IOSR Journal of Computer Engineering (IOSR-JCE)
e-ISSN: 2278-0661,p-ISSN: 2278-8727, Volume 20, Issue 2, Ver. I (Mar. - Apr. 2018), PP 44-53
www.iosrjournals.org

The Research of The Optimized Three-Dimensional Model Algorithm Based on Polygonal Segmentation

Xueyan Lan, Guilin Li
(Dalian Jiaotong University, Institute of Electrical Information, Liaoning Dalian 116028, China)
Corresponding Author: Xueyan Lan

Abstract : *Three-dimensional models are commonly used to describe the display requirements of 3D virtual objects in complex scenes. For the triangular grid model of complex objects, its huge amount of data to the storage, transmission and rendering, etc. has brought great difficulties. On the basis of summarizing the existing algorithms, this paper presents a general triangular simplification algorithm for polygon regions. The algorithm is applied to the triangular plane on a plane, and the two vertices are formed by using the coordinates of the known triangular plane in the space to form the data record, compare and delete the same coordinate record, and use the remaining data to record the polygon. The triangulation of the polygon is re-divided, and a new simplified model is formed to improve the performance of the algorithm effectively. The experimental results show that the algorithm is effective and feasible by using the triangulation model, indicating that the algorithm is practical and effective.*

Keywords: *Three - dimensional model; Triangle; Model optimization; Polygon division algorithm; Data record*

Date of Submission: 01-03-2018 Date of acceptance: 19-03-2018

I. Introduction

In computer graphics and virtual reality technology, the surface of the object often used polygon mesh, usually a triangular mesh to describe. The use of laser scanners and other systems can be a variety of complex, fine grid model; these grid models usually produce millions of polygon patches. With the promotion of digital factory and virtual factory concept, how to use and deal with the complex three-dimensional model produced by 3D mechanical design software, how to meet the real-time and realistic requirements in virtual reality scene becomes an urgent problem to be solved [1]. Three-dimensional model of the optimization algorithm is one of the most popular research topics. Earlier it was suggested that the relevant algorithms, generally divided into two categories. For example, Schroeder proposed a simplified method of vertex deletion, J. Rossignac uses vertex clustering, and Hoppe H. proposes a progressive grid concept and uses contraction operations. The method is too limited to the graphical geometry and is not practical to the 3D model. The other is geometric transformation [2]. For example, M. Eck introduces wavelet theory and reconstructs the original model with wavelet transform. This method is only applicable to geometric models with hierarchical and regular shapes and implements More difficult. At the same time, our research on the three-dimensional model optimization algorithm is more and more. Sun Hongwei et al. Proposed a fast algorithm for triangulation of VRML applications, Wang Rui etc. Proposed a simplified three-dimensional geometric model to preserve visual features Algorithm, Quan Hongyan using a simplified method of the geometric model of the region, proposed in each region to select the same number of vertices or triangles to simplify and so on[3].

At present, the three-dimensional mechanical design software PRO-E, SolidWorks, UG, etc. often use polygon (usually triangular) grid to describe the object model in the design of graphics. When building objects with polygons, there is a lot of redundancy in the artifact model. However, too large three-dimensional model is often impractical in the virtual factory scenario. On the basis of summarizing the existing algorithms, this paper proposes an algorithm to reconstruct the polygon by optimizing the three-dimensional model from the perspective of feasibility and practicability. By calculating the triangles that can be merged, this algorithm can remove the redundant edges [4].

II. Overview of Model Optimization

Three-dimensional model modeling is a kind of entity-oriented plasticization modeling, based on three-dimensional model of product information sharing generally need to be the physical surface of the split, to achieve the entity triangular model expression[5]. In addition to the general requirements of stability, ease of implementation, simplification and clarification, the triangular surface optimization algorithm suitable for three-dimensional model applications should also meet the following requirements: coplanar triangular facets optimized for each triangular face in the direction Optimized before the surface to maintain consistency, and the common classic algorithm can't meet this requirement. Considering the limitation of network bandwidth, the model of optimization algorithm is used to keep the basic characteristics of the model before optimization. At the same time, the triangular surface is better and better. The model optimization process is shown in Figure 1.

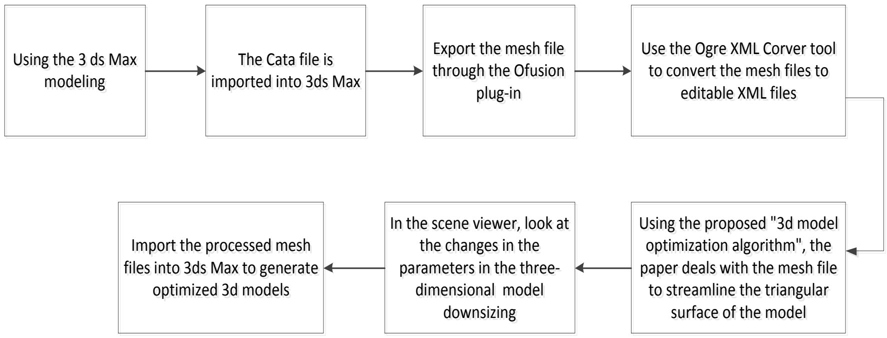


Figure 1: Model optimization process flow chart

III. Implementation of Algorithm

In order to optimize the processing of three-dimensional model, a triangular optimization algorithm is proposed:

The first is to judge whether the triangular plane in the three-dimensional geometry of the space is a common surface, and if the triangular surface is a common surface, it can be merged into the face.Merger of two, three or even more triangles, need to use a space coordinates show each of the three sides of the triangle and generate side records, and then compare the side of the triangle have repeat, if repeated delete, otherwise remain[6].And then determine the polygon edges number (record collection of residual while number, assumed (n + 2)), and then determine to redraw polygon triangle surface after number (at least a (n)), and determine the polygon vertices.In one of the vertices is a triangular common vertex in a plane, and the n triangles that are redrawn are composed of public vertices and two adjacent vertices.The trigonometric optimization algorithm shown here is the process of the whole optimization algorithm:

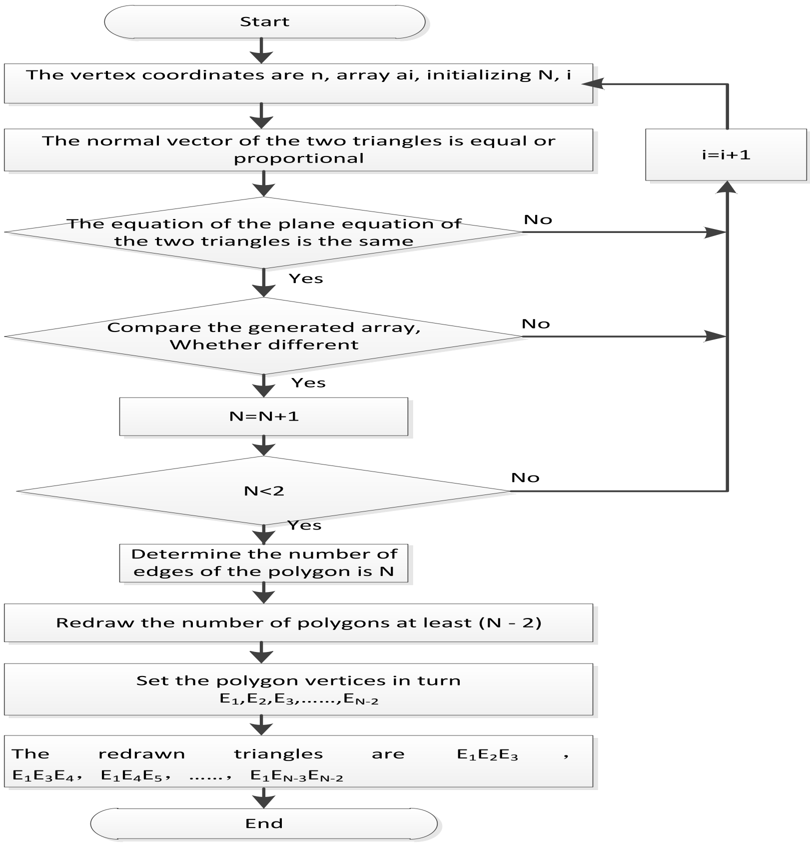


Figure 2: Triangular surface optimization algorithm flow chart

3.1 ALGORITHM BASIC STEP

Step 1: To determine whether the polygon is coplanar (assuming that the two triangles are △ ABC, △ DEF)

Example problem: in spatial geometry, the space coordinates of the six points of the two triangles are known as: a (X_1, Y_1, Z_1), b (X_2, Y_2, Z_2), c (X_3, Y_3, Z_3), d (X_4, Y_4, Z_4), e (X_5, Y_5, Z_5), f (X_6, Y_6, Z_6); Find whether the two triangular faces are coplanar. Examples prove:

(1) The analysis problem can have three sides of the triangle face the direction vector is:

$$\overrightarrow{AB} \quad (X_2 - X_1, Y_2 - Y_1, Z_2 - Z_1) \tag{1}$$

$$\overrightarrow{AC} \quad (X_3 - X_1, Y_3 - Y_1, Z_3 - Z_1) \tag{2}$$

$$\overrightarrow{BC} \quad (X_3 - X_2, Y_3 - Y_2, Z_3 - Z_2) \tag{3}$$

You can also set the normal vector of this triangle as H (l，m，n), according to the definition of the normal vector:

$$\left.\begin{aligned}(X_2 - X_1)*l + (Y_2 - Y_1)*m + (Z_2 - Z_1)*n = 0\\ (X_3 - X_1)*l + (Y_3 - Y_1)*m + (Z_3 - Z_1)*n = 0\\ (X_3 - X_2)*l + (Y_3 - Y_2)*m + (Z_3 - Z_2)*n = 0\end{aligned}\right\} \Rightarrow \text{Solve H (l, m, n)} \tag{4}$$

Similarly, the normal vector for solving another triangle is Q (h，j，k). If the normal vector of the two planes is equal or proportional, then the two triangles are parallel or overlapping [7].

(2) The solution to the plan equation is shown in the following two equations:

$$\begin{cases} l*x + m*y + n*z = 0 \\ h*x + j*y + k*z = 0 \end{cases} \tag{5}$$

The normal vector H (l, m, n), Q (H, j, k), and the six points of the triangle respectively in the above equation to solve, if the two equations in the plane of the same, is to prove that two triangles coplanar. By this analogy, to prove whether multiple planes have a common surface [8].

Step 2: The merger of two, three or even more triangles, need to use a space coordinates, the three sides of each triangle coordinate arrays and generate edge, edge judgment obtained with and without repeated, without reserve; Otherwise, delete from the edge coordinate array[9].

Instance problem: suppose that the vertices of multiple triangular faces on the given space are: (X_1, Y_1, Z_1), (X_2, Y_2, Z_2), (X_3, Y_3, Z_3); (X_4, Y_4, Z_4), (X_5, Y_5, Z_5), (X_6, Y_6, Z_6); ......; (X_j, Y_g, Z_k), $(X_{j+1}, Y_{g+1}, Z_{k+1})$, $(X_{j+2}, Y_{g+2}, Z_{k+2})$; ......;

Case analysis: according to the theorem, a line is determined by any two points on the plane of the theorem and the given two points are given: (X_j, Y_g, Z_k), $(X_{j+1}, Y_{g+1}, Z_{k+1})$.You can set three sides of each triangle in the same plane as three arrays [(X_1, Y_1, Z_1), (X_2, Y_2, Z_2)],[(X_1, Y_1, Z_1), (X_3, Y_3, Z_3)] [(X_2, Y_2, Z_2), (X_3, Y_3, Z_3)](the three sides of the triangle).

Examples to prove: through the above analysis shows that the three sides of rest each triangle another has been set, by setting up the three sides of each triangle coordinate arrays of arbitrary triangle side one by one with coplanar triangles coordinate arrays, judge whether the coordinates of two points in the array in each group (Whether a side of a triangle is a common side), if the same, remove; Otherwise, keep it. Then the table record of the triangle coordinate table is regenerated, and the geometric coordinate information of the redundant triangle is written to the record.

Step 3: polygon demarcation
The location and number of polygon boundary lines are determined by the newly generated border coordinates of the redundant triangle, assuming the remaining number (n).
Step 4: Re-divide the triangle

Reshape the number of triangles at least (n-2) (assuming the remaining convex polygons are (n) edges).

Step 5: Determine the vertices.

Put the data in the array of the edges of the redundant triangle in the one-dimensional array, and then compare one to another. if the same, delete; Otherwise, keep it. It then restores the remaining vertex coordinates to a one-dimensional array. Setting the vertices of the polygon is E_1, E_2, E_3, E_4 ,......, En , That is, to determine the coordinates of each vertex[10].

Step 6: Calculate the flatness of the point cloud data satisfying a certain density to determine the first point (E1) of the seed triangle, and then select the two consecutive points with the closest and the seed triangle as the second and third point's （E2, E3）. For topological work, the recited n triangles can be: $E_1E_2E_3$, $E_1E_3E_4$, $E_1E_4E_5$, ..., $E_1E_{n-1}E_n$.

Step 7: End.

The plane model diagram of the basic step of the algorithm is shown in the image below, see Fig. 3.

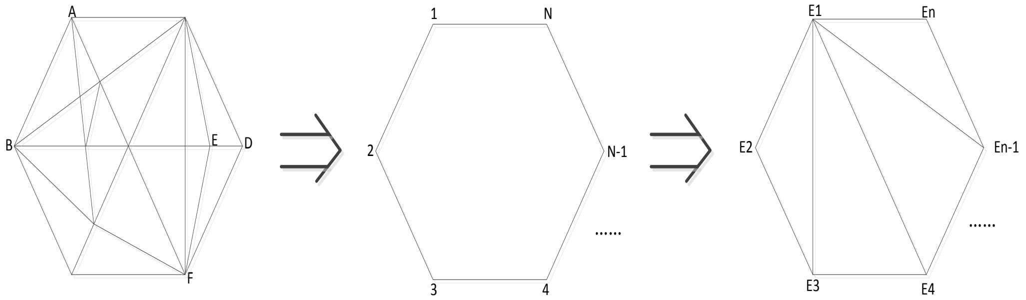


Figure 3: The plane model diagram of the basic step of the algorithm

3.2 THE PROCESS OF THE MESH FILE

The format of the file format for the 3ds Max or the Ogre mesh can be rolled out by code. In 3ds Max mesh files are binary, with text directly open all gibberish, though not clear and readable as the XML text format, the organization itself is very organized.Mesh is the "grid", all the models of Unity3D are composed of mesh, the model is a small grid which also called mesh and the mesh has a different three-dimensional vertices (Vector3), which together constitute a three-dimensional model.

The first part of the mesh file is the triangular face count "faces count" that makes up the three-dimensional model, and the second part is the geometric vertex of the triangle "geometry vertexcount".Mesh file each triangle in the first part of the three vertices (" face v3, v2 and v1 ") corresponds to the serial number of the second part of the geometry of the triangle vertices "geometry vertexcount" number (from "0" to "n-1", where n is the geometric vertices).This paper uses concrete examples to show the concrete execution of the new algorithm(It is known that the instance is a rectangular pyramid with 8 faces and 17 vertices.).

The steps for selecting redundant points are as follows:

Step 1: in order to intuitive, this paper put the mesh file information defined as a record of each triangle faces JL_triangle, use （Vxy，Vzk） said the side of the triangle, Vij represents the jth vertex of the i-th triangle. Assume that the Mesh file has n entries("n" represents the value of "faces count" in the mesh file), as shown below:

JL_triangle1= {（V11，V12），（V11，V13），（V12，V13）} (6)
JL_triangle2= {（V21，V22），（V21，V23），（V22，V23）} (7)
…… ……
JL_trianglen= {（Vn1，Vn2），（Vn1，Vn3），（Vn2，Vn3）} (8)

According to the record of the above definition, the coordinates of each record records the triangle points and the parameters of the edge information, through structured stored in a data set JL_triangle= { JL_triangle1，JL_triangle2，……，JL_trianglen}.

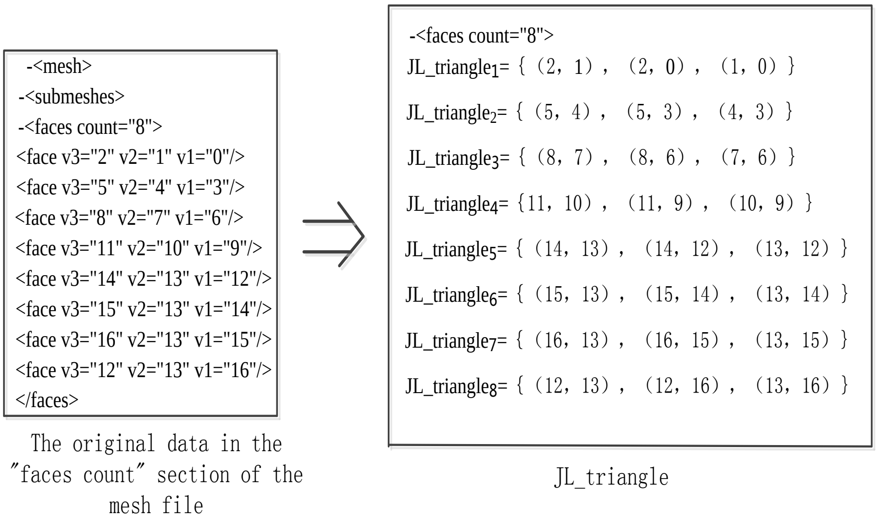


Figure 4: The example mesh file "faces count" section of the diagram

Step 2: store the records of two comparison and to detect whether the two records have the same side, if not, save the record to JL_group1; otherwise, retained to JL_group2. Then two data sets JL_group1={JL_trianglem,JL_trianglek,……}, JL_group2={JL_trianglex1,JL_triangley1,……}are generated, where JL_group1 is a set of records that are not recorded repeatedly and JL_group2 is a set of data with redundant records[11].

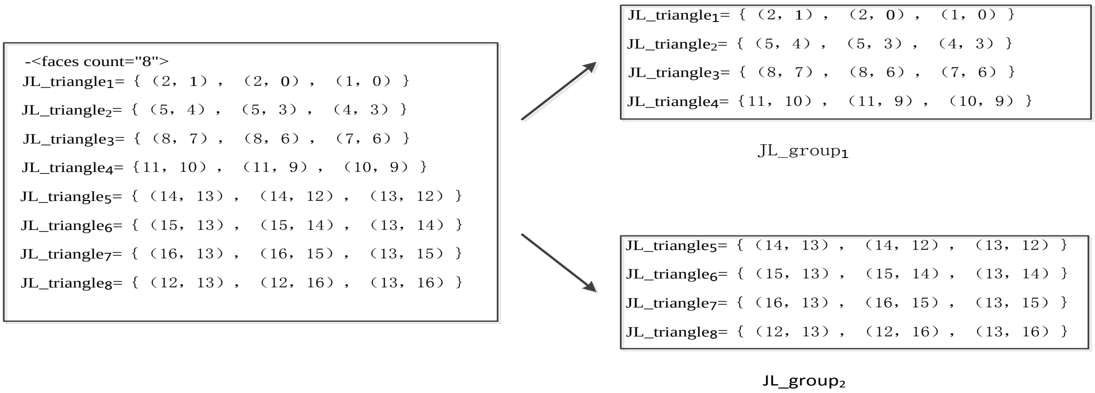


Figure 5: The algorithm performs procedure 1

Step 3: The data record in JL_group2 is processed twice, which is to compare the data in the two groups to see if there is the same side, if the same, delete; Otherwise, keep it.And select a vertex to be a public point, redraw the triangle, and then generate a new recordset JL_new group2={JL_trianglex2,JL_triangley2,……}.

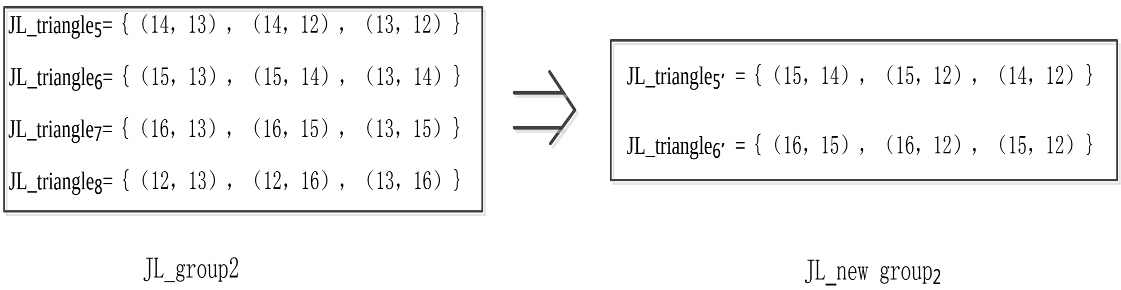


Figure 6: The algorithm performs procedure 2

Step 4:Through the processing above, the data records set JH_triangle= {JL_group1 ∪ JL_new group2 } for the triangular surface is generated.

JL_triangle$_1$= { (2，1)， (2，0)， (1，0) }
JL_triangle$_2$= { (5，4)， (5，3)， (4，3) }
JL_triangle$_3$= { (8，7)， (8，6)， (7，6) }
JL_triangle$_4$= {11，10)， (11，9)， (10，9) }

JL_group$_1$

JL_triangle$_{5'}$ = { (15，14)， (15，12)， (14，12) }
JL_triangle$_{6'}$ = { (16，15)， (16，12)， (15，12) }

JL_new group$_2$

```
-<faces count="6">
JL_triangle1= { (2，1)， (2，0)， (1，0) }
JL_triangle2= { (5，4)， (5，3)， (4，3) }
JL_triangle3= { (8，7)， (8，6)， (7，6) }
JL_triangle4= {11，10)， (11，9)， (10，9) }
JL_triangle5' = { (15，14)， (15，12)， (14，12) }
JL_triangle6' = { (16，15)， (16，12)， (15，12) }
```

JH_triangle

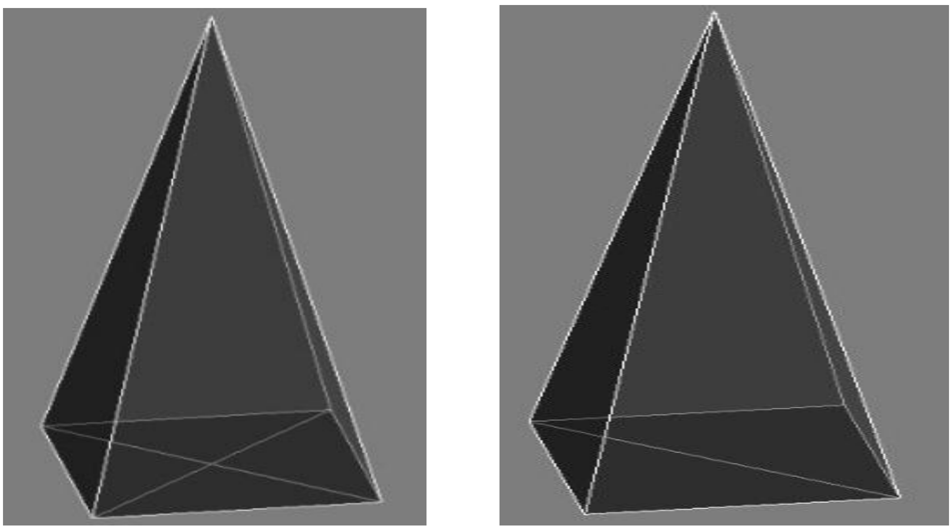
Figure 7: The algorithm performs procedure 3

```
-<geometry vertexcount="17">
-<vertexbuffer positions="true">
<vertex>
<position z="-0" y="4" x="0"/>
<position z="0.5" y="0" x="-0.5"/>
<position z="0.5" y="0" x="0.5"/>
<position z="-0" y="4" x="0"/>
<position z="0.5" y="0" x="0.5"/>
<position z="-0.5" y="0" x="0.5"/>
<position z="-0" y="4" x="0"/>
<position z="-0.5" y="0" x="0.5"/>
<position z="-0.5" y="0" x="-0.5"/>
<position z="-0" y="4" x="0"/>
<position z="-0.5" y="0" x="-0.5"/>
<position z="0.5" y="0" x="-0.5"/>
<position z="0.5" y="0" x="-0.5"/>
<position z="-0" y="0" x="0"/>
<position z="0.5" y="0" x="0.5"/>
<position z="-0.5" y="0" x="0.5"/>
<position z="-0.5" y="0" x="-0.5"/>
</vertex>
```

⇒

```
-<geometry vertexcount="16">
-<vertexbuffer positions="true">
<vertex>
<position z="-0" y="4" x="0"/>
<position z="0.5" y="0" x="-0.5"/>
<position z="0.5" y="0" x="0.5"/>
<position z="-0" y="4" x="0"/>
<position z="0.5" y="0" x="0.5"/>
<position z="-0.5" y="0" x="0.5"/>
<position z="-0" y="4" x="0"/>
<position z="-0.5" y="0" x="0.5"/>
<position z="-0.5" y="0" x="-0.5"/>
<position z="-0" y="4" x="0"/>
<position z="-0.5" y="0" x="-0.5"/>
<position z="0.5" y="0" x="-0.5"/>
<position z="0.5" y="0" x="-0.5"/>
<position z="0.5" y="0" x="0.5"/>
<position z="-0.5" y="0" x="0.5"/>
<position z="-0.5" y="0" x="-0.5"/>
</vertex>
```

Figure 8: The second part of the mesh file is shown in front and back



(a)the three-dimensional model rendering of the previous instance is processed

(b) the three-dimensional model rendering after processing

Figure 9: Examples (four pyramids) rendering

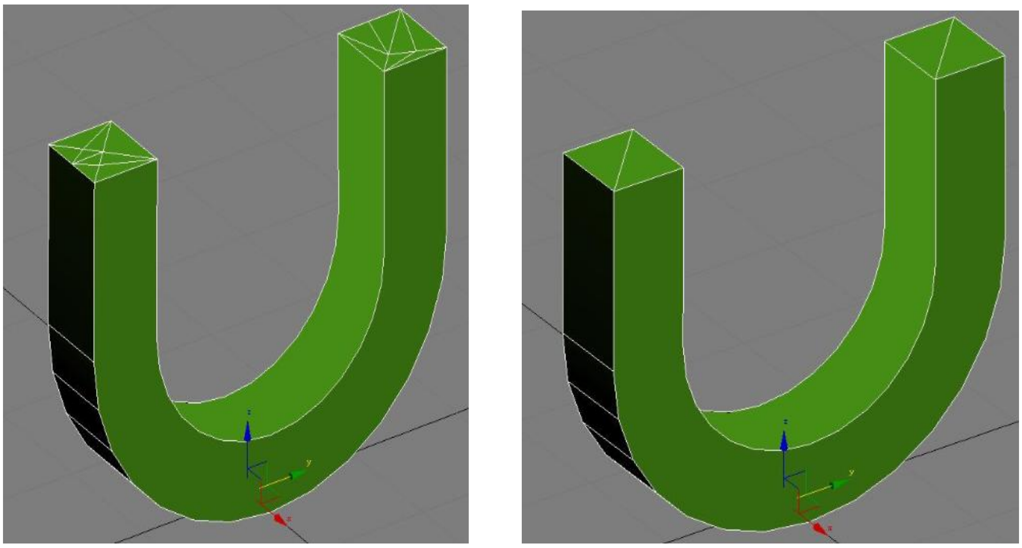
3.3 ALGORITHM ANALYSIS

Through the above description of the algorithm can clear the realization of the algorithm and make the following summary:

(1)The model optimization algorithm proposed in this paper can optimize the rules and irregular models shown below. Based on the theorem of "two points to determine a straight line", it is only necessary to compare the two points in the array record to the same, which reduces the number of distance, speed etc [12].

(2)Compared with other methods, the proposed triangle surface optimization algorithm produces fewer triangles. The application of this method reduces the amount of data and facilitates network transmission, suitable for the processing and application of complex mechanical workpiece model. In addition, the three-dimensional model optimization algorithm proposed in this paper has successfully processed the mesh format files exported by the fusion plug-in and achieved good results [13].

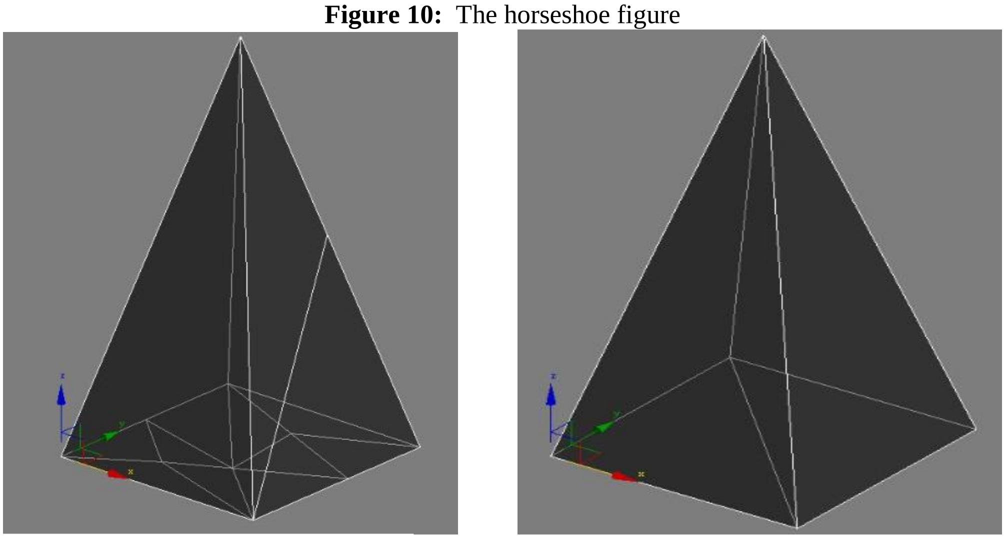
(3)The optimized algorithm applies to still have the limitless extension of parting plane but in the same plane geometry stereo model (for example, the two separate surfaces of the horseshoes shown below (two faces of several triangles) or irregular geometry stereo model (for example, as shown in figure 4 pyramid) and so on, a variety of complex models of irregular surface can take advantage of the proposed optimization algorithm to simplify optimization model [14].



(a)the schematic of the horseshoe optimization

(b)the schematic of the horseshoe optimization

Figure 10: The horseshoe figure



(a)Optimize the first four pyramid scheme

(b)the four pyramid schemes are optimized

Figure 11: Rectangular pyramid figure

IV. Experimental Results And Analysis

Mesh applications are used in the Internet environment where network bandwidth is a must [15]. If you want to be as small as possible in the Mesh format, you need to ensure that the resulting triangular surfaces should be as few as possible. In most cases, the resulting slice is the fewest, According to the triangle surface optimization algorithm described above, most of the cases are the least and only (n-2) (n is the number of edges of a single connected domain). In the experiment, in the DELL OptiPlex 755, the memory capacity of 1G, disk space for the 80GB PC, Visual C ++ 6.0 and OpenGL for the programming platform, the data are processed by Ofusion plug-in derived mesh format file[16].

The geometric model of the proposed algorithm was compared with the three- dimensional model before optimization. Algorithm example is a part drawing on railway vehicle(The artifacts on the steering frame), which is transformed by the CATIA design tool and is a diagram of the artifact model with redundant triangles surface,see Fig. 12.Constraint of the Delaunay algorithm and the parameters of this algorithm are compared,see Form. 1.

Form 1 algorithm comparison

parameter algorithm	Constrained Delaunay algorithm	The article algorithm
complexity	complex	simplicity
velocity	slower	faster
scope of application	arbitrary polygon	arbitrary polygon
Results optimization	optimization	optimization

The artifact model diagram for importing 3ds Max is shown below, see Fig. 13.The optimized 3ds Max artifact model diagram is shown below, see Fig.14[17].The length, width and height of this example are: x = 260.0m, y = 272.0m, z = 90.0m.

The optimization model of the Delaunay algorithm was used to optimize the model, and the number of vertexes before and after the optimization of the example model is 5543,1090and the degree of simplification is 80.3%[18]. The number of triangles before and after the optimization of the model is 6596,2 010 respectively and the degree of simplification is 69.5%. see Fig. 14.

The number of vertexes before and after the optimization of the example model is 5543,495 and the de gree of simplification is 91.1%[18]. The number of triangles before and after the optimization of the model is 65 96,978 respectively and the degree of simplification is 85.2%. see Fig. 15.

Form 2 optimization before and after the vertex comparison chart

optimization vertices algorithm	Constrained Delaunay algorithm	The article algorithm
Before optimization	5543	5543
optimized	1090（80.3%）	495（91.1%）

Form 3 optimized before and after the triangle contrast chart

optimization triangle algorithm	Constrained Delaunay algorithm	The article algorithm
Before optimization	6596	6596
optimized	2010（69.5%）	978（85.2%）

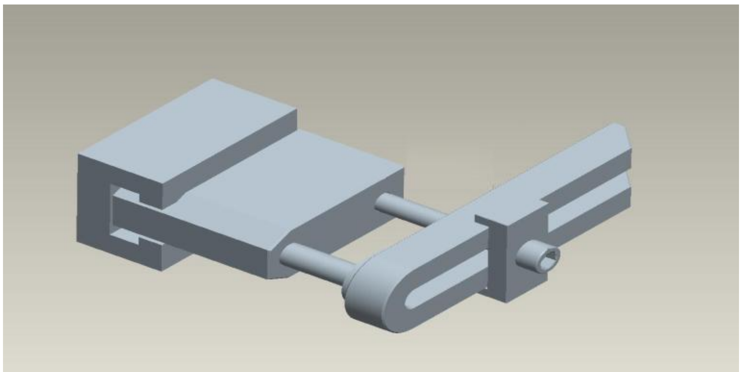


Figure 12: The artifact model diagram created in CATIA

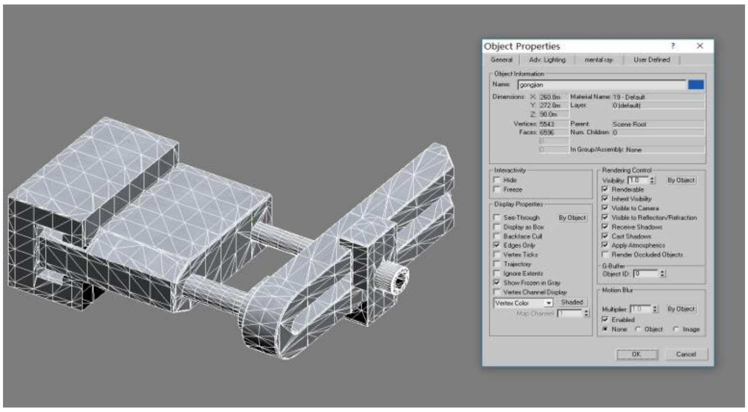


Figure 13: Import the artifact model diagram in 3ds Max

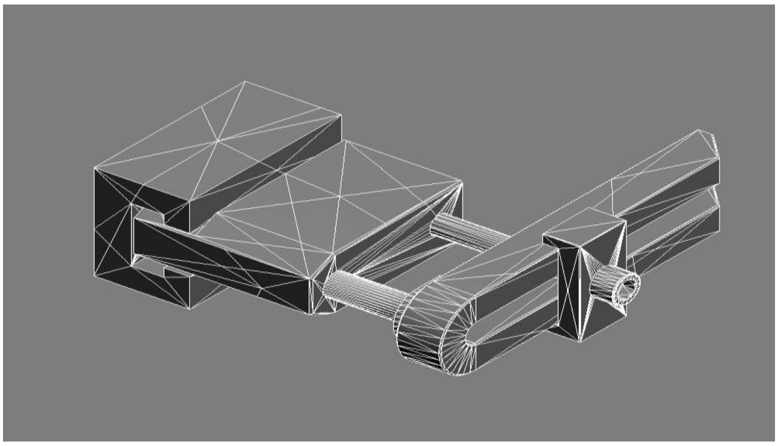


Figure 14: Constrained Delaunay optimized 3ds Max workpiece model diagram

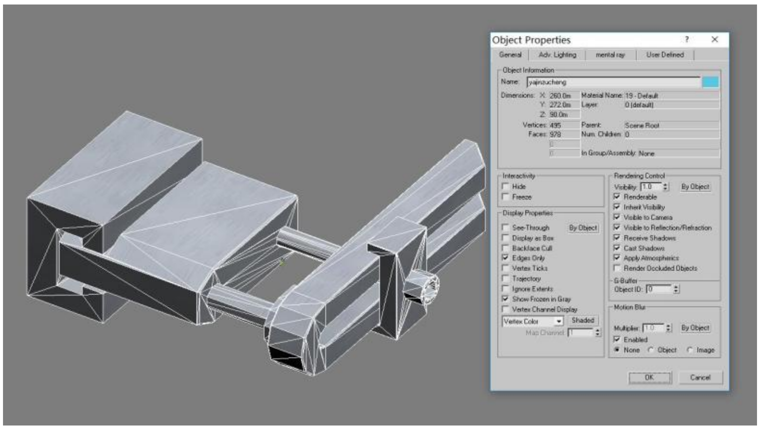


Figure 15: Optimized 3ds Max artifact model diagram

V. Conclusion And Outlook

Based on the study of three-dimensional modeling and the existing theoretical algorithm, this paper has completed three-dimensional modeling and generated the corresponding mesh format file. Then, an optimization algorithm for 3D geometric model is proposed, and the optimization model can be designed and implemented by using the improved optimization algorithm, and the model can be tested.Now emphasizes the comprehensive multi-dimensional optimization model optimization, through the optimization of the three-dimensional surface geometric center of the expansion, will bring new ideas and concepts, model optimization and greatly promote the level of quality and simplify the model optimization. At the same time, the classical optimization algorithms and put forward a new optimization algorithm is closely integrated with the three-dimensional model has profound significance, and has great market potential and development prospects.

References

[1] Peng Yanjun, Shi Jiaoying. based on the shear-warp splatting algorithm of boundary body element. Computer engineering and application, 2002, 38 (13) : 13-16.

[2] Shi Guigang,Chen Xiaojun.The research and implementation of 3d modeling of virtual campus in cyberspace [J]. Journal of engineering, 2008 (2) : 83-88.

[3] Duckham M,Kulik L,Galton A.Efficient generation of simple polygons for characterizing the shape of a set of point in the plane,Pattern Recognit.2008,41(10):3224-3236.

[4] zhou Peide.computational geometry [M]. Beijing: tsinghua university press, 2000:32-40.

[5] Dai Rong,Xie Tiebang,Chang Suping.Vertical scanning white light interference in three-dimensional surface topography measurement system [J]. Optics, 2006, 32 (4) : 545-547.

[6] Jiang Hanqing,Zhao Changfei,Zhang Guofeng,Wang Huiyan,Bao Hujun.Based on multiple views depth sampling three-dimensional reconstruction of natural scene [J]. Journal of computer-aided design and graphics, 2015 (3) : 120-121.

[7] ChengSW，PoonSH.Graded conformingDelaunay tetrahedralization with bounded radius-edge ratio[A]. Proceedings of the 14th Annual ACM-SIAM Symposium on Discrete Algorithms[C]. New York:ACM，2003.295-304.

[8] Sun Hongwei,Wang Jian,Yang Bailong,etc. A fast algorithm is suitable for the application of VRML planar triangular lattices [J]. Journal of computer-aided design and graphics, 2001, 13 (4) : 324-327.

[9] Cai Kangying,Sun Hanqiu,WU Enhua. Manifold-guaranteed out-of-core simplification based on vertex clustering[J]. Journal of Computer-Aided Design & Computer Graphics, 2004, 16(10): 1346-1354.

[10] Ye Jianhui, LI Dehua.Mesh simplif ication of 3D laserscanned data[J]. Infrared and Laser Engineering, 2002, 31(6):522-525.

[11] Xiong Ying,Hu Yujin,Zhang Jianjun. Based on the mapping method and the Delaunay triangular mesh surface partition algorithm [J]. Journal of computer-aided design and graphics, 2002, 12 (1) : 56-60.

[12] Ma Xiuli,Li Jinbo,Zhou Feng, etc. The endocardial surface geometry model of three-dimensional reconstruction algorithm study [J]. Computer application research, 2013, 30 (8) : 2530-2533.

[13] Zhang hui, Chen Yujian,Xu Chengdong,Sun Jiaguang. An arbitrary planar regions based on local priority triangle subdivision algorithm [J]. Journal of computer-aided design and graphics, 2008, 8 (8) : 561-564.

[14] Secchi S，Simoni L. An improved procedure for 2D unstructured Delaunay mesh generation[J]. Advances in Engineering Soft-ware,2003,34(4):217-234.

[15] Kazhdan M.Reconstruction of solid models from oriented point sets[J].Eurographics Symposium on Geometry Processing,2005:73-82.

[16] Huang Mingcong,Zhang Shusheng,Bai Xiaoliang,Li liang.Based on transitional feature recognition and filtering of the 3 d CAD model retrieval [J]. Journal of computer-aided design and graphics, 2014 (5) : 88-90.

[17] Wu Zhuangzhi,Huai Jinpeng,Yang Qin.The Regular triangulation algorithm of the Ed belt right set [J]. Journal of computer science, 2002, 25 (11) : 1243-1249.

[18] Li Haisheng,Yang Qin,Chen Qiming.The research and implementation of Delaunay triangulation [J]. Computer engineering, 2003, 29 (3) : 33-34.

IOSR Journal of Computer Engineering (IOSR-JCE) is UGC approved Journal with Sl. No. 5019, Journal no. 49102.

* Xueyan Lan, " The Research of The Optimized Three-Dimensional Model Algorithm Based on Polygonal Segmentation." IOSR Journal of Computer Engineering (IOSR-JCE) 20.2 (2018): 44-53