Grayscale Enhancement of Spiral CT Scan Image of Human Spinal Skeleton

Shufeng Jiang, Fengjuan Wang and Fansong Meng

***Abstract*—**The digitalization of human scanning information is the support technology of modern medical instrument detection and analysis, and the data acquisition and processing of human skeleton is the premise of human information digitization. It is the key link of reverse engineering technology, and also the basis of human skeleton reverse reconstruction. In this paper, the image data of human spine skeleton is obtained by spiral CT scanning, and an effective gray enhancement algorithm is used to enhance the image data of the human spine skeleton, which provides technical support for the later 3D reconstruction. The measurement of human bone surface data refers to mapping its shape information into geometric coordinates or two-dimensional image information of discrete points through specific measurement methods and measuring equipment. Through comparative analysis, we use high accuracy and advanced technology spiral CT scanning to get human spine and skeleton image data. Based on grayscale theory, an efficient algorithm is constructed, which includes histogram equalization, grayscale transformation, smoothing, sharpening and edge detection. The algorithm can effectively enhance the image features from different angles and different methods, so that the bone feature data can be extracted more quickly and accurately in the subsequent 3D modeling process. The results of the algorithm and technology integration show that the processing features of CT image data are compared with other non obvious regions and the image feature data are more accurate. The results show that the gray image enhancement algorithm is more suitable for human tissue image enhancement than other algorithms, and provides better image data processing support for 3D reconstruction of bone model.

***Keywords*—**human spinal skeleton, data acquisition, image processing, Grayscale enhancement.

I. INTRODUCTION

Reverse engineering technology (RE), also called reverse engineering technology, mainly includes three aspects: Transformation of models, transformation of geometric models, and design and manufacture of products [1]. Based on reverse engineering technology, human skeleton image data is acquired, and data preprocessing is carried out. Finally, 3D geometric modeling is reconstructed and analyzed, involving a series of scientific processing techniques [2]. A new generation of computer tomography as a direct means of human organs and tissues of measured data of complex human bone tissue entity after effective direct digitization, building a bridge between the two-dimensional surface and three-dimensional image processing, then the actual measurement, image processing, feature recognition and feature modeling organs such as high-end modern science and technology and flexible currently used in the biomedical field, expecting to be able to more quickly and accurately and effectively solve many practical problems existing in medical field.

Medical image is a two-dimensional or sectional image of single or serial organs and tissues obtained from relevant scientific and technological researchers based on the principles of physics, using image acquisition devices to sample human tissues and organs, such as CT images, MRI images and so on. In the analysis of the traditional medical image, doctors are mainly through the human eye observation of various organs and tissues to medical images and found that patients with lesions the precise location where the body, which is usually the case on the doctor's experience and professional knowledge is very high, then a lot of experience according to a simple analysis of the patient's condition to determine. In the actual analysis process, due to human organ tissue morphological diversity, complexity, and lesion morphology and position of unpredictability, if physicians are not responsible for the diagnosis of the actual diagnosis of sufficient experience and a solid professional knowledge, to understand the two-dimensional image acquisition, and from the two-dimensional slice structure the relationship between three-dimensional shape of human tissues and organs and each other will be a big problem [3].

Therefore, it is necessary to deal with the image enhancement and image segmentation of the acquired medical images. Image enhancement is useful information in enhanced image. Image enhancement can be a distortion process. The purpose of the image enhancement is to improve the visual effect of the image [4]. Generally, for the application of a given image, it purposefully emphasizes the whole or local characteristics of the image, making the original unclear image clear or enhancing the characteristics of the interested part, enlarging the difference between the different features in the image, and inhibiting the characteristics which are not interested. This can improve the quality of the image, enrich the amount of information, strengthen the image interpretation and recognition effect, and meet the needs of special analysis. Image segmentation is a well-known classic problem, but for

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researchers of medical background, it may be stranger to the image segmentation. An important part of image segmentation is image enhancement. Only the enhancement of data features can better perform image segmentation. Based on reverse engineering technology, this paper studies the acquisition technology of human skeleton CT image based on CT technology, and enhances the processing of human skeleton CT image, so as to achieve the standard of medical diagnosis.

II. Method for Acquiring Image Data of Bone

The measurement of human bone surface data is a process to digitize the surface information, that is, the product digitization. Human skeleton surface data measurement and data acquisition process is a key link of reverse engineering technology application [5]. It is the basis for reverse reconstruction of human skeleton, and its processing results will directly affect the later modeling quality and later biomechanical analysis. The measurement technology of human skeletal surface data refers to mapping the shape information to the geometric coordinates or two-dimensional image information of discrete points through specific measurement methods and measuring devices.

A. Contact Data Acquisition Method

The contact measurement, as shown in Fig. 1, refers to the measurement of the contact between the needle and the parts at the same time when measuring the experimental data. According to the different head of the test, it can be divided into trigger type and continuous type. The main equipment of the contact measurement method is the three coordinate measuring machines (CMM). The components of the three coordinate measuring machine include the main engine, the CNC device, the three dimensional head, the servo system and the electrical system. The main body of the three coordinate measuring machines is made up of precision measuring axis. Electronic technology, numerical control technology, measurement technology and optical technology are used as measuring support technology. The three coordinate measuring machines mainly use three axis movements to realize the free movement of the probe in the three-dimensional space. Through the contact between the precise location of the probe and the surface of the measured object, the 3D geometric coordinates of the contact points can be obtained through mathematical calculation. Theoretically, the three coordinate measuring machines can measure the geometry of any point within the specified range. As long as the position of the probe of the 3D coordinate measuring machine can be directly aimed at, no matter how complex the shape is, it can be accurately measured.

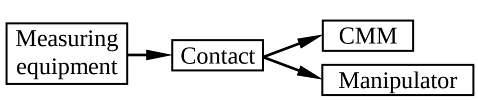


Fig. 1. Contact sampling method

The precision of contact measurement is quite high, and it can reach the micron level. At the same time, the material, surface color, reflectivity and curvature of the workpiece have little influence on the measurement. But because of the characteristics of the contact type itself, it also determines its defects. First, the time of measurement, the measuring force may make objects produce soft material surface deformation, the measurement accuracy will produce certain error; second, at the same time, also can make the contact force measuring head deformed in different degrees, and probe the center location of all need correction and compensation; thirdly, contact force frictions caused by measuring head wear, need to be calibrated; in addition, due to the inertia and time delay, may lead to probe beyond phenomenon, resulting in dynamic error; third, third coordinate measuring machine shortcomings limit its application in three-dimensional measurement field, such as high prices, high use environmental conditions requirements of measurement data is relatively slow, the need for more artificial intervention.

B. Noncontact Data Acquisition Method

The noncontact data acquisition method utilizes a physical analog to interact with the workpiece surface, and then applies the corresponding algorithm to transform it into two dimensional and three dimensional coordinate information. As shown in Fig. 2, there are mainly: laser triangle method, mechanism optical distance method, interference measurement method, laser range finding method, image analysis method, etc. In addition, the methods of measuring by other principles include ultrasonic distance measurement, nuclear magnetic resonance, CT and layer by layer cutting photography.

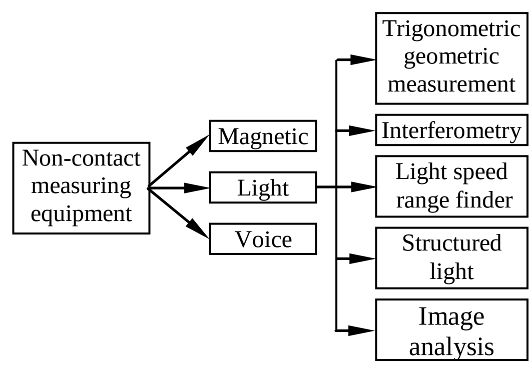


Fig. 2. Non-contact sampling method

The noncontact measurement does not exist for the calibration of the probe and the compensation of the radius, because it does not use the actual head. The direct contact between laser and workpiece surface is much faster than that of contact measurement. It can get a lot of high-density point cloud data. The product details are more specific and complete, which can measure soft, fragile and thin-walled workpieces. But the non-contact measurement accuracy is relatively low, and it is easy to be influenced by noise. There are many noise points, which is limited by the color and curvature of workpiece, and it is more difficult to measure the edge and hole part of workpiece.

The two methods of non-contact measurement and contact measurement have their own characteristics, and the measurement methods should be selected according to the actual needs. This paper takes the human skeletal image data by CT.

III. The Structure and Working Principle of CT

Medical CT scanner is composed of X-ray scanning frame system and computer system [6].

A. X-ray Scan Frame System Structure

The X-ray scanning rack system is mainly composed of the following components.

(1) X ray tube: including the fixed anodic X-ray tube and the rotating anode X-ray tube. Fixed anode X-ray tube parts is mainly used for the 1-2 generation CT scanner; characteristics of rotating anode X-ray tube is the focus of small and large heat capacity, long service life, mainly for the third generation after ct.

(2) High voltage generator: stability of CT on high voltage generator is high, because the change of the X-ray tube voltage at both ends is directly affected by the X-ray energy, so as to determine the key body of X-ray attenuation coefficient is the value of the X-ray energy. So, in the high voltage system of CT is widely used in the high precision of the feedback regulation measures.

(3) Detector: it is used to detect the radiative intensity of the X-ray radiated through the human body, and to convert the received X-ray energy into electrical signals according to its different energy intensity.

(4) The accurate values: the function of the paramer is to reduce the interference of scattered rays and to control the thickness of the scanning layer. The CT value is in two kinds: one is the X ray tube side is another standard value; standard value for the detector side is, the two must be accurately aligned.

B. The Computer System

CT scanner includes two computer systems: the main control computer and fast array processor. The main control computer is used to control the operation of the whole system, usually using minicomputer or microcomputer, including X-ray generation, check bed movement, data acquisition and data exchange between systems. The fast array processor receives data from the data acquisition system or data storage system under the control of the main computer, then carries it back to the main computer and displays it at the terminal.

C. The Spiral CT

Spiral CT is the latest development of modern CT technology. Spiral CT, because of its collection of volume data, and can perform a scan of the target organ during a breath holding process. The spiral CT is very different from the ordinary CT in the design principle and the structure of the machine parts. The most important improvement in hardware is the use of slip ring technology and high heat capacity X - ray tube. Therefore, spiral CT scanning tube does not need to reset and there is no need to remove the restriction cable. So when scanning breath hold, X-ray tube can collect volumetric data around the patient in the same direction. In addition, a high speed computer system is equipped to make a large number of image processing works carried out and completed quickly. For the current technology, spiral CT has acquired the single spiral CT of a single image from rotating 3600 years ago. It has rapidly developed to rotate 3600, and can acquire more than a dozen images of multi-slice CT. The CT scanning time is greatly shortened.

The basic principle of spiral CT scanning can be summarized as: spiral CT scanning machine technician, X-ray scanner tube in a continuously rotating around the patient, at the same time the X-ray tube emits a beam of X-ray machine, manned constantly moving in the longitudinal direction. In this case, the X - ray beam in the scanning area is spiraling relative to the examiner. In the end, the technician further processed the volume data obtained by the computer system and displayed a two-dimensional transverse image on the display. The modern spiral CT is shown in Fig. 3.

Fig. 3. Modern spiral CT

IV. Data Acquisition of Spinal Skeleton Image

The spine is the backbone of the body, located in the middle of the back, the upper end of the skull, and the tip of the tail. The spine is divided into 5 sections of the neck, chest, waist, sacrum and tail. The upper minister is capable of moving, like a stent, hanging a chest wall and an abdominal wall; the lower part is short and fixed. The weight and concussion of the body is conveyed to the lower extremities.

The spine is composed of the spine and intervertebral disc, which is a fairly flexible and active structure. With the movement of the body, the shape of the spine can be considerably changed. There is a considerable change in the shape of the spine. The movement of the spine depends on the integrity of the intervertebral disc and the harmony between the related vertebrae and the joint.

The 3/4 of the spine is composed of the vertebral body, and the 1/4 is made up of the intervertebral disc. The spine is made up of 26 vertebrae and 24 vertebrae (7 cervical vertebrae, 12 thoracic vertebrae, and 5 lumbar vertebrae), 1 sacral bone and 1 coccyx bones. The sacral system is composed of 5 pieces, and the coccyx is made up of 4 pieces, and the normal spine can also be made up of 33 pieces.

Many of the spine, because there are strong ligaments linked to maintain relatively stable, and because the intervertebral joint is connected with each other, with a considerable degree of activity, each vertebra range is small, but if all activities range has increased a lot [7].

Adult male wet atlantoaxial and axis vertebrae were selected. CT (computer tomography) tomography was performed on the above two vertebral specimens. During the CT imaging process, the vertebral specimens remained relatively static. Once every 1mm scans, there were 44 layers of the atlas and 53 layers of the axis. The image directly into the machine, CD, gets that image cone and Atlas vertebral axis of each layer of cross section.

V. Image Enhancement Algorithm for Spinal Skeleton

A. Image Integration

The spinal bone CT scan image data into computer access, using efficient algorithms (including histogram equalization, gray-scale transformation, smoothing and sharpening filter and Prewitt operator Canny operator) program characteristics of the CT scan out bone image enhancement, from different angles, different methods of image features to effectively the data can be enhanced, skeletal features in 3D modeling process of the subsequent more quickly extracted accurately, so as to provide a great convenience to reconstruct the 3D model of three-dimensional human skeleton further study of two-dimensional images.

B. Histogram Equalization

Usually, the frequency of natural image's grayscale histogram on the low value gray interval varies greatly, which increases the difficulty of technicians to distinguish details in darker regions [8] [9]. After dealing with the gray histogram equalization, there is a certain disparity of human vision in the region where the original image is grayscale, so that the overall contrast of the image is more obvious, and it is convenient for further identification and feature extraction. The functions imhist() and histogram equalization function histeq(), which are calculated and displayed for the histogram of the image, are shown in formula (1).

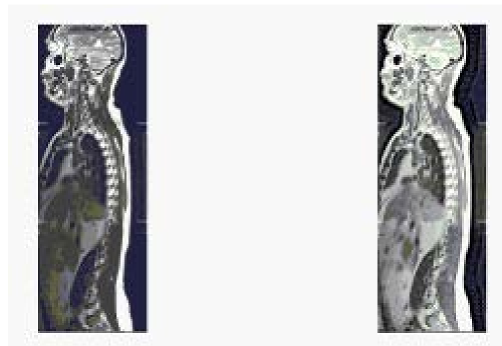
$$s = T(r_k) = \sum_{j=0}^{k} n_j / N = \sum_{j=0}^{k} P_r(r_k) \qquad (1)$$

In the formula, $T(r_k)$ is the conversion function of the k grayscale of original image. $\sum$ is combined. $\sum n_j / N$ is the ratio of the sum of from 0 to j of grayscale pixels with the total number of pixels. $\sum \mathrm{P}_r(r_k)$ is the cumulative sum of the probability of the gray level from 0 to k appeared. Because s is a normalized values $(s \in [0,1])$, to convert the color value of 0 ~255, it need to be multiplied by 255, that is $s = \sum P_r(r_k) \times 255$.

The program code is as follows:

```
I=imread('jz.jpg');
G=rgb2gray(I);
imshow(G);
J=histeq(G);
subplot(1, 2, 1), imshow(G);
subplot(1, 2, 2), imshow(J);
figure, subplot(1, 2, 1), imhist(G, 256);
subplot(1, 2, 2), imhist(J, 256);
```

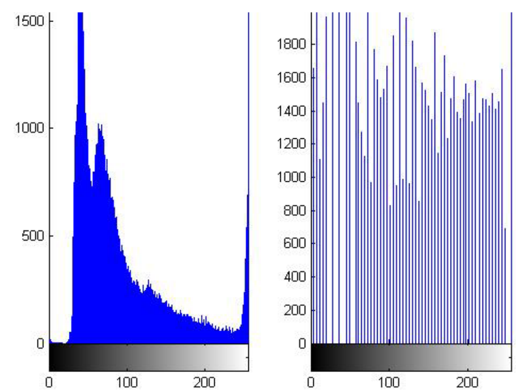
The gray histogram equalization method is used in Matlab, and the effect is shown in Fig. 4. Fig. 4(a) is the original image, and Fig. 4(b) is the effect of performing gray histogram equalization.



(a) (b)

Fig. 4. Gray histogram equalization effect

Fig. 5 (a) and (b) are the original graphs and the histogram of the equilibrium.



(a) (b)

Fig. 5. Histogram before and after equalization

C. Gray Scale Transformation

The essence of image enhancement is to enhance the contrast effect of different parts of the original image in different degrees, so as to facilitate the research of feature extraction of interested parts. The final gray scale transformation between the two images is realized by the dynamic region between the two gray levels in the image original image, as shown in Fig. 6.

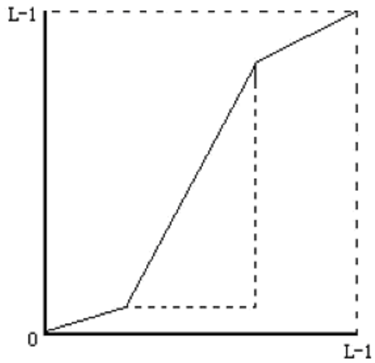


Fig. 6. Gray transform sketch

As shown in Fig. 6, gray transformation can reduce the dynamic range of gray value of higher and lower images, and increase the dynamic range of the front and rear images, so as to achieve the purpose of increasing contrast. Gray transform is the main method of correction is obtained by image data pixel gray value, increase the image gray value to a certain dynamic range, the corresponding expansion of the contrast, the regional characteristics of homogeneous and clear image, to improve image quality and enhance the contrast between the various parts of the standard requirements. The grayscale adjustment function imadjust() can adjust the gray value of the image to a certain range.

Linear transformation: $s = a \times r + b$, s is the grey value after the linear transformation, *r* is the grey value before the linear transformation. *a* and *b* are parameters. When it is $a > 1$, the gray scale expansion. When it is $0 < a < 1$, the gray-scale compression. When it is $a < 0$, we brighten dark area, dim light area.

Piecewise linear transformation: linear scale grayscale range area interested, relative inhibit the gray area which is not interested. We assume $f(x, y)$'s gray scale range area as $[0, M_f]$, $g(x, y)$ gray scale range area as $[0, M_j]$. Expression is shown in formula (2).

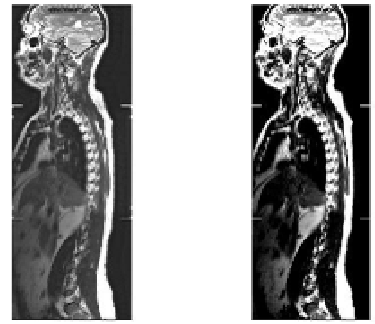
$$g(x,y) = \begin{cases} \frac{M_t - d}{M_f - b}[f(x,y) - b] + d & b \le f(x,y) \le M_f \\ \frac{d-c}{b-a}[f(x,y) - a] + c & a \le f(x,y) < b \\ \frac{c}{a} f(x,y) & 0 \le f(x,y) < a \end{cases} \quad (2)$$

Logarithmic transformation: the general expression for the logarithmic transform is $s = C \times \log(1 + r)$, where *C* is a constant. Nonlinear stretching is the choice to extend the range of the area of the studied gray value to a certain extent, and to compress the gray value of the other area.

The program code is as follows:

```
I=imread('jz.jpg');
J=imadjust(I, [0.25 0.65], [0, 1]);
figure, subplot(1, 2, 1), imshow(I);
subplot(1, 2, 2), imshow(J);
```

The effect of the program before and after the operation of the gray scale transformation algorithm is shown in Fig. 7.



(a) (b)

Fig. 7. Effect of gray scale transformation

D. Smoothing and Sharpening Filtering

In practical research, noise point refers to a distinct point of mutation that distinguishes the gray level of the adjacent pixels of the image, representing a high frequency component. Sharpening technology uses high pass filtering to enhance the high-frequency components as much as possible, so that the blurring degree of the image is reduced, and the blurred edge part is enhanced [10] [11]. The negative effect will enlarge the noise points of the processed image, thus affecting the final processing results. In MatLab, the fspecial () function can be used to create a predefined filter operator and then filter with filter () or conv2f1 () functions.

(1) Neighborhood average method is to take the pixels and its designated neighborhood pixels within the average or weighted average as the new value of the pixel, so as to remove the mutation pixels, to filter out the noise. Mathematical meaning of the neighborhood averaging method is as follows:

$$g(x,y) = \frac{\left(\sum_{j=1}^{mn} w_i z_i\right)}{\sum_{j=1}^{mn} w_i} \quad (3)$$

z_i is (x, y) as the center of the neighborhood pixels value; w_i is the weighting coefficient of each neighborhood pixels or template coefficient; mn is the number of weighted coefficient or being called template size. The commonly used template of neighborhood average method is as follows:

$$T_{Bax} = \frac{1}{9}\begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix} \quad (4)$$

In order to solve the problem of the fuzzy image which neighborhood average method made, we take threshold method, and the given threshold:

$$h(x,y) = \begin{cases} f(x,y) & |f(x,y) - g(x,y)| < T_0 \\ g(x,y) & |f(x,y) - g(x,y)| \ge T_0 \end{cases} \quad (5)$$

$f(x, y)$ is the original image contains noise, $g(x, y)$ is the pixel value of the average of $h(x, y)$ in (5) after filtering.

(2) Median filtering is a nonlinear signal processing technology, its principle is a bit value instead of digital image or in a neighborhood of a point in the median value in the

sequence, so that the pixel area around the range of values is more close to the real value, and to eliminate unnecessary noise.

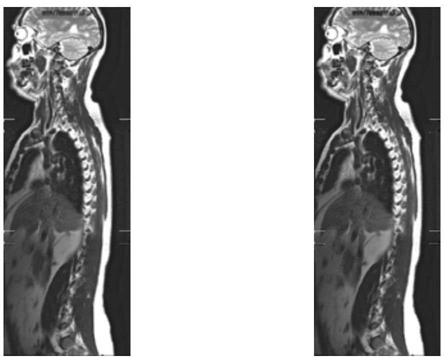
$$g(x, y) = med\{ f(x-k, y-l), (k, l \in w)\} \quad (6)$$

$f(x, y)$ is the original image, $g(x, y)$ is the processed image. w is the two-dimensional templates, whose area is usually 2×2, 3×3, it also can be different shapes, such as linear, circular, cross, circle ring, etc.

The program code is as follows:

```
I=imread('jz.jpg');
J=imnoise(I, 'salt&pepper', 0.03);
K=medfilt2(J);
subplot(1, 2, 1),imshow(J);
subplot(1, 2, 2),imshow(K);
```

After execution of rendering:it is shown Fig. 8(b). Fig.8(a) is the original one.



(a) (b)

Fig. 8. Smoothing and sharpening filter

E. Image Edge Detection

Image edge detection is an important attribute of image feature extraction by technicians in the process of image recognition. Image edge detection includes extraction of edge points, which reflect the change of image area of interest, and connect the edge of image to form a complete edge line. The edge() function can detect edge functions for the Roberts operator, the Prewitt operator, and the Canny operator. The following only use the Prewitt operator Canny operator to detect the edge of the image.

$$\Delta x f(x, y) = [f(x-1, y+1), 2f(x, y+1) + f(x+1, y+1)] - [f(x-1, y-1), 2f(x, y-1) + f(x+1, y-1) \quad (7)$$

$$\Delta x f(x, y) = [f(x-1, y-1), 2f(x-1, y) + f(x-1, y+1)] - [f(x+1, y-1), 2f(x+1, y) + f(x+1, y+1) \quad (8)$$

Soble has certain ability of noise suppression, on the edge of the detection step we could get the edge of the width for at least two pixels.

The program code is as follows

```
I=imread('jz.jpg');
G=rgb2gray(I);
imshow(G);
J=edge(G, 'prewitt');
K=edge(G, 'canny');
subplot(1, 3, 1), imshow(G);
subplot(1, 3, 2), imshow(J);
subplot(1, 3, 3), imshow(K);
```

After running the program, the image edge detection effect is shown in Fig. 9 (b) and (c), and Fig. 9 (a) is the original image.

(a) (b) (c)

Fig. 9. Image edge detection effect

VI. CONCLUSION

Image information is a very important way for people to understand and study the objective world. Digital image processing technology has been widely studied and applied in various fields of the world. MatLab software is very powerful for image enhancement. In the process of processing, people can write programs to define or improve various features of corresponding corresponding functions, or also directly use function programs provided by Matlab toolbox.

Using the powerful image processing function of Matlab software, based on CT human spine and skeleton images, we perform efficient gray histogram equalization, image grayscale transformation, smoothing and sharpening filter processing, so as to achieve spine bone image feature enhancement. Through image enhancement technology, spine and skeleton data can be extracted quickly and accurately in subsequent 3D modeling process, which provides effective data for further research of 2D image to 3D human skeleton 3D model reconstruction.

The final image processing algorithm of gray enhancement effect is obvious compared with the other algorithm is more suitable for the enhancement of human tissue image data, because after human CT image data after processing the algorithm characteristics of spine and other non regional comparison becomes larger, so as to facilitate the next step using the reverse medical software MIMICS for the extraction of the spine part feature model when constructing. Through the gray algorithm, the spine part enhancement processing is carried out on the scanned human image data based on CT technology, and the mass two-dimensional modeling image data are finally obtained.

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