

Imaging and Mesh Generation Issues in Patient-specific Simulation Studies of Coronary Hemodynamics

Mayr M.¹ and B. Quatember¹

¹Division of Diagnostic Radiology II, Innsbruck Medical University, Innsbruck, Austria
E-Mail: Bernhard.Quatember@uibk.ac.at

Keywords: *Image-based simulation, modelling, mesh generation, medical imaging, segmentation*

EXTENDED ABSTRACT

In our simulation studies of coronary hemodynamics, which are described in the companion paper entitled “Image-based Simulation of the three-dimensional Coronary Blood Flow” (Quatember *et al.* 2007), imaging and mesh generation issues are emphasized, particularly the segmentation of the coronary arteries in biplane angiograms, the three-dimensional reconstruction of the coronary artery tree and the determination of the size of the elements in the CFD finite element mesh, which is used for numerical simulations of the patient’s blood flow. Despite the availability of powerful software tools, the largely automatic segmentation of the coronary arteries in biplane angiograms continues to be an extremely difficult task because of noise, artefacts and other flaws which deteriorate the image quality. Since classical methods would not be able to provide satisfactory results, we developed an advanced segmentation technique based on the fact that the coronary arteries have a tree-like tubular structure. Our approach utilises a differential-geometric criterion. In particular, we developed a skeleton-based technique for the representation of the centre lines of the coronary arteries as well as special border detection procedures. Our three-dimensional reconstruction method yields a representation of the geometry of the coronary artery tree in the form of a wire frame model. We will also deal with the problems arising from the need for the generation of a high-quality mesh that is required for our numerical simulations of the coronary hemodynamics with the finite element method. Our imaging and mesh generation procedures are computationally expensive. The computations will be carried out in parallel within the framework of the newly-established “Austrian GRID.”

1 INTRODUCTION

In order to develop a computer system for the simulation of coronary hemodynamics, a precise knowledge of the geometry of the coronary (epicardial) arteries of the patient is required. The companion paper entitled

”Image-based Simulation of the three-dimensional Coronary Blood Flow“ (Quatember *et al.* 2007) deals with three-dimensional simulation studies of the blood flow, especially in stenosed sections of the coronary arteries. These are carried out numerically with the finite element method. In this paper, we focus on the determination of the patient’s coronary arteries and the generation of the mesh which is needed for the numerical simulation studies. An adequate knowledge of the geometry of the coronary arteries can only be acquired by means of medical imagery. Of all the imaging modalities that are currently being used in cardiology, biplane angiography yields the most accurate information. However, complicated image processing methods must be applied to separate the tree-like structure of the epicardial arteries from the rest of the image, especially from background structures. This separation is called segmentation. In this paper we will describe here the development of an advanced method for the largely automatic handling of this task that is based on differential-geometric criteria and the use of special border line detection algorithms. With our advanced method, we are not only able to distinguish the tubular structures of the coronary artery tree from the rest of the image, but can also suppress noise and background structures. Moreover, the method is able to eliminate the errors due to geometric unsharpness (blur) caused by the finite focal size of the X-ray tube. The segmented angiograms provide the basis for our three-dimensional reconstruction of the coronary artery tree and its representation in the form of a wire frame model. However, we will only describe this reconstruction process and the above-mentioned mesh generation in a very brief manner.

