Nudging cardiovascular kinematics within fluid–structure interaction simulations of the left heart

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The development of high-fidelity digital twins of the cardiovascular system presents several challenges, for example, in achieving customization to individual patients. While Fluid-structure interaction (FSI) models represent one of the best tools for this purpose, their practical application is often limited by the necessity for several unknown patient-specific parameters. Medical imaging is often used as the source of in-vivo data needed to personalize these models, however the precise methodology to integrate this in-vivo and in-silico data is still an open research topic. This study aims to assess the reliability of data assimilation techniques for creating high-fidelity digital twins of the cardiovascular system.

An FSI model of the left heart and aorta is created using our in-house multi-GPU code[1] based on the Immersed Boundary method. The model describes both the cardiac tissue dynamics and blood hemodynamics. A variation of the Nudging algorithm[2] is developed to integrate some reference measurements of the tissue kinematics into the simulation. This setting closely mirrors a clinical scenario where the kinematics of the cardiovascular structures is measured from a dynamic CT scan and used as reference to guide the FSI simulation.

Our aim is to assess if the nudging techniques are able to recover the reference data used to guide the system (kinematics of the structures) and also, in a statistical sense, the output hemodynamic variables (blood pressure and velocity). This is performed by comparing the simulation results (in varying assimilation settings) and the reference data across several probes distributed in different heart regions (e.g., atrium, ventricle, and aorta).

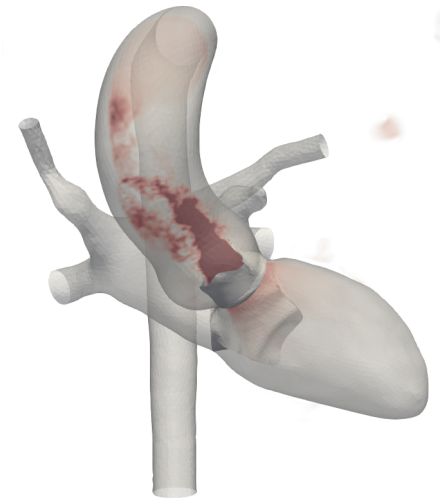

Figure 1: Computational setup.

This project has received funding from the Marie Skłodowska Curie grant agreement No 859836, the ERC Stg-project CARDIOTRIALS number 101039657, the ERC Adg-project Smart-TURB (Grant Agreement No. 882340) and the project MUR-FARE R2045J8XAW.

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[1]Viola, F., Del Corso, G., et al., *PRF*, **8(10), 100502** (2023).
[2]Di Leoni, P. C., Mazzino, A., et al., *PRX*, **10(1), 011023** (2020).