# GENERATION OF GEOMETRIC MODELS AND MESHES FROM SEGMENTED IMAGE DATA

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**SUMMARY**

Domain descriptions for numerical analyses originating from 3D images pose significant challenges as they have to be converted to a discretization suitable for a numerical analysis. Methods that perform this process by converting the image data directly to an analysis mesh suffer from a number of disadvantages with respect to both the flexibility to create well controlled meshes, and with respect to the ability to effectively represent the heterogeneous material regions of the imaged domain. We will present an alternative approach that avoids disadvantages through the construction of a non-manifold model representation.

This paper presents a set of automatic procedures for the construction of a non-manifold model and mesh given a segmented image data set. The process of creating a non-manifold model first allows the user to utilize the same meshing procedures that are applied to CAD models.

The procedures developed are split between (i) operations on the voxel data set and (ii) operations on the non-manifold model. The former deal with idiosyncrasies of the voxel data which are getting in the way of generating a suitable non-manifold model. The procedures developed for the non-manifold model eliminate voxel artifacts by smoothing the surfaces with a specifically designed shape smoothing procedure.

## 1: Introduction

One of the important scales quantifying the behaviour of materials is the mesoscale at which the mechanics of grain interfaces, voids and inclusions can be modelled. The domain descriptions on that scale often originate in the form of 3D imaging data (e.g. MRI or XMCMT data), which provides geometric information in terms of discrete grey scale levels over a uniform grid of voxels. That information needs to be converted to a discretization suitable for numerical analysis software. The first step in the process consists of converting the grey scale data into voxel sets, each containing voxels with similar characteristics. There are a number of approaches (Bankman, 2008) and associated software (Ibanez, et. al. 2005) to carry help in the process, which are beyond the scope of this paper. This paper will focus on our process to construct a non-manifold geometric model from the segmented voxel data set from which in turn a finite element mesh can be constructed. The approach provides advantages with respect to creating a well controlled mesh and allows the user to identify the different material regions related to the segments of the voxel data set.

## 2: Generation of Geometric Model and Finite Element Mesh

The process employed to generate a finite element mesh from segmented image data consists of three steps. The first step operates at the voxel level to eliminate artifacts that need to be eliminated before a non-manifold model can be created. They are caused by noise in the image data or exist due to limitations of the scanning equipment. When left in the data set these artifacts cause small features in the geometric model that often cause self-intersections during the meshing process, or, if meshing is successful they cause the creation of meshes with extremely small elements that will not allow a finite element analysis to finish in a reasonable time frame. Erosion/dilation algorithms, small object removal procedures and algorithms to eliminate voxel configurations that would lead to singularities in the solution caused by non-physical model are available to to apply in the creation of the non-manifold models.

The second step consists of identifying the volumes occupied by a specific voxel set. Geometric faces are created to separate the volumes and geometric edges and vertices are inserted as appropriate, e.g. if three volumes meet along curve, and edge is defined. The result of the second step is a valid non-manifold model where the geometry is described by a triangulation obtained from a discretization of the voxels. The latter implies that the geometry contains quantization artifacts on the scale of the voxels. To eliminate those, a data smoothing algorithm was designed that not only create a smooth interface between voxel regions, but also preserves the geometry of the grain interfaces as much as possible. The algorithm iteratively adjusts the vertex positions of each surface triangle until its normal matches a pre-computed smoothed surface normal. That surface normal was obtained by averaging the normals of a group of neighboring surface triangles.

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The third step consists of generating the actual finite element mesh. Given that a proper non-manifold model exists at this time, the user can apply most of the meshing algorithms that are available to mesh CAD models, e.g. boundary layer meshing, or proximity mesh refinement to name just a couple.

## 3: Results

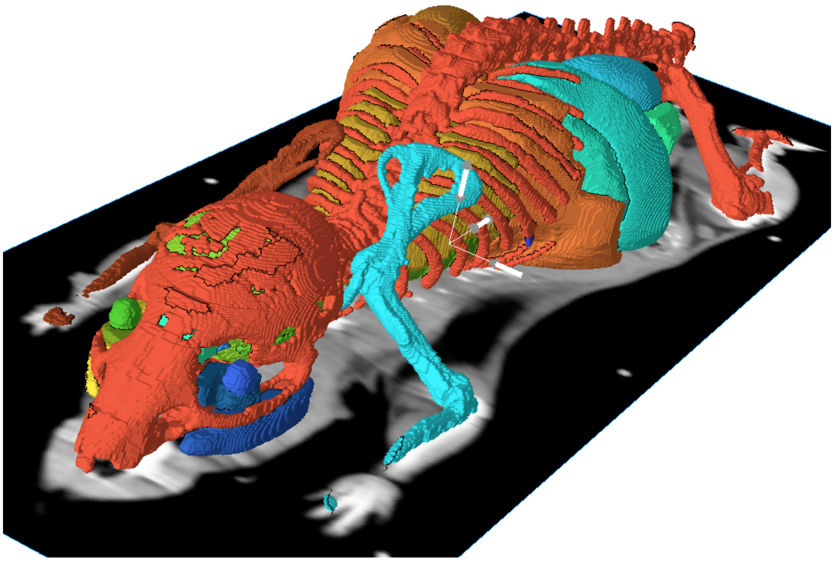

**Figure 1: Geometric model (without outer shell) constructed from segmented 3D image data of the full body of a mouse. One slice of original grey scale image data provided for comparison.**

To demonstrate the developed functionality we chose a data set describing the whole body of a mouse from CT and cryosection data published by Dogdas, Stout, Chatziioannou & Leahy (2007). The authors provided segmented 3D image data as well, which was used as the source material from which we constructed a geometric model. The 3D image data contained 380x992x208 cubical voxels of size. Figure 1: shows the geometric model after erosion/dilation and small object removal procedures were applied, but before any smoothing of the surface was performed. Note that the outer shell of the mouse was hidden in Figure 1: to provide a view into the more intricate interior. One slice of the original grey scale data was superimposed onto a plane and shown in the picture. The developed graphical interface allows the user to drag that plane through the model and use the plane as a cut plane to compare the original data with the constructed geometry.

Given a proper geometric model of the mouse, the surfaces were smoothed using the developed discrete shape smoother procedure. That process eliminated the voxel artifacts and allowed us to generate a 3D volume mesh from the geometric model. Figure 2: shows the final finite element mesh.

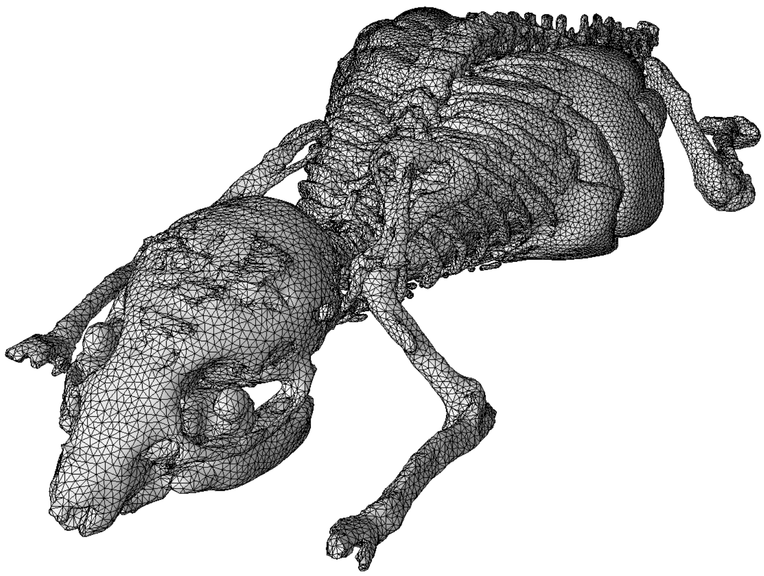

**Figure 2: Finite element mesh (without outer shell) constructed from geometric model shown in previous figure.**

The picture shows that the final mesh does not exhibit any relation to the original voxel structure. The intermediate step of generating a discrete model as the geometry source for the meshing process allowed us to use well established meshing procedures that provide fine grained control over the meshing process to achieve the desired finite element quality.

## REFERENCES

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