3D Reconstruction System on Coarse Aggregate MicroFabric Based on VTK

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Abstract—**Three-dimensional visualization is a new research field in the information processing, and VTK is a visualization toolkits with strong functions. Due to the fact that most two-dimensional microfabric models of coarse aggregate are not accurate, the three-dimensional model is needed. This paper lay its focus on the theoretical model of three-dimensional visualization and the visualization technology based on VTK to study the coarse aggregate microfabric. The experimental reconstruction results show that the particles morphology and pore space are clear, and can describe the morphological features of coarse aggregate microfabric accurately .**

Keywords- three-dimensional reconstruction; coarse aggregate microfabric; VTK; surface reconstruction; volume reconstruction.

I. INTRODUCTION

Because the coarse aggregate microfabric is the main factor which greatly affects the engineering properties of coarse aggregate, the computer processing of coarse aggregate microfabric image is one of the key technologies used in the quantitative research of microfabric. At present, the researches are mainly in two-dimensional (2D) images of coarse aggregate to extract the useful information, thus its three-dimensional (3D) character cannot be completely reflected[1]-[3]. In order to analyze the microfabric information in terms of pore structure and particle size, it is necessary to start from the original data of CT series image, and establish the 3D structure model of coarse aggregate microfabric. There are two main ways to realize three-dimension visualization at present.

- Develop on 3D Engine directly, for example,OpenGL,OpenCV, Direct X and so on. The disadvantage of this kind of development has heavy workload. Besides, for some basic three-dimensional graphics algorithms, it needs self-developed.
- On the basis of development kit of three-dimensional visualization, it is able to do secondary development, which is the most widely used in three-dimension visualization technology now. The advantage of this method is that we need no excess concern about basic three-dimensional graphics algorithms, and can focus more attention on the algorithm implementation for the related industry.

This paper mainly studies the theoretical model of three-dimensional visualization and the visualization technology based on VTK for the coarse aggregate microfabric, and not only realizes the whole three-dimensional reconstruction of coarse aggregate microfabric, but also the three-dimensional particle reconstruction are realized more intuitionistic. The results showed that VTK can be well applied to the analysis and measurement of coarse aggregate microfabric. It's also with much significance and would be more promising for further researches on research on strain softening and failure mechanism of coarse aggregate microfabric.

II. METHODOLOGY

A. VTK summarize

VTK[4]-[6] is an object-oriented visual class library, and three-dimensional visualization technology based on VTK becomes a hotspot of research nowadays[5]-[6].VTK not only is based on C++ class library, but also support a lot of script language and operating system. Pipeline mechanism is used by VTK.

- Data Object: VTK data object has many data types: vtkPolyData, vtkStructureGrid, vtk-UnStructureGrid, vtkStructurePoint, vtk-UnStructurePoint.
- Source: appoint the behavior and interface of source target
- Filter: receive output data of source.
- Mapper: receive input data of filter, and map it into basic unit.
- Actor: receive data attribute of mapper acted as a window entity
- Render: final result demonstration.
- RenderWindow: demonstrative window.

VTK can support and process multi-format data. In addition, the users can also develop their own class library based on VTK base-class. These years, with resorting to its flexibility and openness, VTK has been used in many fields and been continuously perfected.

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B. 3D whole Reconstruction of Coarse Aggregate Micro-fabric Based on VTK

1) Brief introduction to reconstruction algorithm

Surface reconstruction[7] is to extract interested parts in the form of iso-surface, and to generate high quality 3D image by rotation and commutativity illumination effect. This kind of method has a rapid rendering speed and can satisy high real time requirement. The disadvantages of surface reconstruction lie in that it's difficult to realize the reduction of dynamic data and can only deal with interested parts, and the shape feature is not obvious[8].

Volume reconstruction[7]-[8] is a process which directly transforms 3D space samples into 2D image on screen, and restores original 3D data filed as much as possible. Ray casting has been extensively used in the volume reconstruction technology. Volume reconstruction can explore internal structure of objects, with realistic reconstruction results and flexible application. Its defects lie in the large amount of volume data and a long processing time[8].

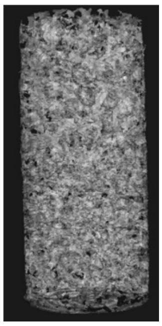
2) Reconstruction process and implementation

According to the above theories, this paper designs and implements surface reconstruction and volume reconstruction of coarse aggregate microfabric based on VTK.

Surface Reconstruction Processing: Firstly, we extract contour for 300 CT series images(DICOM format). Because it has a large number of triangulated surfaces, we choose to use dough sheet curtailment algorithm to realize real time optimization. Then smooth surface, plan image and display 3D image[4],[9]-[11].

The same as surface reconstruction, 300 CT series images(DICOM format) are firstly be input for volume reconstruction algorithm. Then volume reconstruction needs to classify processing of volume data. Different classes endow different colors and transparency, and final image effect is confirmed according to the relative position of space viewpoint and volume data[4]. [10]-[15].

This paper is applied to realize the three-dimensional reconstruction of coarse aggregate microfabric in development platform of VC++6.0. Figure 1 and Figure 2 denote the surface reconstruction result and volume reconstruction result, respectively. Table 1 gives the performance comparison of these two algorithms.



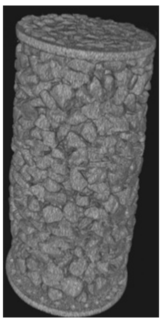


Figure 1. Surface reconstruction result Figure 2. Volume reconstruction result

TABLE I. THE COMPASRISON RESULT OF THESE TWO ALGORITHMS' PERFORMANCE

Renconstruction algorithm	Running Time	Reconstruction results
Surface Renconstruction	15.6s	Fuzzy image,difficult to identificate particle morphology
Volume Renconstruction	28.7s	Clear image and particle morphology

C. 3D Particle Reconstruction of Coarse Aggregate Based on VTK

In this paper, a new 3D particle reconstruction algorithm is proposed for further study on the structural characteristics of coarse aggregate. In order to realize a certain particle reconstruction, the two-dimensional image sequences of the particle must be found. This paper designs a searching algorithm for the vertical boundaries and horizontal boundaries of coarse aggregate particles. The vertical boundaries can be realized through projection algorithm; and the horizontal boundaries (two-dimensional boundaries) can realize can be realized through region growing algorithm from the beginning of one point in the particles. Upper and lower boundary localizations are realized respectively through upward projection and downward projection, their searching algorithms are just the same[4],[9]-[15].

We can find the vertical boundaries and horizontal boundaries of coarse aggregate particles by using the above search algorithm. Then the volume reconstruction algorithm based on VTK is used to realize particle 3D reconstruction. The concrete steps of particle 3D reconstruction are as follows:

- Input two-dimensional slice data of coarse aggregate particles .
- Segment the image sequence and save images.
- Calculate the particle fabric elements of all the two-dimensional images. The fabric elements mainly include[1]-[3],[9]-[11]:

Particle area and circumference: for segmented images, the particle area is the total number of white pixels included in the particle; the particle circumference is the total number of edge pixels in particle region.

Particle centroid : the particle centroid is the center position of particle plane. The centroid coordinate is expressed as the ratio between the ordinate and abscissa of all particles and the total number of particles:

$$(X,Y)=(\frac{\sum x_i}{S},\frac{\sum y_i}{S}) \tag{1}$$

Where, (x_i , y_i) is the X and Y coordinate of every particle, S is the total number of particle pixels, that is particle area.

Particle shape parameter: the particle shape parameter is calculated by particle area and particle circumference:

$$S = \frac{||B||^2}{4pA} \qquad (2)$$

where, ||B|| is the particle circumference , A is the particle area.

Particle circular parameter : The particle circular parameter is defined by all the edge points in particle region:

$$C = \frac{\mu}{\sigma} \qquad (3)$$

Where,

$$\mu = \frac{1}{K}\sum_{k=0}^{K-1} ||(x_k, y_k) - (\bar{x}, \bar{y})|| \qquad (4)$$

$$\sigma^2 = \frac{1}{K}\sum_{k=0}^{K-1} [||(x_k, y_k) - (\bar{x}, \bar{y})|| - \mu]^2 \qquad (5)$$

μ and σ^2 denote the average distance between particle geometric center and edge points and the mean square deviation of distance, respectively. K is the total number of edge pixels, that is the particle circumference. The particle circular parameter is not affected by the scale variation, translation and rotation.

The particle eccentricity is not affected by the scale variation, translation and rotation, and describes the compact characteristic in particle region to a certain extent.

- Click one point P in the certain slice, and use the above particle searching algorithm from point P. The searching results are taken as data object of 3D particle reconstruction.
- Use the ray casting volume rendering algorithm to reconstruct coarse-grained soil particles.
- Three-dimensional particle display.

Figure 3 is the flow chart of searching algorithm for the lower boundary of coarse aggregate particle. Figure 4 shows the results of particle segmentation and calculation of micro-fabric element. Figure 5 represents the 3D particle reconstruction results of coarse aggregate.

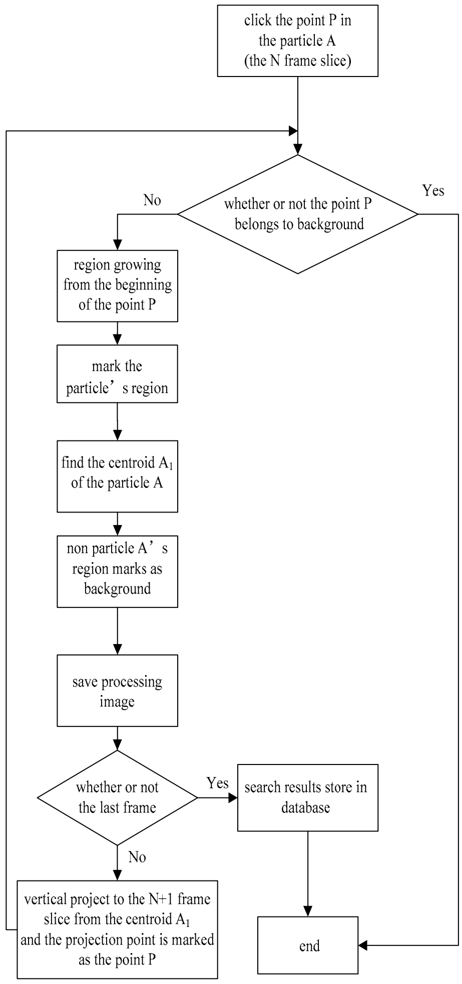


Figure 3. Volume Reconstruction Process

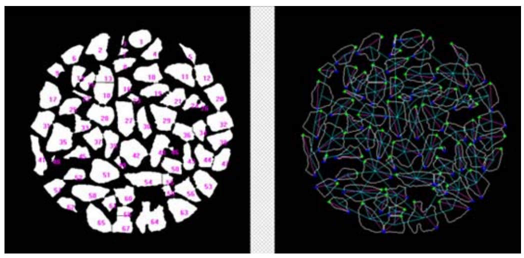


Figure 4. Particle segmentation and Calculation of microfabric element

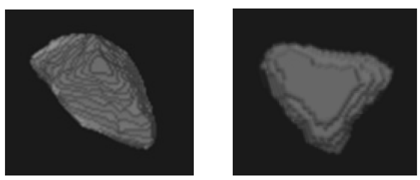


Figure 5. The 3D particle renconstruction results of coarse aggregate

III. Experimental analysis

This paper has applied the three-dimensional algorithm reconstruction based on VTK to the three-dimensional whole and particle reconstruction of coarse aggregate microfabric with VC++ 6.0. The original data includes 300 CT series images. According to the experimental results, we make the following analysis.

The 3D whole reconstruction of coarse aggregate microfabric results show that the volume reconstruction algorithm is suitable for the reconstruction of coarse aggregate microfabric.

- The effect analysis of surface reconstruction and volume reconstruction: the image and particle morphology are clear by using volume reconstruction to reconstruct coarse aggregate microfabric; but the particle morphology is difficult to be identificated and the image is fuzzy by using surface reconstruction.
- The running time of surface reconstruction and volumne reconstruction: the reconstruction time of MC algorithm is less than the reconstruction time of ray casting volume rendering algorithm.
- Considering the fact, the objective of building three-dimensional model of coarse aggregate is to analyses the internal features of coarse aggregate microfabric. It has strict effect requirement for reconstruction, but low real-time requirement.

Based on above analysis, volume reconstruction algorithm is more suitable for the reconstruction of coarse aggregate microfabric. But the algorithm efficiency is still imperfect , which needs further study.

The 3D particle reconstruction of coarse aggregate microfabric results show that the proposed algorithm in this paper is feasible to realize 3D particle reconstruction of coarse aggregate microfabric, and this algorithm has simple design and is applicable.

IV. Conclusions

In this paper, we first use the surface reconstruction algorithm and volume reconstruction algorithm based on VTK to realize the whole three-dimensional reconstruction of coarse aggregate microfabric. Then, aiming to analyses the particle structural characteristics of coarse aggregate more accurately, a new 3D particle reconstruction algorithm has been proposed by introducing a searching algorithm to the vertical boundaries and horizontal boundaries of coarse aggregate particles.

The established three-dimensional models in this paper can be served as the basis of mechanical analysis. It can be used in the researches on the microfabric characteristics of innernal coarse aggregate and qualitative analyses of effects on the mechanical behavior of coarse aggregate particles as well as the statistical analysis of tracked coarse aggregate targets. Definitely, it has a great potential future.

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