Proceedings of the Second Joint EMBS/BMES Conference
Houston, TX, USA • October 23-26, 2002

Model-based Bone Segmentation from Digital X-Ray Images

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Abstract - **A model-based algorithm for long bone segmentation from digital X-Ray images is introduced. The model is based on statistical variations of anatomical data collected after examining diverse bone shapes. This method extends the centroid to boundary distance shape analysis approach. A bone is modeled by two centroid points, one for each of the two epiphysis, and a range of weighted values for the distances between the centroid and the boundary points. To locate the bone in an image, a strong edge belonging to the boundary of the shape should be present within the calculated ranges after edge detection has been performed. The algorithm is scale and rotation invariant. Preliminary results show that the method can identify complete or partial bones, which makes it applicable to detecting common bone fractures.**

Keywords - **Bone fracture, Image segmentation, Model-based shape extraction.**

1. INTRODUCTION

Anatomical structures in medical images are complex objects with wide range of shape variability. Identification and segmentation of bone boundaries in digital X-ray images is a necessary step of automating the process of bone fracture classification, as well as detecting other bone abnormalities. Manual delineation of these boundaries is very tedious and time consuming. The aim of this paper is to automate this process by utilizing a model-based approach to constrain the search for the bone boundary. The proposed algorithm is based on an enhanced version of the centroid-to-boundary distance approach [1], where a 1-D generation of the boundary of a shape is realized by using the shape centroid and the distances from the centroid to points on the boundary selected so that the central angles are equal. This method works well on circular shapes. However, the more elongated the shape, the more disproportional the distance between each border point is at equal central angles. Nevertheless, a long bone can be modeled as having two circular shapes (epiphysis) connected by two long parallel lines (shaft). Thus, the model introduced uses two centroid points to be selected in proximity with the circular parts. To complte the model, a set of training shapes is resized and rotated to horizontal position, edge detection is performed, and the boundaries are layered over a central point.

2. RELATED WORK

Numerous methods are reported that segments objects from digital X-ray images. Saba et al. [4] applies median filtering with multiple mask sizes, subtraction of median filtered images, thresholding using an iterated optimal algorithm, and postprocessing to remove speckle noise to segment a catheter from an X-ray image. Gunsel and Tekalp [5] match 2D shapes and rank similarity of objects by proposing a metric in eigenshape space which employs the selected boundary and/or contour points as a coarse-to-fine shape representation using *m*x*m* positive-definite proximity matrix to describe the relationship between boundary points of the object. Brown et al. [3] provide a high-level description of relevant anatomy in an anatomical model to which the low-level image objects are matched using image edges. The edges are modeled as curves with expected length position, orientation at the endpoints and edge strength. Behiels et al. [2] proposed a search method based on prior knowledge of the anatomical variation of structures' boundary by improving the search procedure for Active Shape Model (ASM). The position of new target points of the boundary is estimated while incorporating a regularization term imposing smoothness of shape changes by using a minimum cost path search algorithm.

3. PROPOSED APPROACH

In this paper, a knowledge-based model is combined with the centroid-to-boundary distance approach [1] to analyze and segment long bones from digital X-ray. Two centroid points are selected each at both ends of the shaft for detecting the circular parts of the bone. A statistical model is created based on anatomical data. Diverse images are examined and the distances from the two centroid to points on the boundary of the circular parts are measured. The extreme values are recorded and used as a range of possible values; thus, creating a fuzzy set. The approach is scale invariant since coefficients are calculated to represent the proportion of an *initial distance* towards all the rest. The *initial distance* is the distance from the centroid to the end of either one of the parallel lines, shown with dotted line on Fig. 1. This figure also shows in gray the range where a strong edge should be present when searching for this bone. The approach is also rotation invariant, since the *parallel lines* can be detected in any position, the centroid point assigned and the distances extended or shrunk in any direction.

4. PRELIMINARY RESULTS

Two sample test images are presented in Fig 3 and Fig. 4. The first one is for a partial humerus detected by identifying 14 out of 18 edges at the determined ranges of distances from the *centroid*. In Fig.4, no long bone was detected as only 8 strong edges were present. This is a correct decision since these bones represent ribs and no humerus existed in the image.

5. CONCLUSIONS

A model-based approach for long bone segmentation from digital X-ray images is proposed. This method combines an enhanced version of the centroid-to-boundary distance approach with a knowledge-based statistical model to identify and segment the bones. The method can identify partial and complete shape and can be applied to any long bone (containing a shaft) including radius, ulna, femur, tibia and fibula; thus, future work includes analyzing variations of anatomical data and creating models for these bones.

References

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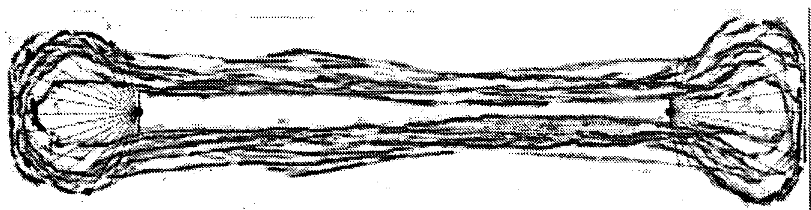

Fig. 1 Anatomical model presenting overlapping diverse humerus shapes to identify extreme values

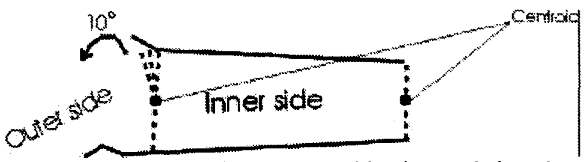

Fig. 2 *Parallel lines* with two centroid points at their ends and closest to perpendicular distance shown dotted

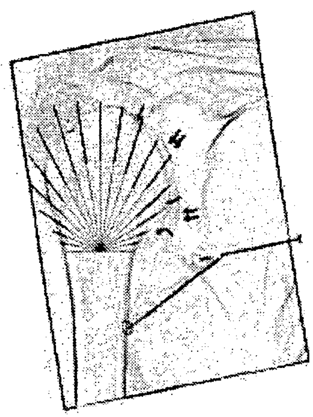

Fig. 3 Partial humerus detected using the proposed approach. The dotted lines show where the range for a strong edge needs to be present.

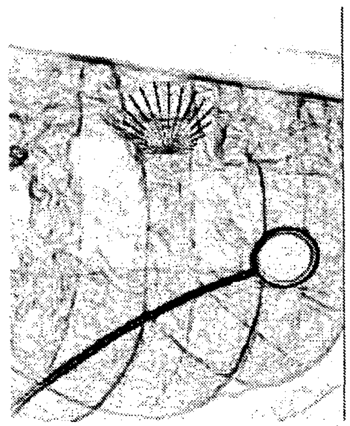

Fig. 4 No humerus detected in this image. The dotted lines show where the range for a strong edge needed to be present.