Region of Interest of Human Lumbar Spine Segmentation using Geometric Triangular Analysis

Watcharaphong Yookwan, Krisana Chinnasarn and Benchaporn Jantarakongkul

Knowledge and Smart Technology Laboratory, Faculty of Informatics,
Burapha University, Chonburi, Thailand
w.yookwan@gmail.com, krisana@it.buu.ac.th and jbenchaporn@gmail.com

Abstract— **Dual-Energy X-ray Absorptiometry Scanner plays an important role in medical diagnosis and clinical routine. Typically, this kind of machine produces two radiography images of human spine consisted of Anteroposterior and Lateral side. However, these two images provided different viewpoints. In this paper, a method for segmenting region of interest on lumbar spine using a horizontal projection and geometric triangulation analysis is proposed. The proposed method offered an automated detection of lumber spine that can reduce computational time and complexity in medical diagnosis. The result of the proposed method can help support many applications such as lumbar vertebrae pose segmentation, bone mineral density analysis and vertebral pose deformation.**

Keywords—Lateral; Lumbar spine; ROI; Segmentation; Geometric; Triangular Analysis;

I. INTRODUCTION

In diagnosis routine of scoliosis, osteoporosis and osteopenia normally performs by using Bone Mineral Density (BMD) and radiography images which are produced from Dual-Energy X-Ray Absorptiometry scanner or DXA Scanner. DXA produces two radiograph images of human spine consist of Anteroposterior (AP) and right side (Lateral), as shown in Fig 2. The two images provide two different view points. Lateral image shows a whole structure of human spine including Cervical, Thoracic, Lumbar and Sacral. But AP image depicts only the Lumbar region of human spine. Thus, to reduce complexity and computational time, the automatic Region of Interest (ROI) segmentation of lumbar region is an important process in diagnosis and Bone Mineral Density measurement. Including applied method or application such as Lateral lumbar vertebrae pose segmentation or Scoliosis detection and automatic deformation of three-dimensional model of human Lumbar vertebrae.

Most recent research works on lateral lumbar vertebrae segmentation use high resolution X-ray image or CT images. In addition, most of them still manually locate lumbar region. R. Sa et. al. [1] proposed a lateral lumbar vertebrae segmentation in scale-variant high radiant X-ray clinical image.

E. Alvarez Ribeiro et. al. [2] presented a procedure to detect lumbar vertebral in lateral high-dose of X-ray images using Gabor filter. R. Sa et al. [3] demonstrated a method which use R-CNN to detect intervertebral disc in X-Ray image. G. Zheng et al. [4] introduced a method to reconstruct a lumbar vertebral from a single fluoroscopic image. These works use manual method to locate human lumbar spine region before processing.

In this paper, we proposed a new method to automatically segment human lumbar spine region to help support specialist or physician in detecting the boundary of lumbar spine. By using the proposed method, it can automatically detect the lumbar region instead of manually segmenting them. However, the Low-resolution radiograph image is quite difficult to automatically segment.

There are three main steps in the proposed method. Starting from a pre-process using binarization and basic morphological. Next, the horizontal projection profile is used to visualize information of the input image and triangular analysis is used to analyst features. Finally, the region of human lumbar spine region is extracted from original image.

II. BACKGROUND KNOWLEDGE

Recently, medical image analysis is very efficient in many medical or clinical diagnosing routine. Thus, understanding of the core information medical images is needed to process and analyst them. The basic background knowledge is described as below:

A. Lumbar Vertebrae

In human anatomy [5], the five vertebrae pose between the rib cage and the pelvis covered the largest segment of the vertebral column which characterized by the absence of the foramen transversarium within the transverse. They are designated into L1 to L5, from top to bottom. The lumbar vertebrae are the main structure that support the weight of the body and permit movement as shown in .

B. Dual-Energy X-Ray Absorptiometry

Dual-energy x-ray absorptiometry or called in short DEXA, [6] uses a very small dose of ionizing radiation to produce images of the bone structure of the patient who might have a bone disease. It is commonly used to diagnose osteoporosis and to assess an individual's risk for developing

fractures. DEXA is quite a simple machine and noninvasive to both patient and physician. It provides a reasonable accurate method for diagnosing osteoporosis.
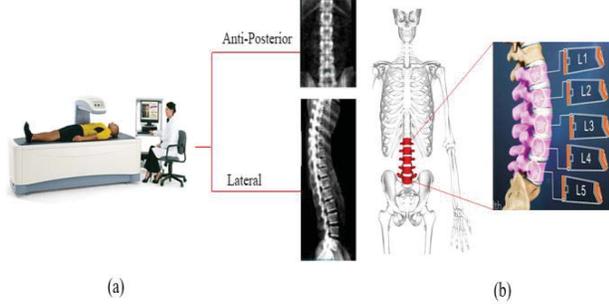

Fig. 1 Dual-Energy X-ray Absorptiometry scanner (a), Lumbar section (b) .

C. Morphology Operation

Morphology Operation [7] is a technique for analyzing and processing of geometrical structures which based on set theory, lattice theory, topology, and random functions. It is commonly applied to digital images. However, it can be employed as well on graphs, surface meshes, solids, and many other spatial structures. Morphology technique is used for filling holes and incomplete parts, enlarge areas, and eliminate exceed parts on digital images. In particular, the binary regions produced by simple thresholding may be distorted by noises. In this regard, morphological technique can properly help to remove those noises.

III. METHODOLOGY

In this section, the three steps for identifying the region of interest on human lumbar vertebrae are discussed. They are preprocessing, features selection and then region of interest segmentation.

In this work, the dataset was collected from Burapha university hospital as the input images. The proposed method started from pre-processing process using an entropy value of each image as an initial threshold value for binarization in order to separate background from foreground. Then, morphological operation is applied to remove small objects. Secondly, after insignificant objects were removed, horizontal projection is used to calculate the summation of intensity to plot a time series graph. On this graph, the triangular analysis is applied using law of cosine to identify potential features. Finally, the featured extracted from previous process are used to identify candidate area of interest. Then those candidate areas are used to segment the lumbar spine from radiography image. The framework of proposed method is depicted in *Fig. 2*
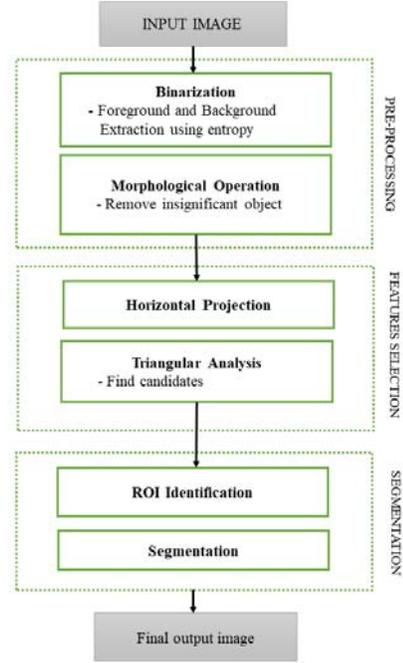

Fig. 2 Overview of proposed method.

A. Pre-processing

Binarization: In this study, Lateral view radiography image produced from DXA scanner is used as an input image. The binarization process is applied to increase the differentiation between the object of interest and background. In order to make a clear distinction, a technique called "entropy value" proposed by Du-Yih Tsai et. al. [8] is used to measure entropy values of each input image. This value is then set as an initial threshold value to extract foreground from its background. The entropy value is defined by equation (1).

$$E(X) = -\sum_{i=1}^{n}\sum_{j=1}^{m} P(x_{ij})\log_2 P(x_{ij}) \qquad (1)$$

Where X is an input image, n is image's width, m is image's height, x_{ij} is intensity in grayscale image and $P(x_{ij})$ is a probabilty of each x_{ij}.

Morphological Operation: After the binarization process to extract object of interest from background using entrophy information, there still be a number of small unconnected objects remained the image. To remove these small objects, the Morphological Opening Operation is employed as defined in equation (2).

$$A \circ B = (A \ominus B) \oplus B \qquad (2)$$

Where A is an input image, B is a specific structure element, $\ominus$ is an erosion operation and $\oplus$ is a dilation operation respectively.

Opening Operation is used to remove small objects from the foreground of an image. In this operation, there are two techniques: Erosion and Dilation. Firstly the Erosion technique is used to remove small object in the foreground which may also remove parts of object of interes. Thus, after the Erosion step, the Dilation technique is used to restores the eroded part of object of interest. After applying the opening operation, inconsiderable objects are removed.

B. Features Selection

Horizontal Projection: The output of the pre-processing process as described above, is then projected as a time series graph using horizontal projection. The horizontal projection is a summation of an image's intensity that transform two dimensional information into one dimensional information to reveal pattern of region of interest. The horizontal projection is employed as defined in equation (3).

$$H_k(X) = \sum_{i=1}^{n} X_{k,i} \qquad (3)$$

Where k is an each image's row number, X is an pre-processed input image and n is an image's column number.

The result of horizontal projection can reveal the characteristics of individual parts of the human spine which can later use to determine lumbar section as shown in *Fig. 3* That is, the lumbar section can be clearly spotted by an area where the graph obtained lower peaks as compared with the surrounded peaks or look similar like a valley.
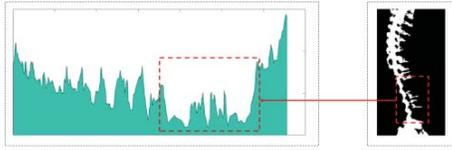

Fig. 3 Horizontal Projection of Lateral X-ray image.

Peaks Finding: In order to identify those peaks, the local maxima information is used to locate each peak. The local maxima is calculated as defined in However, an initial result of local maxima calculation provided too many maxima points or peaks. Therefore, a graph smoothing technique is applied to eliminate those insignificant peaks.

Triangulation: After the local maxima points are identified, the association among peaks are retrieved using triangular shape as shown in *Fig. 4.* Triangular shape is created using a peak with its left and right adjacent peaks. These triangular shape objects are used to locate the valley area.
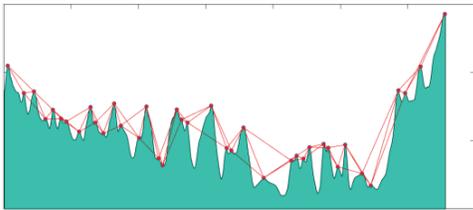

Fig. 4 Triangulate Between Peak Points.

C. Segmentation

Candidates selection: All triangles that generated from peak points in the former step can be classified into 4 patterns: a) left side peak of an examined point is in quadrant two and right side peak is in quadrant one, b) left side peak of an examined point is in quadrant two and right side peak is in quadrant four, c) left side peak of an examined point is in quadrant three and right side peak is in quadrant one and d) left side peak of an examined point is in quadrant three and right side peak is in quadrant four. From those four patterns of triangles, it clearly demonstrated that pattern d) and c) are patterns that corresponding well to the candidate objects. Thus, these patterns are used to determine lumbar section as shown in *Fig. 5* (b) and (c).
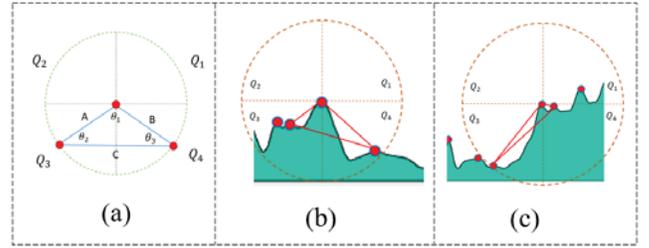

Fig. 5 Example of final candidate triangles.

However, using located quadrant of each triangle is not enough to identify candidate objects. Thus, another feature is needed to help identify them. The proposed method applied interior angle and triangular length to determine candidates. The interior angles are measured using law of cosine [9].

From observation, the boundary of lower lumbar section can be determined by θ_2. In which, the θ_2 has to be an acute angle, where the value of θ_2 has to be in the range of $0 < \theta_2 < 10$. Furthermore, θ_1 has to be an obtuse angle, where the value of θ_1 has to be in the range of $90 < \theta_1, < 180$ as shown in *Fig. 5* (c). Then, triangular length of each object is measured and then compared among all candidate objects to locate the one with maximum value or Length A as shown in *Fig.* (b). The selected triangle is then used to locate the lower bound of the lumbar section. Likewise, the determination of candidate object for upper lumbar section is identified by θ_3 where θ_3 has to be an acute angle and its value fall into the range of $0 < \theta_3 < 45$. Furthermore, the θ_1 has to be an obtuse angle where θ_1 fall into the range of $90 < \theta_1 < 180$ as shown in *Fig. 5* (b). The candidate objects that got the maximum length B is chosen as a selected triangle that used to locate the upper bound of the lumbar section as shown in *Fig.6* (d). Algorithm for finding the candidate objects is illustrated in *Fig. 7*.
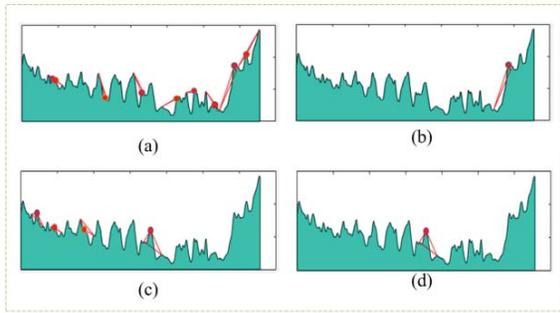
Fig. 6 Finding all possible candidate triangles

Algorithm 1 *Candidates Selection*

Require: *Triangles*
Ensure: *Boundary*

1: **for** $i = 1 : size(triangles)$ **do**
2:      $angles = anglecalculator(triangle(i))$
3:      $minangle = min(angles(1))$
4:      $n = 1$
5:      **if** $minangles \geq 0$ AND $minangles \leq 45$ **then**
6:          $candidates(n) = triangles(i)$
7:          $n++$
8: $maxdistance = min(candidates(i,2))$
9: **for** $i = 1 : size(candidates)$ **do**
10:     **if** $maxdistance = candidates(i, 2)$ **then**
11:        $boundary = candidates(i)$

Fig. 7 Summarize of Candidates Selection Method.

After obtaining information for locating both upper and lower boundary, these information is then used to segment the lumbar region from original input image as shown in *Fig. 8.*

Fig. 8 Segmented ROI of human lumbar spine region

IV. EXPERIMENTAL RESULT

The dataset used in the lab scale experiment consisted of 50 radiography images of lateral human's spine produced from Dual-Energy X-ray Absorptiometry scanner (DXA Scanner) provided by local hospital. The dataset contains variation of image's quality: high, medium and low quality. These differentiations caused from the volume of radiation exposed to each patient. The higher the volume of radiation used, the better the quality of the image obtained. In the experiment, the automated segmentation of lumbar section was compared with the ground-truth images. The performance evaluation method are Precision and Recall (Confusion Matrix). The experimental result showed that the proposed method gained 81.1% for Accuracy, 90.0% for Precision and 88.5% for Recall.

V. CONCLUSION AND DISCUSSION

In this research, a new method using triangular analysis for lumbar segmentation from low-radiation radiography image produced from Dual-energy X-ray Absorptiometry is proposed. The proposed method consists of three main steps. Firstly, the pre-processing step consists of binarization and morphological techniques. These techniques are applied to remove background and noises. Secondly, the output from step one is transformed into horizontal projection. The output of horizontal projection is then used to find local maxima which located the peak points. Triangular shape is formed using a peak with its left and right adjacent peaks. Finally, candidate objects are determined https://goo.gl/M14wtbusing proposed features of the triangular shape. The proposed method can automatically locate the region of human lumbar spine. This can help to reduce work load of radiologist. In general, the proposed method can be used as a preprocess for other research in the area of bone structure identification and segmentation. In future work, the segmentation of lumbar region for special cases of exostosis and bone collapse is going to be attempted.

VI. ACKNOWLEDGEMENT

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