MULTIPLE MATERIAL MESH GENERATION FOR BIOMEDICAL APPLICATIONS

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Abstract

The finite element method is commonly used in biomedical applications for the simulation of the behaviour of biological structures. However, extracting finite element meshes from medical images is still very challenging. We propose an innovative system to create accurate multiple domain tetrahedral meshes from medical images. Our approach is based on an enhanced Marching Tetrahedra algorithm that extracts the boundary surfaces delimiting the different material domains in an integrated manner. Moreover, a surface reconstruction method is employed to ensure that the resulting mesh is a smooth and accurate surface representation of the original sampled structure. Mesh smoothing and decimation algorithms are also revised to conform to the multiple material nature of the system as well as to adhere to the underlying volume data.

Keyword:biomechanics.

1 Approach overview

The proposed approach generates a finite element mesh from a medical image (MRI, CT, …) in five steps.

In a first segmentation step, the structures of interests are delineated in the medical image. As we aim multiple material model generation, multiple labels are used to distinguish among the different material domains.

In a second step, recent advances on *point set surfaces* are used to obtain a continuous representation of the labeled structures contained in the discrete volume. *Point set surfaces* are used in computer graphics to create surface models from a set of unstructured unconnected 3D points [1]. A major contribution of this work is to adapt the Multi-Level Partition of Unity approach proposed by Ohtake et al. [2] to the generation of implicit surfaces from a segmented volume.

A triangular surface mesh is obtained in a third step by a novel approach that extends the classical Marching Tetrahedra algorithm [3] to the multiple material case. The proposed method meshes all the material region boundaries simultaneously and automatically while producing compatible meshes (in the sense of the finite element method) at the material interfaces. This triangulation algorithm is combined with a decimation algorithm that enables simplification of the mesh during its construction.

The quality of the generated mesh is improved in a fourth step by an enhanced Laplacian smoothing algorithm that constrains the node repositioning on the initial surface.

Finally, a volume mesh is obtained from this multiple material surface mesh using one or another volume mesh generator.

2 Results

The procedure was tested on several datasets (brain, skull, mandible and elbow articulation). In each case, a smooth and visually appealing mesh was obtained. Besides, the geometric approximation error, measured by calculating the distance between the mesh and the input points, shows that more than 90 % of the input points are less than one voxel away from the reconstructed surface. In other words, the surface mesh lies somewhere within the bounds of the original voxels. Finally, the generated mesh is of good quality and suitable for further computational analysis.

References

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