POSTER : A Method for Generating Developments using Decomposition into the Meaningful Components of 3D Polygon Models

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ABSTRACT

We propose a method for generating developments from 3D polygon models automatically. The conventional method generates the developments whose components are not interfering each together, by using collision detection between all polygons. However, for the model which consists of a large number of polygons, it is necessary to decompose the development into several parts manually. Therefore it is difficult to generate the development which is easy to be assembled. Our method decomposes the polygon model into meaningful components such as arms, legs, and so on, and develops them. This makes it easy to understand which parts should be glued together, and handcraft bending or folding the developments when a user assembles the paper craft.

Keywords

PAPER CRAFT, DEVELOPMENT, MODELING

1. INTRODUCTION

Recently, CAD or CAM systems are used for designing industrial products. Those make it easy to edit or reuse those designed shapes.

However, those designed shapes are only displayed on the screen as an image, and we cannot touch them with our hand and watch around. Therefore the paper craft has gotten an attention as a easy way to make models recently. With paper craft models, it is useful from the perspective of not only engineering, but also education, to sense those models in three dimensions.

The development of polygon model can be generated by searching all developing patterns. However in the large number of polygons, it takes longer time to be processed. Therefore, some of proposed methods [Mit04]generate developments in consideration of the length of the cutting line, the area of circumscribed rectangle of the development or branch connections of polygons on the development. In addition, in case of large number of polygons, the polygon model is decomposed into several parts not to reduce the number of polygons composing a piece of the development or not to interfere each together.

We propose a method which decomposes complex models with large number of polygons into several components and generates developments which is easy to be assembled. Models are divided at the concave and convex region regarding as characteristics and components are developed to be cylindrical.

2. PARTS DECOMPOSING

Our method decomposes models based on Katz's method[Kat03]. Our method can decompose models into meaningful parts in case of animal shape on concave edges.

The process consists of following procedures.

(1) Generate the dual graph representing the connections of polygons.

(2) Calculate and set the costs to the arc of the graph

(3) Select representative nodes in the dual graph

(4) Categorize the nodes as determined region or undetermined region

(5) Set braches of undetermined region to max-flow regarding as a network with max-flow theorem

(6) Divide the model (part) into two parts at the parting line determined with max-flow min-cut theorem

(7) Continue (3)-(6) procedures recursively

(8) Decompose the polygon model with reference to dual graph

2.1 Calculating the costs

While boundary representation model represents vertices, edges and faces, dual graph represents connection of faces. A Dual Graph G* for Graph G is defined as follows. face f in G is related to node f* in G* and edge e in G is related to node e* in G*. Fig.1 shows an example of the relationship between G and G*.

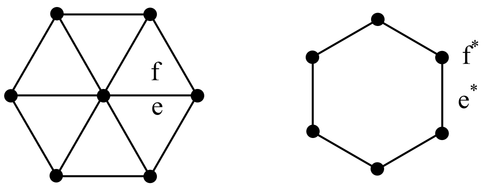

Figure 1. Dual graph

The dual graph related to the graph representing edges and vertices of polygon model, can be considered as a graph which represents connection of faces. Each cost which is set to an arc of dual graph, is calculated with dihedral angle of polygons sharing the edge and geodesic distance between centers of polygons. Eq.(1) shows the cost form the dihedral angle.

$$AngDist(\alpha_{ij}) = \eta(1 - |\cos\alpha_{ij}|) \quad (1)$$

where α_{ij} is dihedral angle between face f_i and f_j, and η is weighting coefficient.

$GeoDist(f_i, f_j)$ is the geodesic distance between centers of face f_i and f_j as shown in fig.2. Eq.(2) is the cost which is set to the edge.

$$Cost(f_i, f_j) = \delta \frac{GeoDist(f_i, f_j)}{GeoDist_{avg}} + (1-\delta)\frac{AngDist(\alpha_{ij})}{AngDist_{avg}} \quad (2)$$

where $GeoDist_{avg}$ is average of geodesic distances and $AngDist_{avg}$ is average of dihedral angles.

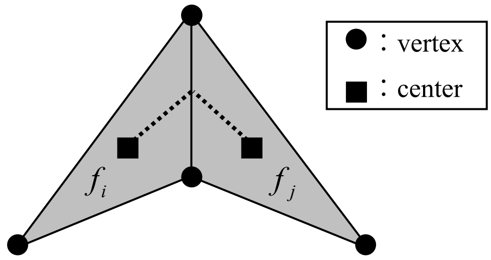

Figure 2. Geodesic distance

2.2 Selecting Representative nodes

This procedure selects a pair of node whose distance is the longest, using Dijkstra's algorithm. We call them representative node. To decompose a polygon model, the process categorizes nodes as determined or undetermined region. The nodes near the representative nodes are categorized as determined region and other nodes are categorized as undetermined region. The nodes categorized as undetermined region can be candidate of cutting path.

2.3 Dividing undetermined region

To divide undetermined region, this procedure regards undetermined region as a network and searches cutting line using max-flow min-cut theorem. The advantage of our method is reduction of meandering of cutting line.

2.4 Termination conditions

The decomposing procedure continues recursively until each decomposed part meets termination conditions as follows.

(a) The number of faces is small enough.

(b) The distance between representative nodes becomes significantly short after division.

(c) The difference between maximum value and minimum value of dihedral angles of a decomposed part.

3. GENERATING DEVELOPMENTS

In conventional method, the process generates developments by cutting out top face and bottom face and by rolling out other faces as shown fig.3.

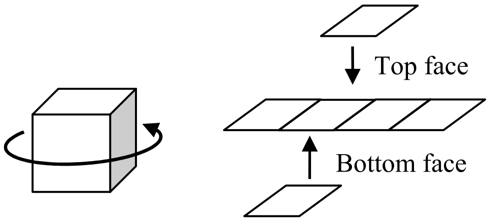

Figure 3. Parts developing

Our method is also based on conventional one. In addition, our method makes it easy to cut out pieces form development and handcraft bending or folding the developments when a user assembles the paper craft. As shown in fig.4, total length of cutting line of left one is longer than right one. Therefore right one is easy to cut out.

In our method, the process modifies developments so that cutting line becomes shorter by attaching and detaching developments each other.

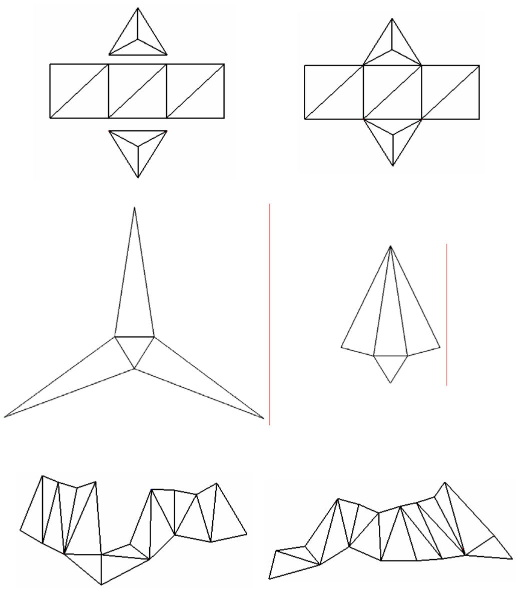

Figure 4. Developments modification

4. RESULTS

To evaluate effectiveness of proposed method, we apply it to develop some three dimensional polygon models as shown in fig.5. Fig.6 shows decomposed models. Fig.7 and 8 shows developments of decomposed parts generated by using our method. In addition, we assembled these developments. Fig.9 shows resulting paper craft models.

Those developments were decomposed into cylindrical parts and rolled out. Therefore it was easy to cut out from development sheet. And also it is easy to bend and grew together.

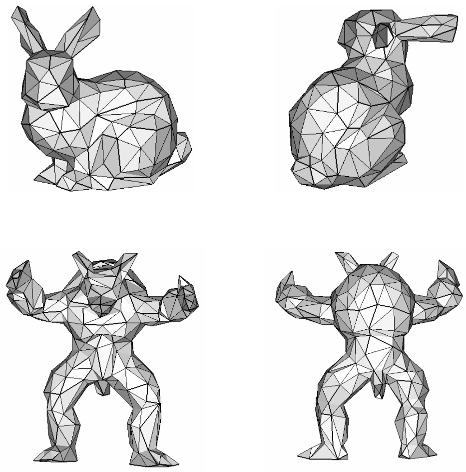

Figure 5. Experimental models

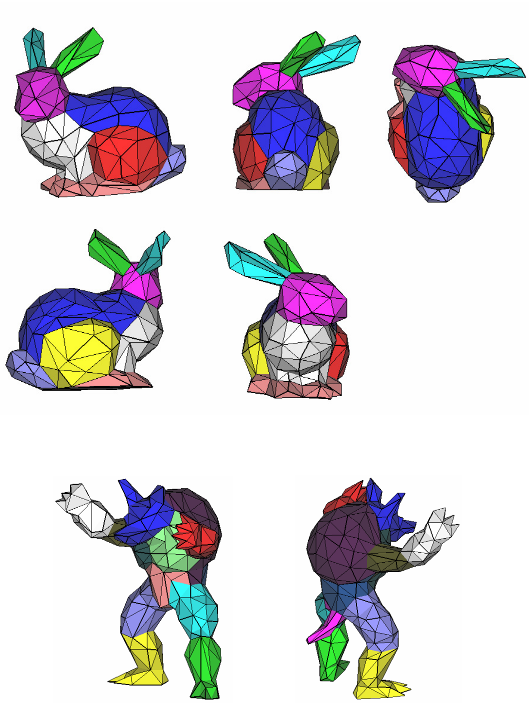

Figure 6. Parts decomposing

 ISBN 978-80-86943-99-2

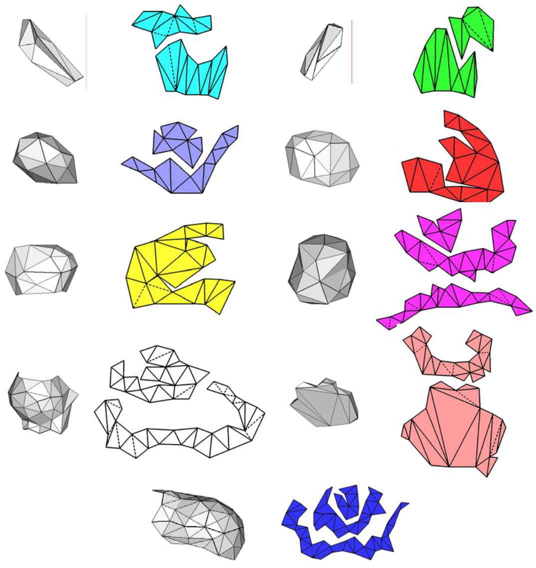

Figure 7. Developments for Bunny

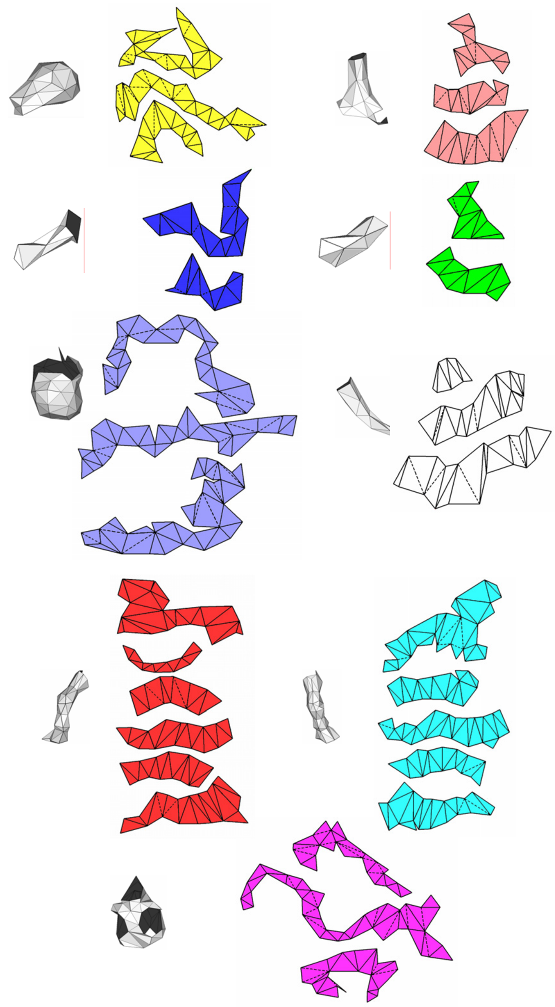

Figure 8. Developments for Armadillo

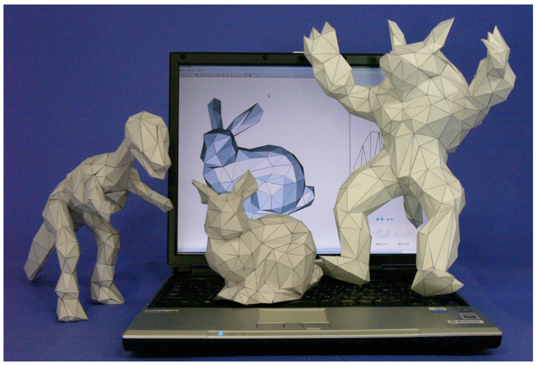

Figure 9. Resulting paper crafts

5. CONCLUSIONS

In this paper, we have described about methods of generating development for polygon model and proposed a method of decomposing polygon model into several parts and generating developments.

The Experimental results shows that our method is useful to generate developments and they are easy to assemble.

6. REFERENCES

[Mit04] Mitani, J. and Suzuki, H., Making Papercraft Toys from Mcshcs using Strip-based Approximate Unfolding, ACM Transactions on Graphics, pp.259-263,Vol.23, No.3, 2004.

[Kat03] Katz, S. and Tal, A. Hierarchical Mesh Decomposition using Fuzzy Clustering and Cuts, ACM Transactions on Graphics, pp.13-18, Vol.22, No.3, 2003.

 ISBN 978-80-86943-99-2