MESH GENERATION FROM BIOMEDICAL IMAGING DATA

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INTRODUCTION

Although a wide range of mesh generation techniques are currently available, these on the whole have not been developed for meshing from segmented 3D imaging data. This paper will describe different approaches to convert medical scan data into computer models, and compare their usability for computational simulation (such as FEA and CFD).

IMAGE-BASED MESHING

Image-based mesh generation raises a number of issues which are different from CAD-based model generation some of which are discussed below.

CAD-based versus Image-based Meshing

'CAD-based approaches' use the scan data to define the surface of the domain and then create elements within this defined boundary [1]. These techniques do not easily allow for more than one domain to be meshed as multiple surfaces generated are often non-conforming with gaps or overlaps at interfaces where two or more structures meet (cf. Figure 1). The 'image-based approach' presented by the authors is a more direct way, as it combines the geometric detection and mesh creation stages in one process. The technique generates 3D hexahedral or tetrahedral elements throughout the volume of the domain [2], thus creating the mesh directly with conforming multipart surfaces (cf. Figure 1). This technique has been implemented as a set of computer codes (ScanIP, +ScanFE and +ScanCAD).

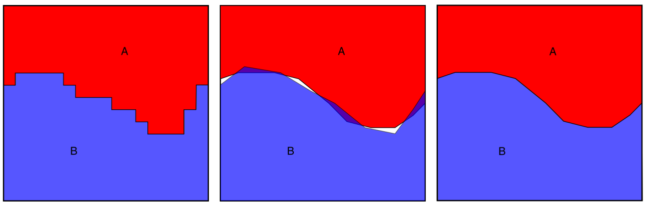

Figure 1: Original segmentation (left), non-conforming (centre) and conforming multipart surface reconstruction (right).

Robustness and Accuracy

Modelling complex topologies with possibly hundreds of disconnected domains (e.g. inclusions in a matrix), via a CAD-based approach is virtually intractable. For the same problem, an image-based meshing approach is by contrast remarkably straightforward, robust, accurate and efficient. Meshes can be generated automatically and exhibit image-based accuracy with domain boundaries of the finite element model lying exactly on the iso-surfaces, taking into account partial volume effects and providing sub-voxel accuracy.

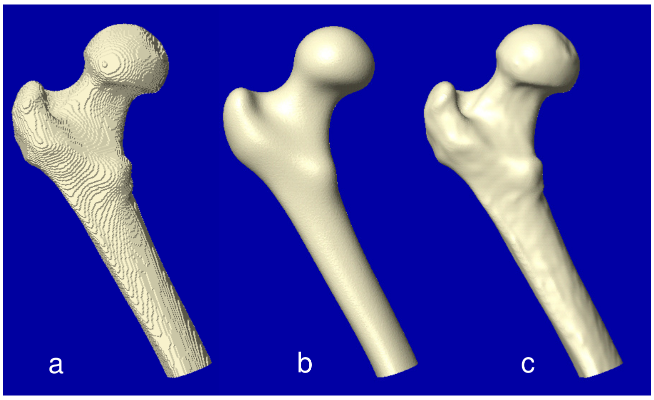

Figure 2: a) Original image, unsmoothed (203,238 mm^3); b) Traditionally smoothed (180,605 mm^3, Δvolume = -11.14%); c) Smoothed with Simpleware's smoothing algorithm (202,534 mm^3, Δvolume = -0.35%).

Anti-aliasing and Smoothing

Where anti-aliasing and smoothing is applied to the segmented volumes, the presented technique is both topology and volume preserving. If appropriate algorithms are not used, smoothing and anti-aliasing the data can introduce significant errors in the reconstructed geometry and topology. Most implemented smoothing algorithms are not volume preserving and can lead to shrinkage of convex hulls and topological changes. Whilst this is not particularly problematic when the purpose is merely enhanced visualization, the influence can be dramatic when the resultant models are used for metrology or simulation purposes.

CONCLUSIONS

The ability to automatically convert any 3D image dataset into high quality meshes is becoming the new modus operandi for anatomical analysis. Techniques have been developed for the automatic generation of volumetric meshes from 3D image data including image datasets of complex structures composed of two or more distinct domains and including complex interfacial mechanics. The techniques guarantee the generation of robust, low distortion meshes from 3D data sets for use in finite element analysis (FEA), computer aided design (CAD) and rapid prototyping (RP). The ease and accuracy with which models can be generated opens up a wide range of previously difficult or intractable problems to numerical analysis.

REFERENCES

1. Cebral JR, et al., *Int. J .Num. Methods Eng.*, **51**:985-1008, 2001.
2. Young PG, et al., *Phil. Trans. Roy. Soc. A*, **366**:3155-3173, 2008