An Improved Ray Casting Algorithm Based on 2D Maximum Entropy Threshold Segmentation

Hou Huiling, Wang Mingquan, Ren Shaoqing
National Key Laboratory for Electronic Measurement Technology, Key Laboratory of Instrumentation Science and Dynamic Measurement of Ministry of Education, North University of China, Taiyuan, Shanxi, 030051, China, 10801153@bit.edu.cn

Abstract
This paper presents an improved ray casting algorithm, in order to solve the problems of powerful computing capacity and slow rendering velocity. In the course of ray casting volume rendering, an algorithm of ICT slice images original data field 2D maximum entropy threshold segmentation prior preprocessing is proposed. It is used to define the extent of threshold, and research the optimal combination of the parameters. The area threshold removing method is combined applied to filter the noise before the binary processing of image. The results of reconstruction show that this algorithm can greatly reduce reconstruction volume data and improve the efficiency of ray casting.

Keywords: Ray Casting Algorithm, Maximum Entropy Threshold Segmentation, ICT

1. Introduction

Visualization in Scientific Computing (ViSC) is a kind of theory, method and technology converting data and results produced from scientific computing process into graphics and images displaying on screen and making interactive management and interpretation of them through with the aid of computer graphics and image processing technique\(^\text{[1,2]}\). The volume rendering technology is one of the important research directions in ViSC\(^\text{[3]}\).

The ray casting algorithm is one of the basic algorithms of volume rendering technology. It has been widely researched and applied as it has the advantage of the simple principle and the easy realization. It can also greatly keep three dimensional image details, enhance overall rendering effects and finally generate high quality images. Compared with the rendering method which based on the traditional computer graphics technology, the key technical problems of volume rendering is powerful computing capacity and slow rendering velocity. Visualization speed still can not satisfy with industrial imaging equipment resolution improvement and huge volume data field. Seeking for the rendering visualization algorithm which can speed up the rendering speed and improve the quality of rendering has become a hot research topic of 3-D visualization technology\(^\text{[4]}\).

Based on the traditional ray casting algorithm, this paper adopts ICT slice images original data field 2D maximum entropy threshold segmentation prior preprocessing. The area threshold removing method is combined applied to filter the noise. Finally, the ICT slice images can be reconstructed and the geometric boundary of overall and partial can be transparency displayed.

2. Algorithm description

2.1. The ray casting algorithm theory

Ray casting technology is assumed to 3D spatial data distributed in a uniform grid or regular grid point; 3D spatial data point can be obtained by interpolation between layers of the two-dimensional image. The process is the 3D data are preprocessed, and then the data value is classified and resample. Finally 3D data field from object space coordinates is converted to the corresponding image coordinates in space and the image is synthesized and Ray casting algorithm flow chart is shown in Figure 1.
The basic principle of traditional ray casting algorithm: Firstly, the idealized physical visual model is constructed out according to the visual imagery principle. Each individual element is regarded as particle which is able to transmission, launch and reflect the light. Secondly, according to the illumination model, based on the medium property of the voxels, we can get their color (grayscale image for brightness) and opacity and integrate along the direction of observation. Finally, the translucent image will be conformed on the image plane. The ray casting algorithm is a concise and stable algorithm, which based on the sampling theory and talked sampling points as the basic processing object [4,5]. The essence is resample and image synthesis. The schematic diagram is shown in Figure 2.

The ray casting algorithm can display a wealth of internal information, even subtle features of data field are not lost. But it is also the gravest weakness. In order to get better rendering effects, the need of the great amount of light projection data and the need to sampling many times for every light, have greatly affected rendering speed. And also volume rendering method can't change external light and
perspective flexibly. Every time change means a new rendering process. So we can see the ray casting algorithm still exists limitation as a classic algorithm of the volume rendering algorithm.

2.2. 2D maximum entropy threshold segmentation

Image segmentation is an important part in the field of image processing. As all image segmentation methods are confront to specific problems, there is not a general segmentation method until now [6, 7]. In such segmentation methods, the threshold method is one of the most important image segmentation technologies. Threshold methods are commonly used, such as Otsu, iteration method and one-dimension maximum entropy algorithm. Most existing methods choose threshold merely through histograms of the image. But, as the signal-to-noise ratio of the image descending, the use of these methods will produce a lot of segmentation mistakes. Some methods began to use the 2-D gray histogram of image for threshold segmentation. The effects were obviously improved than the traditional methods [8-11].

2.2.1. The establishment of 2-D gray histogram

Let \( f(x, y) \) be image with 256 gray levels. Let \( g(x, y) \) be grayscale average of \( 3 \times 3 \) neighborhood’s four pixels which are outside the 4 adjoining points of the current pixels, that is,

\[
g(x, y) = \frac{1}{4}[f(x-1, y-1) + f(x-1, y+1) + f(x+1, y-1) + f(x+1, y+1)]
\]

(1)

Where \( r \) is the set of the integer part of \( r \). \( f(x, y) \) and \( g(x, y) \) can constitute a 2-D histogram, that is,

\[
h(k, m) = p\{\{f(x, y) = k\} \cap \{g(x, y) = m\}\}
\]

(2)

Where \( p\{A\} \) is the set of the number of event \( A \) happens. \( h(k, m) \) is the set of the time when \( f(x, y) = k \) and \( g(x, y) = m \) happen. \( h(k, m) \) can be normalized by Eq. (3):

\[
h(k, m) = h(k, m) / \sum_{i=0}^{255} \sum_{j=0}^{255} h(i, j)
\]

(3)

2.2.2. The basic ideas of the maximum entropy threshold segmentation

In information theory, take the uncertainty of probability distribution as the definition of entropy. So, for a \( n \) state system \( \varepsilon_1, \varepsilon_2, \cdots, \varepsilon_n \), the probabilities are \( p_1, p_2, \cdots, p_n \), the entropy of system is defined as Eq. (4):

\[
H(p_1, p_2, \cdots, p_n) = - \sum_{i=1}^{n} p_i \ln p_i
\]

(4)

Using image entropy as target segmentation is an effective method, as it can effectively reflect the information of events. Image grey is relatively homogeneous when big entropy; the dispersion ratio of image grey is high when small entropy. So targets can be divided out according to the maximization of image entropy, where gray is relatively homogeneous.

The 2-D maximum entropy is to choose the threshold vector as \((S, T)\), and divides the image into the object part \( A \) and background part \( B \). Their different probability distributions are:
\[ A = \frac{p_{00}}{p_n}, \frac{p_{01}}{p_{n-1}}, \ldots, \frac{p_{mm}}{p_1} \]  
\[ B = \frac{p_{(s+1)0}}{1-p_n}, \frac{p_{(s+1)1}}{1-p_{n-1}}, \ldots, \frac{p_{(l-1)(l-1)}}{1-p_1} \]  

Where \( p_n \) is expressed as \( p_n = \sum_{i=0}^{s} \sum_{j=0}^{t} p_{ij} \).

The end result of image segmentation is to make the posterior entropy of the target class and background class biggest. If we ignore the influence of the far away from diagonal part, the entropy related to each of the distribution will be defined as:

\[ H_s(s,t) = -\sum_{i=0}^{s} \sum_{j=0}^{t} p_{ij} \ln \frac{p_{ij}}{p_n} \]  
\[ H_b(s,t) = -\sum_{i=0}^{s} \sum_{j=0}^{t} p_{ij} \ln \frac{p_{ij}}{1-p_n} \]  

To gain the largest information of image objects and background, the total entropy of the image \( H(s,t) \) should be as big as possible. And the gray which made \( H(s,t) \) maximum is the best threshold to \( (S,T) \). Choose the threshold vector \( (S,T) \) must meet the following function:

\[ H(s,t) = \max \{ \min_{i,j=0,1,...,l-1} [H_s(s,t), H_b(s,t)] \} \]  

In addition, a single threshold selection principle can be extended to the multi-threshold selection, thus, the equation (9) can be express as:

\[ \varphi(s_1, s_2, ..., s_k) = \sum_{i=0}^{s_1} \log p_i + \sum_{i=s_1+1}^{s_2} \log p_i + \ldots + \sum_{i=s_1+s_2+1}^{s_3} \log p_i - \sum_{i=0}^{s_1} p_i \log p_i - \ldots - \sum_{i=s_1+s_2+1}^{s_3} p_i \log p_i \]  

Where \( K \) is number of threshold and \( (s_1, s_2, ..., s_k) = \max \{ j \mid (s_1, s_2, ..., s_k) \} \).

The grey value of the area work piece is relatively small. In order to division effectively, we calculate overall image average gray firstly, then search for vector \( (S,T) \) in the scope below the mean value.

### 2.2.3. The area threshold removing method

The area threshold removing method marks the black connection regions firstly, and then statistically marks region area. If the area is less than a given threshold, the current area will be removed.

In the white connection regions, as the pixels area of small black impurities have not the same order of the object, we can simply set threshold value to distinguish the noise and object. Set the white connection regions \( 1, 2 \ldots m, \ldots, n \), the connected regions which mark for positive integer \( m \) are noises. All the markers (n) are changed to value m, in order to reduce the mobile computing quantity effectively. Let \( p \) is the numbers of the noise, and \( p < n \). When all noises are removed, the objects are
marked 1, 2, …, n-p in turn. For black connection regions, we can sure it as objects or noises through the statistics. Change all connected regions which tags value is less than 1 into black pixel can remove all small white hole noise at once.

We make some limits to the size of work piece of CT slice images, and then the small areas will be removed. After the black noise and white noise removed, all the Volume Data will be marked by the only positive integer. The separation result is shown in Figure 3.

![Figure 3. The separation result of the area threshold removing method](image)

### 2.3. The improved ray casting algorithm

The advantage of the traditional ray casting algorithm is that it can display the subtle structure of the object interior. The disadvantages of the traditional algorithm are that it cost a lot of time on calculation, and it will consume large amounts of storage space.

In the improved ray-casting volume rendering algorithm, voxel data is defined in a 3D space, as shown in Figure 4. Voxel data values which defined in a 3D space are the mean of the adjacent eight grid nodes scalar or vector data.

![Figure 4. Volume data model](image)

In the improved ray casting algorithm of volume rendering, in order to reduce the number of voxels in reconstruction process, the concept of image threshold segmentation is introduced to volume rendering. Through to traverse the voxel data set of original data field, using certain decision criteria, divide the voxels of the original voxel data set into two parts: the target voxel data set which is related to reconstruction and the background voxel data set which is unrelated to reconstruction. At the same time, the nodes of the original voxel data set are also divided into two parts. The nodes unrelated to reconstruction are called background nodes and the set composed by background nodes is called the background node set. The nodes related to reconstruction are called target nodes, and the set composed by target nodes is called the target node set.

In the process of data classification, the 2-D maximum entropy threshold method is used to define the extent of threshold, and research the optimal combination of the parameters. Then the area threshold removing method is applied to filter the noise. Binary processing of image is done. When the improved ray casting algorithm which based on this method is used in rendering the image, only the target voxels are processed, but there is no operation for background voxels. In the target voxels, only target nodes are rendered, but there is no operation for background nodes. So, the reconstruction volume data can be reduced and the efficiency of ray casting has greatly improved. The improved ray casting algorithm based on 2D maximum entropy threshold segmentation is introduced to volume rendering.
casting algorithm flow chart is shown in Figure 5.

![Diagram](image)

**Figure 5. Improved ray casting algorithm flow chart**

3. **Experimental results and analysis**

According to the improved ray casting algorithm, make algorithm verification experiment to motorcycle engine ICT slice images original data of 512x512x100 scale, the results are shown in Figure 6. Among them (a) for the whole engine 3-D display, (b) (c) (d) for the local engine 3-D display. The comparison of the rendering times of the engine ICT slice images are shown in Table 1.
Table 1. Comparison of the rendering times

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>Drawing Whole Section (ms)</th>
<th>Drawing Local Section (ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>The traditional algorithm</td>
<td>69700</td>
<td>32700</td>
</tr>
<tr>
<td>The improved algorithm</td>
<td>39500</td>
<td>19600</td>
</tr>
</tbody>
</table>

4. Conclusion

In this paper, an algorithm of ICT slice images original data field 2D maximum entropy threshold segmentation prior preprocessing is proposed. It is used to define the extent of threshold, and research the optimal combination of the parameters. The area threshold removing method is applied to filter the noise before the binary processing of image. The 3-D display is realized for the whole and the local section of the engine ICT slice images. The results of test show that the improved algorithm is enhanced in rendering speed and the results of the improved ray casting algorithm are satisfactory.

5. Acknowledgment

This work is supported by the National Natural Science Foundation of china (Grant No.61171177) and Natural Science Foundation for Young Scientists of Shanxi Province（2009021019-2）.
6. References