Measurement of Spinal Curvature for Scoliosis Classification

Sinta Kusuma Wardani 1), Riyanto Sigit 2), Setiawardhana 3), Seffiana Manik Syah Putri 4), DindaAyu Yunitasari 5)
Informatic and Computer Departement
Electronic Engineering Polytechnic Institute of Surabaya
Surabaya, Indonesia
sintakusuma@ce.student.pens.ac.id 1), riyanto@pens.ac.id 2), setia@pens.ac.id 3), seffiana.putri8@gmail.com 4),
dindaayuyunitasari@ce.student.pens.ac.id 5)

Abstract— Scoliosis is a spine disorder phenomenon that makes spine bend and it will form letter C or S. Manual method in determining the curvature of the spine results in a very low accuracy value. This occurs because of the noise present in the spinal x-ray images of patients with scoliosis. The noise can be either organ, blood, or bone that makes the calculation of curvature of the spine to be inaccurate. Therefore in this research the application of scoliosis classification based on the level of curvature of the spine will be made using images processing approach. The spinal curvature classification consists of several processes. The process begins by preprocessing the spinal bone image using the median filter and morphological watershed method. Then it proceeds with features extraction and then the process of classification begins with artificial neural network method. It is expected that the classification of curvature of the spine to be more accurate and can be handled in accordance with its classification. From the experimental system found 0.26 % error for spinal segmentation using watershed.

Keywords— spine; image processing; scoliosis; watershed; artificial neural network

I. Introduction

Scoliosis is an abnormally curved condition of the spine. About 2-4% of the adolescent population has some degree of scoliosis. About 2.2% of these adolescents will require treatment, which consists of observation, orthotic (clamp), or surgical treatment [6].

Treatment decisions for scoliosis patients are based on consideration of the degree of spinal curvature [2]. Currently the process of determining the angle of the spine is still often done manually by orthopedic doctors. The thing that often happens is the measurement results between doctors with one another can be different because there is still a lack of accuracy in the process of determining cobb angle manually[3].

Therefore, in this research will be classified scoliosis based on curvature of the spine. By doing the classification of scoliosis based on bone curvature it will facilitate the doctor in determining treatment decisions to be performed on the patient.

Segmentation is done by using watershed method with x-ray of spinal image of scoliosis patient. Segmentation aims to get a curved spinal image object [7]. After that calculation of curvature of spinal image by using Euclidean Distance method

Artificial Neural Network is one of the methods used in classification[5]. In this study the artificial neural network method is used to classify scoliosis based on the curvature of the spine. This method shows the result of classification according to the desired. There are two stages in the classification by using ANN, are the training phase and the testing stage. At the testing stage, the pattern as input on the ANN produces output which presents what is believed by ANN as the correct output. Nevertheless, for a successful test phase should be preceded by a training phase. At this stage the ANN receives a set of entries corresponding to a set of outputs. In other words, ANN learns to pair the correct outputs to the corresponding input patterns [2].

II. Methodology

To measure the distance of the curvature of the spine, the procedure is load the image, do preprocessing, segmentation and then calculate the distance curvature. A procedure to segmentation and measure the curvature of the spine in this system described by figure 1.

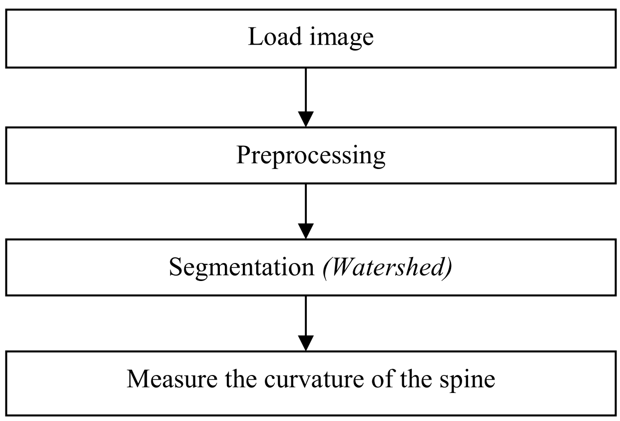

Fig. 1. System Diagram

A. Load Image

In this research the first process is to read the input data from the spinal x-ray image of the scoliosis patient. Figure 2 is a x-ray image of scoliosis patient.

Fig. 2. X-Ray Image

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B. Preprocessing

Preprocessing is process to enhance and improve the image quality of radiology image that have a lot of noise. These are some steps for *preprocessing*:

1) Histogram Equalization

Histogram equalization is a histogram alignment process, in which the gray-degree value distribution in an image is made flat. Histogram equalization also a process where the histogram is leveled based on a linear function (straight line). To be able to do this histogram equalization, needed a distribution function which is overlap from the histogram [4].

The purpose of histogram equalization is to get a histogram equalization so that each degree of gray has the same relative number of pixels. The histogram equalization value is obtained by changing the gray level of a pixel with a new gray degree with the transformation function. The formula of histogram equalization can be represented as:

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$$P_r(r_k) = \frac{n_k}{n}, \text{ when } r_k = \frac{k}{L-1}, 0 \leq k \leq L-1 \qquad (2)$$

result of histogram equalization process can be seen in a Figure 3

(a) (b)

Fig. 3. Comparison between histogram equalization and input image (a) Input image (b) Histogram equalization

2) Median Filtering

After going through the equalization process, the next image is processed by using median filter. Median filtering is a non-linear filter commonly used to reduce noise and can maintain the edge of the image. The median filtering obtained from the original image pixel value is composed from small to large and replaced by the middle pixel value. [12]. The following is the median filter equation:

$$f(x,y) = med_{(p,t) \in Pxy} \{f(p,t)\} \qquad (1)$$

Figure 4 is the result of median filtering process

(a) (b)

Fig. 4. Comparing median filter with input image(a) Input image (b) Median filter

C. Segmentation

Watershed method is the method used to do the segmentation, so that only produce spinal image only. The watershed process begins with the drawing or initialization of watershed points. This point will determine the segmentation area of the image. The system will determine 2 segmentation areas[9]. Area consists of:

1. Area inside the spine
2. Area outside the spine

Image intensity is used as a reference in a watershed algorithm. This intensity will be used to convert images into topography of valleys and mountains. The valley part is a value that indicates low image intensity, while the mountain part indicates that the image intensity is high.

Markers are used to mark the topographical area that will be flooded, as if the marker is the source of the springs of the topography. The water source will flood the valley on the topographical area based on the marker made. Water flows from the lowest point in the topographic area, the water flows to the same height as the other markers. After reaching the same height fill the water together until you see the peak [1]. The result of watershed segmentation represented by figure 5

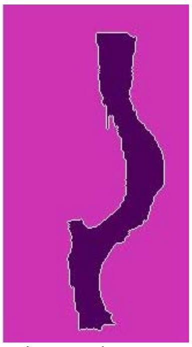


Fig. 5. Watershed Segmentation Result

D. *Crop*

Cropping process serves to remove the remaining noise after segmentation process. The cropping process is taken from watershed segmentation. The watershed output is used as a masking to cut the area in the original image. So obtained the results of cutting the area of the spine. The result of the watershed segmentation of the previous process in convert first becomes gray scale. Then the image will be processed with threshold with binary threshold type. The system will then make the background white to look contrast with the crop object. The image to be cropped and past thresholding is then copied to the prepared background. The result of cropping represented by figure 6.

Fig. 6. Crop Operations Result

E. *Threshold Binary*

Thresholding applied to this system is Binary Thresholding, which is Thresholding with two colors (black and white). The function of thresholding is used to identify and separate the desired object from the background image based on gray level distribution or image texture [11]. The algorithm for binary thresholds is that if the pixel value is smaller than the threshold, the pixel value will be replaced by 0 and if the pixel value in the image is greater than the threshold value, the pixel value will be replaced with the maximum value. Threshold is used to segment the entire spine image [8].The result of threshold binary represented by figure 7.

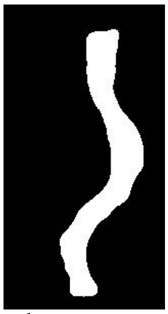


Fig. 7. Threshold Binary Result

F. *Thinning*

One of the thinning algorithms is Zhang Suen. This algorithm is a simple thinning algorithm. First, below is the condition given by Zhang Suen's algorithm:

1. 2 <= N (G1) <= 6
2. T (G1) = 1
3. G2 * G4 * G6 = 0
4. G4 * G6 * G8 = 0
5. 2 <= N (G1) <= 6
6. T (G1) = 1
7. G2 * G4 * G8 = 0
8. G2 * G6 * G8 = 0

The above has presented the conditions given by Zhang Suen's algorithm. Next make a rule, so this rule should be followed. We will use the binary image, where the white pixel as the foreground and the black pixel as the background [10].

G. *Calculate The Curvature of The Spinal Image*

To calculate the curvature of the spine is used distance and standard deviation parameters. First to find the distance used euclidean distance equations and second to find standard deviation used find contour command to find the position value of x from the image then the value is sought standard deviation.

$$s = \sqrt{\frac{\sum (x_i - \bar{x})^2}{(n-1)}} \qquad (3)$$

Where,

s = standard deviation

n = number of samples

$$|Dist| = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2} \qquad (4)$$

Where

x1 = x maximum coordinates

x1 = x minimum coordinates

y1 = y coordinates (0)

y1 = y coordinates (0)

III. Experimental And Result

This section will be explain about the final results of the system. The data used as input for this research were x-ray data of scoliosis patients obtained from the radiology unit of Surabaya Haji Hospital. The results of this study are explained in table form. In Table I is the result of the segmentation process with the watershed method and image cropping. In Table II is a comparison of segmentation results using watershed algorithm and find contour. Next in Table III is a comparison between the results made by the system and manual calculations. From this table shows that the accuracy generated by very high systems is almost close to manual calculation.

TABLE I. WATERSHED SEGMENTATION AND CROPPING

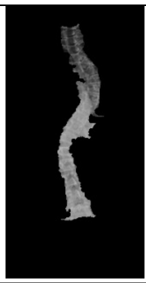
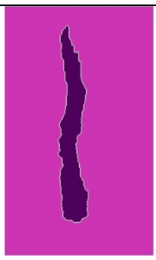
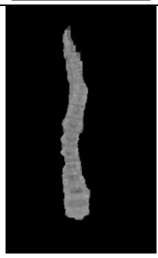
Input	Watershed	Crop
		
		
		

TABLE II. COMPARISON BETWEEN FIND CONTOUR AND WATERSHED METHOD

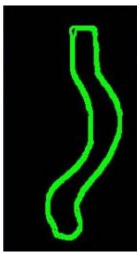
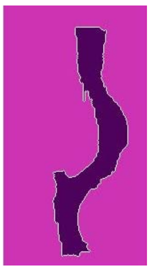
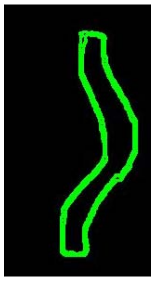
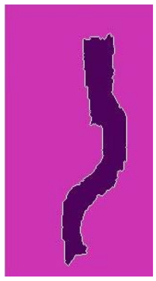
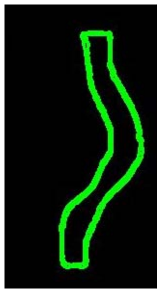
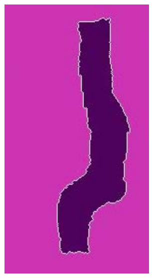
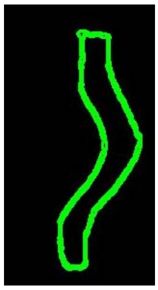
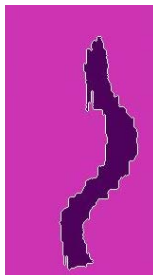
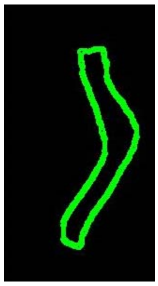
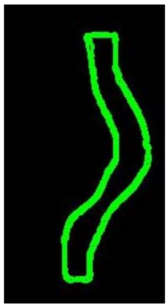
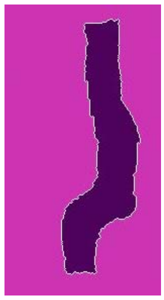
Picture	Filter (kernel)	*Find Contour*	*Watershed*
1.	Median (27)		
2.	Median (37)		
3.	Median (47)		
4.	Gaussian (17x17)		
5.	Gaussian (27x27)		
6.	Median (47)		

TABLE III. DISTANCE CALCULATION

Data	Manually	Watershed	Error
1	5	5.2	0.2
2	4	4.3	0.3
3	3	3.1	0.1
4	4	4.5	0.5
5	10	10.2	0.2
Mean			0.26

IV. CONCLUSION AND FUTURE WORK

The purpose of making this system is for segmentation the spinal image then calculate the curvature of the spinal image to knowing scoliosis classification. Preprocessing is use to enhancement and improve the image quality using Median Filtering and Histogram Equalization. The segmentation using Wateshed. Then to calculate the spinal curvature using Euclidean Distance. This system has a 99.74% presentation of success. For future research, can do optimization by automatically segmentation using watershed algorithms to improve the accuracy of results.

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