An Edge Optimization Method Based on Segmented Surfaces of Stone Flakes

Tianfang Lin
Graduate School of Engineering
Iwate University
Morioka, Japan
lintianfang@lk.cis.iwate-u.ac.jp

Xi Yang
Graduate School of Engineering
Iwate University
Morioka, Japan
yangxi@lk.cis.iwate-u.ac.jp

Katsutsugu Matsuyama
Graduate School of Engineering
Iwate University
Morioka, Japan
m18u@iwate-u.ac.jp

Kouichi Konno
Graduate School of Engineering
Iwate University
Morioka, Japan
konno@cis.iwate-u.ac.jp

Abstract- **In our previous research, [3] has put forward a method to extract surfaces of stone flakes. But for reassembling stone flakes, it is necessary to obtain the suitable flake surface. Extracting accurate and smooth edges of stone flake surfaces plays a significant part. The former method extracted the boundary edges of stone flakes based on the density of points. However, some surface boundaries are rough. It is hard to match flake surfaces with these irregular edges. To solve this problem, an effective method is proposed for optimizing edges based on a mesh. According to experiments, results of our optimization method indicate that the boundary edges become smooth, which will make a contribute to stone flake matching.**

***Key words*:** Optimization, Stone flakes, Triangle mesh

I. Introduction

In archaeology, excavated materials are very important evidences for anthropological research[1]. In ancient time, the stone tools were used as cutting tools or weapons made by striking or polishing rocks. It is pretty meaningful to reassemble stone flakes for obtaining good knowledge of ancient human activity. On the other hand, the problem of reassembling fractured 3D objects in a fully automatic way has gained an importance, due mainly to the increasingly wide-spread use of shape acquisition devices in multiple fields[2]. In the process of reassembling, the speed and accuracy of searching the best matching surface are the key of reassembling.

In this study, we use stone flakes excavated in Japan. Since the climate of Japan is marine warm temperate damp monsoon, the air is humid and the soil is acidic. Therefore, organics like bones and woods perish except stones, and some edges of stone flakes are vague and ambiguous. In the above situations, for obtaining the best matching surface, extracting accurate and smooth edge of stone flakes plays a critical role. The flake surface extraction method[3] has extracted the edges of stone flake surfaces according to the density of points. Nevertheless, part of results are irregular, the boundary edges are not smooth.

This paper proposed a novel method of optimizing the edges based on segmented surface to get smooth boundary. Our method mainly includes obtaining boundary edges of stone flake surface, calculating the angle between adjacent boundary edges and modifying the triangle polygon mesh. Compared with the method which optimizes boundary edges with simple straightest geodesics[5], our method do not need to move or add points. It can retain the original meshes as much as possible.

II. Related Works

The segmented results of stone flakes are mesh-based point clouds. Because the normal vectors of boundary meshes vary violently, the curvature of points is large around edges and it is small inside flake surfaces. The feature is utilized to extract edges of flake surfaces and generate closed surfaces. The flow of the flake surface extraction method is shown in the Fig. 1.

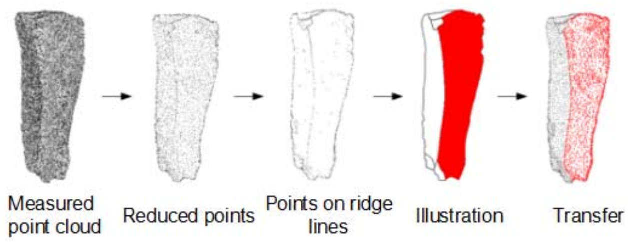


Fig. 1. Flow of flake surface extraction

Meshes are simplified by using Quadric Error Metrics[4]. When triangle meshes are generated, low-density points will cause irregular surface boundaries as shown in the Fig.2.

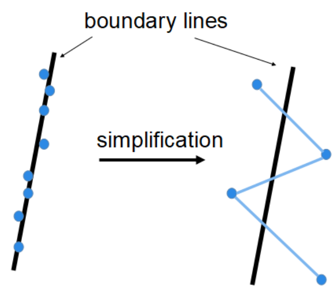


Fig.2. Analysis of irregular boundary generation

III. Our Method

In our method, we use the above segmented stone flake surfaces as our experimental data, there are three steps for optimizing the boundary edges of a stone flake surface.

Step1: Traverse the triangle mesh of the surface to obtain triangles that on the boundary edges. The boundaries are judged by boundary conditions (1). Assume that the number of mesh traversal times as T. If edge e_i of triangle polygon

978-1-5386-2615-3/18/$31.00 ©2018 IEEE

is traversed only once, it is regarded as a boundary edge. Otherwise, e_i is traversed twice, which is not a boundary edge.

$$e_i = \begin{cases} boundary, & T(e_i) = 1 \\ inside, & T(e_i) = 2 \end{cases} \quad (1)$$

Step2: Judge adjacent triangles that have the boundary edges whether they are in the direction of edge or not. As shown in Fig. 2, assume the angle between two triangle meshes as θ, if θ is greater than R, the adjacent triangles are in the same direction. Otherwise, if θ is equal to or smaller than the threshold R, the adjacent triangles are not in the same direction, a new triangle mesh need to be inserted for optimization. As shown in Fig. 3 and Fig. 4 , when inserting a triangle mesh, we have to keep the normal vector to be consistent. For instance, if the triangle meshes of a surface are clockwise, triangle mesh insertion must be clockwise.

Step3: Repeat the operations of step 2 until all of triangle meshes are optimized.

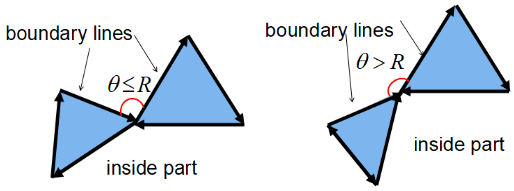


Fig. 2. Judgment of edge direction

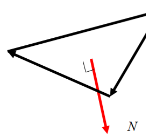


Fig. 3. Normal vector of a triangle mesh

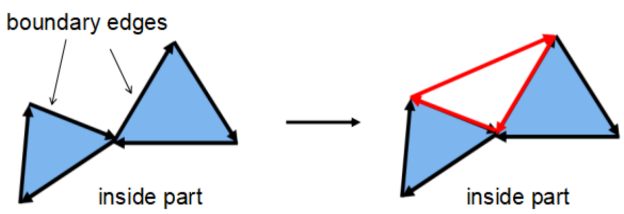
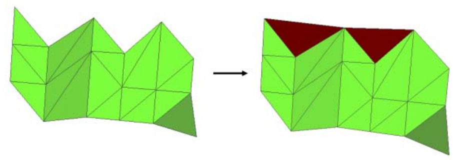


Fig. 4. Consistence of normal vector

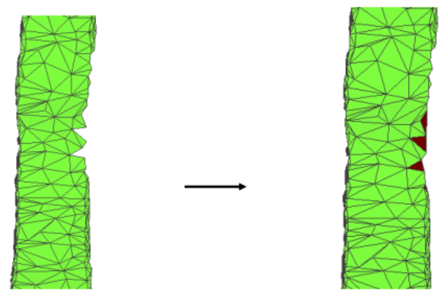
IV. Experimental Result

We have implemented the proposed method in a PC with the CPU of Intel(R) Core(TM) i7-6700 3.40GHz and 8.00GB RAM. The C++ programming language and PCL (Point Cloud Library) is used with Visual Studio 2013 and Qt 5.4.2. We applied our optimization algorithm to extracted irregular stone flake surfaces. By our method, the former boundary became smooth. The results of optimization are shown in Fig. 5, Fig. 6 and Fig. 7. In these experiments, we set R as 120 degrees. (a), (c) and (e) are original surfaces, and (b), (d) and (f) are optimized surfaces.



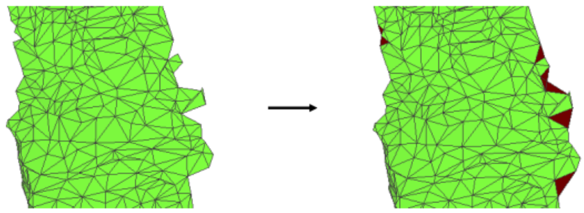
(a) (b)

Fig. 5. Result of optimization



(c) (d)

Fig. 6. Result of optimization



(e) (f)

Fig. 7. Result of optimization

V. Conclusion And Future Works

This paper presented an edge optimization method based on stone flake surfaces. Our method can arrange triangle mesh according to the boundary edges of stone flakes. In the future, the extracted surfaces with regular edges are applied for implementing the reassembling work of stone flakes.

References

[1] Ed. Muraki. Excavation investigation report of OROSE: Technical report, Iwate Culture Promotion Agency, Iwate, JP, 2013.

[2] Q.-X. Huang, S. Flory, N. Gelfand, M. Hofer and H: Pottmann. Reassembling fractured objects by geometric matching. In ACM *Transactions on Graphics*(*TOG*), Vol.25, pp 569-578, ACM, 2006.

[3] A. Chida, K. Matsuyama, K. Konno, F. Chiba: A Rapid Searching Method of Adjacent Flake Surfaces in Stone Implements by Using Sets of Measured Points for Generating a Joining Material, NICOGRAPH 2014, 2014.

[4] M. Garland, P. Heckbert: Surface simplification using quadric error metrics, SIGGRAPH '97 Proceedings of the 24th annual conference on Computer graphics and interactive techniques, pp.209-216, 1997.

[5] C. Yang, H. Suzuki, Y. Ohtake, T. Michikawa: Boundary Smoothing for Mesh Segmentation, 11th IEEE International Conference on Computer-Aided Design and Computer Graphics, 2009.