

# Adaptive Extended Marching Cubes

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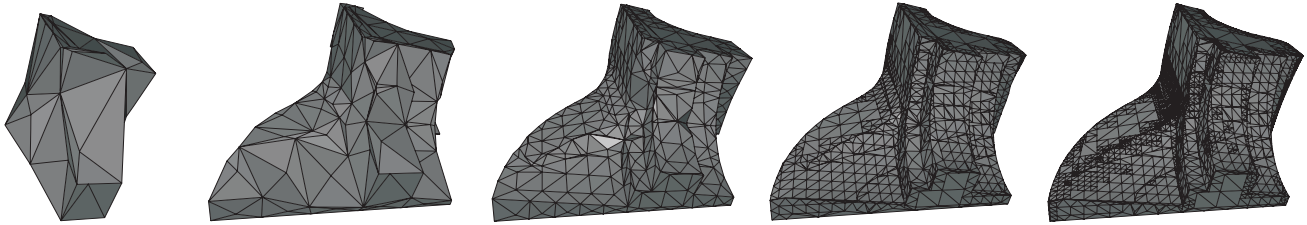


Figure 1: Pictures of isosurfaces using marching cubes with adaptive resolutions and sharp features. The maximum octree level are 2, 3, 4, 5, 7 from left to right.

## ABSTRACT

The demands related to Volumetric Models are increasing rapidly due to the availability of 3D scanner, but its application in the manipulation of volumetric data raises several issues that need to be addressed. The fundamental of manipulating volumetric data includes isosurface extraction, while sharp features of 3D models are well preserved with Extended Marching Cubes algorithm (EMC). However, the resulting isosurfaces will be huge in contrast to adaptive resolution. An adaptive resolution improvement to EMC is proposed to let different resolutions coexist at different locations to meet different requirements. In addition, due to correlated nature of adjacent cubes, isosurface extracting using standard error minimization methods needs to take special considerations while resolution goes adaptive. A performance driven method and guidelines are suggested in this paper. Furthermore, progressive transmission is easy to achieve by using the adaptive octree.

## Categories and Subject Descriptors

I.3.5 [Computer Graphics]: Computational Geometry and Object Modeling; I.3.6 [Computer Graphics]: Methodology and Techniques-Interaction techniques;

## Keywords

Adaptive resolution, Isosurfaces, Progressive

## 1. INTRODUCTION

Several isosurface-extracting techniques have been proposed to visualize volume data with sharp features [6], adaptive resolution [5], and even progressive encoding [7]. However, there are still some secrets hiding behind those techniques. In formally, standard Marching Cubes [9] has some remarkable characteristics that its successors do not have. That is adjacent cubes are not corre-

lated, but the “marching” nature makes the opposite faces of adjacent cubes have edges at the same location. Those edges connect cubes to form an Isosurface, and the calculations of cubes are still independent. However, the successors did overcome problems of sharp features, crack patching, adaptive resolution, etc.

Fitting the resolution adaptively may cause problems when cubes are correlated. The key point of adaptive resolution technique is to make resolution higher at where it needs to preserve more details. That makes the space requirement as low as that in lower resolution, but the details are preserved as well as those in higher resolution. Figure 1 shows the results of adaptive resolution. The standard way to determine the extracted isosurface and the original data. In the middle of the process, cubes that change its resolution may interfere its neighbors. Figure 2 depicts a situation of this kind.

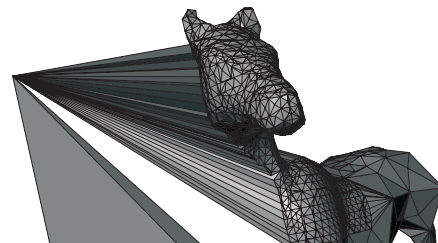


Figure 2: Sharp features that are interconnected between adjacent cubes will interfere with the estimated error.

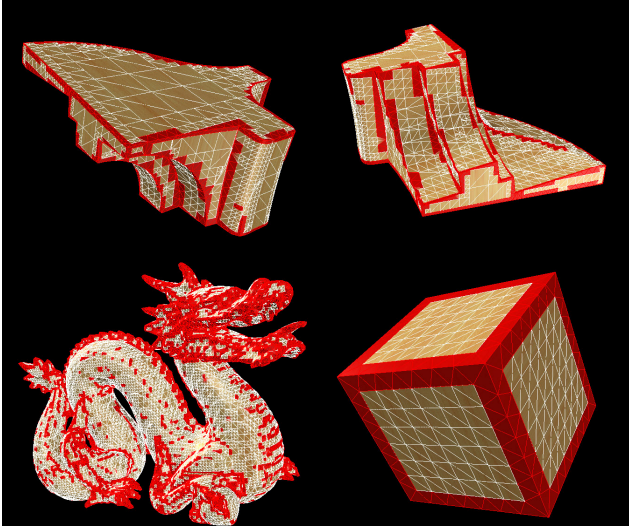


Figure 3: Triangles with sharp features are highlighted by red color.

In contrast to the Dual Contouring method, the Extended Marching Cubes explicitly identifies and processes sharp features. That means portions of cubes remain as the same as standard Marching Cubes. Usually, sharp features consist of much fewer portions at most 3D models. Figure 3 shows some 3D models with highlighted sharp features. In this kind of situation, the fewer of correlated cubes the less impact of interconnection.

However, the lack of adaptive resolution motivates us to develop Adaptive Extended Marching Cubes algorithm to overcome problems described above.

## 2. ISOSURFACE GENERATION OF ADAPTIVE EXTENDED MARCHING CUBES

All the cell structures, sample points, and feature samples of Adaptive Extended Marching cubes are the same as described in [6]. We organize cells into an Octree to form the adaptive resolution.

In uni-resolution, sharp features are connected to restore the shape of edges and corners by edge flipping. Basically, edge flipping is a modified substitution of 4 points triangulation. Figure 4 shows the triangles before and after the flip.

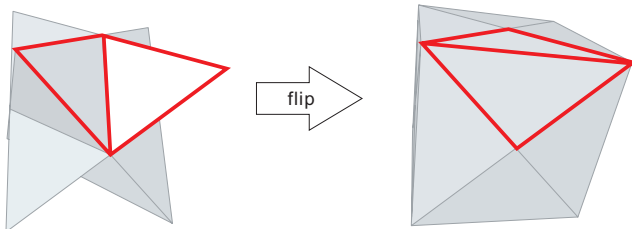


Figure 4: edge flipping in uni-resolution

In adaptive resolution, because neighbors could be in different resolution, things become more complex. In this situation, there is no common edge between sharp features to perform the edge

flipping. We define an operation named SharpLink which performs similar to edge flipping in uni-resolution. SharpLink is a triangulation between a sharp feature and a sharp path. This operation can be used in adaptive resolution. The idea is illustrated in Figure 5.

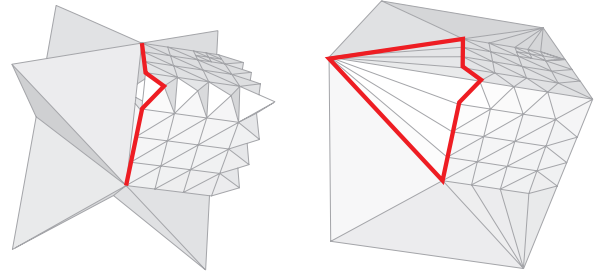


Figure 5: (a) Sharp Path, (b) SharpLink

Sharp path is a path contains edges on the common face between two octree nodes. If a common edge is part of a triangle containing a sharp feature, substitute the edge with the other two edges in the triangle. These two nodes must have the same level, and one of them must be a leaf node. If a cell is a non-leaf node, all edges of child leaf nodes of it are taking into account.

Once we have the sharp path, we generate a triangle fan between a sharp feature and a sharp path. The shape of the sharp feature is rebuilt by the Sharp link.

## 3. ISOSURFACE EXTRACTION OF ADAPTIVE EXTENDED MARCHING CUBES

Connecting sharp features between adjacent cubes will interfere with the estimated error as described in the first section. Figure 2 shows the situation in the middle of the extraction process. The estimated error is higher when neighbors are still in very low resolution. There are many ways to reduce the impact of this problem, such as extraction in BFS order or merging cells from a higher resolution. Although it still can converge, but such varying behavior makes additional unnecessary increase to the depth of octree level.

For performance and storage efficiency, our implementation of the extraction process has two steps. First, we extract and estimate the error using the adaptive version of standard marching cubes algorithm until a given sparse threshold or a base depth of octree level is reached. Second, we extract and estimate the error using Adaptive Extended Marching Cubes algorithm with different weighting parameters between triangles with and without sharp features.

## 4. RESULTS

Figure 1 shows the result of extracted and generated isosurfaces in different levels from the mesh model of a fan disk. A threshold value is given to determine the condition to further subdivide a cell. The error between new cell and that of a source model is under the error bound defined by the threshold. However, the



Figure 6: Results of imported models with modifications, such as a ball is added into the dragon's mouth in realtime.

Octree level is limited by a predefined maximum level for performance reason.

Due to the octree structure, progressive encoding and transmission is simple. At the base level, we encode the hermite data of each cell. At the successive level, only the vertex and samples not included in previous level are needed to be encoded. The encoding is using similar methods described in [9] and replaces the Dual Contouring to Adaptive Extended Marching Cubes. Figure 1 shows the results.

## 5. CONCLUSION

Digital sculpting [1-5] is a new trend for creating 3D models. This work is a part of our Virtual Sculptor project [10-12] which is a real-time interactive modeling system for fast generating of prototyping 3D models. The proposed Adaptive Extended Marching Cubes successfully extract and generate isosurfaces of different kinds of 3D models to be imported into our system. Given a threshold value, the error between imported and original 3D model is bounded. Also, the adaptive resolution can save storage while manipulating large 3D models.

## 6. ACKNOWLEDGMENTS

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