Multi-material Mesh Generation from Complex 3D Images

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Background. Three-dimensional models of complex multi-material structures are widely used a wide range of areas such as medical image processing, computer graphics, or computer-based process modeling and manufacturing. Frequently, such structures are represented as *3D image*, i.e., collections of three-dimensional pixels—commonly referred to as *voxels*. For many downstream applications such as physical simulations or analysis tasks it is necessary to generate *triangular surface* or *tetrahedral volume meshes* conforming to the multi-material structure of the 3D image. Performing this process in a robust and efficient manner while keeping the number of elements in the resulting meshes as low as possible is a highly challenging task and an active field of research.

Objectives. The overall objective of this internship is to explore a novel approach to multi-material mesh generation. The recent work of [1] introduces a powerful technique to generate surface triangle meshes from an input tolerance volume, i.e., an envelope enclosing a target shape within a certain distance. The method can be used to faithfully approximate a given high resolution triangle mesh with a much coarser, low triangle-count mesh. The core task for this internship is to extend this approach to a multi-material setting: Instead of approximating an existing single-material surface mesh a new mesh representing the multi-material boundaries of the 3D image has to be generated. To this end, the notion of a tolerance volume has to be extended to correspond to the different materials contained in the 3D image. In a second step we will extend the approach from [1] to take the multiple materials into account during mesh generation. Finally, the extended version of the algorithm should be thoroughly evaluated on a set of real-world test cases originated from semiconductor applications. Therefore, this internship not only offers the possibility to do cutting edge research in a modern and exciting field, but also to apply the results obtained in a practically relevant setting.

Prerequisites. The required qualification for this internship is a BS or MS degree in Computer Science, or equivalent. The basic requirement is a solid understanding of 3D geometry (data structures, algorithms) as well as proficiency with generic programming in `C++`. In addition, the candidates should be familiar with important geometric concepts such as surface and volume meshes or Delaunay triangulations. Familiarity with common geometry processing algorithms such as remeshing or simplification is a clear plus. Similarly, previous experience with 3D image processing as well as numerical optimization techniques and applied mathematics is highly relevant.

References

[1] Manish Mandad, David Cohen-Steiner, and Pierre Alliez. Isotopic approximation within a tolerance volume. *ACM Transactions on Graphics*, 34(4):64:1–64:12, 2015.

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