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Full and Reduced Order Models for Multiphysics and Multiscale Simulations in Cardiovascular Applications

Scientific area: Computational Applied Mathematics

Cardiovascular diseases are the most common cause of death worldwide [1]. Their treatment largely involves the implantation of cardiovascular devices, such as drug-eluting stents, ventricular pumps like LVADs, artificial heart valves, etc., which can alter the physiology of the cardiovascular system. To predict disease progression, critical areas (e.g., thrombus formation [2], blood stagnation, hemolysis, in-stent restenosis) and risk factors for patient-specific treatments, the development of reliable in-silico models is of paramount importance [3].

Models of the cardiovascular system require addressing several challenges. Its function and pathologies stem from a complex interaction of multiple physical processes: cardiac electrophysiology, active and passive solid mechanics, hemodynamics, valvular dynamics, and cellular scale processes, in both blood and tissue. Furthermore, all these processes occur at different spatial and temporal scales. For instance, in terms of spatial scales, hemolysis and thrombus formation occur at the cellular level, but modeling each cell in bulk blood flow would be computationally expensive. Additionally, time scales can pose a challenge: a single heartbeat is in the order of seconds, while some treatments and risk factor prediction can require up to days or months.

The need for cost-efficient and patient-specific simulations requires fast and robust computational models of the cardiovascular system. Their cost can be reduced with techniques such as reduced order models (ROMs) and data-driven methods. More accurate patient-specific physiology can be represented by incorporating medical imaging data for geometry and flow features. We are looking forward to contributions on multiphysics and multiscale simulations, possibly involving the development of numerical methods for the coupling of multiple subsystems. Furthermore, we are interested in the presentation of ROMs, data-driven methods, and imaging-based methods for the cardiovascular system and attached medical devices.

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