Extraction of A Smooth Surface from Voxels Preserving Sharp Creases

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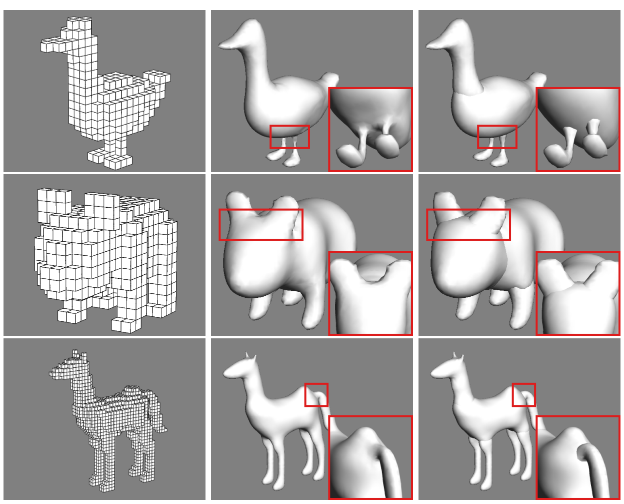
1 Introduction

Construction of a free-form 3D surface model is still difficult. However, in our point of view, construction of a simple voxel model is relatively easy because it can be built with blocks. Even small children can build a voxel model. We present a method to convert a voxel model into a free-form surface model in order to facilitate construction of surface models.

A straightforward approach is to apply smoothing (surface fairing) to the given voxel model [Muniz et al. 2010]. However, typical surface smoothing algorithms also smooth sharp creases (Figure 1b), which may not be the desired result for users. To address this problem, we present an alternative workflow where the system first segments the voxel model into several parts, and then applies smoothing to each part independently in order to obtain a smooth surface while preserving sharp creases. The results of our method are shown in Figure 1c. The process takes approximately five minutes for simple models and thirty minutes for more complicated models. Our method is designed for a relatively small-scale voxel model with a rotund shape, such as those shown here.

Our work is inspired by Kopf and Lischinski's work on pixel art [2011]. They vectorize pixel art by computing a connectivity graph over pixels and expressing borders of colors using B-spline curves. But they do not attempt to extract and preserve sharp creases along the boundary, which is the focus of our work.



(a) (b) (c)

Figure 1: *(a) Input voxel models, (b) models smoothed using a naive approach, (c) our results. Our results have sharp creases.*

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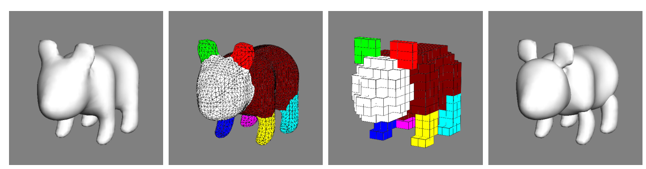
2 Algorithm

The overall workflow of our method is shown in Figure 2. We use an existing method [Shapira et al. 2008] for the mesh segmentation. Since this method is designed for surface models and cannot be directly applied to voxel models, we compute a smooth surface model before segmentation. The detailed algorithm is as follows.

We first extract a boxy boundary surface mesh from the voxels as shown in Figure 1a. We then compute a dual of the mesh, apply subdivision and triangulation, and then apply surface smoothing (Figure 2a). Our current smoothing algorithm is based on Igarashi and Hughes' work [2003]. We next apply the surface segmentation algorithm to this smoothed surface (Figure 2b). We then decompose the voxel model into parts based on the surface segmentation result (Figure 2c). Lastly, we apply the same surface smoothing process to the voxel parts independently and merge them together by applying CSG union operation (Figure 1c). The junctions between the components can exhibit discontinuities if we directly use the decomposition result (Figure 2d), so we expand each voxel component toward the adjacent components before applying surface smoothing.

A drawback of our current workflow is that all creases must form a loop and hence it is not possible to apply our method to open creases. This may not be desirable when designing a shape such as a bent arm where a crease exists only on one side. We plan to address this problem in the future by integrating the smoothing and merging processes.



(a) (b) (c) (d)

Figure 2: *(a) A surface model smoothed by fitting smooth patches piecewise, (b) the segmentation of the mesh, (c) the decomposition of the voxel model, (d) the result without voxel part expansion. The junctions between the components exhibit discontinuities.*

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