Medical Imaging Solution for Mesh Generation in Bioengineering Applications

Gabriel PREDA, Radu Cristian POPA, Mihai REBICAN
Advantec Solutions, Titulescu 89-91, Bucharest, Romania

Radu MARIAN, M.D.
Clinical Emergency Hospital - Bucharest, Floreasca 8, Bucharest, Romania

Alexandru POPIEL, M.D.
Emergency Hospital "Bagdasar-Arseni", Berceni 12, Bucharest, Romania

Iolanda COSTACHE
ITC, Calea Floreasca 167, Bucharest, Romania

Abstract. Various bioengineering applications based on electromagnetic field computation simulations use approximate models of human body parts and organs. In our solution, starting from raw scanned data in DICOM format, we create meshed models with problem specific adapted decimation after segmentation of targeted organs in a medical imaging software solution. The surface mesh is then exported in a portable format and forwarded to a specialized mesh generator for further processing.

1 Introduction

In recent years there was a considerable increase in the number of papers treating bioengineering subjects, including simulation of electromagnetic field problems using FEM or FEM-BEM methods where the analysis domain is an anatomical part, an organ or a group of organs of human body. Models range from very coarse estimation of body parts geometry and material properties to accurate models derived from libraries of predefined anatomical models using advanced medical imaging tools [1]. In our paper we propose a method to generate meshes with controlled accuracy directly exported from a professional medical imaging software presented elsewhere [2].

2 Method

Sets of radiological data are imported in DICOM format in a medical imaging software. From the sets of 2D tagged images a volume is first formed. The targeted anatomical parts or organs are segmented from the 3D image data using a region growing connected threshold or watershed algorithm [2]. For visualisation, the segmented parts are first triangulated on the surface using a Marching Cubes algorithm. After triangulation, a mesh decimation step is performed. Usually, an algorithm for surface simplification [3-6] is used to reduce mesh complexity without affecting the surface shape and rendering quality. In VTK [7], four algorithms for mesh decimation are implemented, vtkDecimate, vtkDecimatePro, vtkQuadricClustering and vtkQuadricDecimation; whilst vtkDecimate is the algorithm of choice in our software for surface simplification in view of reducing CPU time for visualisation purposes, we investigated effectiveness of the other three algorithms for mesh reduction with the purpose to produce quality meshes for partial differential equations analysis.

VtkDecimatePro and vtkQuadricDecimation were not effective for user-controlled mesh size and quality. Using vtkQuadricClustering we were able to obtain both mesh size accurate control by user and mesh quality, appropriate for analysis using partial differential equations (PDE) solvers. Implementation of this algorithm is based on vertex clustering method proposed in [6] and a quadric error metric described in [3]. The software then exports the mesh in portable formats, from VTK library defined STL and VRML to in-house developed mesh convertors for mechanical and electromagnetic analysis : ATLAS, FEMAP Neutral and MSC.NASTRAN formats. Figure 1 sumarize the entire process to obtain from raw radiological 2D data the PDE-ready meshes, having user controlled quality and size.

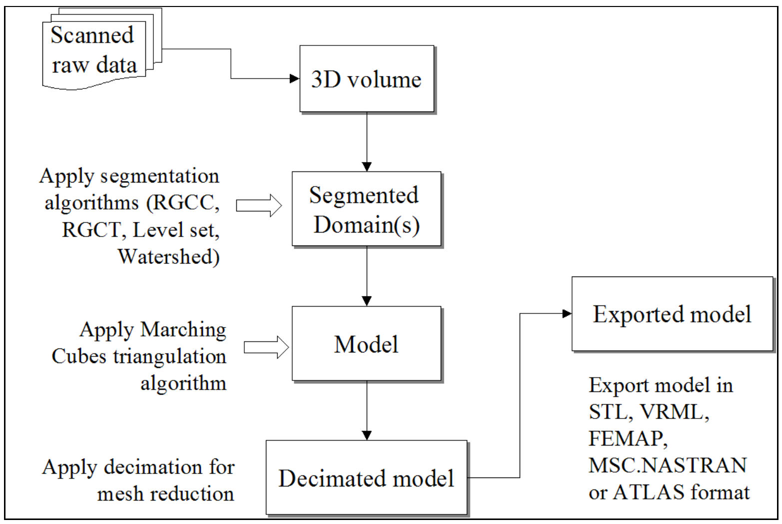


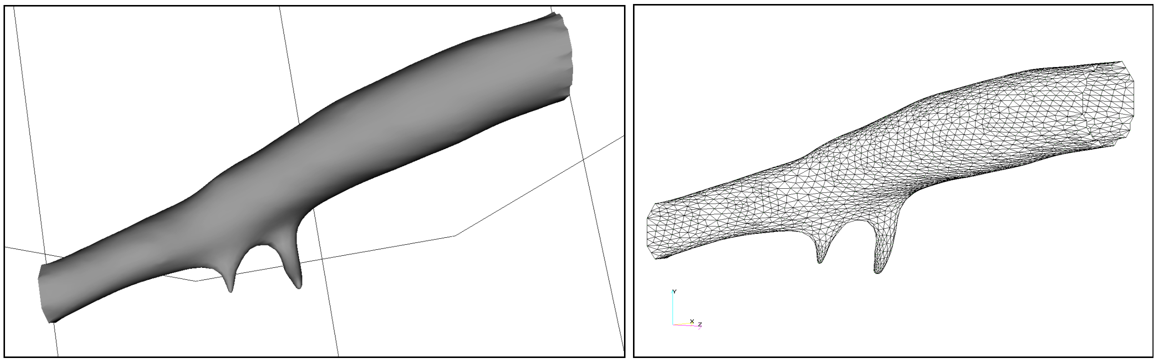
Figure 1: Mesh generation process from import of DICOM formated radiologic raw data to export in portable mesh formats

3 Results

We present the results for two sets of data: MRI aorta section and CT aorta with contrast substance from a full abdominal procedure. We import the raw scanned 2D data in the medical imaging software and we segment the targeted organ using for these testes only region growing connected threshold (RGCT) algorithm.

For the first data set we show in Fig. 2 the segmented aorta section modeled and without any mesh decimation, rendered with the medical imaging software system (a) and with a professional preprocessing system for electromagnetic analysis (b), after mesh was exported in a portable FEMAP Neutral format. The boundary surface mesh has 2679 nodes and 5870 triangular elements. Using vtkQuadricClustering for mesh decimation algorithm we obtained a significant mesh reduction while keeping the mesh quality. Figure 3 shows the resulted mesh, with 829 nodes and 1554 elements.

We analyse a second dataset, from a complete CT abdominal procedure using contrast substance; aorta is completely segmented and we focus on a bifurcation section (where aorta is splitting in the iliac arteries). Figure 4 shows the original model, without mesh decimation, obtained after applying a Marching Cubes algorithm to the segmented domain. In Fig. 5, (a), (b), (c) and (d) we show the exported mesh obtained after applying mesh decimation using vtkQuadricClustering with user-controlled size-reduction (25%, 50%, 75% and 90% respectively) to the original mesh. From the original mesh with 29,410 nodes and 58,286 surface elements we reduced the mesh in the (d) case to 3243 nodes and 5829 elements (10 times) while keeping a good mesh quality, suitable to PDE analysis.



(a) (b)

Figure 2: Surface rendering of a MRI of aorta, after model without mesh decimation using (a) medical imaging software; b) preprocessor for electromagnetism with imported portable format exported from medical imaging software; 2679 nodes and 5870 triangular elements on surface.

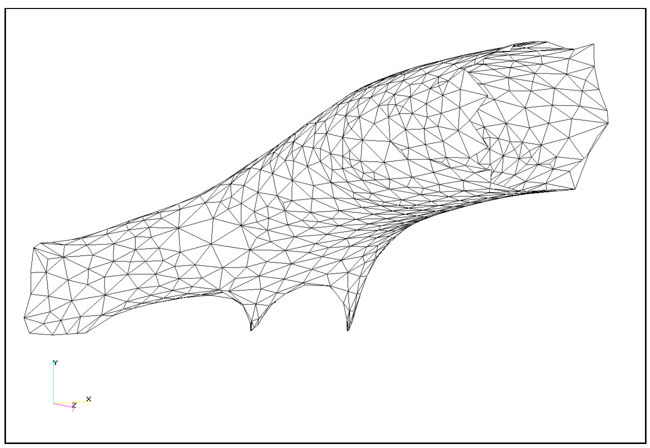


Figure 3: Model after decimation using vtkQuadraticClustering of MRI aorta shown in Fig. 2; mesh with 829 nodes and 1554 elements

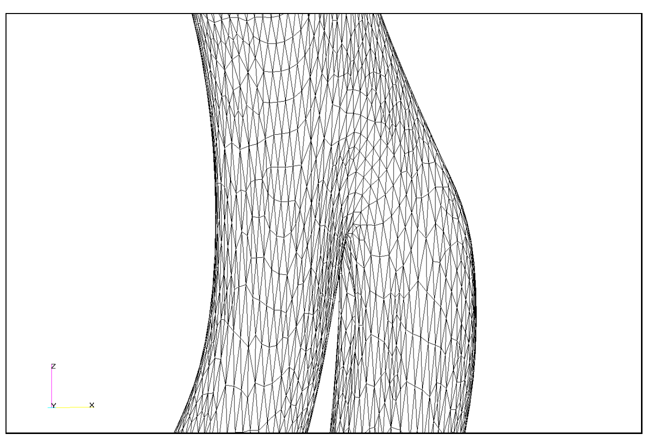


Figure 4: Surface rendering of segmented model of aorta from CT abdominal procedure with contrast substance, zoom on the iliac arteries bifurcation of aorta; 29,410 nodes and 58,286 surface elements.

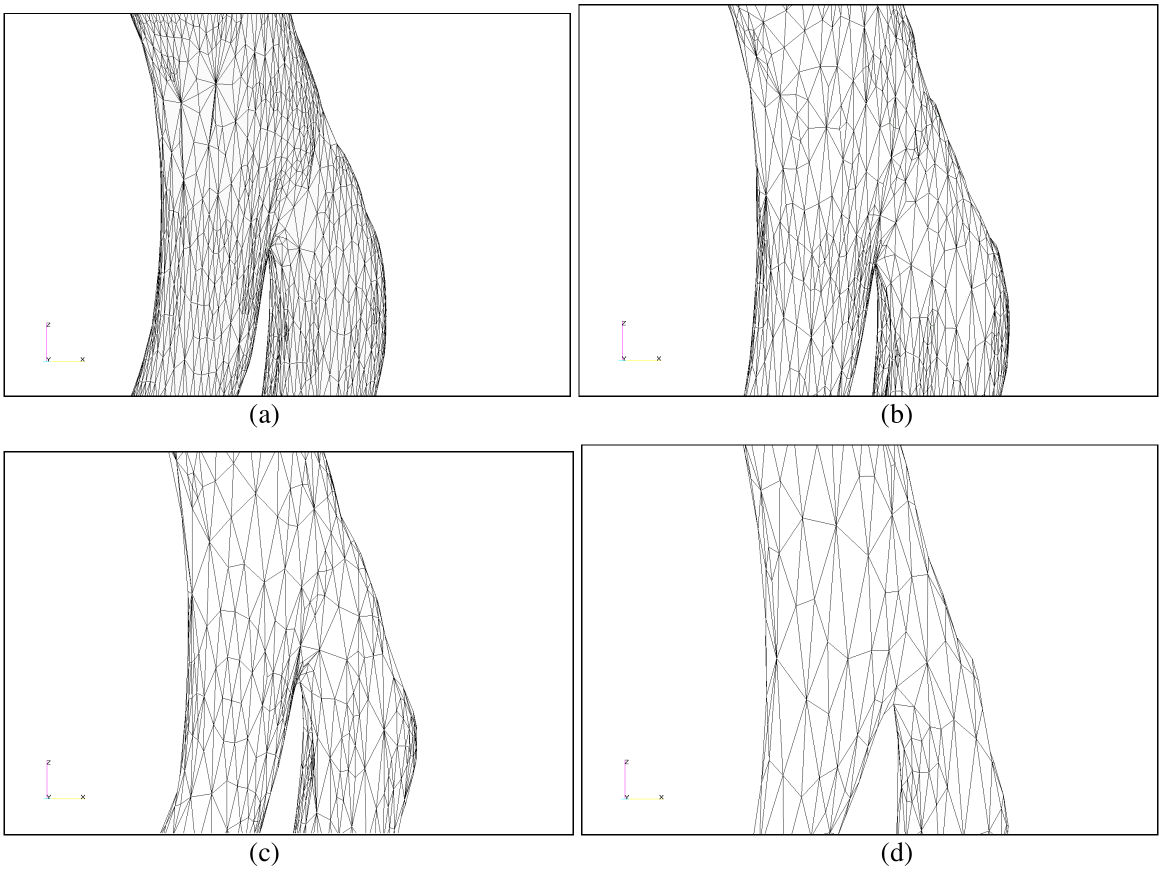


Figure 5: Surface rendering of segmented model of aorta from CT abdominal procedure with contrast substance, zoom on the iliac arteries bifurcation of aorta; user-controlled mesh reduction using vtkQuadraticClustering with (a) 25%, (b) 50%, (c) 75%, (d) 90% while keeping good mesh quality.

Figure 6 shows the linear dependence between imposed mesh reduction coefficient and resulted mesh size decrease. The algorithm is proved therefore effective to control mesh dimensionality whilst preserving mesh quality appropriate for PDE analysis.

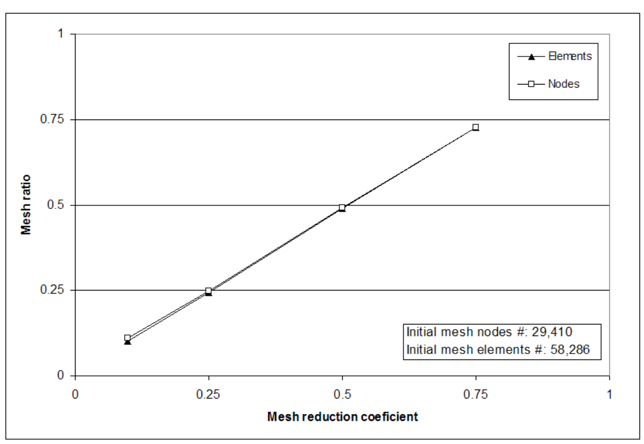


Figure 6: The input parameter for mesh reduction is effective to control the exact mesh reduction as selected by the user

4 Conclusion

Meshed domains for electromagnetic simulations in bioengineering applications are obtained from scanned medical imaging data through segmentation and model. Mesh quality is controlled by setting the decimation ratio of original mesh obtained for visualisation purpose.

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Acknowledgments - This work was supported by the Romanian Government grant 55 CEEX II 03/24.07.2006 "Advanced Medical Imaging System for Diagnose, Guidance and Pre- and Intra-Operative Intervention: Model, Simulation and Analysis in Virtual Endoscopy".