An Improved Interpolation Algorithm Using Nearest Neighbor from VTK

Yanan Wang, Wanggen Wan*, Rui Wang, Xueli Zhou
*School of Communication and Information Engineering, Shanghai University, Shanghai, P.R.China
E-mail: wanwg@staff.shu.edu.cn

Abstract

This paper proposes an improved image interpolation algorithm using nearest neighbor. The algorithm uses the mathematical morphology to determine the contours of each region for the two slicing images, obtains the interpolation image boundary based on distance transform, and then gets the gray values of all the corresponding points through the nearest neighbor image interpolation. This algorithm can greatly reduce the errors caused by nearest neighbor. By the means of VTK, the experimental result shows that the robust algorithm can improve the quality of the reconstruction image.

1. Introduction

Visualization in Scientific Computing was proposed by the B. H. McCormick when the National Science Foundation's scientific visualization was held in 1987 [1]. Visualization based on computer graphics and images processing is a technology that transfers the calculation results into graphics and images displayed on the screen.

Through three-dimensional reconstruction techniques, doctors can accurately get the size and volume of lesion location and other information. Virtual Surgery can improve the success rate of surgery and the quality of completion. Consequently, three-dimensional medical image reconstruction, whether in clinical or in the research, has significant meaning. Current visualization tools commonly use OpenGL, VTK and so on [2].

Interpolation method is one of the key technologies in the three-dimensional medical image reconstruction. The distance between the slicing images is always greater than the pixels, which affects the quality of the image reconstruction seriously. Therefore, the interpolation proposed improves the resolution, which generates an intermediate image between the original slicing images. The gray-based interpolation algorithm and the shape-based interpolation algorithm are the two traditional interpolation methods. The gray-based interpolation algorithm is applicable to binary image, however, in most cases, the result is not accurate. The shape-based interpolation algorithm is applicable only to the two value image in an early stage [3]. In this paper, we propose the improved interpolation algorithm based on the two traditional algorithms and show how to reconstruct three-dimensional models of human body from CT slices.

2. Fundamental theory

With the improvement of three-dimensional visualization technology, the achievements of 3D visualization technology are continuously applied to all fields. It changes a series of two-dimensional images into three-dimensional and provides the doctor an intuitive and accurate model when three-dimensional reconstruction is used in clinical medicine.

2.1. VTK platform

VTK (Visualization Toolkit) is an open source, object-oriented software system for computer graphics, visualization and image processing, used by thousands of researchers and developers all over the world [4].

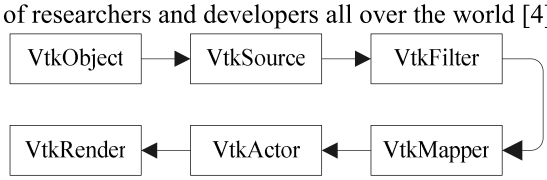


Figure 1. The frame of VTK

Figure1 shows the framework of VTK expressed by object-oriented model. VtkObject is the library of the basic classes for the entire visualization process and provides the basic methods. It has many data types, just like polygon data (vtk Poly Data), network structure (vtk Structure Grid), structure (vtk Structure Point), unstructured (vtk UnStructure Point), etc [5].

VtkSource defines the behavior and interface of the source and target. VtkFilter deals with all kinds of data and converts the raw data through a variety of filter into a type that can be processed in a certain algorithm directly. VtkMapper receives the filter input data and maps it into the basic unit. VtkActor describes the entity. In the other words, it draws the actor in the scene. VtkRender demonstrates the final result [6].In particular, visualization of data is shown in the window only through the VtkActor.

2.2. Surface Rendering

Three-dimensional reconstruction technique builds 3D images from a range of 2D slices. We generally use surface rendering or volume rendering [7]. In real-time rendering, the two rendering techniques have their own advantages and disadvantages. Both of them can be used to undertake the three-dimensional medical image reconstruction. In this paper, we choose the surface rendering technique.

Surface rendering constructs the middle of geometric primitives in three-dimensional data area, such as triangles, polygons, etc. Then it achieves the object surface rendering, using computer image processing, computer graphics science and virtual reality. It is characterized as high efficiency in three-dimensional imaging. Moreover, it can change the rotation with high-speed. In the whole process, it abandons the inside information of object and only retains the surface information, so it can not reflect the details of the original object. It usually applies to draw the legible shape of tissues and organs.

3. The improved interpolation algorithm

The gray-based interpolation algorithm and the shape-based interpolation algorithm are the two common interpolation methods between layers. The gray-based interpolation algorithm only uses neighborhood gray values of the two slicing images to estimate the corresponding pixel. It is simple and fast, but the result is not very well, especially for the complex gray-scale medical image. The shape-based interpolation constructs the contour directly through the slicing images. It improves the quality of the interpolation image, but its calculation is large and time-consuming. In order to solve the problem, in this paper, we propose an improved algorithm which combines the advantages of the two methods.

In order to obtain the image S_k between the two slicing images S_{k-1} and S_{k+1} by interpolation, we choose the set S= (V, F) to express all known images, V to signify the set of all points, the element v=(x, y, z) to represent the coordinates of the points in space, and the function f: V→Y to define the gray value at any point.

Step 1: Get the values of different density materials through the segmentation of the two slicing images.

As medical images for different organs have different gray values, the threshold segmentation algorithm has mainly two steps:

(1) Determine the threshold of the division T_0, T_1, T_2, $\cdots$, T_k;

(2)Classify the pixel f(x, y) through the comparison between the segmentation threshold value and the pixel value.

Gray value distribution of medical images can be clearly demonstrated that coexistence of the organization for the distribution of the gray values. The values from low to high represent the air, fat, soft tissues and bones as shown in figure2.

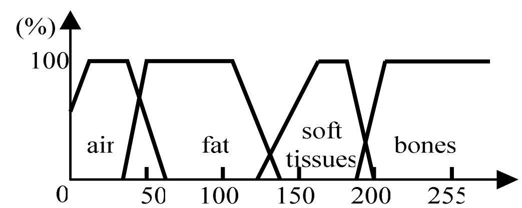


Figure 2. Gray value distribution in CT image of human foot

In the condition of the multi-threshold in the general, the image segmentation can be expressed as:

$$g(x,y)=k \qquad T_{k-1}<f(x,y)\le T \qquad k=0,1,2,\cdots K \tag{1}$$

k: the different regions label in the image segmentation

g(x, y): the function to save the different regions labels.

Step 2: Obtain the contours of each region for the slicing image by mathematical morphology.

We get the two slicing images in four values at the first step. Then we need to determine the contours of each density material and choose C_{k-1} and C_{k+1} to represent the boundaries of the four different density material regions.

Any point $v_i=(x_i,y_j,z_{k-1})$ on the profile of image S_{k-1}, $(x_i,y_j,z_{k-1})\in C_{k-1}$, which corresponds to the point $v_i=(x_i,y_j,z_{k+1})$ of the image S_{k+1}, can only be the following three kind of situations:

(1) The point $v_i=(x_i,y_j,z_{k+1})$ locates in the contour C_{k+1}, but not on the contour C_{k+1}. At this time, we choose $(x_i,y_j,z_{k+1})\oplus B$. $\oplus$ — dilation; B — the structure operator.

(2) The point $v_i = (x_i, y_j, z_{k+1})$ neither locates in the contour C_{k+1}, nor on the contour C_{k+1}. In other words, v_i and (x_i, y_j, z_{k-1}) are not belong to the same density of material. At this time, we choose $(x_i, y_j, z_{k+1})\Theta B$. Θ —erosion.

(3) The point $v_i = (x_i, y_j, z_{k+1})$ locates on the contour C_{k+1}, $(x_i, y_j, z_{k+1}) \in C_{k+1}$. At this time, we do not need to take any action.

In sum, the three circumstances above can be expressed as:

$$F(C_{k-1} | C_{k+1}) = ((C_{k-1}\Theta B) \bigcup ((C_{k-1} | C_{k+1}) \oplus B)) | (C_{k-1} \bigcup C_{k+1}) \quad (2)$$

$$F(C_{k+1} | C_{k-1}) = ((C_{k+1}\Theta B) \bigcup ((C_{k+1} | C_{k-1}) \oplus B)) | (C_{k+1} \bigcup C_{k-1}) \quad (3)$$

As a result, we can obtain the same image using formula (2) or formula (3).In this way, the contours of each region for the slicing image can be gained.

Step3: Find out all the points correspond to the S_k in the S_{k-1} and S_{k+1}.

For any point P_k in the slicing image S_k, we find the coordinates of the point P_{k-1} in the S_{k-1} and the coordinates of the point P_{k+1} in the S_{k+1} on the z-axis, as shown in figure3.

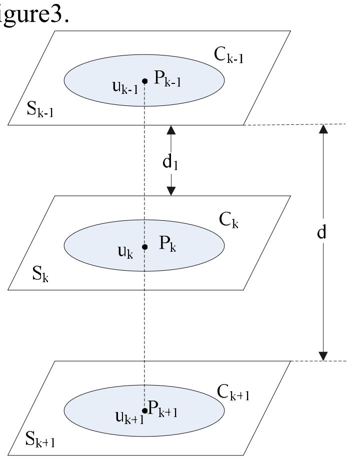


Figure 3. Diagram of the improved algorithm

u_{k-1} is the shortest distance from P_{k-1} to S_{k-1}. u_{k+1} is the shortest distance between P_{k+1} and S_{k+1}. Then, u_k, the shortest distance from P_k to S_k, can be expressed as:

$$u_k = (d - d_1)u_{k-1} + d_1 u_{k+1} \quad (4)$$

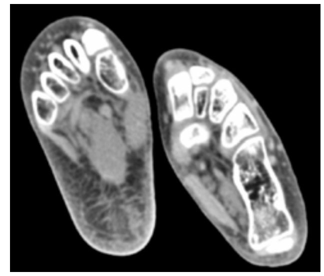
u_k explains the relationship between the point and its edge. In this way, we can get the C_k.

Step4: Get the gray values of all the points in S_k.

$f(P_k)$ is the gray value of P_k in the S_k:

$$f(P_k) = \begin{cases} f(P_{k-1}), \ if\,(d_1 \le 0.5) \\ f(P_{k+1}), \ otherwise \end{cases} \quad (5)$$

In this way, the final interpolation image S_k can be obtained. Figure 4 shows the interpolation CT images.



(a) Traditional interpolation image

(b) Interpolation image using the improved algorithm

Figure 4. The interpolation CT image

4. Experimental Results

The experimental data is a set of 250 feet CT images. The image size is 256×256 pixels and the data space is 0.5mm base on VTK platform, use the surface rendering to reconstruct the foot.

Figure5 shows the surface rendering process by VTK.

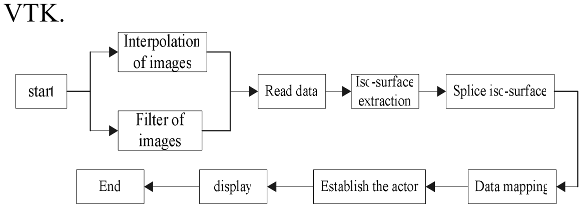


Figure 5. Surface rendering flow chart

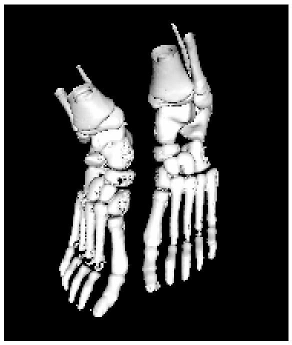
Step1: After the interpolation and filter of the images, it reads slice data and converts it into a data expression supported by VTK[8].

Step2:It extracts the iso-surface from the CT value using vtkMarchingCubes class. At this time, iso-surface is actually still just a few triangles. We should use vtkStripper class to joint them together and form the equivalent surface.

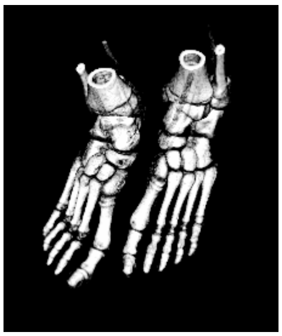
Step3: vtkPolyDataMapper would be mapped to geometric data and assigned its properties to the actors in the window [9].

Step4: Show the data in the window.

The final result is presented in Figure6.



(a) Reconstruction without the improved interpolation algorithm



(b) Reconstruction after the interpolation algorithm

Figure 6. Reconstruction of the foot model

5. Conclusion

This work proposed an improved interpolation algorithm using nearest neighbor based on VTK. The interpolation algorithm has the advantage of the two traditional algorithms, which is more efficient and can greatly improve the quality of the interpolation image. After the interpolation, we chose the surface rendering in the three-dimensional reconstruction.

Figure6 shows the interpolation is an important part in the three-dimensional image reconstruction and has direct effect on the image reconstruction. We can get the satisfactory result from VTK.

.

Acknowledgements

The paper is supported by National Natural Science Foundation of China (60873130) and Shanghai's Key Discipline Development Program (J50104).

References

[1] Weiguang Guan, *Volume visualization technology and its applications*, Publishing house of electronics industry, Beijing, 1998

[2] Wang Hongjian and Pu Xiaoming, "3D Medical CT Images Reconsruction based on VTK and Visual C++", ICBBE 2009.3rd International Conference on Digital Object Identifier, Beijing, 2009, pp. 1-4.

[3] Chen M J, Huang C H, and Lee W L, "A fast edge-oriented algorithm for image interpolation", *Image and Vision Computing*, SCI, 2005, pp.791-798

[4] A.C. Pavao, E.V.S. Pouzada, and M.A. Mathias, "Electromagnetic Field Visualization through VTK software", Microwave and Optoelectronics Conference,2001.IMOC 2001.Proceedings of the 2001 SBMO/IEEE MTT-S International, Belem-Para, 2001, pp. 21-24.

[5] Ning Fangli and Wei Juan, "3D Visualization of Stratum with Faults Based on VTK", Computational Intelligence and Software Engineering 2009, Wuhan, 2009, pp.1-3.

[6] Wenli Yang, Zhiyuan Zeng, and Yujie Bai, "3D Reconstruction System on Coarse Aggregate MicroFabric Based on VTK", Intelligent Computing and Intelligent Systems 2009, Shanghai, 2009, pp. 85-88.

[7] Gregory M. Nielson, "On marching cubes", *Transactions on Visualization and Computer Graphics*, IEEE Computer Society, 2003, pp.283-297.

[8] Limei Song, Jingluo, and Yuhua Wen, "Three-dimensional Virtual Surgery Based on CT Images", Bioinformatics and Biomedical Engineering, Beijing, 2009, pp. 1-4.

[9] William J. Schroeder, Lisa S. Avila, and William Hoffman, "Visualizing with VTK: A Tutorial", *Computer Graphics and Applications*, IEEE, 2000, pp. 20-27