Feature Extraction of X-ray Fracture Image and Fracture Classification

Zheng Wei, Ma Na
School of Electronic and Information Engineering
Hebei University
Baoding, China
mana1314.love@163.com

Sun Huisheng, Fan Hongqi
The Orthopaedic Department
252 Hospital of PLA
Baoding, China

***Abstract*—X-ray images are the essential aiding means all along in clinical diagnosis of fracture. So the processing and analysis of X-ray fracture images is particularly important. Extracting the features of X-ray images is a very important process in classifying fracture images according to the principle of AO classification of fractures. A proposed algorithm is used in this paper. First, use marker-controlled watershed transform based on gradient and homotopy modification to segment X-ray fracture images. Then the features consisted of region number, region area, region centroid and protuberant polygon of fracture image are extracted by marker processing and regionprops function. Next we use Hough transform to detect and extract lines in the protuberant polygon of X-ray fracture image. The lines are consisted of fracture line and parallel lines of centerline. Through the parallel lines of centerline, we obtain centerline over centroid and perpendicular line of centerline over centroid. Finally compute the angle between fracture line and perpendicular line of centerline. This angle can be used to classify femur backbone fracture.**

Keywords- X-ray image; marker-controlled watershed transform; Hough transform; fracture image; features

I. INTRODUCTION

In clinical, the classifying of bone fracture type by computer automatically may save the diagnosis time and doctor will be liberated from the arduous work.

The fractures of each bone segment according to their morphological characteristics are divided into: types, groups and subgroups. For example, the fractures of femur backbone, they can be classified into three types according to morphological characteristics: simple fracture, wedge fracture and complex fracture. Simple facture can also be classified into three groups: spiral fracture, oblique fracture and transverse fracture. For example: the Fig. 2 (c) is diagnosed as transverse fracture by doctor [1]. In order to classify oblique fracture and transverse fracture, an algorithm based on Hough transform is used to extract the morphological features of X-ray fracture images in this paper.

The Hough transform [2] is a feature extraction technique in image analysis, computer vision, and digital image processing. It is concerned with the identification of straight lines, position of arbitrary shapes, most circles or ellipses. The important case of Hough transform is the linear transform for detecting straight lines. Compared with other algorithms that detecting straight lines, it can be used to find and link segments in an image. The main advantage of the Hough transform technique is that it is tolerant of gaps in feature boundary description and is relatively unaffected by image noise. So we use Hough transform to detect the lines in minimal protuberant polygon of X-ray fracture images that have been segmented. The lines include fracture line and parallel lines of centered line.

Hough transform is using on the binary image, and good segmental result is propitious to extract features, so X-ray fracture image need to be segmented first. In this paper, marker-controlled watershed transform based on gradient and homotopy modification is be used [3].

II. IMAGE SEGMENTATION BASED ON IMPROVED MARKER-CONTROLLED WATERSHED TRANSFORM

The morphological segmentation algorithm of watershed transform based on the operators has been successfully applied to many fields including medical and military. Its advantage is the robustness, that is to say, the segmentation result is independent of the shape or placement of the zones of interest. But, it often results in over-segmentation to use watershed transform directly on an original image [4][5]. In order to segment X-ray images of human body fracture that having low contrast and sharpness, an improved marker-controlled watershed transform is presented in this paper.

Edge extracting of X-ray orthopedic image is improved in the basis of marker-controlled watershed algorithm, and mainly introduce morphological direction gradient algorithm and marker selection algorithm. According to characteristics of morphological structuring elements, the paper proposed use of the four directions of the linear structuring elements calculating direction gradient, so that the representative rate of gradient information also have directional. Marker selection algorithm selects the object markers under gray difference. The morphological directional gradient is modified by means of object markers and background markers that called as homotopy modification. Main procedure of the proposed algorithm is shown as below.

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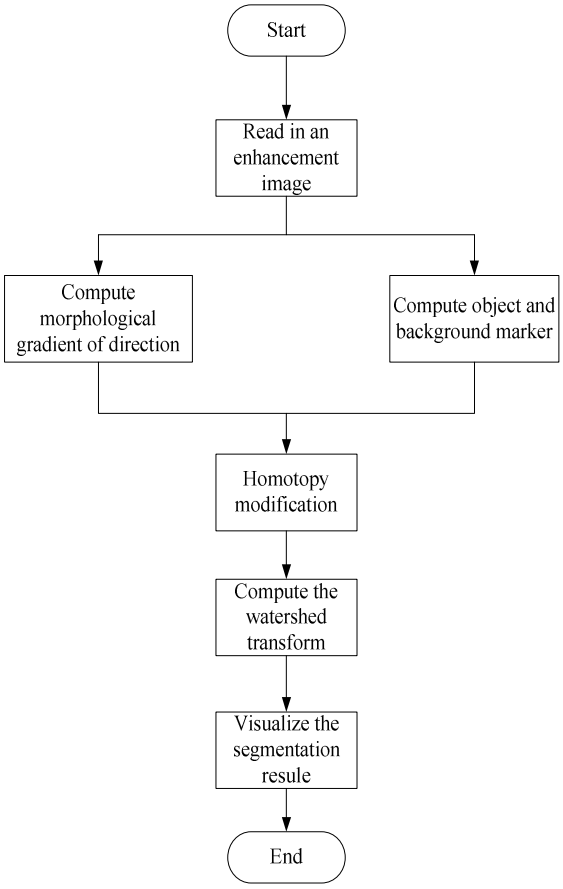
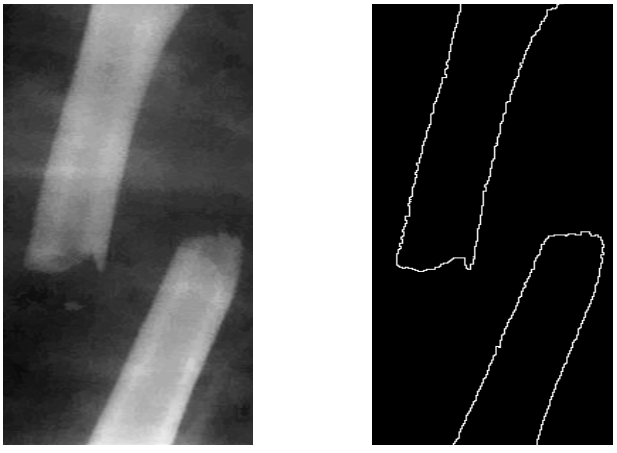
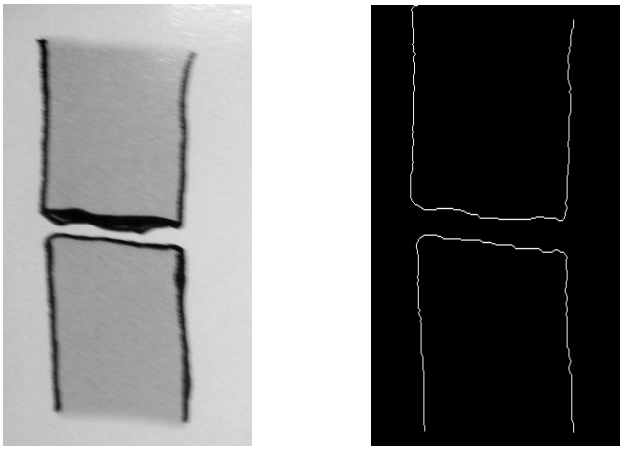


Figure 1. Principle of segmentation

The results of image segmentation using marker-controlled watershed transform are shown as below.



(a) (b)



(c) (d)

Figure 2. Segmentation experimental results

The results of applying algorithm to segment X-ray images are from Fig. 2 (a) to Fig 2 (d). Fig. 2 (a) and Fig. 2 (c) are original images that have been enhancement. Fig. 2 (c) and Fig. 2 (d) are the segmentation results edge of X-ray fracture bone. It is easy to draw a conclusion that the marker-controlled watershed algorithm based on gradient and homotopy modification is useful for X-ray fracture image segmentation

III. LINES DETECTION BASED ON HOUGH TRANSFORM

A. The principle of Hough transform

The important case of Hough transform is the linear transform for detecting straight lines. In the image space, the straight line can be described as y = ax + b and can be graphically plotted for each pair of image points (x, y). In the Hough transform, a main idea is to consider the characteristics of the straight line not as image points x or y, but in terms of its parameters, here is the slope parameter a and the intercept parameter b. Based on that fact, the straight line y = ax + b can be represented as a point (b, a) in the parameter space.

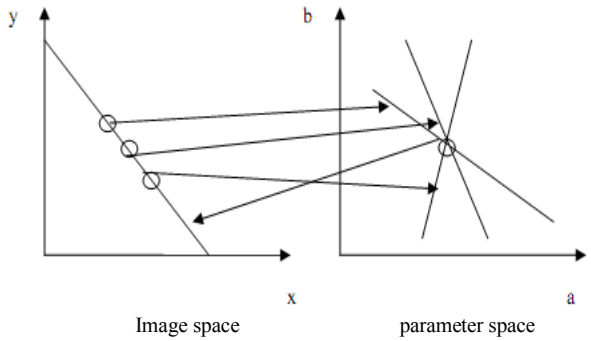


Figure 3. Principle of Hough linear transform

In principle, the parameter-space lines corresponding to all image points could be plotted, and then image lines could be identified by where large numbers of parameter-space

lines intersect. A practical difficulty with this approach, however, is that a (the slope of the line) approaches infinity as the line approaches the vertical direction. One way around this difficulty is to use the normal representation of a line:

$$x\cos\theta + y\sin\theta = \rho \tag{1}$$

The parameter ρ represents the distance between the line and the origin, while θ is the angle of the vector from the origin to this closest point.

B. Hough transform lines detection

The first step in using the Hough transform for line detection and line linking is peak detection. Finding a meaningful set of distinct peaks in a Hough transform can be challenging. Because of the quantization in space of the digital image, the quantization in parameter space of the Hough transform, as well as the fact that edges in typical images are not perfectly straight, Hough transform peaks tend to lie in more than one Hough transform cell. One strategy to overcome this problem is the following: find the Hough transform cells containing the highest value and record its location; suppress Hough transform cells in the immediate neighborhood of the maximum found in above; repeat until the desired number of peaks has been found, or until a specified threshold has been reached.

When a set of peaks has been identified in the Hough transform, it remains to be determined if there are line segments associated with those peaks, as well as where they start and end. The first step is to find the location of nonzero pixels in the image that contributed to that peak. In this paper, functions hough, houghpeaks, and houghlines [6][7] are be used to extract the lines in X-ray fracture image. The experiment shows that this algorithm can extract the lines that needed.

IV. FEATURES EXTRACTION OF X-RAY FRACTURE IMAGE

Hough transform is an important part in extracting morphological features of fracture image. As while, marker processing and boundary tracking are also introduced in this proposed algorithm. First, read in the image that has been segmented by improved watershed transform, and convert it into single-pixels image. Boundary tracing links the pixels in single-pixels image and changes it into a continuous image. Convert continuous image into color image, and obtain region number, region area, region centroid through regionprops function, and obtain protubcrant polygon as while. Next use Hough transform to detect and extract lines in the protuberant polygon of X-ray fracture image. The lines are consisted of parallel lines of centerline and fracture line. Through parallel lines of centerline, obtain the centerline over centroid and perpendicular line of centerline. Compute the angle between fracture line over centroid and perpendicular line of centerline over centroid. If the angle less than thirty degree, it will be classified into transverse fracture. Detailed procedure of this proposed algorithm for extracting the features of X-ray fracture images is shown as below.

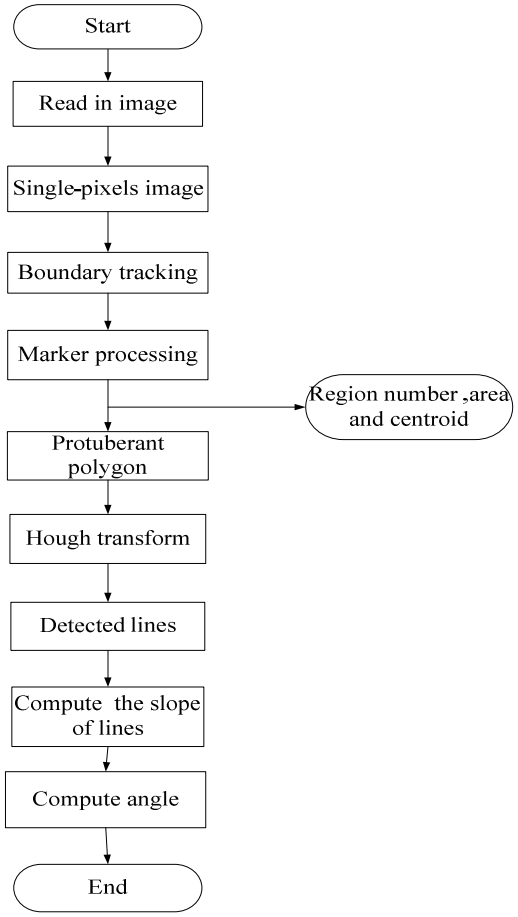
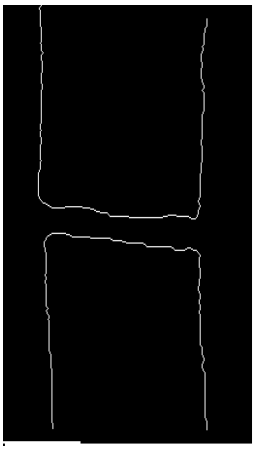
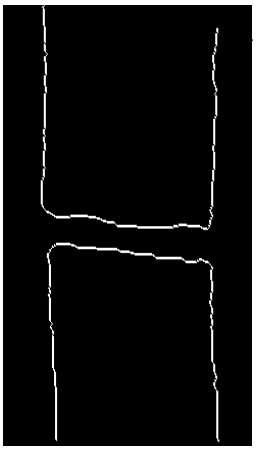


Figure 4. Principle of the proposed algorithm

The experimental result of applying proposed algorithm to extract feature of segmentation image are shown as below. The features have been extracted are: region area; region number; region centroid; fracture line over centroid; centerline over centroid; perpendicular of centerline over centroid; the angle a between fracture line and Perpendicular of centerline; The following result figures show the main steps of algorithm.



(a)



(b)

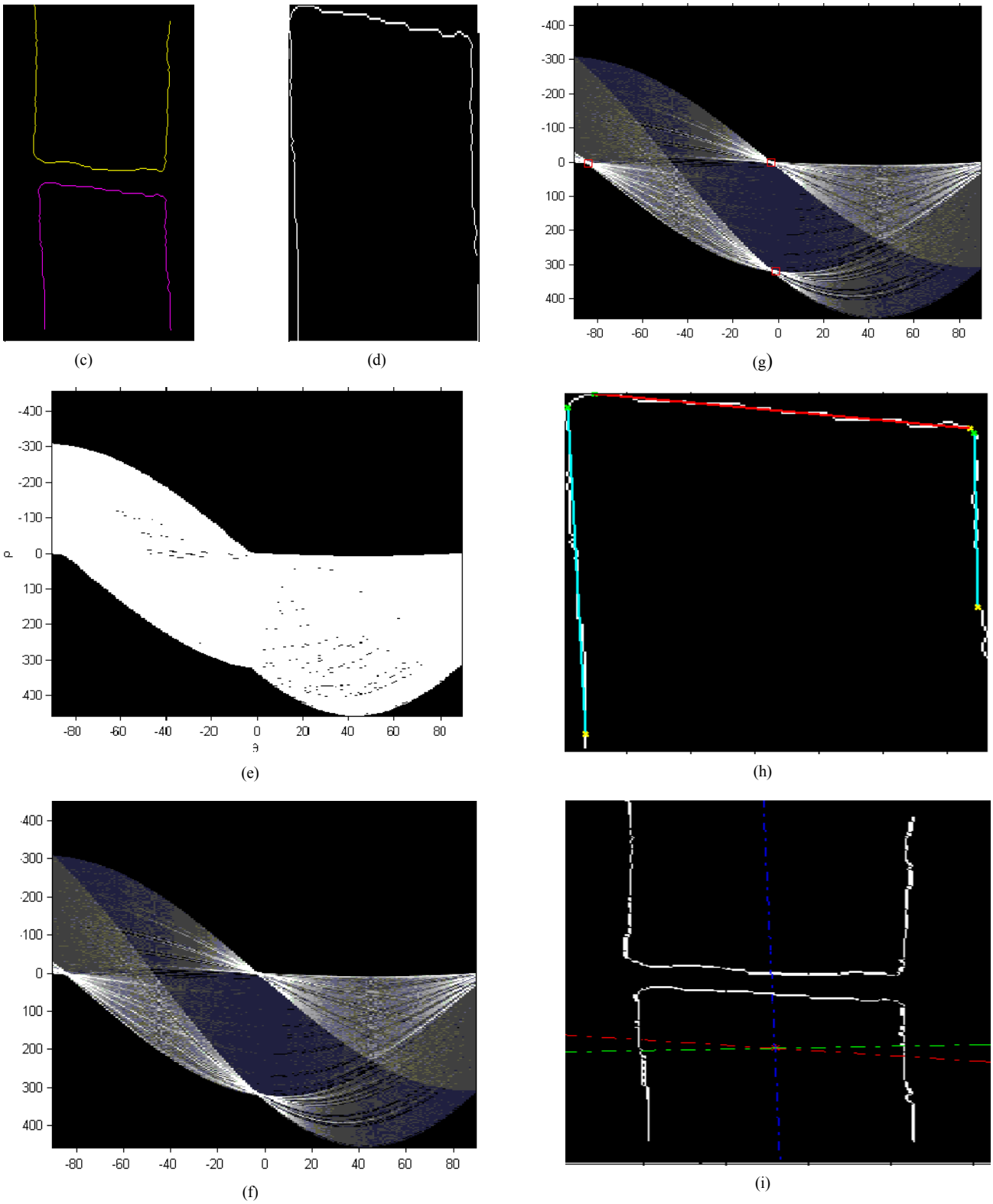


Figure 5. Results of features extraction based on proposed algorithm

The experimental results of applying the proposed algorithm to extract features of X-ray fracture image are

from Fig. 5 (a) to Fig. 5 (i). Fig. 5 (a) is single-pixels image of X-ray image with thin operation. Fig. 5 (b) shows the result of boundary tracking. Fig. 5 (c) displays the boundary tracking image that been marked with color. Based on the single-pixels image that have been marked, region number, region area, region centroid and protuberant polygon are extracted by using marker progress and regionprops function.

num (region number): 2

area (region area): [482 445]

centroid (region centroid): [126.1660 117.1369
129.5798 245.4292]

Fig. 5 (d) is the protuberant polygon that has been extract from Fig. 5 (b). In this paper, we use protuberant polygon instead of the x-image to extract the features of X-ray image. Fig. 5 (e) is the result of protuberant polygon using Hough transform. By adjusting, the result of Hough transform changes into Fig. 5 (f). In Fig. 5 (g), function houghpeaks is used to identify the peaks in the Hough transform. The peak number is decided as three according to the character of image in this paper. The peaks are marked on the Fig. 5 (g) with red square marker. According to three peaks, there must be three lines in the protuberant polygon. Function houghlines is used to find and link line segments. The parameters FillGap and Minlengthe in houghlines are ordered as 60 and 15. If the value of FillGap less than 60, there will be more than three lines in the protuberant polygon. Fig. 5 (h) is the final result we wanted in the protuberant polygon. On the Fig. 5 (i), red line is the fracture line over centroid, blue line is the centerline over centroid, green line is the perpendicular line of centerline over centroid. Compute the angle between red line and green line. The result is:

a: 7.4272° .

This angle is less than 30 degree. So this femur fracture image is classified into transverse fracture

V. CONCLUSION

The proposed algorithm is useful for feature extraction of X-ray fracture image. Region number, region area, region centroid, and protuberant polygon of X-ray fracture image are extracted by marker processing and regionprops function. Fracture line, centerline and perpendicular line of centerline are extracted based on Hough transform successfully. The angle computed between fracture line and perpendicular line of centerline is accurate. The angle is less than 30 degree by computing. So this fracture is classified into transverse fracture according to AO classification of fractures. But this algorithm is not very accurate for complex fracture, especially the fracture line extracted. We need search new accurate algorithm to extract features for complex fracture.

ACKNOWLEDGMENT

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