude is,
\[ |G| = |G_x| + |G_y| \]  
(2)

Angle orientation relative to pixel grid is given by,
\[ \theta = \arctan \left( \frac{G_y}{G_x} \right) \]  
(3)

2.2. ROBERT OPERATOR
Robert operator is a two dimensional spatial gradient image measurement. It is simple and compute easy. This operator has pair of $2 \times 2$ matrix convolution kernel. Any of one kernel is rotated in 90. Based on pixels, it will responds in maximum to edges in vertical and horizontal directions at 45. In each orientation of input image produces separate measurements from each kernels. This will helpful to combine each orientation that is in magnitude[5].

Angle orientation relative to pixel grid is given by,
\[ \theta = \arctan \left( \frac{G_y}{G_x} \right) - \frac{3\pi}{4} \]  
(4)

2.3. Prewitt Operator
It is used to detect horizontal and vertical orientation of an image and developed by Judith M. S. Prewitt. This operator has pair of $3 \times 3$ matrix convolution and rotated by 90. Based on pixels, it will responds in maximum to edges in vertical and horizontal directions. In each orientation of input image produces separate measurements from each kernels. This will helpful to combine each orientation in magnitude[6]. The masks are as shown as

\[
\begin{bmatrix}
-1 & 0 & 1 \\
-1 & 0 & 1 \\
-1 & 0 & 1 \\
\end{bmatrix}
\quad
\begin{bmatrix}
-1 & -1 & -1 \\
0 & 0 & 0 \\
1 & 1 & 1 \\
\end{bmatrix}
\]

Gradient magnitude is given by
\[ |G| = \sqrt{G_x^2 + G_y^2} \]  
(5)

2.4. CANNY OPERATOR
This operator was developed by John F. Canny. The noise is identified in images for better analysis. Therefore, canny operator is efficient compared to other operators [7].

1. The canny algorithm shows good detection of real edges in images.
2. The edges detected by this operator appear close to the real image and there is no overlapping of edges.
3. The canny operator does not shows false edges.

The canny algorithm uses five steps to detect the edges:

1. The images are smoothened by removing noise.
2. The edges are found by marking the maximum gradient of the image.
3. Local maxima alone are marked as edges of the input image.
4. Thresholding values are used to determine the potential edges of image.
5. Only strong edges that are connected to a very certain point are marked as final edges.

3. SOFTWARE DESCRIPTION

3.1 MATLAB
The full form of MATLAB is MATrix LABoratory developed by MathWorks. It is a proprietary programming language and multi-paradigm computing environment. MATLAB allows algorithms to implement, data and functions plotting, programming interfaces with different languages like C++, C, Java, Python and user interfaces. It has additional packages, Simulink, graphical simulations and used for engineering, science and economics. Therefore matlab code or simulation can be done to run the program or models for various applications. The file extensions using MATLAB are .m, .mat, .mlx, .rpt. Simulink extension are .mdl, .slx, .mdlp. MATLAB became important for applications like deep learning, computer vision, signal processing, robotics, control systems, image processing, etc.[10]

Features of MATLAB are:

- High level language for numerical computations, application development and visualization.
- Provides interact with environment for designing, problem solving and iterative exploration.
- Mathematical functions and graphics.
- Improve code quality maintain and performance.

Using this software the project is developed for detecting bone in human body from X-ray image as input in SIMULINK.

4. Implementation
The figure 2.1 shows the Simulink model for fractured leg. Various blocks have been used to detect input images.
4.1. Working
The input x-ray image is taken from the hospitals or from internet. The image is uploaded in the MATLAB software. Then the image is pre-processed. The enhancement of input x-ray image is done in this stage, so that output image is obtained with better performance. Noise removal, image enhancement and colour enhancement are the main procedures. The unwanted pixels which affect the quality of image are called noise. Different types of noises are Poisson, Gaussian, salt and pepper, etc. the common type of noise found in x-ray image is Gaussian noise. It is very good to remove noise in image. After removal of noise the brightness and colour of the input image is enhanced to obtain the desired output image [8]. To reduce the processing time the image is converted to grey scale image. The region in which the red, green and blue elements have similar intensity is called ‘grey’ colour region. It contains grey scale values. The input image may contain some defects such as low contrast. These defects have huge impact on the contrast of an image.

The important step to analyse the image and read the data from the image is Image segmentation. Image segmentation is the processes of breaking down the picture to segments or pixels. It is used to identify the edges in an image. The different methods to find edges of an image are:

1. Based on discontinuities in intensity, finding boundaries.
2. By using pixel property thresholds are obtained.

Figure 2. Simulink model for various edge detector operators of fractured leg
3. Regions are found directly. The problem is considered by the image segmentation technique. There is a region based method, which is found by continuity. Depend on some rules, image is divided into sub regions, like same grey scale level and pixel in one region. This technique depends on patterns of intensity values with nearby pixels. Based on anatomical and functional roles the clusters are identified. The simplest way of image segmentation is by finding the threshold. Regions are classified based on range values by using Thresholding techniques. Thresholding is stated as the transformation of input image to an output image. These methods are called as Edge or Boundary based methods. Edge detection is most commonly used technique. Various edge detection techniques used here are Sobel, Robert, Prewitt and Canny. These techniques are discussed above in chapter 3. Median filter is a non-linear filter used for smoothing of image by removing noise in an image. Image segmentation is done by analysing the changes in image intensity [9].

The output from the edge detector is viewed through video viewer. The video viewer 2 is used to view the gray scale image of the input image. The video viewer shows the output of the canny edge detection. The video viewer 1 shows the output of the Sobel edge detection. The video viewer 3 shows the output of the Prewitt edge detection. The video viewer 4 shows the output of the Robert edge detection [11].

5. Result
The results of normal leg and fractured leg images of various edge detection techniques are compared below.

Figure 3.a Normal Leg Image for Grey Scale

Figure 3.b Broken Leg Image for Grey Scale

Figure 4.a Normal Leg Image for Sobel

Figure 4.b Broken Leg Image for Sobel
The above figures show the image results of different edge detection techniques using MATLAB. The figure 3.a and 3.b shows the greyscale image of normal leg and broken leg respectively. The figure 4.a and 4.b shows the Sobel image of normal leg and broken leg respectively. The figure 5.a and 5.b shows the Prewitt image of normal leg and broken leg respectively. The figure 6.a and 6.b shows the Robert image of normal leg and broken leg respectively. The figure 7.a and 7.b shows the Canny image of normal leg and broken leg respectively.
Table 1. Analysis of Accuracy Measures of edge detection Techniques

| Algorithm | Accuracy in % |
|-----------|---------------|
| Sobel     | 88.7          |
| Prewitt   | 78.71         |
| Robert    | 76.19         |
| Canny     | 74.85         |

Table 2. Execution Speed of edge detection Techniques

| Algorithm | Time in Seconds. |
|-----------|------------------|
| Sobel     | 34.9             |
| Prewitt   | 35.26            |
| Robert    | 36.1             |
| Canny     | 32.5             |

From the Table 1 & 2 shows the analysis of accuracy and execution speed for four edge detection techniques. This paper compares the performance characteristics of canny algorithm with other edge detectors such as Sobel, Robert, Prewitt, that are applied to the x-ray image of lower leg bone. Thus canny operator provides better edge detection for bone structure.

7. Conclusion and Future Work
Edge detection is most important stage in pre-processing to obtain an information from the input image. It help to reduce the amount of data that need to be processed and as well as minimize the time for detecting the boundaries. This paper presents the image segmentation technique to detect the bone fracture. The fully automatic detection of fractures is important but also a difficult problem. Here in the four edge detection operators performance is analysed, and compared, which in turn discovered that the Canny operator attains an accuracy of 88.7 %, whereas the accuracy of Sobel, Prewitt, Robert are 78.71%, 76.19%, 74.85% respectively. The edge detection by canny Operator has improved performance over other operators because canny has better noise immunity than other techniques. The future work of this project are ankle fractures, ribcage analysis, spinal cord imaging, analysis of MRI images of brain, tumour detection, edge detection in tissues of plant and animals, and other medical imaging applications may be considered.

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