FROM 4D MEDICAL IMAGES (CT, MRI, ULTRASOUND) TO 4D STRUCTURED MESH MODELS FOR PATIENT-SPECIFIC FLOW SIMULATIONS IN THE HUMAN HEART

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1. INTRODUCTION

Cardiovascular disease (CVD) remains the most important cause of death worldwide [1]. Risk stratification and early detection of abnormalities is essential, which implies a profound insight in and knowledge of the (patho)physiology of cardiovascular function. Intra-cardiac flow is an important component of ventricular function, where vortex formation has been shown to interplay with the function of valves, motion kinetics, wash-out of ventricular chambers and ventricular energetics [2]. Coupling between Computational Fluid Dynamics (CFD) simulations and medical images is still required to study intra-cardiac flow in sufficient temporal and spatial detail, and can play a fundamental role in terms of patient-specific diagnostic tools. From a technical perspective, CFD simulations with moving boundaries could easily lead to negative volumes errors and the sudden failure of the simulation. The generation of high-quality 4D meshes (3D in space + time) with 1-to-1 vertex becomes essential to perform a successive CFD simulation with moving boundaries. In this context, we developed a semi-automatic morphing tool able to create 4D high-quality structured meshes starting from a segmented 4D dataset.

2. MATERIALS AND METHODS

Our morphing tool was developed in PyFormex, a python-based open-source software environment. The general strategy behind the morphing tool is to cover the segmented surfaces of the 4D dataset [Figure 1.c] , which typically have a non-adequate quality of the surface mesh, with a patch [Figure 1.a] that has the desired mesh topology by means of isoparametric transformations. Therefore, by applying sequentially the isoparametric transformation [Figure 1.d], the patch containing the desired mesh topology is repetitively attached to the parts which compose the entire LV endocardial wall. Since it is impossible to mesh the LV as a whole, the semi-automatization process of the algorithm was performed by subdividing the LV in three different subdomains: the ventricular sac, the atrium and aorta, and the zone connecting both.

3. RESULTS AND DISCUSSION

The method was tested on three different 4D datasets (Ultrasound, MRI, CT) to prove its versatility. Both the quality and accuracy of the resulting 4D meshes were evaluated to assess the performance of the tool. Furthermore, an estimation of some physiological quantities was accomplished for the 4D CT reconstruction. Future research will aim at extending the region of interest by taking advantage of image fusion, further automation of the meshing algorithm and at generating structured hexahedral mesh models both for the blood and myocardial volume.

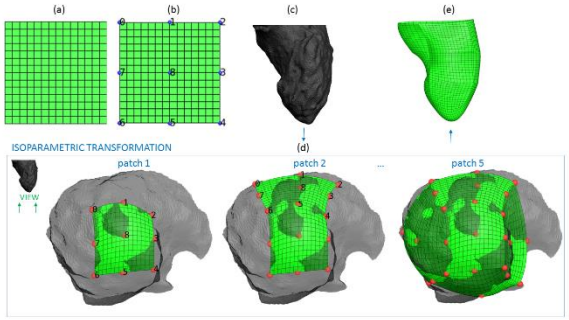

Figure 1

References

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