

FROM IMAGING TO SIMULATION: DATA-DRIVEN AND PHYSICS-BASED COUPLING IN CLINICAL BIOMECHANICS

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ABSTRACT

Modern clinical biomechanics has reached a transformative juncture where medical imaging, experimental quantification, and numerical simulation are no longer isolated disciplines but are inextricably integrated. Across the diverse spectrum of human physiological systems, biomechanical behavior is rarely governed by a single field variable or confined to a single spatial or temporal scale. Rather, the underlying phenomena involve intricate multidisciplinary couplings, including nonlinear solid deformation, fluid dynamics, mass transport, and fluid-structure interaction, often occurring alongside long-term biological growth and tissue remodeling. For these complex systems, achieving high mechanical fidelity requires advanced computational frameworks where imaging defines patient-specific anatomy, experimental measurements inform constitutive behavior, and robust numerical methods resolve the resulting coupled field equations.

This invited session aims to highlight recent advances in mathematical modeling, numerical discretization, inverse analysis, data assimilation, and validation of coupled biomechanical systems. Particular emphasis is placed on methodological developments that bridge data-driven paradigms and physics-based modeling. This focus aligns directly with the core themes of the ECCOMAS Thematic Conference on Coupled Problems, including data-driven modeling approaches, multidisciplinary formulations, and efficient solution techniques.

We invite contributions covering a broad range of topics, including image-based model construction; segmentation and registration; inverse estimation of constitutive parameters and boundary conditions; uncertainty quantification; reduced-order modeling; and hybrid machine-learning and mechanistic formulations. Applications of interest include, but are not limited to, ventricular and vascular hemodynamics, congenital heart disease, heart valve mechanics, musculoskeletal and soft-tissue systems, and orthopedic joint biomechanics. By bringing together experts working at the interface of imaging, experimentation, and simulation, this session seeks to foster a comprehensive dialogue on the future of predictive, patient-specific modeling in clinical biomechanics.