A Novel Approach towards X-Ray Bone Image Segmentation using Discrete Step Algorithm

Prafull Sharma[1],   (Assistant Professor) Joshua Madhukar Singh[2]

[1,2]Teerthanker Mahaveer University, College of Engineering
NH-24, Delhi road, Moradabad (Uttar Pradesh), India

Abstract: *The usefulness of image processing as a tool in the quality analysis of Medical images is very much evident and has motivated researchers to carry out new works, leading to the development of new algorithms for better results. X-Ray images are indubitably one of the oldest yet informative ways of analyzing anomaly in bone structures. This paper introduces a new algorithm i.e. discrete step algorithm for X-Ray bone image segmentation, which is successfully tested on multiple X-Ray images obtained from various sources giving comparatively better results. A comparison of results of existing image segmentation techniques such as Watershed segmentation and Otsu's segmentation method has been investigated; along with the results of Discrete step algorithm to corroborate the algorithm.*

Keywords: Otsu's Segmentation, Tibia bone, Watershed segmentation, Thresholding, Discrete step algorithm.

1. INTRODUCTION

One of the oldest and frequently used devices to capture human bones is X-Ray. An X-ray makes images of any bone in the body[2].A new approach in the segmentation of X-Ray image is introduced known a Discrete stage algorithm which gives better results than the watershed & Otsu's algorithm, these are the conventional segmentation techniques. The result of this algorithm is the separated bone structure from X-Ray image. The result is then segmented again to identify the diaphysis region the experimental results prove that the proposed algorithm has significant gain in terms of segmentation accuracy and speed. Image processing has moved into the mainstream wave, not only in the engineering world; but also to the public[4] Magnetic Resonance Imaging(MRI), computed tomography (CT), digital mammography and other imaging modalities are in ever increasing use as critical components in diagnostic techniques[5].
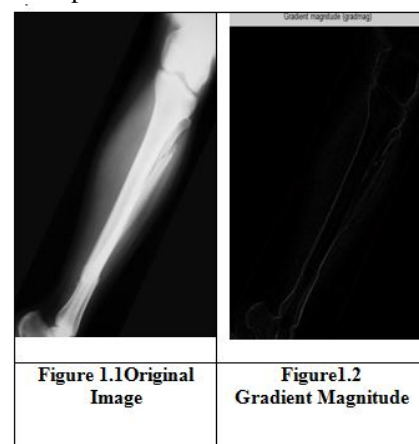
2. WATERSHED SEGMENTATION

The Watershed segmentation is a popular region based segmentation technique. This technique is especially useful in applications where we need to segment two touching objects. Theoretically it looks fine to implement it over X-Ray images where we have to segment tibia and fibula (thinner) bone areas. However, its drawbacks are quite a bit conspicuous when it is practically implemented to segment Bone areas in X-Ray images. The watershed segmentation is known to face over segmentation error

due to irregularities in the gradient of the image to be segmented [1]. The gradient of any image could be understood by following equations.

$$\nabla F(x, y) = \frac{dF}{dx}, \frac{dF}{dy} \;\;\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\; \text{(i)}$$

$$|\nabla F| = \sqrt{\left(\frac{dF}{dx}\right)^2 + \left(\frac{dF}{dy}\right)^2} \;\ldots\ldots\ldots\ldots\ldots\ldots\ldots\; \text{(ii)}$$

Gradient of any image F(X,y) is actually a vector and the coordinates are given by derivative of F in x- direction. Derivative of F in y-direction. According to fundamental calculus the derivative of any sharp change is given by a delta function. This delta function helps in determining the edges within a function. Since, a gradient is a vector so it is obvious that it should be explained in terms of magnitude as well as direction. The magnitude of the gradient value of any image F is given by the above equation. Whenever we move from a point on the edges of the image to any other point lying apart from the boundaries then there is some significant change in the pixel values. The gradient direction is the direction which shows maximum change in the pixel values. The results of Watershed S segmentation over X-Ray image for segmenting bone structure shows the over segmentation error and other problems.

Figure 1.1 Original Image   **Figure1.2 Gradient Magnitude**

In the above figure two images are shown

, **Figure 1.1** is the Original image which is given as input to the Watershed Segmentation Algorithm.

Figure 1.2 Shows the gradient magnitude of the input image giving us the edges and gradients of the image. The gradient magnitude is nothing but the one which is discussed in paper earlier and is given by equation.
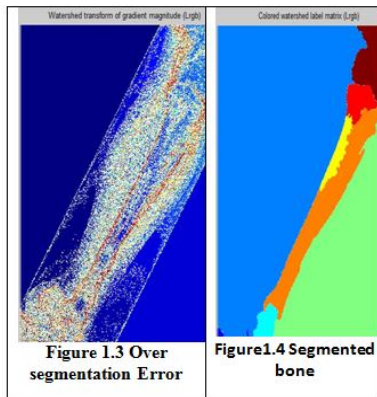

Figure 1.3 Over segmentation Error

Figure1.4 Segmented bone

Figure 1.5 Final Output

Figure 1.3 This figure shows the result of Watershed Segmentation applied directly over gradient magnitude of the image and the resultant output is an over segmented image.

Figure 1.4 This figure shows the label matrix of the segmented image. The Label matrices, such as those produced by watershed and bwlabel, can be converted to true color images for visualization purposes by using label2rgb command in MATLAB.

Figure1.5 Shows the Final output of the Marker controlled Watershed segmentation method; it is obtained by superimposing Lrgb transparently over final image.

3. OTSU'S SEGMENTATION METHOD

Otsu's algorithm depends upon the Histogram of any image over which the segmentation is to be implemented. For each image of the stack, the algorithm determines a threshold by histogram partitioning. The histogram is divided in two classes and the threshold is the value that minimizes the within-class variance. There is no use of spatial coherence, nor any other notion of object structure. Otsu's thresholding method involves iterating through all the possible threshold values and calculating a measure of spread for the pixel levels each side of the threshold, i.e. the pixels that either falls in foreground or background. The aim is to find the threshold value where the sum of foreground and background spreads is at its minimum.

MATHEMATICAL ANALYSIS

$$\sigma_v{}^2(t) = q1(t)\ \sigma_1{}^2(t)\ +\ q2(t)\ \sigma_2{}^2(t) \qquad \ldots\ldots\ldots\ (i)$$

$$. \ q1(t) = \sum_{i=1}^{t} p(i) \ , \ \ q2(t) = \sum_{i=t+1}^{I} p(i)$$

$$\mu1(t) = \sum_{i=1}^{t} \frac{ip(i)}{q1(t)} \ , \ \ \mu2(t) = \sum_{i=t+1}^{I} \frac{ip(i)}{q2(t)}$$

$$\sigma_1{}^2(t) = \sum_{i=1}^{t} [i - \mu1(t)]^2 \frac{p(i)}{q1(t)} \qquad \ldots\ldots\ldots\ldots\ldots(iv)$$

$$\sigma_2{}^2(t) = \sum_{i=t+1}^{I} [i - \mu2(t)]^2 \frac{p(i)}{q2(t)} \qquad \ldots\ldots\ldots\ldots\ldots(iii)$$

$$\sigma_v{}^2(t) = q1(t)\ \sigma_1{}^2(t) + q2(t)\ \sigma_2{}^2(t)\ldots\ldots\ldots\ldots(iv)$$

$$\sigma^2 = \underbrace{\sigma_v{}^2(t)}_{A} + \underbrace{q1(t)\ [1 - q1(t)]\ [\mu1(t) - \mu2(t)]^2}_{B}\ldots (v)$$

The basic idea behind Otsu's method is very simple. We need to minimize the weighted within-class variance. The class variance is given by equation (i) and the threshold which we are looking for is given by **t**. The value of threshold for gray scale image could lie anywhere between 0 to 255. In equation (i) the variables q1 & q2 are the probability of each one of the class. The value p(i) is what we get from histogram i.e., we start from the histogram and we normalize it then we compute the probability for each pixel values in the image. The probability is calculated for class 1 and class 2 then we compute the mean for class 1 and class 2 which is given by µ1 and µ2. On further computation we get the values of variance for both the classes which is given by eq (iii) and eq (iv). These intermediate values are important in calculation of the right threshold value, which if computed wrongly could create a huge variance.

The trivial way of computing the right value is starting with 0 lasting to 255, the lowest noted value is our desired threshold value. eq (v) is a result of some simple algebraic manipulations by we which we could find the total variance which is the sum of A+B i.e within-class and between classes. The threshold could be computed in a recursive way using this equation. In MATLAB this could be done very easily.
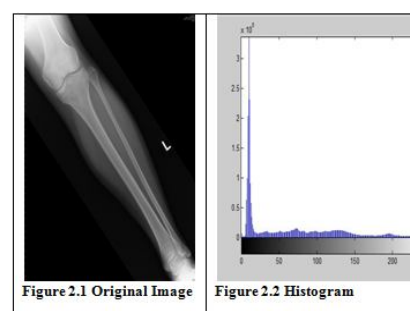

Figure 2.1 Original Image   Figure 2.2 Histogram

, **Figure 1.1** is the Original image which is given as input to the Otsu's Algorithm.

Figure 2.2 Shows the histogram of the image with X axis varying from 0 to 255 .It can be seen that most of the higher intensity pixel values lies between 0 to 50.
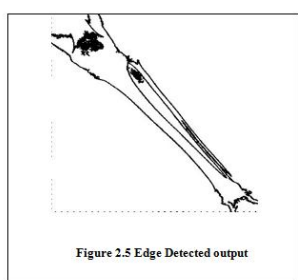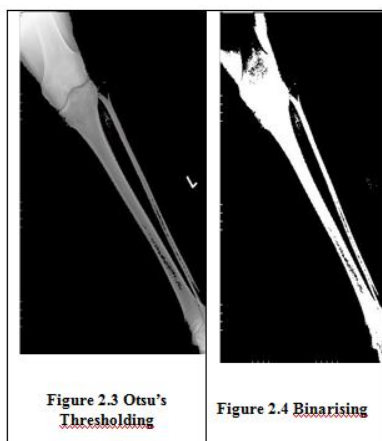

Figure 2.3 Otsu's Thresholding   Figure 2.4 Binarising

Figure 2.5 Edge Detected output

Figure 2.3 Shows the result of Otsu's thresholding this can be achieved by simple command *graythrresh()* in MATLAB.

Figure 2.4 Shows the result of binarization of the thresholded image for segmentation. It can be obtained by simple command *im2bw()* in MATLAB.

Figure 2.5 Shows the Edge detected output of the image.

The results of Otsu's segmentation method can be observed in the above given images. In proceeding section a comparative analysis of Otsu's method, Watershed segmentation method and proposed algorithm is presented.
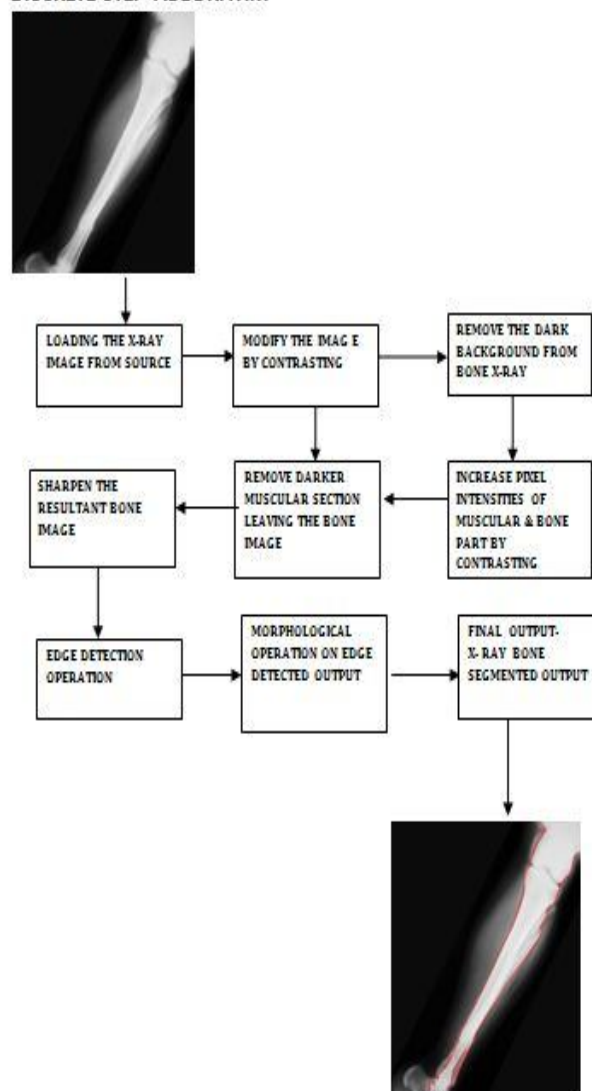
4. DISCRETE STEP ALGORITHM

The proposed algorithm is named as Discrete Step Algorithm because of its step by step approach in segmenting the bone in X-Ray images. As stated earlier, most of the X-Ray images emanate similar features, namely- The darkest area which serves as the background of the image, comparatively lighter emerea which is the muscular section and lightest area which is the bone area. The bone section is the most desirable area or in other words our Region of Interest. Usually medical practitioners seek various kinds of anomaly in bone

structures and analyze them in order to treat the patient accordingly.

In Discrete steps algorithm our main focus is on segmenting the bone area. This is achieved by eliminating the undesired sections of the image, one by one using fundamental image processing techniques. The steps of algorithm are arranged in such a way that first the background area is removed, then the muscular area removed and then all we are left with is the bone area. Some, fundamental image processing concepts such as sharpening, edge detection and morphological operations are then used to get the final segmented image as output.

DISCRETE STEP ALGORITHM

The following steps shows concept of Discrete Step Algorithm-
Step 1- Load the X-Ray image from the source.
Step 2- Perform rgb2gray to convert it in gray scale.
Step 3- Modify the image by contrasting.
Step 4- Remove the dark background from the image. If the pixel value lies in the range of background value the eliminate it. This is done by simple if condition and nested loop to reiterate over each pixel value.

Step 5- Contrast the image to make the lighter bone area more light and darker muscular area darker.

Step 6- Remove the comparatively darker muscular area. If the pixel intensity lies in the range of muscular pixel intensity, eliminate it. This is done by simple if condition and nested loop to reiterate over each pixel value. This step will give the segmented bone image.
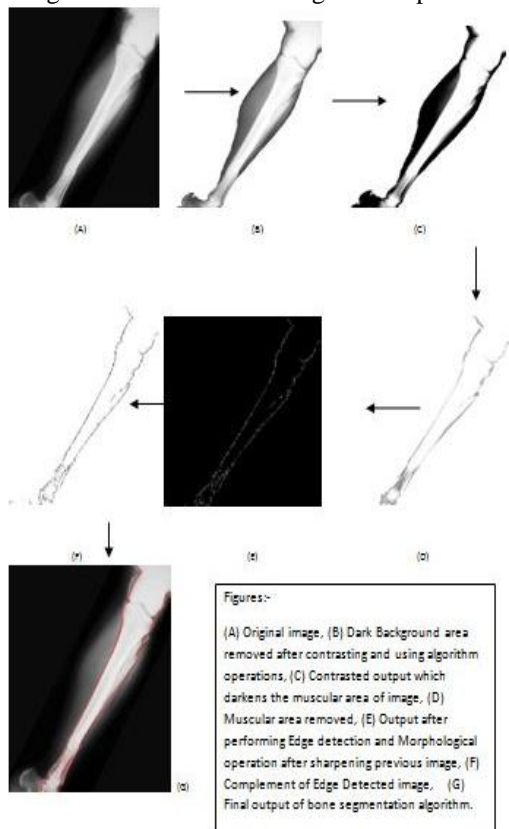
Step 7- Perform image sharpening to get better Edge detected output in next step.

Step 8- Obtain the edges of sharpened segmented image by edge detection

operation.

Step 9 Perform Morphological operations on Edge detected output .

Step 10- Final Output- X-Ray Bone segmented
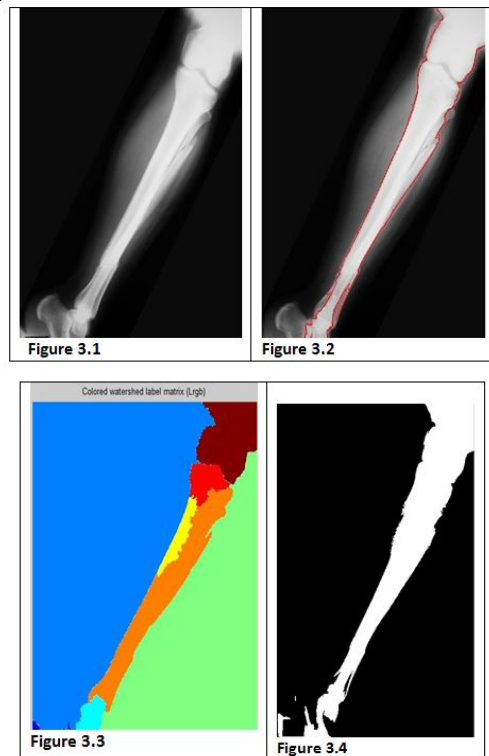 output of Discrete step algorithm.

These steps are implemented in MATLAB and image processing toolbox is used for processing of image. After implementing the algorithm various intermediate results were obtained before getting the final output. Following block diagram shows different stages of output.

Figures:-

(A) Original image, (B) Dark Background area removed after contrasting and using algorithm operations, (C) Contrasted output which darkens the muscular area of image, (D) Muscular area removed, (E) Output after performing Edge detection and Morphological operation after sharpening previous image, (F) Complement of Edge Detected image, (G) Final output of bone segmentation algorithm.

5. COMPARITIVE DISCUSSION OF RESULTS

The image segmentation method discussed above along with the proposed algorithm was tested on various sets of images obtained from various sources. Under this section difference between the results could be observed by seeing the two sets of test images.

Set A-

Figure 3.1

Figure 3.2

Figure 3.3

Figure 3.4

Above figures shows a pictorial comparison of results of various image processing techniques.

Fig 3.1 Shows the original image.

Fig 3.2 Result of Discrete step algorithm.

Fig 3.3 Result of Watershed segmentation.

Fig 3.4 Result of Otsu's thresholding method.

Set B-

Figure 4.1

Figure 4.2

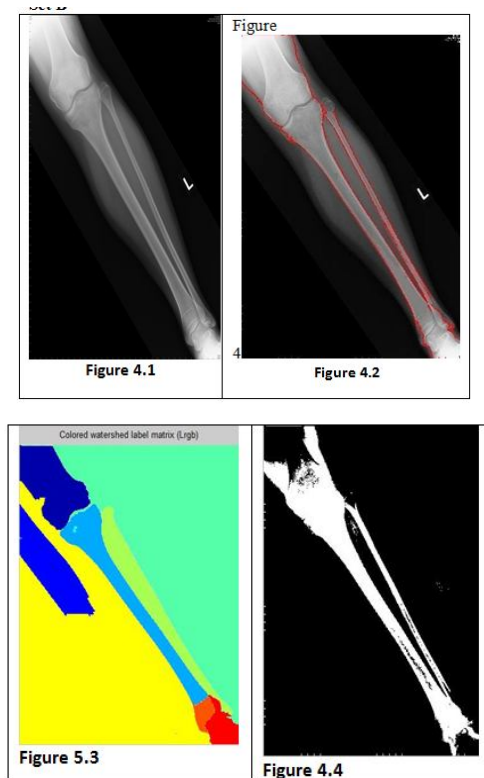Figure 5.3

Figure 4.4

Fig 4.1 Shows the original image.
Fig 4.2 Result of Discrete step algorithm.
Fig 4.3 Result of Watershed segmentation.
Fig 4.4 Result of Otsu's thresholding method.

6. CONCLUSION

The complexities associated with the analysis of X-Ray images make it difficult to analyze them in effective way. An X-Ray image is very much prone to noise and unwanted information hindering the analysis of the real problems in bone structures. Image segmentation is one of the ways of isolating the desired areas from the unwanted areas. However, widely used techniques such as Watershed Segmentation, Otsu's Segmentation techniques are still open to a lot of improvements for making them effective in segmenting desired areas in X-Ray images. The discrete step algorithm provides a quick and efficient method to analyze the abnormalities and problems associated with bone structures. It gives an easy step by step approach in X-Ray image segmentation, which gives better bone segmentation results comparatively; with minimum steps it gives desired results in a matter of seconds when implemented in MATLAB. The incorporated results can be useful for the researchers in their respective area.

References

[1] Nathanael .E. Jacob, M.V. Wyawahare, , *"Tibia Bone Segmentation in X-ray Images A Comparative Analysis"* International Journal of Computer Applications. (0975 – 8887) Volume 76– No.9, August 2013

[2] N.Umadevi, Dr. S.N Geethalakshmi, "Enhanced *Seg-mentaion Method for Bone Structure and Diaphysis Extraction from X-ray Images"* IJCA (0975 –888) Volume 37– No.3, January 2012.

[3] N.Umadevi, Dr.S.N.Geethalakshmi, *"Bone Structure and Diaphysis Extraction Algorithm for X-Ray Images"*, Volume 2, Issue 2, February 2012 ISSN: 2277 128X

[4] Ching Yee Yong, Kim Mey Chew, Nasrul Humaimi," *Image Processing Tools Package in Medical Imaging in MATLAB",* International Journal Of Education and Information Technologies, Issue 3, Volume 6, 2012.

[5] Aditya A. Tirodkar, *"A Multi-Stage Algorithm for Enhanced X-Ray Image Segmentation"* (IJEST), Vol. 3 No. 9 September 2011, ISSN: 0975-5462.

[6] S.K.Mahendran, S.Santhosh Baboo, *"An Enhanced Tibia Fracture Detection Tool Using Image Processing and Classification Fusion Techniques in X-Rays Images"* International Research Journal, Publisher: Global Journals Inc. (USA Volume 11, Issue 14, Version 1.0 August 2011.

[7] **S.**.K.Mahendran, S.Santhosh Baboo, *"Enhanced Automatic X-Ray Bone Image Segmentation using Wavelets and Morphological Operators"* , International Conference on Information and Electronics Engineering IPCSIT vol.6 (2011) ©(2011) IACSIT Press, Singapore.

[8] Amir Shahzad, Muhammad Sharif, Mudassar Raza, Khalid Hussain , *"Enhanced Watershed Image Processing Segmentation "*Journal of Information & Communication Technology, Vol. 2, , No. 1, (Spring 2008) 01-09.

[9] Marcel Krˇcah, G´abor Sz´ekely, R´emi Blanc *"Fully Automatic and fast segmentation of the Femur Bone from 3D-CT images with no shape prior"* .

[10] Matthias Seise, Stephen J. McKenna, Ian W. Ricketts and Carlos A. Wigderowitz *Segmenting Tibia and Femur from Knee X-ray Images"* This paper appeared in Medical Image Understanding and Analysis, pp. 103 – 106, 2005.