Fast Matching of Volumetric Functions using Multi-Resolution Dual Contour Trees

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Abstract

In this paper, we propose a method for fast matching of volumetric functions using multi-resolution dual contour trees. We develop a hierarchical representation of the volumetric data that allows for efficient processing and matching of the data at different levels of detail. Our method utilizes the dual contouring algorithm to extract the boundary surfaces of the volumetric data and constructs a dual contour tree to represent the topological features of the surfaces. We then build a multi-resolution representation of the dual contour tree that enables efficient matching of the volumetric functions. We demonstrate the effectiveness of our method on several examples from the fields of computer graphics and biochemistry, including the matching of protein surfaces, voxelization of point clouds, and mesh generation from implicit functions.

1 Introduction

Volumetric data plays an important role in many fields, including computer graphics, scientific visualization, and medical imaging. However, the large size of volumetric data and the complexity of the data structures pose significant challenges for processing and analysis. In this paper, we propose a method for fast matching of volumetric functions using multi-resolution dual contour trees. Our method is based on the dual contouring algorithm, which has been widely used for extracting boundary surfaces from volumetric data. We extend the dual contouring algorithm to construct a dual contour tree, which is a hierarchical representation of the topological features of the surfaces. We then develop a multi-resolution representation of the dual contour tree, which enables efficient matching of the volumetric functions at different levels of detail.

2 Related Work

Several methods have been proposed for matching volumetric functions, including Fourier-based methods, wavelet-based methods, and multiscale methods. However, these methods have limitations in terms of efficiency, accuracy, and robustness. The dual contouring algorithm has been used for extracting boundary surfaces from volumetric data, but its applicability to matching volumetric functions has not been explored extensively. The dual contour tree, which is a hierarchical representation of the topological features of the surfaces, has been proposed as a tool for processing and analyzing the surfaces. However, its use in matching volumetric functions has not been investigated in detail.

3 Method

We propose a method for matching volumetric functions using multi-resolution dual contour trees. Our method consists of several steps:

1. **Extract boundary surfaces:**

   The first step is to extract the boundary surfaces of the volumetric data using the dual contouring algorithm. The dual contouring algorithm is a technique for generating a surface mesh that accurately captures the features of the underlying volumetric data. This involves evaluating the volumetric function at the corners of each voxel and generating a surface that passes through the zero-crossings of the function.

2. **Construct a dual contour tree:**

   The second step is to construct a dual contour tree to represent the topological features of the surfaces. The dual contour tree is a hierarchical data structure that captures the relationships between

3. **Build a multi-resolution representation:**

   The third step is to build a multi-resolution representation of the dual contour tree. This involves recursively subdividing the tree into smaller sub-trees and merging the leaf nodes that represent similar features. The result is a hierarchical tree structure that captures the features of the surfaces at multiple levels of detail.

4. **Compute feature sets:**

   The fourth step is to compute a set of features for each node in the multi-resolution tree by analyzing the geometry and topology of the surfaces. The features capture properties such as the position of the node, the size and shape of the surface, and the types of critical points. The feature sets enable efficient matching of surfaces by identifying similar features across different scans or simulations.

5. **Match volumetric functions:**

   The final step is to match the volumetric functions by comparing the feature sets of the corresponding nodes in the multi-resolution trees. This involves computing a similarity measure between the feature sets, such as a distance metric or a correlation coefficient. The similarity measure enables efficient comparison of different scans or simulations by identifying regions that are similar or different.

4 Results

We demonstrate the effectiveness of our method on several examples from the fields of computer graphics and biochemistry. In the first example, we match protein surfaces by comparing their volumetric functions. We show that our method can achieve high accuracy and efficiency compared to other methods. In the second example, we voxelize point clouds using our method and show that it can produce high-quality results with minimal artifacts. In the third example, we generate meshes from implicit functions using our method and show that it can handle complex surfaces with high accuracy and efficiency.

5 Conclusion

In this paper, we propose a method for fast matching of volumetric functions using multi-resolution dual contour trees. Our method is based on the dual contouring algorithm and the dual contour tree representation of the surfaces. We demonstrate the effectiveness of our method on several examples from the fields of computer graphics and biochemistry, and show that it can achieve high accuracy and efficiency compared to other methods. Our method has potential applications in many fields, including scientific visualization, medical imaging, and computer-aid.