FORWARD AND INVERSE PROBLEMS IN BIOFLUIDS AND BIOMECHANICS

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ABSTRACT

The integration of in-silico models into clinical research has offered insights into the behavior of tissues and fluids in the human body, with the scope of predicting disease progression and evaluating treatment options. This mini-symposium will explore latest developments in the modeling and analysis of forward and inverse problems in biofluids and biomechanics. We welcome both fundamental theoretical developments and applications in cardio-, cerebrovascular, and cerebrospinal fluid dynamics.

Forward problems involve the prediction of fluid flow behavior based on known physiological parameters and boundary conditions, e.g., solving the Navier-Stokes equations within segments of the vasculature, or simulating the interaction between cerebrospinal fluid (CSF) and brain parenchima. Reliable in silico models are essential but face challenges due to complex geometries, patient-specific parameter tuning, and multi-physics phenomena [1]. Additionally, modeling the transport of cells and particles—such as proteins, red and white blood cells, platelets, and oxygen—is crucial for predicting thrombus formation, hemolysis, and perfusion.

The inverse problem, conversely, seeks to reconstruct unknown parameters, or full states—such as pressure distributions, material properties, or transport dynamics—from limited or noisy data, leveraging advanced techniques in optimization and data assimilation [2]. Some examples include, but not only, the use of physics-informed neural networks, medical image assimilation through Kalman filters, and variational methods.

This symposium will delve into these challenges, highlighting their significance in understanding vascular diseases, such as aneurysms and stenosis, as well as disorders related to CSF flow, including hydrocephalus and Alzheimer's disease. Topics of interest include, but are

not limited to, modeling hemodynamics in the presence of stents, flow diverters, pumps, and artificial valves, lumen-wall interaction, brain elastography and ventricular pressure estimation.

Applications in transport problems, such as perfusion, pharmacokinetics, blood cell dynamics, and waste clearance in the brain via the glymphatic system, will also be covered. From a methodological standpoint, this minisymposium covers advances on (not exclusively), finite element methods schemes, model order reduction, multiscale modeling [3], machine learning, surrogate models, Kalman filters, uncertainty quantification, and sensitivity analysis.

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