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Bone Structure and Diaphysis Extraction Algorithm for X-Ray Images

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Abstract— **Medical imaging systems have been used in various medical application domains like trauma centre, orthopedic, pain management and vascular and non-vascular. One of the oldest and frequently used devices to capture human bones is X-Ray. During the process of identifying fractures, a vital step is the extraction of bone structure from the x-ray image. In this paper, a model that combines multi-resolution wavelets, region growing algorithm and active contour model is proposed to segment the bone structure from the x-ray image. Further a fast Hough transformation is used to extract the diaphysis region from the segmented bone structure. Experimental results prove that the proposed algorithm is efficient both in the manner of segmentation and speed of segmentation.**

Keywords— **Region growing, Contour model, multi-resolution wavelets**

I. 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 and is mainly used to identify ailments in human bones. Tibia (leg) bone fracture is one of the most common injuries encountered in clinical routine and trauma surgery and is still considered challenging as these injuries are different and variable in presentation [2] and their outcomes are unpredictable. In any computer aided fracture detection system, an important step is to segment the bone image (Region of Interest) from the x-ray image before locating the fractured region. Among the various techniques available, active contour-based models have proved to be more efficient. The main challenge while using active contour models for bone segmentation is the initial seed selection. Different initial seed values leads to different segmentation result and incorrect selection often produces inaccurate segmentation. To solve this problem, this paper proposes a model that uses the region growing algorithm [7] to provide initial seeds which are used by the active contour model for efficient segmentation of the bone region from the x-ray image. The proposed method further uses wavelets and morphological operators to enhance the segmentation process. Moreover, a fast hough transformation method is used to identify the diaphysis part of the segmented bone image. The rest of the paper is organized as follows. Section 2 presents the proposed segmentation algorithm. Section 3 presents the experimental results while Section 4 concludes the work along with future research directions.

II. PROPOSED SCHEME

The proposed segmentation scheme extracts the diaphysis using a two-step procedure. The first step 'Bone Structure Extractor (BSE)' identifies the bone structure from the x-ray image and the second step uses the resultant image to extract the diaphysis from the tibia bone structure. The BSE is designed as an amalgamation of image processing techniques. Initially, the BSE algorithm uses a noise removal method [6],[9] to improve the quality of the image. A multi-resolution wavelet transform is used to obtain multi-resolution representation of the enhanced image. The motivation behind using multi-resolution wavelets is as follows. The bone structure in an x-ray images are normally of different sizes. Wavelets have the ability to represent an image at different resolutions; each resolution characterizes different structures of the image. As the resolution gets coarser, it is possible to obtain general context image details of larger structures without complex details. The segmentation process can be simplified by starting the analysis with coarse resolution and then gradually increase the resolution [8]. Additionally, this method has the advantage that it is very close to the method used by Human Visual System (HVS).

The result of wavelet transformation is a set of images at different resolutions, which are segmented using an active contour segmentation [1]. The problem of initial seed selection in active contour segmentation is solved by using region growing algorithm. The steps are given below.

1. Convert the RGB (Red, Green, Blue) colour space to a HIS (Hue, Saturation, Intensity) colour space [4].
2. For each resolution image, determine the maximum and minimum intensity (I Component) and calculate its mean value. Also calculate the standard deviation. Let this be denoted as μ and σ respectively.
3. Calculate the threshold T as $\sigma + 0.2\mu$. The value 0.2 was obtained after performing several experiments and selecting the one which gave optimum result.
4. Mark regions less than T as background and the rest as foreground regions.

The result of the region growing method is then used as initial seeds by the active contour model. The procedure used is given below.

1. Obtain initial contours from region growing algorithm
2. Set the contour shape as circle and obtain the initial assumed distance.
3. At the beginning of each iteration calculate external energy (E_{ext}) with respect to x and y separately.
4. Call level set algorithm
   for all N iterations do
      Find shortest traveling time from a point x to boundary
      Estimate Energy (E_{ext}) and calculate Partial Differential Equation
      Determine distance, curvature terms, gradient, speed
      Update level set function
      if Iterations ≤ N then
         Reinitialize seeds
         Calculate change and record in Contour
      end
   end
5. Display Segmented image

The result of the above algorithm is the separated bone structure from the x-ray image. This result is then segmented again to identify the diaphysis region. The approach used for this purpose is the same as [3]. In this method, a Hough transformation is used to identify peaks. In the proposed framework, the traditional Hough algorithm is replaced by a fast Hough transformation [5] to optimize the speed of the algorithm. The two-step process of the proposed method reduces the time complexity of automated fracture detection system by removing regions that do not need attention during diaphysis fracture detection. Further, the actual process of segmentation is easy to implement and simplifies tedious tasks. The algorithm is consolidated in Fig.3.

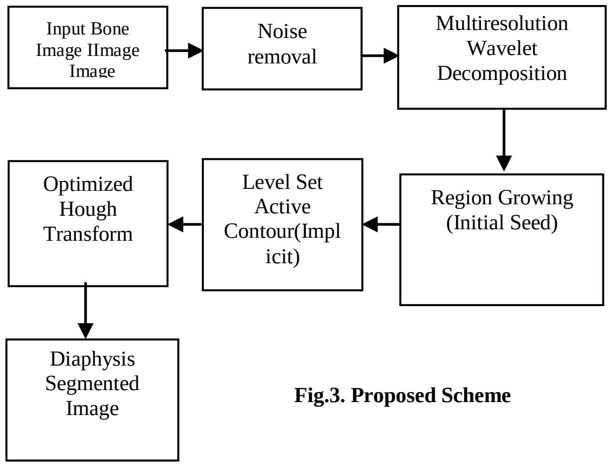


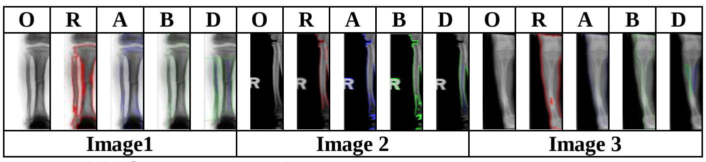
Fig.3. Proposed Scheme

EXPERIMENTAL RESULTS

Several experiments were conducted to analyze the performance of the proposed segmentation algorithm. The experiments were conducted on a dataset containing 25 x-ray images containing both fractured and normal bones. Fig.4 shows the segmentation results for three sample images selected randomly from which it could be seen that the proposed BSE algorithm produces better segmentation results than the traditional region growing and active contour algorithms. Execution speed is another performance metric that is used to analyze the performance of the algorithms. The results obtained are shown in Table 1 and it is evident that the BSE algorithm produces quick result when compared to the traditional region growing and active contour segmentation models. Thus, the experimental results prove that the BSE algorithm is an improved version than the traditional algorithms and can be used to segment bones from x-ray images. These promising results further prove that it can be used by any computer aided fracture detection systems.

TABLE 1 : Segmentation Time (Seconds)

Image	Region	Contour	BSE
Image1	14.62	15.98	13.64
Image2	13.56	15.26	13.16
Image3	14.81	16.18	13.99



O – Original Image; R – Region Growing; A – Active Contour; B – BSE; D – Diaphysis

Fig. 4. A Visual Comparison

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IV CONCLUSION

This paper introduced a segmentation model that segments the bone structure and diaphysis region from a x-ray image. The BSE algorithm used wavelet decomposition, region growing algorithm and active contour model in a serial fashion to extract the bone structure from the x-ray image. A fast Hough transformation was used to detect the diaphysis region. The experimental results prove that the proposed algorithm has significant gain in terms of segmentation accuracy and speed. In future, this algorithm will be combined with a fracture detection algorithm to detect and locate the region of fracture.

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