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Research About Three Dimensional Reconstruction of Medical Image

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Abstract

In this paper, through comparison of different reconstruction algorithms for volume rendering, we put forward Ray Casting algorithm as the scheme of 3D reconstruction of medical image. We improved the image synthesis operator, and combined section sampling mode to reconstruct the image. Finally, we rendered images on GPU. By using improved operator, we not only made the rendering speed accelerated, but also made the quality of rendering images improved.

Keywords: medical image, 3D reconstruction, ray casting

1. Introduction

In the past few decades, three-dimensional medical image reconstruction has been under computer graphics on the basis of the development of a new discipline. After the 1980s, with the development of medical image technology, although the computed tomography (CT) scan and magnetic resonance imaging (MRI) can provide high resolution about two-dimensional image [1], however, these medical instrument(s) can only provide human internal two-dimensional image. CT is a medical imaging procedure that utilizes computer-processed X-rays to produce slices of specific areas of the body. Doctors can image a quasi three dimensional organ while reading these slices. The cross-sectional slices created by the early CT machine is thick and the image interval is large, according to traditional technology, CT usually have around 10 pictures and, less than 40 in most cases, due to factors such as slow scanning speed. Doctors find it easier to read a small number of images, but on the other hand, limited by the condition of software and hardware, realizing 3D reconstruction is also difficult. But in recent years [2], with the development of computer technology, continuous improvement of scanning technique and the emergence of a spiral CT scanning way, faults can be very thin and layer spacing can be very small. View of some organic fault (section) can reach from hundreds to thousands of images, the traditional reading tablet way makes reading these fault by doctors become difficult, and three dimensional reconstruction research is developed. In addition, the medical clinical application requirements promoted the progress of 3D reconstruction.

Radiation therapy of medical images is the orientation of 3D reconstruction application requirements. The development of medical imaging technology for 3D reconstruction research provided the necessary security [3], 3D reconstruction technique for the application of medical image provided important technical support and broad application prospect. After years of development, the three-dimensional medical image reconstruction from auxiliary diagnosis has become an important means of adjuvant therapy. Use of 3D reconstruction technology on medical image processing, 3D model structure, and the three dimensional model from different direction projection display, the extracted relevant organs information, can make quantitative description of the size, shape and space position of the doctor interested organs. And three dimensional reconstruction technique makes it possible for doctor to directly, observe organs of the three dimensional structure [4] quantitatively. It also strengthens the image various details, so as to help the doctors make the correct diagnosis. Therefore, the 3D visualization processing of medical image data, which provides a highly efficient intuitive auxiliary diagnostic tool has

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profound significance, this makes medical image 3D visualization studies become one of the most active field of research.

3D Reconstruction of Medical Image is one of the key technologies for medical image visualization [5]. Since the last century, with the rapid development of computer hardware and software technology, a variety of new digital image devices have emerged in an endless stream. However, with the increasing of the image data quantity, the traditional diagnostic method of observing the two-dimensional topographic image has been insufficient to meet up with the diagnosis of disease needs, and this diagnostic modality with very strong subjectivity factors largely depends on the physician's clinical experience, which have very large uncertainty. So, medical image data for 3D reconstruction, which provide an efficient auxiliary visual diagnostic tool, has far-reaching significance. Volume rendering is an important part of the visualization [6], because it provides high quality image rendering result, receiving scientific researchers attention, and thus have developed a lot of different volume rendering algorithms. Among those algorithms, Ray Casting is widely used by researchers, because of its high image quality, but because of slow rendering speed; some improvements of Ray Casting are put forward.

2. The Typical Methods of Volume Rendering

2.1. The Process of Volume Rendering

Firstly, we get the initial continuous 3D data field based on reconstructing the discrete 3D data field. Then, we get the functional value of the sampling point by resampling in the continuous 3D data field. For the new sample points, classification and color assignment are according to the set opacity and color model. Finally, according to the volume rendering of the optical model, we get the entire data field projection image through the image synthesis.

The process of volume rendering is shown in Figure 1.

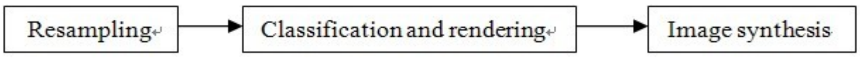

Figure 1. The Process of Volume Rendering

Volume rendering method can map out the data field in subtle and difficult to use geometric representation details, fully reflecting the data field of the whole information. Therefore, the method brings to attention, a variety of specific methods. Based on resampling and synthesis methods, the method of volume rendering can be divided into the image space scan body drawing method [7], object space scan volume rendering method and frequency domain volume rendering. Frequency domain volume rendering method due to its own principle limits which include single rendering mode and difficulty on achieving complex display effect is still in the stage of laboratory research.

2.2. The Comparison of Several Volume Rendering

Regular data field volume rendering research mainly has 4 kinds of algorithms: Ray Casting, Splatting, Shear-warp and 3D texture-mapping hardware.

Ray Casting [8]: It only relates to the amount of projection light and it can also promote synthesis. Therefore, it is particularly suitable for the volume rendering of 3D data field which feature large volume data field and tight distribution. Ray Casting's principle is simple and it is easy to realize. It can easily achieve a perspective projection with high image quality, so it is appropriate for the medical 3D reconstruction algorithm.

Splatting [9]: Three-dimensional data points are projected onto the screen to achieve data resampling and image synthesis. Therefore, the drawing time, which is highly sensitive to the size of the data field, depends primarily on the quantity of opaque vowels and the size of generic footprint table, and, as a result, not suitable for large-scale data field reconstruction of medical image.

Shear-warp [10]: A software rendering method, which is able to obtain interactive rendering speed in real time by software, possesses the fastest rendering speed by far. This method, however, exhibits many inherent defects: its two linear resampling may result in loss and in distinction of details; since there is no interlaminar resampling, the quality of images decreases significantly during magnification; the distribution of the inputted data in the three axial directions must be equally spaced, otherwise, interpolation should be executed in advance; because the offset encoding of three facets' direction needs to be pre-stored, and consequently, result in large amount of memory occupation.

3D texture-mapping hardware [11]: is based on hardware to improve the rendering speed, it needs special graphics hardware. Resampling interpolation operation in texture space and operation of the image synthesis with opacity values, is completed by hardware, thus take up a lot of memory space. And rendering quality is also poor. Evaluation of four kinds of algorithm is shown in Table 1.

Table 1. Algorithms Performance Evaluation

Volume rendering algorithm	*Algorithm* features	*Image* quality	*Rending* speed
Ray Casting	Each voxel has different color	Highest	Slow
Splatting	and opacity	High	Fast
Shear-warp	Footprint spline sampling	Medium	Fastest
3D texture-mapping Hardware	Data access is continuous	Lower	Fast
	Calculation required Hardware		

In summary, this paper uses Ray Casting algorithm for three-dimensional reconstruction of the medical image.

3. Ray Casting

3.1. The Principle of Ray Casting

Ray Casting [11] is a kind of images order volume rendering method. It sets out from each pixel point F (x, y) of the image space, according to the direction of line sight cast ray I, the ray go through the 3D data field at a certain step m, along the ray selection K equidistant sampling points, by the distance of the color values and the opacity values of the eight data points in a recent sampling point for the three linear interpolation [10], then find out opacity value and color value of this sample point. Synthesized color and opacity values of each sampling point from front to back can get the color value of pixels point from the ray, then gets the final image on the screen. The principle of Ray Casting is shown in Figure 2.

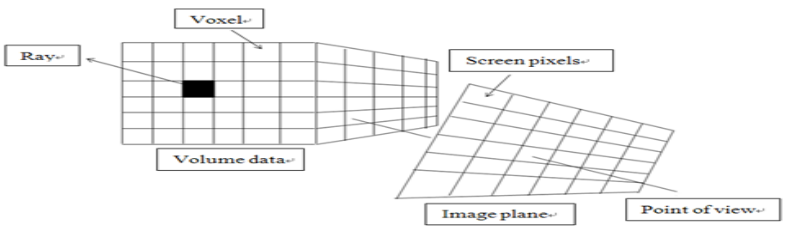

Figure 2. The Principle of Ray Casting

3.2. The process of Ray Casting

Ray casting algorithm which is based on image space is often used in direct volume rendering algorithm, the basic idea is that each pixel point on the screen sends a sampling rays which goes through a data field, resampled according to the sampling step [12]. Color and opacity of each resampling point composed is calculated by various interpolation algorithm, and then image synthesis from front to back or from rear to front, until the light passes through the volume data field or is absorbed completely [13]. The process of algorithm includes: gradient calculation, material classification, intensity calculation, resampling and image synthesis. The detailed process of algorithm is shown in Figure 3.

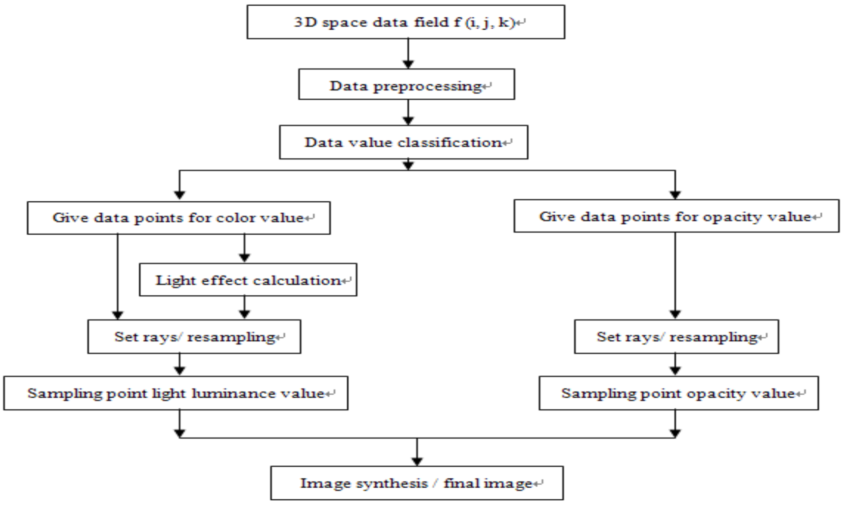

Figure 3. The Process of Ray Casting

The algorithm assumes that the 3D spatial data are distributed in a point of uniform grid or regular grid, data preprocessing flow diagram includes format conversion of raw data, canceling of redundant data, and image pre-processing.

Then, data classification, whose objective is to classify correctly all data points and different values of color and opacity for each data according to difference of related information of the data value, in order to show correctly the different distribution of a variety of substances or multiple attributes of a single material [14]. Then resampling, namely a ray is launched from each pixel of the screen according to the set direction of observation, that ray passes through the 3D data field, choosing K equidistant resampling point along the ray, and the interpolation calculation according to the color value and opacity of eight data point which is the nearest to sampling point, calculating color value and opacity of the sampling point. Obviously, before the resampling, color and opacity values of 3D data field should be transformed from model coordinate space into space of the corresponding image coordinates.

Lastly, Algorithm which is image synthesis, namely color and opacity values of each sampling point on every ray is compounded from front to back or from rear to front, color values and opacity of screen pixel for which ray can be obtained [15]. Resampling and image synthesis are conducted according to every pixel of each scan line on the screen, so this algorithm belongs to volume rendering algorithm which is scanned by image space.

4. The Basic Idea of Improving Ray Casting Algorithm

Although ray-casting is an effective method for three-dimensional reconstruction, we discovered some of its drawbacks after the test. Its rendering speed is slow. Therefore, considering this drawback, the rendering speed should be improved to acommplish volume rendering needs like basic resampling, image classification and rendering, and image synthesis, we concentrated our research on resampling and image synthesis, and improved the traditional ray-casting algorithm as below.

4.1. The Improvement of the Sampling

The point sampling is changed to the segmented sampling between two adjacent sections (two sections compose a thin plate) when light passing through. Thus in the mixing process, the mixing of sampling point RGBA value is turned to be the mixing of corresponding segments respectively. The calculation of the pre-integration table is often time-consuming, in order to meet the needs of real-time rendering, the pre-integration algorithm is accelerated. On the premise of the linear interpolation, firstly, we calculated the RGBA values on the one range interval 0-1, 1-2… 9-10. Then after accumulating the RGBA values we could obtain the value on interval 0-1, 1-2… 9-10. Next, when calculating the value on 1-11 range, we just need to add the value of 1-10 and 10-11 together; the calculation method on other intervals is analogous. Pre points accelerated algorithm principle is shown in Figure 4.

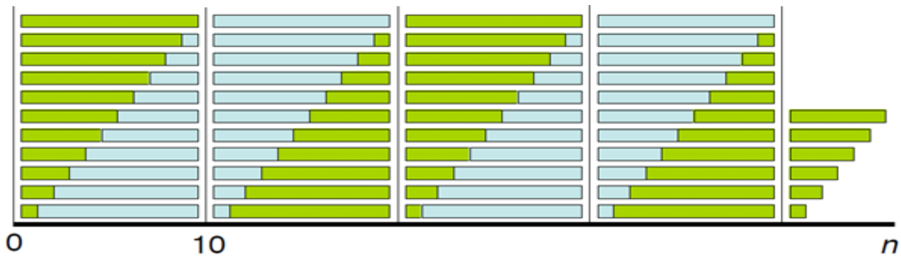

Figure 4. The Principle of Pre Points Accelerated Algorithm

4.2. The Improvement of the Image Composition Operator

For completing the volume rendering needed steps like basic resampling, image classification and rendering, image synthesis, we did special research on the image synthesis. We found that the image composition operator could be simplified when using a front end to rear end image synthesis operator. It needs five times of multiplication, addition and subtraction. Every sampling point needs to be synthesized. The traditional image synthesis operator is shown in formula (1), (2).

$$C_{out}^{i}\alpha_{out}^{i} = C_{in}^{i}\alpha_{in}^{i} + C_{now}^{i}\alpha_{now}^{i}(1-\alpha_{in}^{i}) \quad (1)$$

$$\alpha_{out}^{i} = \alpha_{in}^{i} + \alpha_{now}^{i}(1-\alpha_{in}^{i}) \quad (2)$$

The rendering speed will be further improving if the composition operator is simplified. Assuming the color value of the i individual element is C_{now}^{i}, the opacity value is α_{now}^{i}.The color value which enter the i individual element is C_{in}^{i}, the opacity value is α_{in}^{i}. The color value which pass through i individual element is C_{out}^{i}, the opacity value is α_{out}^{i}. Reaching to the point n, $a_{out}^{n} = 1$.So the improved operator is shown in (3).

$$C = C_{out}^{n} = \sum_{i=1}^{n} C_{now}^{i}\alpha_{now}^{i}(1-a_{in}^{i}) \quad (3)$$

This improved image synthesis operator only needs three multiplications and a subtraction operation, it can effectively improves the image synthesis efficiency. Using this improved Ray Casting algorithm. Using improved operator, we not only accelerated the rendering speed, but also improved the quality of rendering images.

4.3. The Improvement on the GPU

For traditional drawing on the CPU, the rendering speed is not fast enough and the image quality is also not very high. As known, GPU is a specialized processing hardware of image processor and it can bring extremely high image quality. By using the improved light projection algorithm on GPU, the software and hardware acceleration can be achieved at the same time.

5. Analysis of Test Result

In this paper, we used the improved Ray Casting algorithm for 3D reconstruction of the medical image. Three groups of experimental data were chosen to prove that this improved algorithm is successful.

The three sets of data are respectively on the resolution of 512×512, 48 skull images, 361 kidney images and 463 upper images. From the result, using improved operator, we not only accelerated the rendering speed, but also improved the quality of rendering images. The reconstruction of the image well preserved body in detail.

From the head, the kidney and the upper part of the image we can prove that the improved algorithm is successful. We can see that rendering speed is accelerated apparently, and the improved algorithm based on GPU rendering result is higher than in the CPU graphics, and the speed is faster.

The time using a different algorithm is shown in Table 2.

Table 2. The Comparison of Different Rendering Time

Body parts	Data field scale	The traditional Ray Casting algorithm for rending time(ms)	The improved Ray Casting algorithm based on CPU rending time(ms)	The improved ray casting algorithm based on GPU rending time(ms)
Head	512×512×48	420	270	170
Kidney	512×512×361	930	500	320
Upper body	512×512×463	1160	830	560

From table 2, we can see that the rendering time using improved Ray Casting algorithm based on GPU is faster than traditional Ray Casting algorithm.

6. Conclusion

In this paper, we introduced volume rendering algorithm in detail. For medical images, high quality rendering effect is important for health care workers. Therefore, in contrast to the classic volume rendering algorithms, we chose the ray-casting algorithm as the scheme of three dimensional reconstruction of medical image, and improved the traditional Ray Casting algorithm, finally achieving 3D medical image reconstruction of three groups of data's. The rendering speed which used improved Ray Casting algorithm is faster than that using traditional Ray Casting algorithm, combined with the GPU, achieving the image rendering with higher quality, faster results. With the development of computer hardware systems, volume rendering method in 3D medical image reconstruction will be more mature, and more widely use.

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