11th World Congress on Computational Mechanics (WCCM XI)
5th European Conference on Computational Mechanics (ECCM V)
6th European Conference on Computational Fluid Dynamics (ECFD VI)
July 20 - 25, 2014, Barcelona, Spain

FROM IMAGE/VIDEO TO COMPUTATIONS OF CARDIO-VASCULAR FLOWS

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Key Words: *Numerical Simulations, Image-based modelling, Cardiovascular flows.*

Cardiovascular flow computations in patient-specific geometries require integrating image acquisition and processing with fluid flow solvers. Typically, image-based modeling processes involve several steps, such as image segmentation, surface mesh generation, volumetric flow mesh generation, and finally computational simulation. These steps are performed separately, often using separate pieces of software, and each step requires considerable expertise and investment of time on the part of the user. In this paper an alternative framework is presented in which the entire image-based modeling process (illustrated in Figure 1) is performed on a Cartesian domain where the image is embedded within the domain as an implicit surface. We also incorporate an object-labeling scheme that allows different surfaces found during the segmentation process to be distinguished from each other within the context of smooth contours, reducing the need for a closely cropped region of interest (ROI) and allowing for

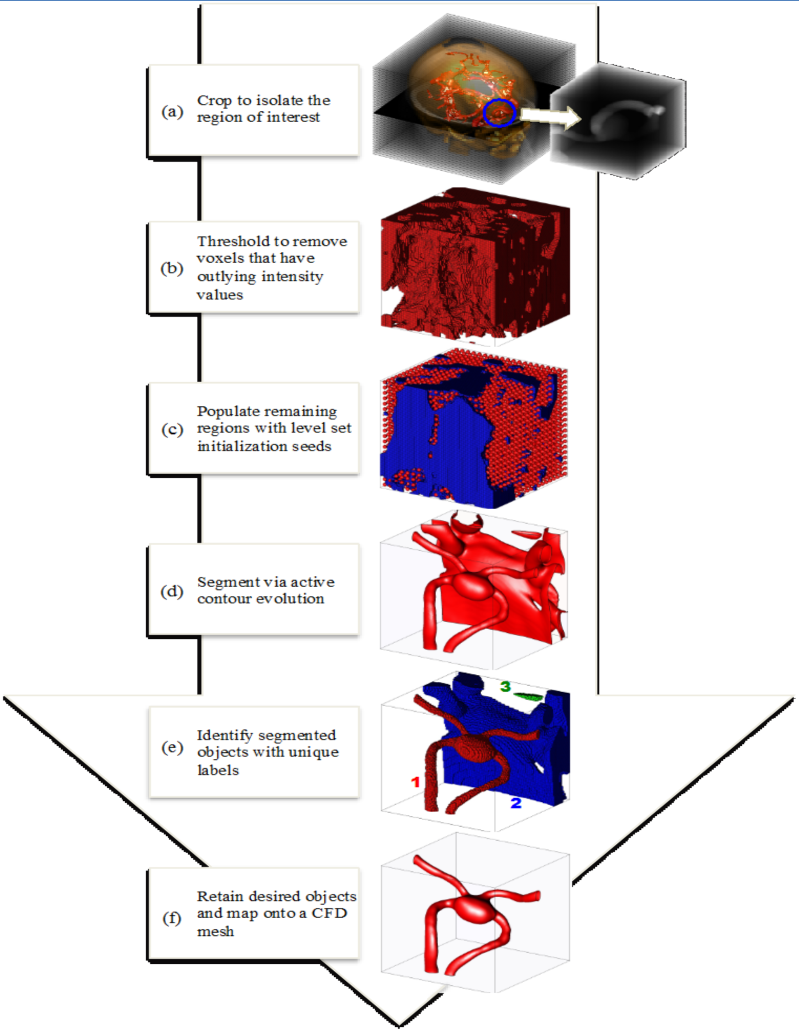

Figure 1. Illustration of the steps en route from image to computations performed on a Cartesian grid.

retention of contiguous features spanning the image domain.

The Cartesian grid flow solver[1] circumvents the need for generating surface meshes to fit complex geometries and subsequent creation of body-fitted flow meshes. Cartesian mesh pruning, local mesh refinement, and parallelization provide computational efficiency; the image-to-computation techniques adopted are chosen to be suitable for distributed memory architectures. The complete framework is demonstrated first with flow calculations computed in a 3D computed tomography image reconstruction of an intracranial aneurysm[2]. The flow calculations are performed on multiprocessor computer architectures and are compared against calculations performed with a standard multi-step route. We then present a general approach for simulating large deformation moving boundary problems in an Eulerian fashion with boundary information drawn from four-dimensional (4D) imaged data sets. The level set representation of embedded boundaries employed in this work provides a convenient means for representing moving boundaries; the Eulerian nature of the method eliminates the need for surface node tracking and correspondence, and eliminates the need for re-meshing the flow solver domain each time the boundary moves – something that can quickly become prohibitively expensive in the presence of complex, deformable geometries. Additionally, velocity boundary conditions can be obtained for moving objects from time-series of images through the application of image processing techniques such as optical flow. With this approach in place, the current methodology provides a comprehensive approach to modeling bio-fluid dynamics using a variety of patient-specific 3D and 4D imaged imaging modalities.

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