Approximate Convex Decomposition for Real-time Terrain Fracturing

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***Abstract*— This paper proposes the Terrain Approximate Convex Decomposition (TACD) method. It extracts features from the regularly-sampled height map, uses the features to decompose the height map into a set of convex hulls, and then applies the fracture patterns to the convex hulls. The TACD method runs at real time and presents realistic effects. It can be integrated with games and virtual reality applications.**

Keywords-terrain; height map; fracturing.

I. Introduction

Fracturing or fragmentation refers to the process by which an object is shattered into small pieces. It is a desired effect especially in games, but real-time terrain fracturing is not easy to implement.

It is generally required to use pre-defined *fracture patterns* for real-time fracturing, but the terrain area is basically a 2D surface and is too wide to apply such a pattern. This paper tackles the problem by decomposing the input terrain surface into 3D convex hulls, each of which is independently combined with a fracture pattern.

This paper presents the real-time terrain fracturing algorithms in the following organization: Section II presents the basics of pattern-based fracturing. Section III proposes what we call Terrain Approximate Convex Decomposition method. Section IV presents the experimental results and Section V concludes the paper.

II. Convex-Hull Fracturing

This section first presents how fracturing is made with a pattern, and then how the terrain is fractured in terms of features and convex hulls.

A. Pattern-based Fracturing

For real-time fracturing, we use a pre-defined fracture pattern. Figure 1 shows the flow of fracturing. The input object is decomposed into convex hulls, to which the fracture pattern is applied so that the intersection of the convex hulls and fracture pattern produces many facture cells. The cells will be physically simulated to bring the fracturing effects.

B. Feature Extraction

The most commonly used terrain model is the *height map*, which stores discrete elevation data on the grid. The first step of terrain fracturing is to extract features from the height map.

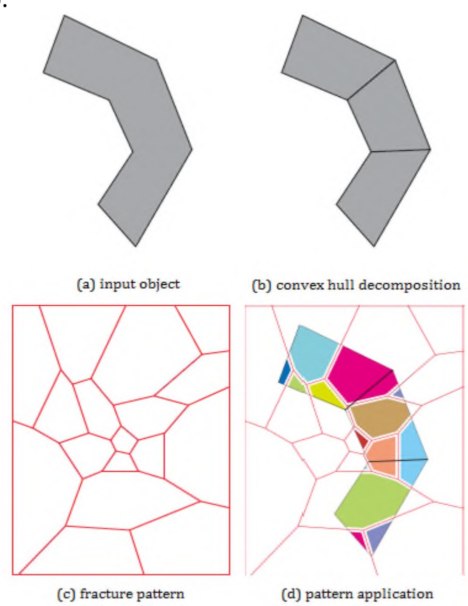

Figure 1. Fracturing flow.

In our study, we used a 256×256-resolution height map. Its base is the *xz*-plane with *y*-coordinate zero, and the terrain surface is a mesh of 3D triangles constructed with 256^2 vertices. Figure 2-(a) shows a cross section of an example height map, which was simplified to have 11×11 samples just for visualization purpose. The red and green points represent the features. The red-colored features are extracted through the Laplacian operation on the surface curvatures of the height map. The green-colored features represent the boundary of the 256×256-resolution height map volume.

C. Convex Hull Decomposition

If we computed the convex hull for the entire height map shown in Figure 2-(a), we would have a big convex hull, as illustrated with the red boundary. It is not efficient to apply the fracture pattern to such a big convex hull.

In order to decompose the height map into a set of smaller convex hulls, we need to extract another group of features, such as the red point in Figure 2-(b). It represents a point with the locally-maximal concavity. A wide height map may contain a number of such features, and they are

 ISBN: 978-1-61208-577-7

extracted through flooding-based watershed technique [1]. Figure 3 illustrates the process.

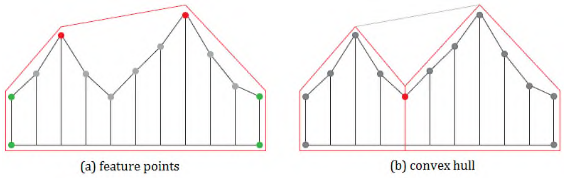

Figure 2. Features in the height map.

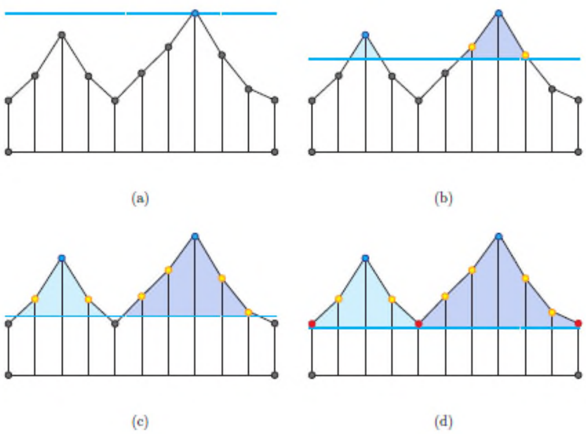

Figure 3. Flooding-based watershed.

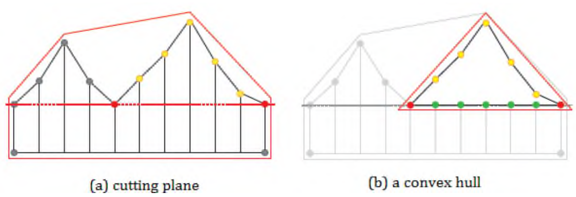

Figure 4. Convex hull computation.

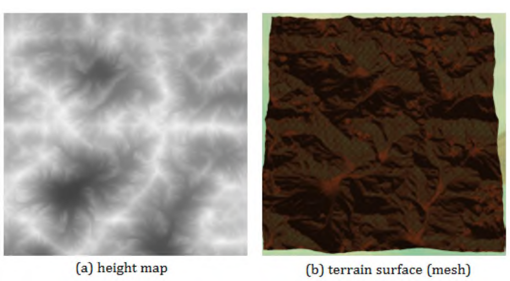

Figure 5. Height map and terrain surface.

Given a set of four or more nearby feature points, a *cutting plane* is defined, as shown in Figure 4-(a). Then, a convex hull is obtained with the cutting plane, as illustrated in Figure 4-(b). In the current implementation, we use the Random Sample Consensus (RANSAC) method [2] for defining the plane and the Quickhull method for computing the convex hull [3].

III. Experimental Results

The proposed system was implemented in Direct3D 11 on Intel i7-3770 3.40GHz CPU, 16GB RAM, and GeForce GTX 980 Ti.

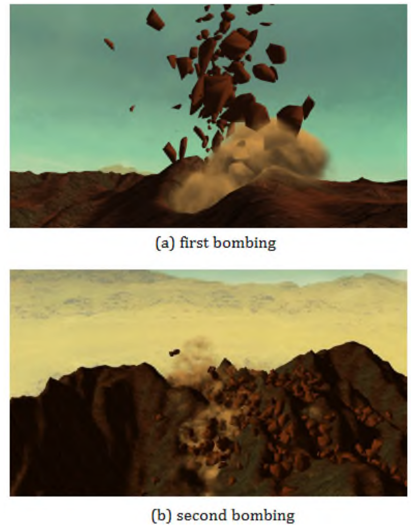

Figure 6. Terrain fracturing due to bombing.

Figure 5 shows the height map of resolution 256^2 and the 3D polygon mesh constructed from it. Figure 6 shows the fracturing effects. The low-frequency terrain in Figure 6-(a) produces 142 fracture cells, and fracturing takes 28.6ms. The high-frequency one in Figure 6-(b) produces 205 fractures, and fracturing takes 30.63ms. The higher-frequency terrain surface produces more fractures, which consume more time.

IV. Conclusion

This paper presented a novel terrain fracturing method based on fracture pattern, where the features are extracted from the height map, and then the height map is decomposed into convex hulls using the features. The fracture patterns apply to the convex hulls. The method can be integrated with games and virtual reality applications.

Acknowledgment

This work was supported by Institute for Information & communications Technology Promotion (IITP) grant funded by the Korea government (MSIP) (No.R0115-16-1011). J. Han is the corresponding author.

References

[1] E. Zuckerberger, A. Tal, and S. Shlafman, “Polyhedral surface decomposition with applications,” *Computers & Graphics*, vol. 26, no. 5, 2002, pp.733 –743.

[2] M. A. Fischler and R. C. Bolles, “Random sample consensus: A paradigm for model fitting with applications to image analysis and automated cartography,” *Commun. ACM*, vol. 24, no. 6, 1981, pp.381–395.

[3] C. B. Barber, D. P. Dobkin, and H. Huhdanpaa, “The quickhull algorithm for convex hulls,” ACM Trans. Math. Software, vol. 22, no. 4, 1996, pp. 469–483.