Design of Intelligent Control Platform for Boiler Overhaul and Maintenance Based on Model Lightweight

Hui YAO, Hai-rong SUN*, Yue ZHANG and Ya-ting GUO

Hebei Technology Innovation Center of Simulation & Optimized Control for Power Generation, North China Electric Power University, Baoding 071003, China

*Corresponding author

Keywords: Model lightweight, Triangular folding, Boiler equipment, Maintenance.

Abstract. In order to realize the three-dimensional display of boiler equipment model across the Internet, this paper proposes a lightweight method for the three-dimensional model of boiler equipment: a mesh simplification algorithm based on triangle folding. To make full use of the limited computing power, rendering power and storage space of mobile devices for rapid display and interaction of three-dimensional models, and realize the Internet publishing of models. The design scheme of intelligent control platform for boiler maintenance and maintenance based on model lightweight is put forward.

Introduction

Three-dimensional data model has broad application prospects in computer animation, virtual reality and interactive visualization, and it is also one of the research hotspots in recent years. However, the three-dimensional model is not only complex, but also associated data is very large. In most cases, the network bandwidth of enterprises is not enough to support the huge data transmission of the three-dimensional model. Therefore, in order to realize fast browsing and precise geometric information retrieval of boiler equipment data on the network, it is necessary to lighten the boiler equipment model, make the data exchange file smaller, and retain detailed geometric model information.

The model simplification technology is based on geometry, which reduces the segmentation accuracy of the model surface and minimizes the number of polygons on the premise that the shape of the model is basically unchanged[1]. At present, the typical simplification methods are geometric element deletion method [2], global mesh optimization algorithm[3], vertex clustering method[4], and wavelet-based method[5]. Therefore, this paper presents a simplified grid algorithm based on triangular folding[6], which can lighten the three-dimensional model of boiler equipment. In view of the practical problems faced by boiler equipment maintenance and daily maintenance [7], the design idea of intelligent management and control platform for boiler maintenance and maintenance based on model lightweight is put forward.

Model Lightweight

Mesh Simplification Algorithm Based on Triangle Folding

The triangle folding simplification algorithm is based on certain criteria, by calculating the folding cost of each triangle, sorting the triangles from small to large according to the folding cost, forming a queue, then selecting the triangle with the lowest folding cost from the queue for folding operation, repeating the above steps until the model meets the user-defined error requirements, the algorithm terminates, otherwise it succeeds. Continue the above process. The basic idea of the algorithm is shown in Figure 2. Folding triangle I can delete triangle $T_i$, $T_1$, $T_2$, $T_3$, vertex $v_{i1}$, $v_{i2}$, $v_{i3}$, and finally generate a new vertex $v_{i0}$. 

71
Implementation of Mesh Simplification Algorithm Based on Triangle Folding

There are two main problems in this triangle folding operation. One is how much the cost of the triangle folding operation is, that is, how much error it brings. The other is how to choose the position of \( v_i \) so that the error of the folding operation is as small as possible.

**Triangle Folding Operation.** In this paper, a symmetric matrix \( Q_i \) of \( 4 \times 4 \) is assigned to each triangle \( T_i \) in the original mesh, which is called error matrix. If the triangle \( T_i \) is folded as a point \( v_i = [x_i \ y_i \ z_i \ 1]^T \):

The cost of this folding operation, i.e. the error, is determined by the following formula:

\[
\varepsilon(T_i) = v_i^T Q_i v_i \\
= q_{i11}x_i^2 + 2q_{i12}x_i y_i + 2q_{i13}x_i z_i + q_{i14} + 2q_{i22}y_i^2 + 2q_{i23}y_i z_i + q_{i24} + 2q_{i33}z_i^2 + 2q_{i34}z_i + q_{i44} \tag{1}
\]

There are many choices about the location of \( v_i \). The simplest way is to take the center of \( T_i \). The best way is to take the location of \( v_i \) to the minimum \( \varepsilon(T_i) \). Derive the partial derivatives of \( x_i, y_i \) and \( z_i \) in equation (1) and make them zero, that is: \( \partial \varepsilon(T_i)/\partial x_i = \partial \varepsilon(T_i)/\partial y_i = \partial \varepsilon(T_i)/\partial z_i = 0 \).

So we get a system of linear equations (2):

\[
\begin{bmatrix}
q_{i11} & q_{i12} & q_{i13} & q_{i14} \\
q_{i12} & q_{i22} & q_{i23} & q_{i24} \\
q_{i13} & q_{i23} & q_{i33} & q_{i34} \\
0 & 0 & 0 & 1
\end{bmatrix}
\begin{bmatrix}
v_{i01} \\
v_{i02} \\
v_{i03} \\
v_{i04}
\end{bmatrix}
=
\begin{bmatrix}
0 \\
0 \\
0 \\
1
\end{bmatrix} \tag{2}
\]

If the system of linear equations is solvable, then the position of \( v_i \) is given by equation (3); if equation (2) has no solution, our method is to take the position of the center of \( T_i \) triangle, three vertices and the midpoint of three sides as the position of \( v_i \).

\[
\begin{bmatrix}
q_{i11} & q_{i12} & q_{i13} & q_{i14} \\
q_{i12} & q_{i22} & q_{i23} & q_{i24} \\
q_{i13} & q_{i23} & q_{i33} & q_{i34} \\
0 & 0 & 0 & 1
\end{bmatrix}
\begin{bmatrix}
v_{i01} \\
v_{i02} \\
v_{i03} \\
v_{i04}
\end{bmatrix}
=
\begin{bmatrix}
0 \\
0 \\
0 \\
1
\end{bmatrix} \tag{3}
\]

**Error Matrix Calculation and Error Transfer.** The error criterion of the algorithm is the distance from point to plane.

For each triangle \( T_i \) in the original mesh, we obtain the triangle set \( C_i \) related to the triangle by finding the union of the triangle set associated with its three vertices. Our error standard \( \varepsilon(T_i) \) is the maximum distance between the new point \( v_i = [x_i \ y_i \ z_i \ 1]^T \) obtained after folding the triangle and the plane of each triangle in the triangle set. The smaller the distance, the better.
\[ \varepsilon(T_i) = \max_{p \in Ci} \left( p^T v_{i0} \right)^2 \]  

(4)

Among them, \( p = [a \ b \ c \ d]^T \) represents the plane equation \( ax + by + c + d = 0 \) of each triangle in the triangle set Ci related to triangle \( T_i \), and \( a^2 + b^2 + c^2 = 1 \). Formula (4) can be transformed into the form of Formula (1):

\[
\varepsilon(T_i) = \max_{p \in Ci} \left( v_{i0}^T p \right) \left( p^T v_{i0} \right) \\
= \max_{p \in Ci} \left(v_{i0}^T \left(p p^T \right) v_{i0} \right) \\
= \max_{p \in Ci} \left(v_{i0}^T M_p v_{i0} \right) 
\]

(5)

Among them, \( M_p \) is a symmetric matrix of \( 4 \times 4 \), while the error matrix \( Q_i \) is the matrix that minimizes \( \varepsilon(T_i) \)

\[
M_p = pp^T = \begin{bmatrix}
    a^2 & ab & ac & ad \\
    ab & b^2 & bc & bd \\
    ac & bc & c^2 & cd \\
    ad & bd & cd & d^2
\end{bmatrix}
\]

(6)

For a boundary triangle, the set of triangles associated with it cannot form a triangle ring. Our method is to make a plane on each boundary edge of the triangle set that passes through the boundary edge and is perpendicular to the boundary triangle where the boundary edge is located. These planes are also taken into account in calculating the error matrix. Practice has proved that this method is very effective for preserving the boundary characteristics of the original mesh.

For each triangle in the original mesh, we can calculate its error matrix according to Formula (6). When we fold some triangles in the original mesh, the coordinates of some vertices sharing vertices with the folded triangles (if they still exist) have changed. So we need to recalculate the matrix error so that each triangle folding operation can be carried out. The resulting error is passed on. As shown in Figure 1, for point \( v_{i0} \) folded by triangle \( T_i = \{v_{i1}, v_{i2}, v_{i3}\} \), it is not difficult to find physically related triangle \( \Delta v_{i0}v_{i1}v_{i7}, \Delta v_{i0}v_{i2}v_{i8}, \Delta v_{i0}v_{i3}v_{i6}, \Delta v_{i0}v_{i4}v_{i9}, \Delta v_{i0}v_{i5}v_{i17} \), in Figure 1 (b). From the perspective of error transfer, we consider that logically \( v_{i0} \) related triangles are \( T_i \) related triangles, including \( \Delta v_{i1}v_{i2}v_{i3}, \Delta v_{i1}v_{i3}v_{i6}, \Delta v_{i1}v_{i6}v_{i8}, \Delta v_{i1}v_{i3}v_{i8}, \Delta v_{i1}v_{i2}v_{i5}, \Delta v_{i2}v_{i3}v_{i4}, \Delta v_{i2}v_{i4}v_{i9}, \Delta v_{i2}v_{i5}v_{i6}, \Delta v_{i3}v_{i4}v_{i7}, \Delta v_{i3}v_{i6}v_{i17} \).

Because \( v_{i0} \) is a combination of \( v_{i1}, v_{i2} \) and \( v_{i3} \), we must consider the triangle related to \( v_{i1}, v_{i2} \), that is, the triangle related to \( T_i \), among the errors caused by the subsequent \( v_{i0} \)-related folding operation. In this way, we need to recalculate the logically related triangle and recalculate its error matrix for the physical \( J \)-related triangle generated by the \( T_i \)-related folding of the triangle. We pass on the errors generated by each triangle folding operation. Practice has proved that this error transfer method is very effective.

A surface is simplified by using the above algorithm. The comparison results are as follows:

![Figure 2. Simplification of Surface Models by Algorithms.](image-url)
The comparison of water wall scene before and after compression is shown in Table 1.

Table 1. Data comparison before and after water wall scene compression.

<table>
<thead>
<tr>
<th></th>
<th>Before compression</th>
<th>After compression</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objects (individuals)</td>
<td>15034</td>
<td>2653</td>
</tr>
<tr>
<td>Graphics (individual)</td>
<td>3873</td>
<td>33</td>
</tr>
<tr>
<td>Vertex (number)</td>
<td>6501778</td>
<td>501378</td>
</tr>
<tr>
<td>Face number (number)</td>
<td>11723576</td>
<td>44634</td>
</tr>
<tr>
<td>Physical memory</td>
<td>11141. 1M</td>
<td>6517. 6M</td>
</tr>
<tr>
<td>Virtual memory</td>
<td>15237. 2M</td>
<td>7689. 1M</td>
</tr>
</tbody>
</table>

Algorithm Summary

The proposed mesh simplification algorithm based on triangle folding can be described by the following algorithms:

Step 1. Calculate the error matrix \( Q_i \) for each triangle \( T_i \) in the original mesh.

Step 2. For each triangle \( T_i \) in the original mesh. Through its error matrix \( Q_i \). The position of the new vertex \( v_{i0} \) generated after folding is calculated and the folding error is calculated by \( \| v_{i0}^T Q_i v_{i0} \| \).

Step 3. Arrange triangles according to folding error from small to large.

Step 4. Take the triangle with the least folding error from the triangle sequence and perform the folding operation to update all relevant information.

Step 5. If the triangle sequence is empty or the error has reached the user’s requirement, turn to step 6; otherwise, turn to step 4.

Step 6. End.

Design of Intelligent Control Platform for Boiler Maintenance and Maintenance Based on Model Lightweight

General Thought

The general idea of the intelligent management and control platform for boiler overhaul and maintenance is to use virtual reality technology and computer aided design technology to build the three-dimensional model of boiler equipment and build the model library of overhaul equipment. The Internet publishing of the model is realized by model lightweight technology, seamlessly connecting the Web end and the mobile end, breaking through the site and regional constraints, and realizing data management, use and collaborative interaction of different role subjects. At the same time, it combines with the process of boiler overhaul, completes the data release and quality and time management of overhaul records by visual way, and gives suggestions and guidance for overhaul based on data-driven model analysis.

Model Display

After three-dimensional modeling of boiler equipment and lightweight processing of the model, the model is obtained as shown in Figure 3.

Figure 3. Picture of boiler equipment model.
Conclusion

In this paper, a simplified algorithm based on triangle folding is proposed for the real-time and fast display of the three-dimensional model of boiler equipment on the Internet, which makes the display of the three-dimensional model of boiler equipment not restricted by hardware equipment. It has been applied to the design of the intelligent management and control platform for boiler maintenance and maintenance, and has realized the three-dimensional display of boiler equipment on the browser platform. The online display of the model has achieved good results.

References