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EDGE DETECTION OF THE SCOLIOTIC VERTEBRAE USING X-RAY IMAGES

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Abstract

Bones act as a mineral storage reservoir for calcium and phosphorus. Proper well grown bones give a perfect posture to the human body. In other case, if the bone has an improper growth, it might lead to an abnormal posture or an awkward posture. Scoliosis is a condition where the scoliotic vertebrae are wedge shaped and differ with the shape of normal vertebrae. Treatment for scoliosis depends on Cobb angle which can be measured using spine X-rays. Recent development in the medical imaging techniques brought us to a new research area in image processing which includes medical image enhancement, detailed visualization of internal organs & tissues and edge detection. Bone edges are important feature in an X-ray image. The purpose of application of segmentation in medical imaging is to develop a detailed framework on human anatomy, whose primary objective is to outline the anatomical structures. Whereas edge detection is a technique which extracts vital features like corners, lines, angles and curves from an image. In this study, we are going to deal with the edge detection technique on scoliotic vertebrae. The objective of this paper is to compare the performance of edge detectors using filters and operators.

Keywords: X-rays, Scoliosis, Cobb angle, Edge detection.

1. Introduction

Bones are the basic blocks of human body [1]. It gives the shape and structure to our human body. Bone density depends on several variables. They are: Age, Gender, Location in the body, its Mineral content, Water and Diseases. These variables are inter-related to each other. For instance, mineral content and density will vary depending on the bone's location in the body. As humans get old, their bones become osteoporotic. Their strength decreases, which means they are more susceptible to fracture. Osteoporosis is a disease which leads to a decrease in bone mass. It is mostly found in geriatrics patients. Bone is considered to be a responsive material. The formation and resorption of bone occur in a cyclic manner. Our body responds to different stress levels from different parts of the body in different areas of bone to ensure that, the right amount of healthy tissues of bone is present, so that the bone can be continuously reshaped.

A stress of 25–40 MPa is sufficient to maintain the correct levels of bone [1]. If the bone is under stress for a prolonged duration, bone formation and resorption process is disturbed and leads to wastage in bone tissues. Due to this, bones become thinner. This can be an issue for patients who are bedridden for a long duration and with the astronauts after a long stay in the space. Similar effect occurs during osteoporosis too. In osteoporosis osteoblast gets reduced, leading to thinner and weaker bones. Whereas scoliosis is a deformity, in which mal alignment of vertebral bones and improper stress distribution (trabecular system) lead to wedge shaped vertebrae.

The objective of this study is to do edge detection in patients with scoliotic vertebrae using x-rays. In early stages of image processing, identifying any features in an image that are relevant to estimating the structure and properties of the objects in that image was the primary motive. Edges are a significant local change in an image. Edges are one such feature which typically occurs in the boundary between two different regions or colours in an image. Edge detection method is the first step in recovering information from images. The importance of edge detection is that it can help in predicting and comparing the bone density of the scoliosis patients before operation and after operation [2, 3]. Due to its importance, edge detection continues to be an active research area [4]. Hence, this study will be helpful to understand and identify the edge detection methods in x-rays.

Edge detection is an image processing technique, mainly used for finding the boundaries of objects, within the different regions in the image. It works by detecting the discontinuation in the brightness of the image and the boundaries of objects in a scene. In an image, an edge is a curve that follows a path of rapid change in image intensity. Edge detection is used to identify the edges in an image. Discontinuities in the image intensity can be either step or line discontinuities. In step discontinuities, the image intensity abruptly changes from one value on one side of the discontinuity to a different value on the opposite side. While in the line discontinuities, the image intensity abruptly changes value but then returns to the starting value within some short distance. However, step and line edges are rare in real images. Because of low-frequency components or the smoothing introduced by most sensing devices, sharp discontinuities rarely exist in real signals. Step edges become ramp edges and line edges become roof edges, where intensity changes are not instantaneous but occur over a finite distance. Illustrations of these edge profiles are shown in Fig. 1.

2. Review of Literature

2.1. Edge detection on X-rays

Several studies were done to find the edge detection of an image. Certain studies were done on the X-ray images too. Priya et. al. conducted a study on X-ray image acquisition and analysis. They used edge detection techniques for various dental X-rays [5]. Mahendran did a study on edge detection algorithms for computer aided fracture detection systems, where, he analyzed the applicability of five different edge detection algorithms for detecting the edges of X-ray images [6]. Shubhangi et. al. conducted a study on edge detection of femur bones in X-ray images. It was a comparative study of edge detectors [7]. Stolojescu-Crisan from Politehnica University of Timisoara done a study on edge detection techniques for X-ray image segmentation on hand X-rays [8]. Kudale and Pawar conducted a study on analysis of various edge detection methods for X-ray images [9].

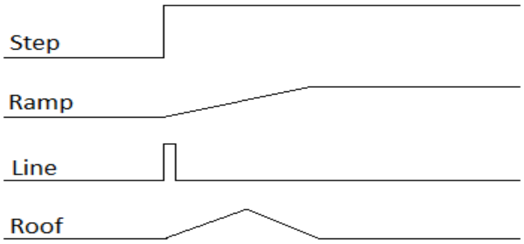

Fig. 1. Types of edge profiles.

2.2. Cobb angle detection

Sardjono et. al. conducted a study on automatic Cobb angle determination from radiographic images [10]. Lenka et al. done a study on Cobb angle quantification for scoliosis using image processing techniques, where they found the Cobb angle using different filters and though transform [11].

3. Methods

Subjects with history of scoliosis in the age group between 10 to 25 years were selected. Informed consent was obtained prior. Baseline assessment like age and sex were noted for all the subjects participated in this study. After the baseline assessment, X-rays were obtained from the patients, for edge detection. These algorithms have been coded in order to detect the edge of the X-ray images of spine. There are several methods to detect the edge of the X-ray images of spine using the gradient method. In this study different types of edge detection methods like Sobel operator, Prewitt operator, Robert operator, Log operator and Canny operator were used to analyze X-ray images. Original image is shown in Fig. 2.

Fig. 2. Original X-ray image.

3.1. Sobel operator

The Sobel operator uses a 3 × 3 convolution, which is the x and y direction of an image. It is discovered at the first derivative level. The horizontal and vertical pixel masks for Sobel operator is shown below. The Sobel operator calculates the opposite of the gradient of the input image. The formula to find the gradient magnitude is:

$$|G| = |G_x|\ |G_y| \quad (1)$$

where G_x and G_y are given by the formulae:

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

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

where c is a constant with a value 2. The horizontal and vertical pixel masks for Sobel operator is given below:

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

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

Edge detection is applied to Fig. 2 using Sobel operator. The algorithm of the edge detection must include grey scale function to convert the colour image to grey scale before proceeding to edge detection to avoid any occurrence of error.

3.2. Prewitt operator

Prewitt operator is a discrete differentiation operator, which computes an approximation of the gradient of the image. It is based on the central difference concept. Prewitt is more sensitive to noise effect. The properties of Prewitt operator are similar to Sobel operator. Prewitt operator is similar to Sobel operator except that the constant c = 1. The convolution mask of Prewitt operator is given below:

-1	**0**	**1**
-1	**0**	**1**
-1	**0**	**1**

1	**1**	**1**
0	**0**	**0**
-1	**-1**	**-1**

Prewitt operator is based on the central difference concept and is given by:

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

3.3. Robert operator

Robert operator uses 2 × 2 convolution mass. It uses (+1, -1) operator that will calculate the value for (i, j) pixel. Robert 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 neighboring pixels. Robert operator provides a simple approximation to the gradient magnitude. The gradient can be defined as:

$$\nabla I(u,v) = G(u,v) = \sqrt{Gu^2 + Gv^2} \quad (3)$$

where $I(u, v)$ is a point in the original image, $G_u(u, v)$ is a point in an image formed by convolving with first kernel and $G_v(u, v)$ is a point in an image formed by convolving with the second kernel. The convolution mask of Robert operator is given below:

1	**0**
0	**-1**

0	**-1**
1	**0**

3.4. Laplacian of Gaussian (LOG)

The Laplacian of Gaussian (LOG) filter is used to filter out the noise in the image. LOG is used as an enhancement to the image. Enhancement is done by transforming edges into zero crossings. This is done by using 3x3 mask. Detection is done by finding a zero crossings. The Laplacian $L(x, y)$ of image with pixel intensity values $I(x, y)$ is given by:

$$L(x, y) = \partial^2 I / \partial x^2 + \partial^2 I / \partial y^2 \quad (4)$$

Three commonly used small kernels are shown below

0	**1**	**0**
1	**-4**	**1**
0	**1**	**0**

-1	**2**	**-1**
2	**-4**	**2**
-1	**2**	**-1**

1	**1**	**1**
1	**-8**	**1**
1	**1**	**1**

3.5. Canny operator

Canny edge detection method is a more robust gradient based edge detection algorithm. The canny edge detector is the first derivative of a Gaussian and closely approximates the operator that optimizes the product of signal to noise ratio and localization. In canny, edge detection is done on 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. Finally, the edge strength of each edge pixel is set to zero if its edge strength is not larger than the edge strength of the two adjacent pixels in the gradient direction. The remaining pixels after this process are labeled as candidate edge pixels.

4. Results and Discussion

In Figs. 3, 4 and 5, the Sobel, Prewitt and Robert operators were used to detect the edge of the image. Prewitt operator is basically a discrete differentiation operator which involves in evaluating an approximation of the gradient in the scene. By comparing the results from Figs. 3, 4 and 5, it is clearly seen that the difference in these three figures are minor. That being said, the properties of the Prewitt operator is close to the Sobel operator which resulting the edges that can be detected in both horizontal and vertical direction. On the other hand, Figs. 6

and 7 delivers a better edge detection image with corresponding to the previously discussed Sobel, Prewitt and Robert operators.

Figure 6 refers to the edge detection using Laplacian of Gaussian filter. Whereas Fig. 7 refers to the edge detection on X-ray spine image using the built-in Canny operator in MATLAB software. When comparing the Figs. 6 and 7, Fig. 7 (Canny) provides more detailed edge detection than the Fig. 6 (LOG). This is because the Canny operator detects a wide range of edges in image using multi-stage algorithm [12-20].

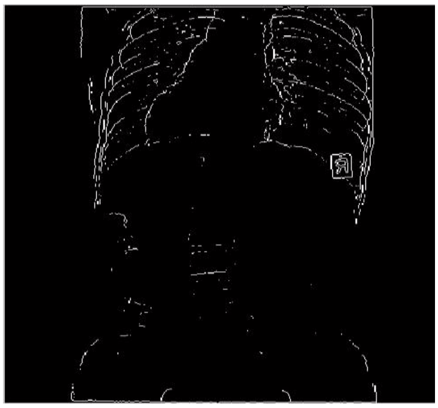

Fig. 3. Edge detection using Sobel operator.

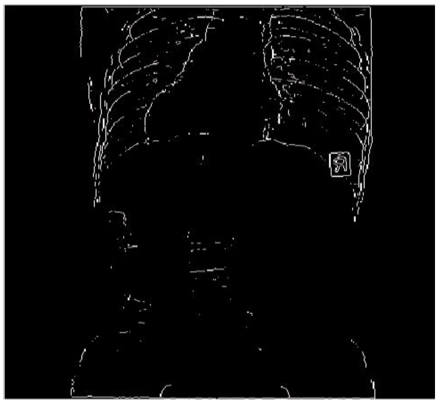

Fig. 4. Edge detection using Prewitt operator.

Fig. 5. Edge detection using Robert operator.

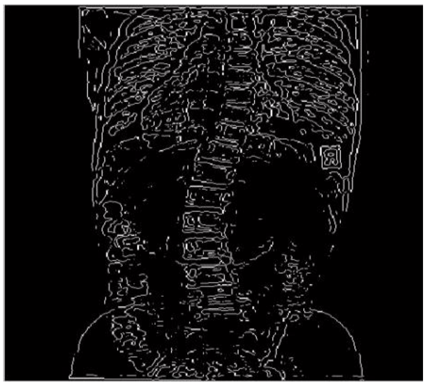

Fig. 6. Edge detection using LOG operator.

Fig. 7. Edge detection using Canny operator.

Images obtained from the edge detectors are converted into histograms and mentioned in *Appendix A* to have a better understanding**.**

5. Conclusions

By comparing the obtained results from different types of operators, the Canny operator clearly has a better advantage in edge detection when compared to the Sobel operator and Prewitt operator as Canny operator has a wider range of detection in edge detection. All the algorithms proposed in this report are simple and easy to implement and at the same time, it increases the efficiency of analysing and synthesizing medical radiographic images. All the above mentioned operators were used and tested on a Spine X-rays only. It is advisable and recommended to the readers that to try these operators on other several types of X-rays.

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Appendix A

Representation of Figures in Histograms

The outcome of the image obtained from the Sobel, Prewitt, Roberts, Laplacian of Gaussian and Canny edge detectors are converted into histograms to have a better understanding**.**

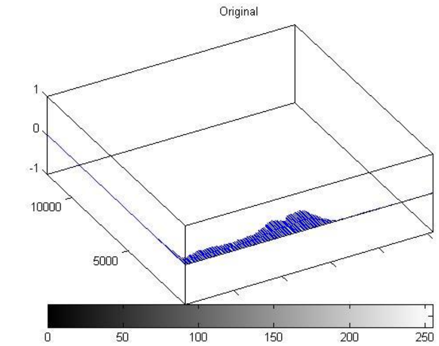

Fig. A-1. Histogram of original image.

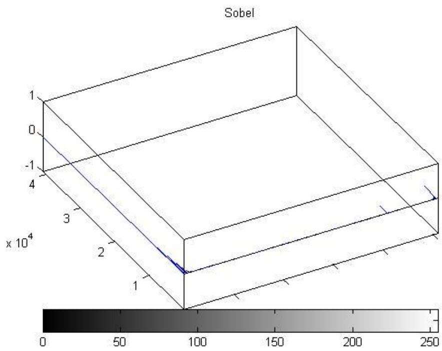

Fig. A-2. Histogram of Sobel output.

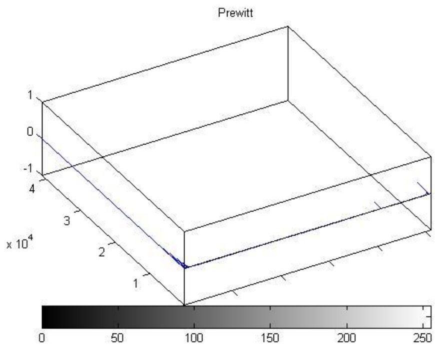

Fig. A-3. Histogram of Prewitt output.

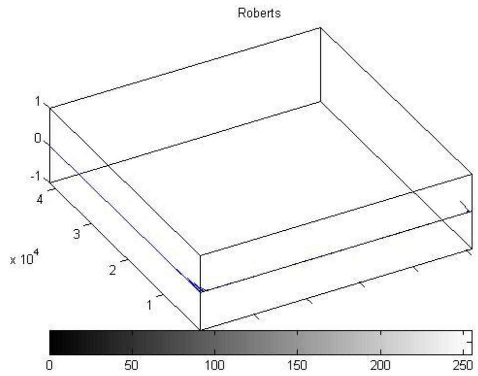

Fig. A-4. Histogram of Roberts output.

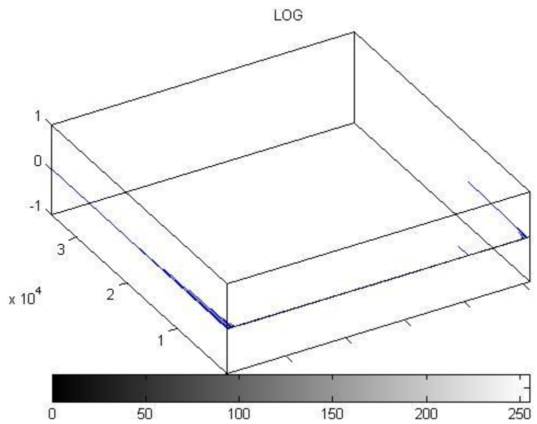

Fig. A-5. Histogram of LOG output.

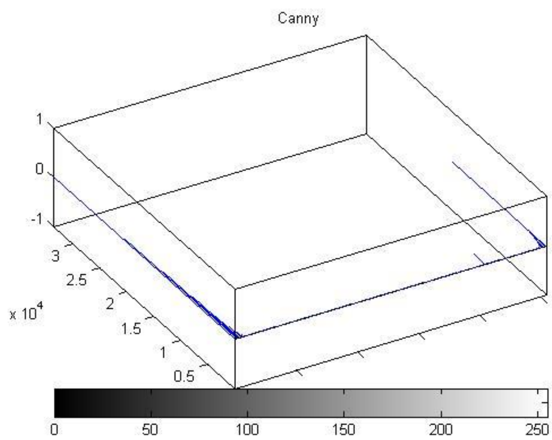

Fig. A-6. Histogram of Canny output.