

Semi-Automated Block Definitions in Multi-Block Finite Element Meshing

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INTRODUCTION:

Finite element analysis has allowed for investigations of the human musculoskeletal system and orthopaedic implant design. The generation of a volumetric mesh is often the most challenging step in performing a finite element study; this has limited the number of patient-specific finite element studies that have been performed. IA-FEMesh[1], an open-source hexahedral meshing software package, provides tools to develop volumetric meshes on a patient-specific basis. Currently, IA-FEMesh relies on manual placement of building blocks around a surface. We hypothesize that identifying the centerline of a bone will advance automated building block definitions for anatomic models[3].

METHODS:

Our algorithm was developed using the C++ programming language, Visualization Toolkit (VTK), and Vascular Modeling Toolkit (VMTK)[2]. The input to the algorithm is a surface representation of the structure of interest, while the output is a building block structure corresponding to this surface. The algorithm consists of six steps: (i) surface reorientation, (ii) centerline generation and smoothing, (iii) incremental centerline angular analysis, (iv) building block placement, (v) cylindrical projection of vertices, (vi) reorientation of the building block structure. The finalized building block structure is imported into IA-FEMesh to generate a hexahedral mesh for finite element analysis.

RESULTS:

Several key steps in automating the building block definitions are demonstrated on the third rib in Figure 1. After the centerline has been generated for the surface of interest (Figure 1B), an incremental angular measurement of the centerline is used to automatically define the building blocks (Figure 1C). After completing the block structure (Figure 1D), cylindrical projection of the building block vertices is performed (Figure 1E/F).

DISCUSSION:

We have developed an algorithm that defines a building block structure for hexahedral mesh generation using centerline analysis, semi-automatically. This algorithm was specifically designed to address the challenges encountered when automating building block structures for bones exhibiting long and curved geometries[3]. This work represents advancement towards automating the manual procedures in the IA-FEMesh mesh generation protocol.

Future improvements to the algorithm will include varying the size of building blocks to better represent a given segment of the surface and also incorporating centerline branching into the growing algorithm. Further testing of the algorithm will include investigating its

efficacy on the long and curved bones of the upper/lower extremities and the thoracic cavity.

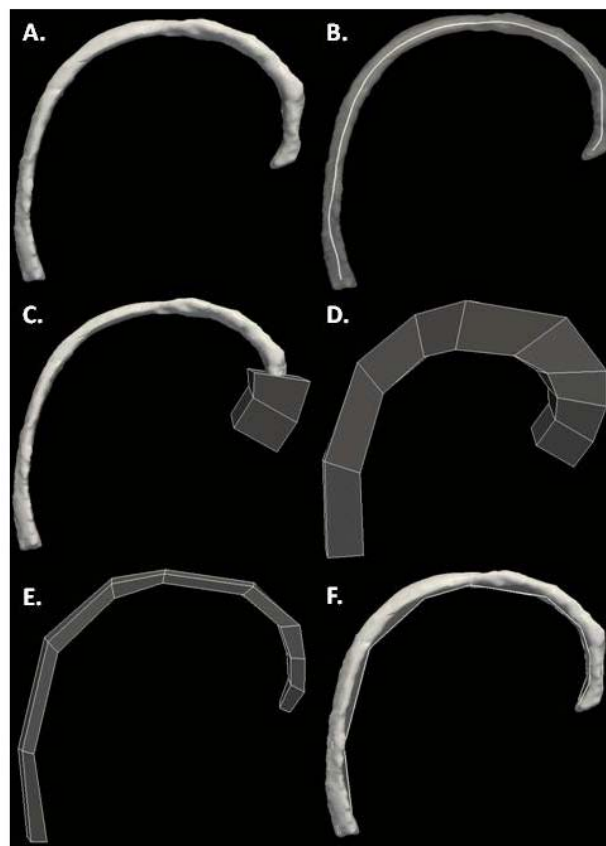


Figure 1: Steps in the building block growing algorithm. (A) A bony surface of the third rib. (B) Centerline for the third rib. (C) Incremental building block additions using the centerline for coordinate system orientation. (D) Completed building block structure for the third rib. (E.) Cylindrical projection of building block vertices onto the surface of the rib. (F.) Overlay of building block structure and third rib surface.

REFERENCES:

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