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PUBIC BONE FRACTURE AND DISPLACEMENT DETECTION USING X-RAY IMAGES

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ABSTRACT

Diagnosing minute fractures in the cases of pubic bone injuries is crucial for speedy and successful patient treatment. Due to low resolution and dissimilar visual characteristics of fractures by their position, minute fracture detection using x-ray images can be challenging and time consuming to examine. The pubic bones are most dense, due to which visual detection of the fracture is very difficult. This paper presents a fracture detection technique for the pubic ring using Distance Regularized Level Set Evolution (DRLSE) technique for segmentation and detection of fracture using Canny Edge detector. Also examination of displacement of the pubic bone is done using Gray Level Co-occurrence Matrix (GLCM). Results so far have been positive and will be helpful in guiding the physicians and for better treatment of the patients.

Keywords: Biomedical image processing, Distance regularized level set evolution, Image processing, Pubis bone fracture.

I. INTRODUCTION

Traumatic injuries in pubic region can result in severe hemorrhage, multiple nerve injuries, organ dysfunction, and internal organ damage. Even if injuries of this intensity does not occur, acute pain and impaired mobility are usually bound with pubic fractures. Faster and accurate diagnosis is necessary for patient's survival. But, highly dense and complex bone structure makes diagnosis difficult in intense situations. There has been development in biomedical image processing to assist the physicians in many biomedical fields, but so far research in image processing techniques to diagnose fractures especially in pubic region is scarcely done. Biomedical image processing techniques on x-ray image is also a challenge due to its high inhomogeneity, noise and varying intensity. Moreover, pubic bone x-ray images are rare and images collected in the hospitals are not stored for future references. Furthermore, physicians prefer higher and pricier imaging techniques in the cases where the fracture is not assertively diagnosed. Therefore it becomes essential to provide better image processing techniques that can be cost effective as well as precise to help the physicians for better treatment.

This work emphasizes on extracting information from the x-ray images, detection of fracture in pubic bone and judgement of the displacement of the pubic bone. X-ray images are used as lead diagnostic technique due to its faster availability and low cost. However image noise, complexity in pelvic and pubic bone structures and inhomogeneity makes it difficult to find minute fractures thus consuming time. Discussions with medical experts reveal difficulty at times in detecting fractures. A system that can assist the physicians will thus save time and guide

them in decision making.

Fracture detection using x-ray images is an under-explored field. Studies that detect fractures in bones such as arm, femur, leg, skull, joints etc. exist [1]-[5]. Research on detection of different types of fractures such as transverse fractures, open fractures, simple fractures, spiral fractures, commuted fractures etc. have also been done in past [6]. However, study on pubic bone region, which is in fact an area which does not form clear image using x-rays is very rare. Also many studies have been badly suffered due to improper database. Database with similar visual characteristic are very rare. According to our study, there has been least research to detect fractures in the pelvic and pubic bone [7], [8], [9]. Researches done in past on pelvic and pubic bone fracture detection include using of Active Shape Model (ASM) for segmentation of the bone [9]. ASM has been extensively used in many biomedical image processing researches since it occupies the desired shape of the object automatically. The idea of ASM is derived from Active Contour Algorithm, which is the basic form, widely used for segmentation [10]. It is the means of matching the deformable model to an object in the image. Fractures detection includes techniques such as Sobel operator and Canny edge detection as described in [2], [4], [9]. Features extracted in many biomedical image processing is done by Gray Level Co-occurrence Matrix (GLCM) [2], which is widely used.

Our method is based on DRLSE segmentation of the pubic ring [11], canny edge detection to detect fractures in the pubic ring and also feature extraction for the assessment of the displacement in the bone using GLCM technique as shown in figure 1. Each step will be broadly explained in the following sections.

II. SEGMENTATION USING DRLSE

Detection of fractures is affected extremely due to varying visual characteristics of the radiograph. It is essential to segment the desired portion for effective fracture detection. Previous work have focused on using Contour models to segment biomedical images [9], [10] and Chapter 2 in [12]. Active contour models are capable of accommodating a wide range of shape variability over space and time in a geometrically constrained framework, as explained in Chapter 2 in [12]. This geometric constraint imparts a compact form of shape information.

This paper focuses on the use of Distance Regularized Level Set Evolution (DRLSE) [11] for segmentation, which is a new level set formulation in which the regularity of the level set function is intrinsically maintained during the level set evolution. Conventional level set evolutions create irregularities during its evolution. Therefore re-initializations are done to avoid irregularities using a signed distance function. However re-initializations reduces the numerical accuracy. Thus due to this problem, a self-regularizing level set method is considered , which would regularize the level set function during its evolution without re-initializing the level set function every time. The DRLSE is a gradient flow technique, which is based on the energy function, which decreases as the solution converges.

In order to study this method, the gradient flow algorithms are to be discussed as a prerequisite.

The gradient flow or the gradient descent algorithm starts with an idea of developing a curve that would minimize the function 'f', whose derivative exists or can be approximated. The Level Set Evolution is a technique in which the energy functional must be minimized using the distance regularization term along with another external energy functional, which would drive the function towards the solution location.

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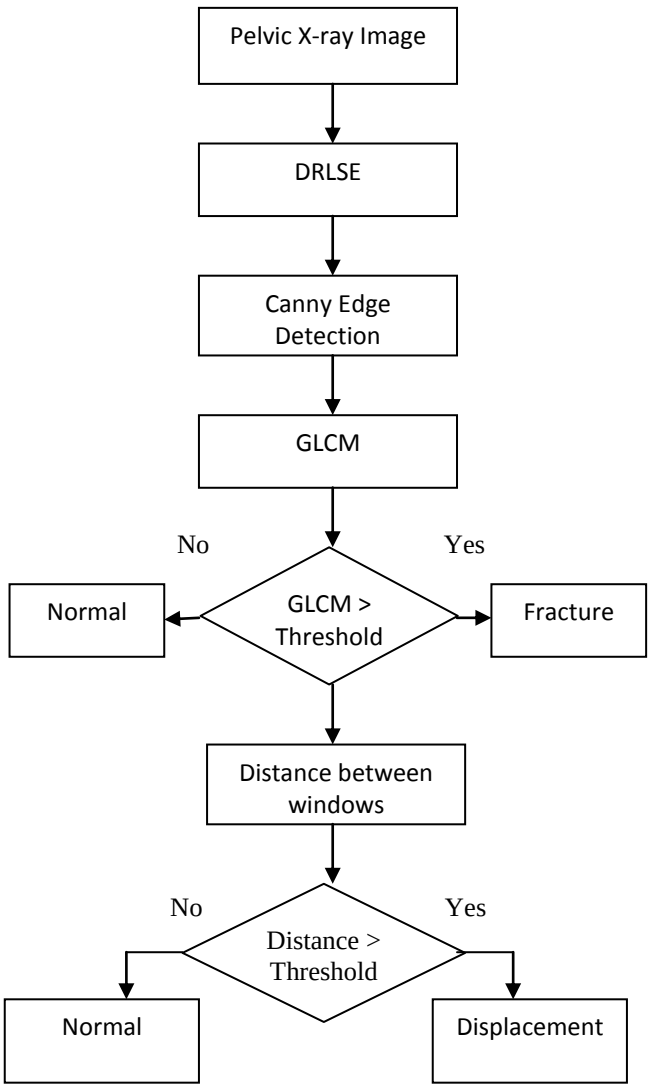

Fig. 1 Outline of detection process in pubis

The initialization stage comprises of the template creation stage, which would be used for template matching in the later stages by the use of particle filter framework. The DRLSE introduced in [11] has been used for the segmentation of the initial templates. The level set evolution is deduced as an inclination stream that minimizes the energy useful with a distance regularized term and an external energy that drives the zero level set towards the homogeneous segment areas. The distance regularization term is characterized with a potential capacity such that the determined level set evolution has Forward-and-Backward expansion impact, which can keep up a desired state of the level set capacity, especially a marked separation profile close to the zero level set. This produces a different level set advancement termed as DRLSE. The distance regularization impact eliminates the requirement for re-initialization and subsequently reduces numerical mistakes. The energy functional $\varepsilon(\phi)$ of the LSF ϕ in the domain Ω is given by,

$$\varepsilon(\phi) = \mu R_p(\phi) + \varepsilon_{ext}(\phi) \quad (1)$$

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where R_p is the distance regularized term and $\varepsilon_{ext}(\phi)$ is the external energy function which is dependent on the data of interest.

As opposed to cofounded implementations of usual level set plans, a less problematic and more effective limited contrast plan can be utilized to realize the DRLSE. DRLSE permits use of more broad and proficient introduction of the level set capacity. In its numerical usage, moderately vast time steps can be utilized as a part of the limited distinction plan to decrease the quantity of emphasis, while ensuring adequate numerical accuracy.

The DRLSE is applied on both the pubic rings separately. Since there are wide variations in the structure, size and direction in the viewing angles in different x-ray images of the patients, the seed points for initial LSF in the pelvic ring as well as pubic cannot be maintained constant. So we develop an algorithm wherein the user can direct the pointer at the location where the initial LSF is required to be generated. The DRLSE expands up to the pubic rings and takes the shape of the rings. Higher energy is required to advance the Level Set Function (LSF) towards higher intensity variation. Since the energy is kept low, the LSF stops at the boundary of the bone which is of a higher intensity than the background. The segmentation process of left pubic ring and the right pubic ring are shown in figure 2(a) and 2(b) respectively.

III. CANNY EDGE DETECTION

Edge detection is essential to detect the edges in the segmented image. Canny edge detector has been used to detect the edges of the pubic ring. It is the most prevalent technique for the detection of edges with low error rate and minimal false edges while using reduced amount of data. The outputs of Canny edge detection are shown in figure 3.

(a (b)

Fig. 2 Segmentation process output of left and right pubic ring

IV. FEATURE EXTRACTION USING GLCM

Feature extraction is an important step in many image processing applications. Gray-Level Co-occurrence Matrix (GLCM) is used for feature extraction. GLCM is a significant tool used in image texture analysis. Textures of an image are complicated visual patterns comprised of objects or regions with sub-patterns having characteristics like

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color, size, brightness, shape etc. It shows image texture structure by statistically sampling the patterns of gray levels arising in relation to other gray levels.

Decision of whether the pubic rings have fractures or not will be decided depending upon the GLCM values. The GLCM values of the right pubis and the left pubis are compared for co-occurrences. If it is greater than the threshold, the bones are considered to be fractured. Threshold values might vary depending upon the visual characteristics of the image.

V. DETERMINING DISPLACEMENT

Pubic bones are compromised to being displaced from its original location along with having fractures. This results in acute pain and therefore should be diagnosed properly and quickly.

Displacement is determined by finding the minimum or the first row in the image matrix of the segmented outputs of the right and the left pubic rings. By comparing the difference in distance between the first rows of both the right and left pubic rings, after the edges are detected by the canny edge detector, we can determine whether there is a displacement in the pubis or not. If the displacement incurred is more than threshold value, then the pubis is diagnosed to be displaced.

VI. RESULTS

The database was provided by Healthway hospital. A total of 21 pubis x-ray images have been taken of the patients upon their arrival at the hospital. Some images after the surgery or internal fixation are also included. All the images were resized to a standard width and height of 300 pixels each. Out of the total images, 18 images were normal and the rest were having some defects. The results were discussed with the experts and they suggest a good accuracy of 85.71%.

Our database contained very few images of pubic fractures, as patients can suffer fractures in other bones also. Improved valuation will be done with more x-ray images. The same is true for detecting displacement.

(a) (b)

Fig. 3 Edge detection of left and right pubic ring

VII. CONCLUSION

This paper presents a method to detect fractures in the pubic ring in x-ray images using Distance Regularized Level Set Evolution and then gathering the features from the edges obtained by Canny edge detection technique. Further, displacement of the pubis is also determined. The results are promising so far, having been tested for three cases (normal, fracture, displacement). The results and techniques use in this research is better and comparable to [8] and [9]. Once the approach is validated with more data, the proposed method will be very effective for larger systems in computer-aided evaluation making system.

Future work will involve testing with larger database of x-ray images. Further systems can be developed to detect the fractures in the pubic ring without having the need to insert seed points manually for each image. Geometrical analysis of the features extracted from the pelvic ring can also be compared with the normal bone to determine whether there is a fracture or not. Also, the classification of the severity of the fractures can be done in future.

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