A study on watermarking of 3D polygonal models using topological Information

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1. Introduction

With the widespread use of 3D graphics in recent years, 3D data came to be frequently distributed via the Internet. The primary advantage of digital data lies in the ease of duplication, distribution, and modification. These advantages, however, have prompted unauthorized duplication and distribution of data [1]. This paper discusses techniques to embed data into 3D models, specifically 3D polygonal models, using the redundancy of topological information.

2. Embedding Procedure

Generally, 3D model which consists of polygons has geometrical values [2], that are the coordinates of vertices and topology (connectivity) among them. In this paper, data are embedded by changing the description of the shared edge between two triangles.

2.1. Definition of edge number

Assume that the topology information is described as [A,B,C,-1,]. Let the edge between A and B be edge①, B and C be edge②, and C and A be edge③.

The order of vertices of triangles must be unified to clockwise or counter-clockwise to define the direction of the surface. Under that condition, there are three possibilities of the order. For example, the triangle of Figutre1 can be described as [A,B,C,-1,], [B,C,A,-1,] or [C,A,B,-1,].

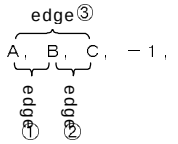


Figure1. Definition of edge number.

2.2. Construction of Message

By utilizing the redundancy of vertex order description, we can embed some information into the shared edge. For example, in the case of [1,2,3,-1,] and [3,2,4,-1,], the edge② of the former and the edge① of the latter is identical and shared between two triangles. There are nine combinations because each triangle has three possibilities for shared edge. 8 patterns out of 9 can represent 3 bit information, and the 9th possibility is utilized in the next section. To embed a letter (8 bit), a couple of triangle pairs are required as shown in the next section, because each pair can only represent 3 bit.

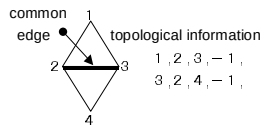


Figure2. Construction of Embed data.

2.3. Embedding and Extracting Procedure

First, find triangles as shown in Figure3(a) from the input triangular mesh (16 triangles are necessary to embed 8 bit data). Here, avoid triangles that have already been used for the embedding.

For each selected triangles, embed three parts {marker, data, order} as mentioned in Section2.2 by changing relation of edge connect. Figure3(b) shows this procedure. Marker is represented by the unused representation for data embedding (the 9th pattern).

The extraction of embedded symbols can be implemented in the similar manner, beginning from marker search.

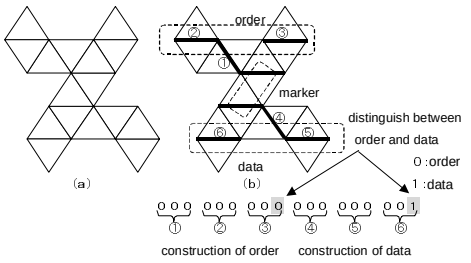


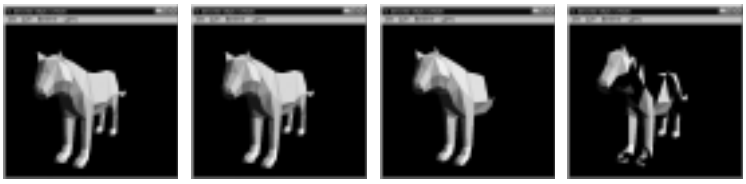
Figure3. Embedding algorythm. a bit string is embedded into connectivity of triangles in a preordained.

2.4. Implementation and Evaluation

Table1 shows the data capacities of various models. Figure4(a),(b) show the original and embedded model where no difference can be recognized. Figure4(c) shows the model cut in half, in which 8 letters are left intact. Figure4(d) shows random cutting of the model, in which 3 out of 16 bytes are left intact.

Table1. Model size, embedding data capacity,

Model	Number of vertices	Number of triangles	Data capacity per model
scud.wrl	136	240	8
chess1.wrl	389	772	27
gumby.wrl	406	760	26
x_wing.wrl	3099	6084	210



(a) The original model. Number of triangles 602

(b) Message embedded. Embedded Message (16bytes) Akabane Kazuhiko

(c) Cut in half. Extracted Message Akabane Kazuhiko

(d) Delete in random. Extracted Message Akabane Kazuhiko

□ is part that extracted form model.

Figure4. Result of embedding data into 3D models by proposed method.

3. Conclusion

This paper presented a technique to embed watermark into 3D polygonal models by using redundancy of topology information. The technique described in this paper is resistant to some disturbances including cut operations and affine transformation.

However, embedded message can be removed by changing the vertex order in the topological information. More research on robust watermarking method is desired.

References

[1] R. Ohbuchi, H. Masuda, and M. Aono, "Watermarking 3D Polygonal Models," presented in November 1997 at ACM Multimedia ' 97.

[2] ISO/IEC JTC1 SC24/N1596 CD #14772 Virtual Reality Modeling Language (VRML 2.0) .