Finding Geometric Parameters of the Vertebrae on Spine X-ray Profile Pictures

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***Abstract*—In this paper we offer an searching algorithm of the vertebrae in profile image of a human spine and an algorithm for calculating the geometric parameters of the vertebrae. These algorithms have been developed to diagnose osteoporosis automation.**

***Keywords*—Biomedical image processing, DICOM**

I. Introduction

X-ray photography is one of the best ways to study the internal state of human bodies [1]. The advantages of this method are easy and fast taking pictures process and a small dose of radiation. Also, modern equipment allows to receive images in digital form, which makes it possible to process images on a computer. Image file format was standardized and named DICOM. It contains information about the survey, patients, doctors, scanner characteristics, etc. [2].

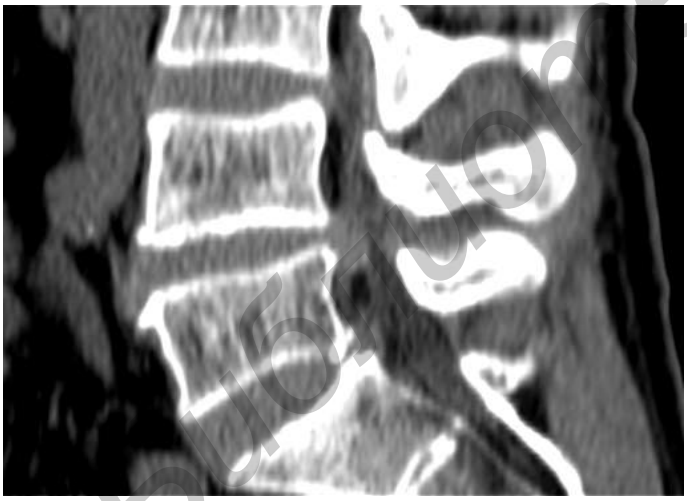

Figure 1. Lateral vertebra image

X-ray DICOM images contain two-dimensional matrix of densities, which represents part of human body picture. Each of these values corresponds to a tissue site. To identify the type of tissue it is used Hounsfield Scale [3], which describes the relative tissue density relative to the density of water. So practically all tissues contain water, it is difficult to uniquely identify tissue.

For diagnosing osteoporosis there are three types of parameters necessary to determine [4]:

- Vertebrae shape parameter
- Intervertebral joint parameters
- Spinous processes parameters

According to the statistical analysis of data for the diagnosis of osteoporosis patients significant parameters form the vertebrae are:

- Height of the ventral h_a and dorsal h_b (sagittal plane) of the vertebral body contour
- Length of the cover l_a and basal l_b end plate
- Wedging angle α_p and trapezoidal angle α_t of vertebrae
- The angle of inclination of the vertebral body to the vertical α_v and to the horizontal plane α_h

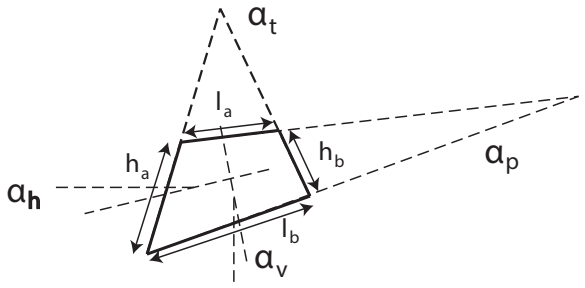

Figure 2. Vertebrae shape parameters

Significant diagnostic parameters of the intervertebral joints are:

- Height of the ventral d_1 and dorsal d_2 (in sagittal plane) parts of intervertebral disk
- Wedging angle α_d of intervertebral dis
- Angle α_m between vertebrae bodies
- Linear displacement s of vertebral body in the plane of the disk
- Displacement angle α_s of vertebrae

Significant diagnostic parameter of the spinous processes is:

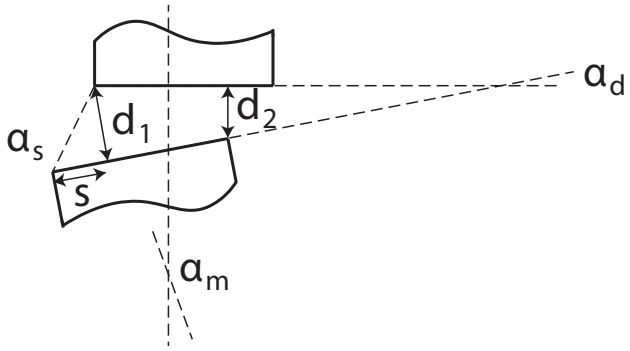

Figure 3. Intervertebral joint parameters

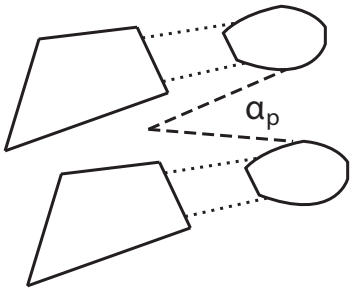

Figure 4. Spinous processes parameters

- Angle α_m between spinous processes

The process data description parameters for a long time was mainly manual work, which took a lot of physician time. Also, one of the disadvantages of manual separation of vertebrae is subjectivity in defining the boundaries of anatomical structures of the vertebrae, which in turn may reduce the value of diagnostic and prognostic investigation. complete set of parameters for the calculation is quite time-consuming manual calculation, and, moreover, the calculation results is difficult to store, organize and use statistical analysis.

Therefore, automation of the vertebrae and calculate their parameters search problems will accelerate the diagnosis of disease and to predict the effects of surgical procedures.

II. Formulation of the problem

Based on the format of X-rays and the parameters of the vertebrae to be obtained, the task is divided into the following main sub-tasks.

- Finding vertebrae on the image
- Calculation vertebrae parameters
- Calculation intervertebral joints parameters

A. Finding vertebrae on the image

For isolation of bone tissue on image authors proposed to use clustering densities. The pixels on image after the clustering procedures are replaced by the centers of clusters, which belong to the pixels, and thus, the image is smoother and

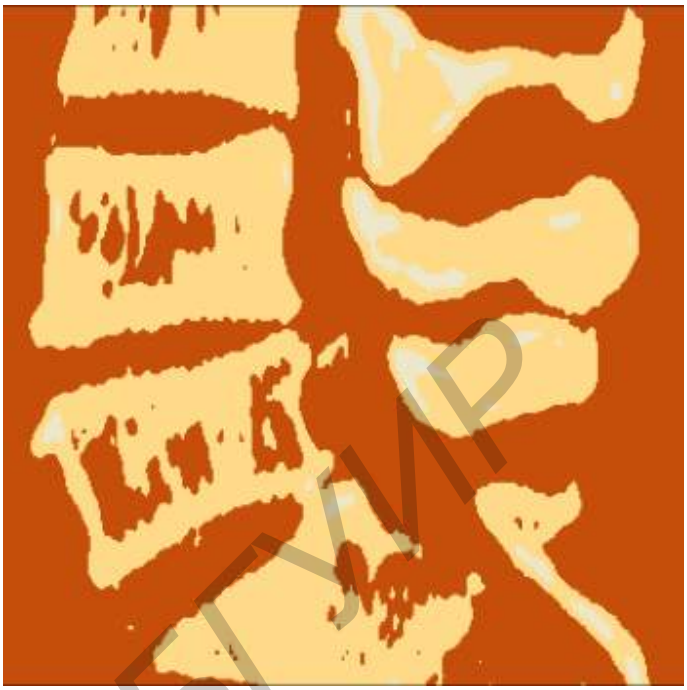

Figure 5. Clustered vertebrae image(bone tissue is marked by beige color)

tissues essentially differ from each other, have a clear border [5].

To determine the geometric characteristics of vertebrae and intervertebral joints we need to have information about the shape of vertebrae on image. Good vertebra forms characteristic of image is the contour. Following contours of the tissue clustering can easily identify on image.

Since the images are monochrome, then they can apply a significant range of image processing operations. The most commonly used operations to highlight the following statements are the contours:

- Sobel operator [6]
- Canny operator [7]
- Laplace operator [6]

For edge enhancement the image Laplacian was selected which showed the best results among the test.

Mathematically, the Laplace operator is the sum of the squares of the second partial derivatives of the function. Discrete analog Laplace operator used in image processing, in particular for determining the edges of objects in the image. The ribs are formed of a plurality of pixels, wherein the Laplacian becomes zero, since zero second derivatives of the function correspond to the intensity of extreme differences.

$$D^2_{xy} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & -8 & 1 \\ 1 & 1 & 1 \end{bmatrix}$$

Contours, after image processing Laplace operator, can be seen in the picture 6.

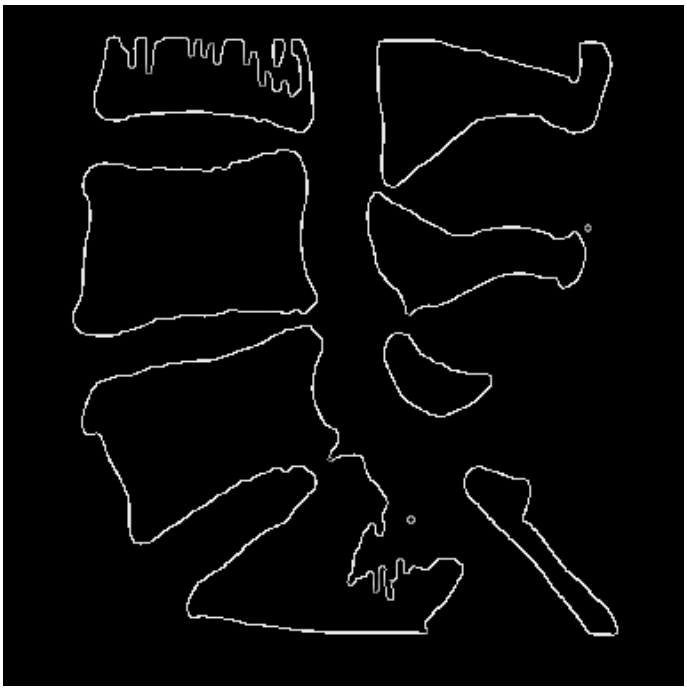

Figure 6. Found contours on the image

After selecting the contours of image must correctly identify the contours that belong to the vertebrae, and discard those that belongs to other tissues.

Since the vertebral body at the cut has a certain shape, vary slightly depending on the type of vertebra, the presence of individual vertebrae circuits is not a difficult task.

However, by using clustering or manually adjust the image contrast, some vertebrae can be ”glued” in one contour that prevents their recognition.

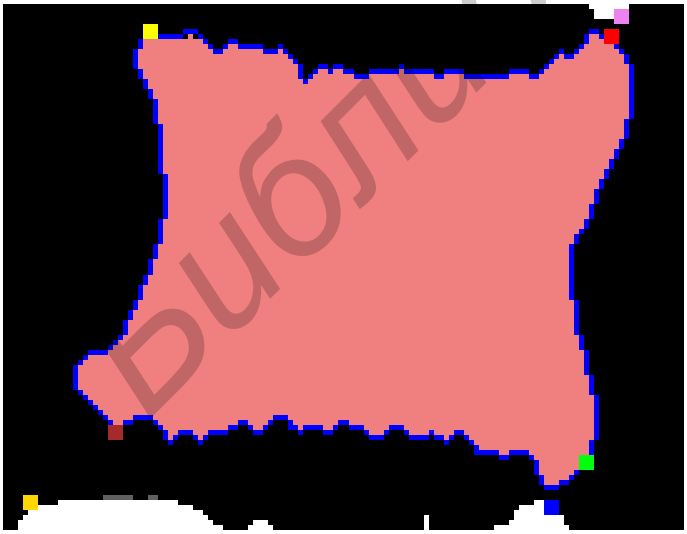

Figure 7. Found vertebrae on the image(color points – edges of vertebrae)

To solve this problem the authors was an algorithm that separates the vertebrae from each other in case of ”gluing”. This algorithm is based on the following assumptions:

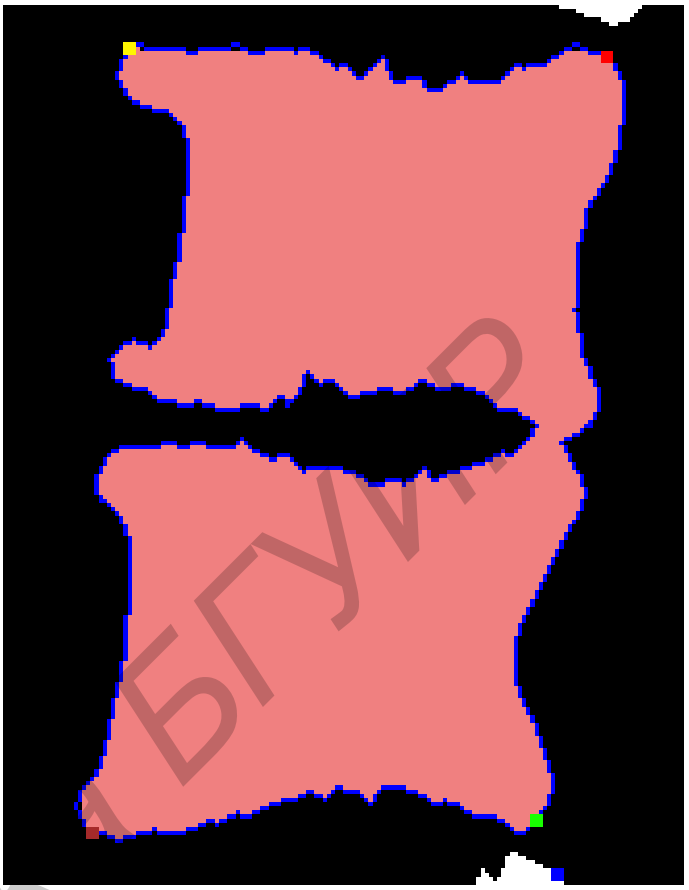

Figure 8. ”Glued” vertebrae

- Vertebrae are connected in a single place, and this place does not change its position
- Height of connected vertebrae equal to the sum of vertebrae height and the height of connections between vertebrae

Algorithm consists of the following steps:

- Based on the height of the vertebral group calculated the number of vertebrae
- Prepared histogram the number of pixels belonging to the vertebrae, with each row
- According to an exemplary arrangement of jumpers from an assumed vertebra height and number of pixels per line, lines are built, which are separated from each other vertebrae

After that separated vertebrae treated in the same way as standing alone.

B. Calculation of parameters of vertebrae and intervertebral joints of image

Since finding of vertebrae on image was also searched edge points, building a line passing through these points, it can be quickly found the shape parameters vertebra.

III. Analyzing vertebrae software

Software which uses algorithms has been developed and it allows to carry out the processing of X-ray images of vertebrae. The software has been implemented as a client application. To design was used C# programming language. Main features of the software are:

- View images in DICOM format
- Adding images to the database for later use in research
- Possibility of manual tagging vertebrae in images
- Possibility to automate finding the vertebrae in the image according to the developed algorithms
- Possibility of calculating parameters of vertebrae and export them as Excel table
- Export in XML format

```
<?xml version="1.0" encoding="utf-8"?>
<storage pixelWidth="0.127124846" pixelHeight="0.127124846">
  <spines>
    <spine key="L5">
      <points>
        <point x="1119" y="1642" />
        <point x="1155" y="1845" />
        <point x="1432" y="1727" />
        <point x="1389" y="1558" />
      </points>
      <geomertry>
        <param key="alpha_h" value="-20.268518447875977" />
        <param key="alpha_p" value="5.7921614646911621" />
        <param key="alpha_t" value="4.2190437316894531" />
        <param key="alpha_v" value="11.989548683166504" />
        <param key="h_a" value="26.208999633789063" />
        <param key="h_b" value="22.168619155883789" />
        <param key="l_a" value="35.946445465087891" />
        <param key="l_b" value="38.275558471679688" />
      </geomertry>
    </spine>
```

Figure 9. Output XML file content

	A	B	C
1	Участок	Угол наклона к горизонтали	Угол клиновидности
2	L5	-20.26851845	5.792161465
3	L4	-9.926244736	-3.393434048
4	L3	0.902995527	-3.833319426
5	L2	5.99253273	-3.928757191
6	L1	2.711440563	-6.212532997
7			
8	Диск	Угол клиновидности диска	Угол между телами позвонков
9	L4-L5	9.11943531	9.11943531
10	L3-L4	14.39763546	14.39763546
11	L2-L3	8.865114212	8.865114212
12	L1-L2	1.847606421	1.847606421
13			
14	Угол между остистыми отростками		
15	L4-L5	19.10409927	

Figure 10. Output XLS file content

IV. Conclusion

The work was proposed algorithm and corresponding software search vertebrae and determining their size and relative position with the purpose of diagnosing osteoporosis automation. These software tools allow as to obtain more accurate diagnosis of the disease and predict the actions of operational and other treatments.

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ОПРЕДЕЛЕНИЕ ГЕОМЕТРИЧЕСКИХ ПАРАМЕТРОВ ПОЗВОНКОВ НА ПРОФИЛЬНЫХ РЕНТГЕНОВСКИХ СНИМКАХ ПОЗВОНОЧНИКА

Курочка К. С., Цалко И. Н.

В статье приведен алгоритм поиска позвонков на профильном изображении позвоночника человека. В ходе работы алгоритм сегментирует изображение по тканям. Следующим шагом алгоритм классифицирует сегментированные области изображения с целью нахождения тел позвонков и межпозвоночных дисков. Следующий алгоритм, вычисляет геометрические параметры найденных частей позвоночник. Данные алгоритмы были разработаны с целью автоматизации диагностики остеопороза.