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Advancements in human heart modeling and simulations based on computational fluid dynamics

The modeling and visualization aspects underpinning the analysis of the numerical simulation data of the bidirectional Fluid-Structure Interaction (FSI) characterizing the human heartbeat are discussed in details. This approach involves the general-purpose Computational Fluid Dynamics (CFD) FlowVision code and the SIMULIA Living Heart Human Model (LHHM). LHHM is a dynamic, anatomically realistic, 4-chamber heart model having 2 mechanical valves, which couples the multiphysics electrical and mechanical fields acting during the heartbeat. Their synchronous actions regulate the heart filling, ejection and overall pump functions. Originally, LHHM comes with a 1D fluid network model, only capable of simulating the dynamic pressure/volume changes of the intra and extra-cardiac circulation network model. A full 3D blood circulation is numerically modeled with FlowVision, which makes possible to apply a very detailed spatial and temporal resolution for modeling the cardiac hemodynamics, together with its time-varying boundary conditions of the heartbeat. In order to validate such an approach, the bidirectional coupling between the Flow Vision blood flow model (CFD) and the LHHM model (FEM) is integrated with the SIMULIA co-simulation engine. The performed numerical modeling and simulations of the human heartbeat, as fluid-structure interaction multiphysics phenomena are further analyses and discussed, together with the envisaged potential applications of such coupled modeling and simulation approach. Thus, especially interesting when the device interactions are necessary to be upfront considered to correctly predict their influence in the heart diseases treatment. Finally, it is concluded that such complex multiphysics heartbeat simulations data analysis requires advanced modeling and visualization techniques to achieve the multidisciplinary integration of 3D electrical, structural and fluid numerical models, expected to move this technology towards more realistic simulations of the cardiac mechanisms and thus, create new ways to treat cardiovascular disease in the future.

Biography

Dean Vucinic joined Vesalius College (VeCo) in 2017 as the senior scientific advisor and he is continuously affiliated to Vrije University Brussel from 1988. Before joining VeCo, he was the Guest Professor and Senior Research Scientist at the VUB Faculty Of Engineering Sciences being the member of its 2 departments: Mechanical Engineering and Electronics & Informatics. He is also the part-time Associate Professor at the Faculty of Electrical Engineering, Computer Science and Information Technology, University of Osijek, holding the chair of visual computing. His work is mostly related to research and development projects and his interest covers the topics of scientific visualization, modeling and simulation, optimization methodologies and techniques, which are very often found together in solving complex problems within the multidisciplinary engineering and computer science domains. His PhD thesis became a book in 2010, ISBN 978-3-8383-3500-1. In early 90's he developed "CFView- Computational Field Visualization System", first-time-ever interactive visualization software adapted to numerical simulation solvers, completely based on the object-oriented technology and fully implemented in C++. During almost 30 years at VUB, he successfully participated in more than 20 European projects under the European frameworks, EUREKA/ITEA and Tempus educational programs. He is an author of more than 60 scientific papers in the international reviewed journals and conferences proceedings. He is the European Commission Expert in H2020 and member of the following international organizations: AIAA, IEEE, ACM, SAE & ASME.

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