

A geometric modeling method based on OpenGL in virtual gallbladder surgery

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Abstract—With the virtual surgery simulation system playing an increasing role in the medical filed, this paper puts forward a method of reconstructing a virtual gallbladder geometric model based on the OpenGL graphics library. Firstly, we can use 3ds Max software to build a gallbladder model and write program to read and store the information only related to the contour vertexes and facets of the gallbladder model in Visual C++ environment. Then the information of vertexes and facets are indexed and sorted, so that they are related to each other and can produce realistic deformation in the latter part of the virtual surgery. Finally we can create a realistic model of the virtual gallbladder geometric through the later rendering such as anti-aliasing.

Keywords-virtual surgery; geometric modeling; OpenGL; 3ds Max

I. INTRODUCTION

Usually, Surgeon use the cadaver, animals or other teaching equipment for surgical training[1], but this way is limited by ethical and cost. However, establishing a virtual surgery simulation system can effectively solve this contradiction.[2,3] Through accurate modeling of human tissues and organs, virtual surgery simulation system can simulate the deformation even cut of tissues and organs under the interaction of the external forces acted by the surgical instruments and provide a realistic surgery to surgeon feeling through visual, auditory, tactile, and other channels of sensory feedback[4]. Virtual surgery system includes some fields such as medicine, computer graphics, biomechanics, robotics, human-computer interaction, control, multimedia technology and so on[5].

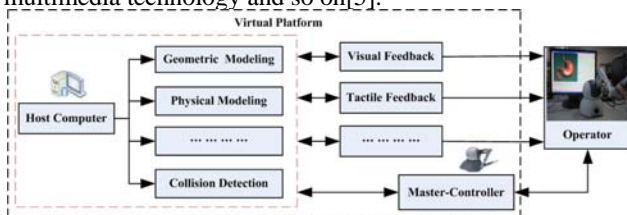


Figure 1. Virtual surgery simulation system.

In general, the process of establishing virtual surgery system include geometric modeling[6], collision detection[7], physical modeling[8], visual and tactile interaction[9] and so on, shown as Figure 1. Geometric modeling is to establish the shape of the objects in three-dimensional space. A reasonable method for geometric modeling is an important prerequisite to improve the authenticity of virtual surgery,

and the need to ensure the running efficiency of simulation program, so how to establish a reasonable organ geometric modeling plays a vital role in virtual surgery system.

Usually geometric modeling including data acquisition, data preprocessing, three-dimensional reconstruction, post-processing in virtual surgery study. We choose gallbladder as reconstruction object in this paper. Obtaining gallbladder contour data is the premise for the gallbladder three-dimensional reconstruction. Then the realistic geometry model can be obtained through repainting gallbladder based on these data later and correlation processing. There are three methods to obtain the relevant data of the tissues and organs at present. Firstly, the necessary data can be obtained from medical images or the library of virtual human. This method is more accurate, but its disadvantages are heavy workload and low efficiency. Secondly, the necessary data can be obtained by using three-dimensional scanner and other equipment directly, but the equipment is expensive, at the same time it is limited by the size of the scanned object. Thirdly, the date can be obtained through manual creation method based on the prototype of the organs or artificial model, this method is low cost, high speed, and the other new model can also be got by changing the data.

This paper choose the third way namely using the popular 3D software-3ds Max to establish gallbladder model. The contour vertexes and the facets data of gallbladder can be read through the C++ program, and this information can be repaint with OpenGL. Then a vivid three-dimensional gallbladder model can be got after calculating vertex normals vectors, anti-aliasing, multiple-aliasing and so on to . To reconstruct a gallbladder includes three parts: Obtain the data of gallbladder; three-dimensional reconstruction of gallbladder and later rendering of gallbladder. Shown as Figure 2.

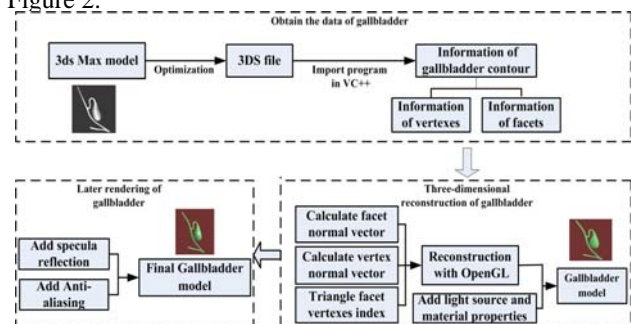


Figure 2. The concrete process of reconstruction a gallbladder.

II. OBTAIN THE DATA OF GALLBLADDER

A. gallbladder modeling by 3ds Max software

Because of the powerful curve modeling capabilities, 3ds Max software is chosen to build the original gallbladder model. Through optimization treatment, Gallbladder model have 1597 vertexes and 3120 triangular facets, each triangular facet is drawn by three vertexes from the 1597 vertexes, shown as Figure 3.

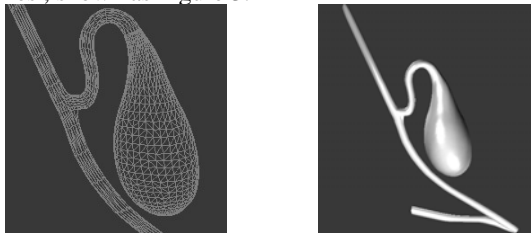


Figure 3. gallbladder model drawn with 3Ds Max.

B. Obtain gallbladder contour data

Gallbladder model is saved as 3DS file in 3ds Max. Then using software Visual C++ write the relevant import program to read the information of gallbladder. Usually through VC++ the all information about 3DS file is directly read for real-time rendering and interactive control. But some of the information is not required, such as materials, lighting, texture and so on, reading this information must cost some time and affect the real-time of entire operation. In fact, repainting a gallbladder only need the information of model vertexes and polygons facets vertexes with OpenGL, and other information can be ignored. Therefore, the information about model vertexes and polygons facets vertexes can be stored in a text document by function "fopen". when repaint the gallbladder we can extract this information directly from the text document, but not to read 3DS file again, which will save more time to be applied to physical modeling and collision detection. As shown in the figure 4

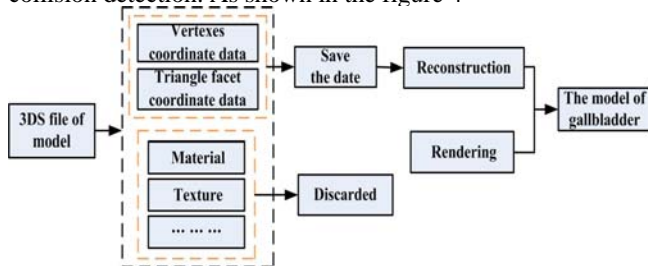


Figure 4. The process of reading and instore the 3DS file information.

3DS file is made up of many blocks, each block is actually a hierarchy, and different types of blocks have the different hierarchies. The block which appear firstly in the main block is the basic block, and it mainly includes two blocks: 3D editing program block and key frame block. Each block use ID to identify its function and meaning and use the length to identify its size. The ID of block is used to identify the block function and meaning, it will be defined as

a macro in program to improve the efficiency and the readability of program.

The organization of 3DS file is the block structure and there exists nested relationship between the blocks, so we need get a block ID from the model file firstly, then judge its function and information according to the block ID. The program can recognize that whether the file is a 3DS file or not. If it is, the program will continue to read the subblock. we take this same manner, namely reading a subblock, then judging its information according to the ID, and extracting and depositing the corresponding data if the ID meet the requirement. So we can define a function "Read_Object()" to read the 3DS file. if the ID of block which is reading meet the requirement, this function will be called. And the process of this function is shown as Figure 5 (a).

We also define three classes "MaterialDict", "CTriobject" and "CTriList" to process model information of 3DS file. "MaterialDict" corresponds to the material library of model, it defines and encapsulates the data including the quantity of the material, name, specific information. "CTriobject" corresponding to triangle mesh information about reading model, mainly including the information for processing the triangle list, such as vertex, surface, surface material and so on. "CTriList" is a triangle mesh list of model, it mainly use for handling object sequence which contains number, name and other data of a triangle mesh object in 3DS model. "CTriobject" also encapsulates and defines a series of reading data operations, such as reading the information about point, surface, material, object name and so on. As shown in Figure 5 (b):

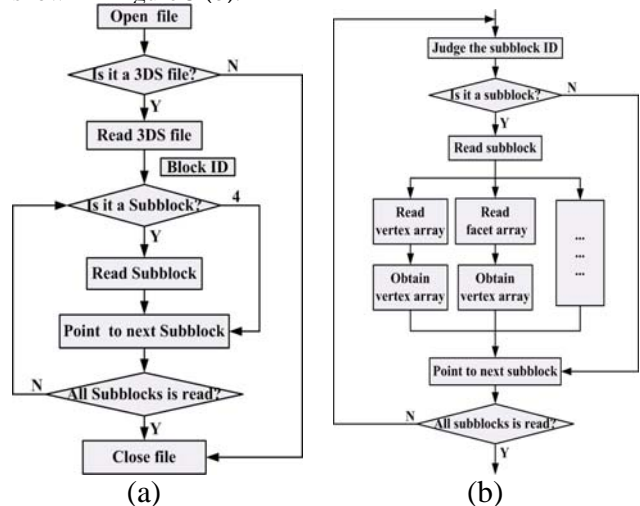


Figure 5. The process of reading block and its subblocks of a 3DS file.

Through the above program, the vertexes coordinates and the each triangle vertexes coordinates of Gallbladder contour can be read out, and saved in a text document by statement freopen ("G: XXX.txt", "a", stdout). We can draw this vertexes through function plots in MATLAB. The contour of the gallbladder can be exhibited. Show as in Figure 6.

	A	B	C
1	Organ_Point Array		
2	3.465507	-1.414176	-2.66676
3	3.452004	-1.387108	-2.59801
4	3.413948	-1.487988	-2.874634
5	3.474313	-1.467192	-2.88016
6	3.402846	-1.553895	-3.088428
7		
8	3.475281	-1.496501	-2.991669
9	3.392658	-1.597222	-3.283395
10	3.503879	-1.553132	-3.2923
11		
12	Organ_Face_Point Array		
13	3.43069	-1.428549	-2.662603
14	3.465507	-1.414176	-2.66676
15	3.452004	-1.387108	-2.59801
16		
17	3.413948	-1.487988	-2.874634
18	3.474313	-1.467192	-2.88016
19	3.465667	-1.443181	-2.76022
20		

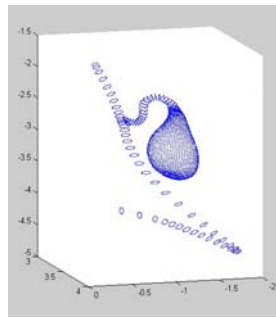


Figure 6. The date of vertexes and each triangle vertexes.

III. THREE-DIMENSIONAL RECONSTRUCTION OF GALLBLADDER

No matter through a three-dimensional scanner or 3D software, three-dimensional model of gallbladder will can be reconstructed with OpenGL if we can get the gallbladder contour data.

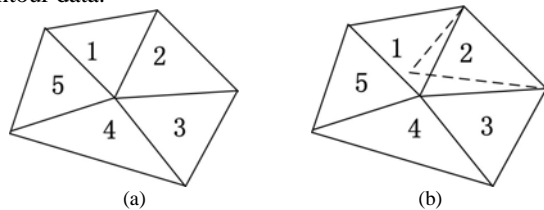


Figure 7. Triangular facets.

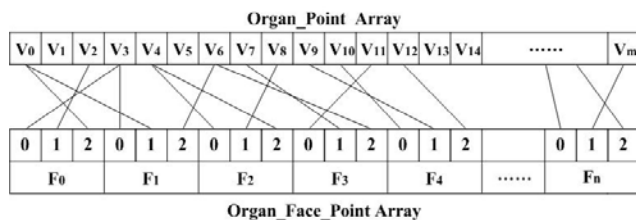


Figure 8. Find out the storage location of triangular facet vertexes in vertex array.

Make the triangular facet information (three vertexes) stored in the array "Organ_Face_Point" and all vertex data stored in the array of "Organ_Point". If we use original triangle data to reconstruct directly, shown as Figure 7 (a), although this five triangles share a same vertex, each of the vertex of the triangle are mutually independent. When gallbladder deformation occurs, assuming that the shape of triangle 1 have been changed, but other triangle does not change, this will cause a noncontinuous "fault", as shown in Figure 8 (b). In order to avoid this phenomenon, those triangles can be associated with each other by the shared vertex, so that when the shape of one triangle have changed, the triangles which share the same vertex will be also changed. As known that every vertex of triangular facet is from the "Organ_Point" array, so we can find out the position of every triangle faces vertexes in "Organ_Point" array through vertex indexing. As shown in Figure 8, the three vertexes of triangle facet F0 can be represented by V3, V2, and V0. If we want to change the shape of triangular F0,

we can change the magnitude of vertex V0 in "Organ_Point", at the same time triangle F1 which share the same vertex V0 will be also changed. According to this thinking, find out the storage location of triangular facets vertexes in vertex array "Organ_Point". So when use the glBegin (GL_TRIANGLES) to reconstruct gallbladder model, triangle vertexes coordinates can be obtained by indexing from the vertex array. For example the three endpoints of triangular 32 are corresponding to the vertex 35, 48, 156 respectively.

The calculation of vertexes normal vector in the three-dimensional modeling is very important with OpenGL. It affects the model effect directly. The light reflection of triangle model depends on the settings of the vertexes normal vector in OpenGL, if the calculation of vertexes normal vector is reasonable and precise, the model surface is very smooth, shiny, otherwise it is rough fuzzy, or dimness. As shown in Figure 9 (a). Based on the solid geometry, the vertexes normal vector should be equal to the sum of all the triangle facets normal vector which share this vertex as its endpoints. So we should calculate the face normal vector of each triangle, and each face normal vector can be added to the normal vector of three vertexes which consist of this triangle through storage location array "Num_Face_Point".

When triangle facet vertex index and the calculation of the vertex normal vector are accomplished, the gallbladder can be reconstructed by using the OpenGL command "glBegin (GL_TRIANGLES)" to repaint each triangle face. It must be noted that the numerical in glVertex3f is obtained from "Organ_Point" through array "Num_Face_Point", but not from "Organ_Face_Point", the specify vertex normal of each vertex should be provided vertexes normal vector in the program.

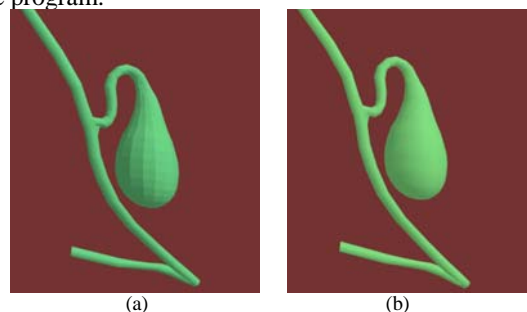


Figure 9. The gallbladder model before later rendering.

After adding light source, lighting for the scene and setting the material properties through the OpenGL command, the gallbladder model can be reconstructed, as shown in figure 9 (b). Obviously, this graphics have no stereo perception and gloss. In order to make the gallbladder more vivid, rendering later is necessary and important.

IV. LATER RENDERING OF GALLBLADDER

Later rendering including specula reflection and Anti-aliasing.

Specular reflection make the gallbladder look glossy and substantial. The specular reflection for gallbladder can be created by enabling the color track and setting the material properties. OpenGL commands are shown as follows.

```
glEnable(GL_COLOR_MATERIAL);
glColorMaterial(GL_FRONT, GL_AMBIENT_AND_DIFF
USE); //Setting Material Properties
glMaterialfv( GL_FRONT, GL_SPECULAR, specref);
glMateriali( GL_FRONT, GL_SHININESS, 1);
```

Anti-aliasing makes the edge of the polygon smoother, we can use a new function "multiple sampling" to complete the polygon anti-aliasing with OpenGL, and the commands are shown as follows:

```
glutInitDisplayMode(GLUT_DOUBLE|GLUT_RGB|GLUT_
MULTISAMPLE);
glEnable(GL_MULTISAMPLE);
```

After adding the function of specular reflection and anti-aliasing later rendering, The gallbladder model is is visual and true to nature, and shown in the Figure 9-c.

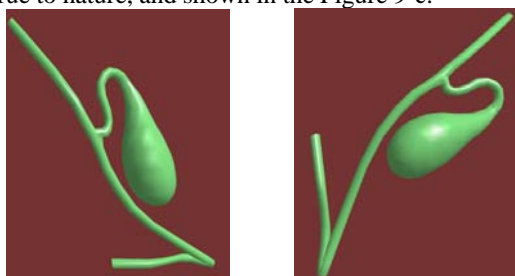


Figure 10. The gallbladder model after later rendering.

V. CONCLUSION AND OUTLOOK

The paper puts forward a method of reconstructing a vivid virtual gallbladder geometric modeling by using the OpenGL graphics library, Visual C++ and 3ds Max software. This method use Visual C++ to write import program, then save the geometry information of gallbladder contour which is related to reconstruction, and discarded something irrelevant such as materials, textures and so on. In the process of reconstruction, it need to input the data of gallbladder contour vertexes and facets, but not to read the entire 3DS file again, which will undoubtedly save more time and more beneficial to real-time interactive control in the post-virtual surgery. The method also change the independent facets into an interrelated whole by indexing and finding out storage location of triangular facets vertexes in vertex array. When a triangular facet is deformed, the associated triangular facets will also produce deformation, so that the gallbladder is able to produce realistic deformation process in virtual surgery and provide a more vivid visual effect to the operator. Physical modeling, collision detection,

and real-time interactive should be accomplished based on the geometric model in order to establish a realistic virtual surgery system.

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