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Research on the three-dimensional segmentation of tissue content based on CT

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Abstract. The proportion of bone, fat, and muscle in the body is depended on the growth status and meat quality of livestock. In order to extract and measure the proportion of each tissue directly from living body, this paper proposes a framework of tissue segmentation and measurement based on CT images. This framework is mainly composed of bone extraction methods based on level set, visceral culling, muscle and fat segmentation based on threshold segmentation methods. It can accurately exclude internal organs, exactly segment and detect bones, fats, muscle tissue, and obtain the weight and proportion of bones, fats and muscle in the body. Through experiments and tests in real data sets, and comparison with anatomical data, the results prove that the proposed framework has high theoretical and practical value.

1.INTRODUCTION
Computed Tomography (CT) was first applied to clinical medicine and achieved certain achievements[1]. With the development of computer technology and the promotion of material level, the application of CT technology in breeding livestock has been widely concerned. In order to improve the breeding ability of raising livestock, the combination of CT and computer technology has become an important research direction. Many studies at home and abroad have shown that the breeding capacity of livestock is closely related to bone, fat, and muscle content[2]. Traditional measurement method requires the living body slaughtered to separate bones, fats, muscles through artificial cutting. This method requires a certain amount of financial, material and human resources, and the measurement result cannot be applied to the whole group after slaughtering, so cannot judge whether the breeding capacity of livestock is related. Liu[3] et al. proposed to improve the breeding ability from the process of muscle development in pigs, mainly discuss the molecular mechanism of myogenesis regulation and the transgenic pigs for pork improvement. Qian[4] et al. collected the digital images of pigs through B-type ultrasound system, extracted the characteristic parameters of B-ultrasound images by special image processing technology, and combined the characteristic parameters of individual pigs to analyze the correlation between living intramuscular fat and breeding ability. In this paper, the pigs were scanned in vivo using CT equipment to obtain CT images. Combined with computer image processing segmentation technology, the body bone, fat, and muscle contents of pigs were determined and the relationship between the test results and breed breeding was studied and analyzed, for
researchers to explore the establishment of more effective measurement methods to provide reference. Classical image threshold segmentation methods such as double-threshold method and Otsu method often have good segmentation effects when there is a large contrast between objects. More complex image segmentation methods can segment the ideal part well. Based on the rough segmentation of the three-dimensional regional growth method, Dai[5] et al. refined the results of the segmentation, and removed the trachea and the main bronchus through the connected-domain labeling method and morphological method to obtain a preliminary lung parenchyma mask. Based on the classic graph cut theory, Dai[6] et al. proposed an image segmentation algorithm using super-pixel technique and improved iterated Graph cut algorithm. With the improved simple linear iterative clustering algorithm, a super-pixel image with more complete preservation of foreground edge information can be obtained. In this paper, the CT bed was separated by three-dimensional regional growth method, and the bone, fat and muscle parts were segmented using level set method, three-dimensional double threshold method and corresponding morphological operations.

2.METHOD

2.1 Separation of CT bed
Due to the use of CT scans on pigs, the bed of the CT machine would also be the part of the original data, which would cause a large error in the measurement result. Therefore, removing other interference factors besides the living body became an indispensable process. In this study, the three-dimensional region growing method[7] was used to remove the CT bed.

The basic idea of region growing was to combine pixels with similar properties to form regions. The method first selected one or a group of seed points, and then merged the similar pixels around the seed pixels in sequence to the area where the seed pixels were located. The three-dimensional region growing method could process the image sequence, greatly improving the segmentation speed, and only one seed point needed to be selected in the segmentation process, which reduced manual intervention. In this experiment, the 26-neighborhood three-dimensional region growing method was used to segment the bed of CT machine and living body.

2.2 Bone extraction
In CT images, the unit of measurement we use was no longer the grayscale value of a pixel, but a measure of the density of a certain tissue or organ in a living organism called Hounsfield Unit (HU). The CT values of the bone part ranged from approximately 200 to 1300 HU, the ordinary threshold segmentation method could extract the outline of the bone, but because the bone contained a certain amount of bone fluid and bone marrow, their density was much less than the bone density, and the CT values was also much smaller, so could not be splitted. To obtain a complete skeleton part, we chose a level set method that could evolve contours on 3D images.

Level set was originally proposed by Osher and Sethian to solve the evolution of geometric curves[8]. The basic idea was to implicitly express the plane closed curve representing the interface as the zero-level set of a high dimensional surface function \( \Phi(x,y) \), i.e. \( \{ \Phi = 0 \} \), the set of points with the same function value. The motion of the curve was represented by the motion of the high-dimensional functional surface, the position of the curve was characterized by a zero-level set of high-dimensional functions at each moment. The level set method used in image segmentation was to first give a closed initial contour in the image to be divided, then the initial contour approached the target in a series of interactions between external forces and internal forces, and finally stopped in accordance with constraints. In the experiment, we applied the level set method to 3D bone segmentation. The final segmented contour was marked in red.

2.3 Visceral removal
In the CT image, the CT values of the visceral portion ranged from approximately -800 to 200 HU, including the CT value of fat and muscle. Therefore, the visceral portion should be removed before the
fat and muscle portions were divided. For visceral segmentation, combined with image segmentation algorithms and morphological operations, it was divided into the following steps:

1. The living pig mask was selected for removing the CT bed and the segmented bone mask was selected to perform the three-dimensional corrosion expansion operation. For the living mask, a nucleus with a size larger than $101 \times 101 \times 101$ was selected for a three-dimensional corrosion operation to obtain a mask $A$ with a visceral size. For the bone mask, a kernel with a size larger than $41 \times 41 \times 41$ was selected for a three-dimensional expansion operation, and a logical non-operation was performed on the expanded result to obtain a mask $B$.

2. A logical and-operation on mask $A$ and mask $B$ was performed, and a kernel with a size smaller than $61 \times 61 \times 61$ was selected to perform a three-dimensional expansion operation on the operation result to obtain mask $C$.

3. The dual threshold segmentation method was used to set the threshold values as -800 HU and -200 HU, and the pixels in the CT sequence image whose threshold was between this range as the air mask part were selected. The air mask and the mask $C$ obtained in the previous step was taken as a logical or-operation, the obtained images were the complete visceral part.

2.4 Fat and muscle segmentation

After removing the visceral part of the CT image, the segmentation of fat and muscle became simple. In CT images, the CT values of fat ranged from approximately -200 to 0 HU, and the CT values of muscle ranged from 0 to 200 HU. Threshold values were set as -200 HU and 0 HU using the dual threshold method, selected the pixels in the CT sequence image where the threshold was between this range as fat parts. Threshold values were set as 0 HU and 200 HU using the dual threshold method, selected the pixels in the CT sequence image where the threshold was between this range as muscle parts. The whole segmentation process was shown in Figure 2.

2.5 Determination of bone, fat and muscle content

In the foregoing, images of bone, fat, and muscle have been obtained through the three-dimensional image segmentation algorithm. Based on the number of pixels and the volume of each pixel contained in the CT image of each part, combined with the density of bones, fats and muscles in actual production, the content of each part in the body tissue could be calculated separately. The formula was as follows:

$$W_t = \rho_b V_b + \rho_f V_f + \rho_m V_m$$  \hspace{1cm} (1)

$$P_b = \frac{\rho_b V_b}{W_t}$$  \hspace{1cm} (2)

$$P_f = \frac{\rho_f V_f}{W_t}$$  \hspace{1cm} (3)

$$P_m = \frac{\rho_m V_m}{W_t}$$  \hspace{1cm} (4)

$P_b$, $P_f$, $P_m$ were the proportions of bone, fat, and muscle in the body.

3. Experiments and analysis

Ten varieties of the American Duroc sows were collected from a pig farm in Anhui Province and marked from No.1 to No.10. The breeding pigs were anesthetized to prevent them from interrupting the process during the scan. According to the CT scan instruments currently available, the pigs were clinically scanned with the appropriate power and the tissue information of the body parts of the breeding pigs generated by the scan was selected using computer equipment to generate CT images. Thereafter, the bone, fat, and muscle contents of the breeding pigs were determined in combination with computer image processing techniques. The measurement data were saved and analyzed.
In this experiment, CT scans were performed on pigs. The parameters of the CT scans were 110kV, 160mAs. Under these parameters, the CT scan produced relatively low noise. The thickness of each CT slice was 4.999mm, the width and height of the CT slice were 512 pixels and 512 pixels respectively and the size of each pixel in the image was 0.977mm. The number of pixels was large, and the CT image was composed with high spatial resolution, which could well reflect the change of HU value of each tissue in the image. The bone, fat, and muscle content data obtained through the experiment were compared with the data collected from the on-site slaughter, and data were collected in the form of tables and line charts. It can be seen from the table that in the proportion of bone, fat, and muscle in the body, the proportion of bone is the smallest, fat is the second, and muscle is the largest. For the selected 10 pig samples, the proportion of bone in the body was between 6% and 8%, fat was between 25% and 40%, and muscle was between 50% and 65%. Comparing the experimental data with the real data, it is found that the proportions of bone, fat, and muscle in the real data are in agreement with the experimental data, and the error between the experimental data and the real data does not exceed 3%, thus verifying the experiment has certain feasibility. In the line chart, the abscissa indicates the serial number of the breeding swine, and the vertical axis indicates the proportion of the ratio. Each marked point of the broken line indicates one time of data. Accounting from the line graph, it can be seen that the data of the proportion of bones are basically in the same horizontal line, indicating that the proportion of bones in the body of different breeders is not much different. The ratio of fat to muscle accounts for a symmetrical pattern in the line chart, indicating that there is an inverse relationship between the two.
Table 1. Data contrast

| Test Sample | Bone (%) | Fat (%) | Muscle (%) | Real Data | Bone (%) | Fat (%) | Muscle (%) |
|-------------|----------|---------|------------|-----------|----------|---------|------------|
| 1           | 6.69     | 37.46   | 55.85      | 1         | 7.37     | 38.84   | 53.79      |
| 2           | 6.24     | 40.90   | 52.86      | 2         | 6.11     | 41.34   | 52.55      |
| 3           | 6.55     | 28.77   | 64.68      | 3         | 6.31     | 30.71   | 62.98      |
| 4           | 7.43     | 30.48   | 62.09      | 4         | 7.02     | 31.95   | 61.03      |
| 5           | 6.29     | 38.77   | 54.94      | 5         | 6.07     | 40.20   | 53.72      |
| 6           | 7.03     | 33.53   | 59.44      | 6         | 6.83     | 36.52   | 56.65      |
| 7           | 7.87     | 29.76   | 62.37      | 7         | 8.05     | 31.21   | 60.74      |
| 8           | 6.95     | 33.81   | 59.24      | 8         | 6.77     | 36.95   | 56.28      |
| 9           | 6.16     | 33.31   | 60.53      | 9         | 6.98     | 36.77   | 56.25      |
| 10          | 7.20     | 33.30   | 59.50      | 10        | 7.65     | 35.53   | 56.82      |

4. CONCLUSION
This experiment realized the combined application of CT and computer image processing technology, and finally achieved certain results. Three-dimensional image segmentation is one of the hot topics in current image processing research. In clinical medicine, three-dimensional models provide doctors with intuitive, comprehensive, and accurate information on lesions and normal tissue. Accurately extracting the target object from the medical image is the basis of the three-dimensional segmentation, and is also the practical basis of the medical image processing system in clinical practice. Applying 3D image segmentation technology to actual production and studying more effective image segmentation methods will have important theoretical and research value.

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