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ADAPTIVE MESHING FOR NEXT-GENERATION SIMULATION: FROM COMPLEX PHYSICS TO SCALABLE WORKFLOWS

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ABSTRACT

High-fidelity simulation is increasingly expected to support the design, optimisation and operation of complex systems across engineering, energy, manufacturing, environmental sciences and emerging technologies. Yet the predictive potential of advanced mathematical models can only translate into real impact if simulations remain reliable, computationally affordable and sufficiently automated to operate within increasingly demanding workflows. In this setting, mesh adaptation has become a key enabling technology, allowing computational resolution to follow the physics, geometry and evolving scales of the problem rather than being fixed a priori.
Mesh adaptation becomes particularly critical in simulations involving multiphysics and multiscale phenomena, moving interfaces, evolving geometries, localized structures, strongly directional features and large computational domains, where a uniform discretization rapidly becomes impractical. At the same time, the growing complexity of industrial and scientific applications is pushing mesh adaptation beyond traditional refinement strategies, towards scalable, geometry-aware, data-informed and increasingly autonomous computational pipelines.

The session will explore recent advances and emerging directions in adaptive meshing, with particular attention to the challenges that arise when moving from methodological developments to large-scale and real-world applications. Established ingredients such as a posteriori error estimation, goal-oriented strategies and isotropic or anisotropic adaptation remain central, but they increasingly need to interact with new computational paradigms, including HPC architectures, parallel mesh modification, automated workflows, machine learning, and data-driven decision mechanisms.

Topics of interest include, but are not limited to:

- adaptive methods for multiphysics and multiscale problems;
- anisotropic and geometry-aware adaptation;
- moving meshes and evolving domains;
- error estimation and goal-oriented adaptation;

- parallel and distributed mesh adaptation;
- scalable algorithms and HPC implementations;
- adaptive strategies for complex industrial workflows;
- machine-learning and data-driven adaptation;
- adaptive simulation pipelines for design, optimisation and digital twins;
- applications across engineering, energy, manufacturing, environmental sciences and other large-scale computational settings.

We are confident that the cross-fertilisation of ideas and expertise fostered within the session among numerical analysts, computational scientists, HPC and data experts, software developers, engineers and industrial practitioners will help shape the next generation of adaptive simulation workflows, bridging complex physics, scalable computation and real-world applications.