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EFFICIENT SOLVERS FOR LARGE-SCALE COUPLED PROBLEMS

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ABSTRACT

Modeling and simulation of coupled and multiphysics systems are central challenges in computational science, and prerequisite for identification or optimization. Such systems arise in a wide range of applications – from biomedical engineering to geophysics – and often require the integration of heterogeneous physical processes across multiple scales and domains. This minisymposium brings together researchers developing robust, efficient, and scalable numerical methods for coupled problems, with a particular emphasis on addressing nonlinear interactions, heterogeneous materials, and stochastic effects.

The focus is on innovative algorithms that account for the mathematical structure of coupled problems leveraging the potential of modern computing architectures. Key topics include:

- **Hybrid and data-driven methods** for coupled PDE systems, including scientific machine learning to accelerate simulations and integrate experimental data;
- **Scalable solvers** for nonlinear dynamical systems, such as those in cardiac electrophysiology or fluid-structure interaction;
- **Variational and constraint-based formulations** for problems involving contact, friction, or other nonsmooth coupling conditions;
- **Adaptive discretization strategies** guided by physical laws or a posteriori error estimators to enhance accuracy in critical regions;
- **Domain decomposition methods** for strongly coupled systems bridging heterogeneous subdomains or distinct physical models;
- **Communication reduction techniques** to overcome scalability bottlenecks in parallel environments, especially in multiphysics coupling; and
- **Randomized and stochastic approaches** to improve determinism and scalability in coupled simulations.

The invited session aims to foster interdisciplinary exchange among theorists, algorithm developers, and practitioners. It highlights not only the mathematical foundations of these methods but also their practical implementation in real-world applications. By emphasizing cross-disciplinary approaches, the invited session seeks to inspire new directions in addressing complex coupled problems.

Keywords: simulation, efficient solvers, multiscale, multiphysics