Scientific Visualization in Human Heart Modeling and Simulation Analysis
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Abstract: The 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 approach, the bidirectional coupling between the FlowVision 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 advance visualization techniques to obtain a complete picture integrating 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.

Keywords: Scientific visualization, Biomedics, Computational Fluid Dynamics (CFD), two-way CFD Coupling, Living Heart Model, Fluid-Structure Interaction (FSI), blood flow numerical modeling and simulation, heartbeat multiphysics phenomena.

Visualization of the blood velocity distribution in the human heart