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FROM MESH TO PRODUCT WITH SPACE-TIME FINITE ELEMENTS: MESH GENERATION AND ADAPTATION, FORMULATIONS AND APPLICATIONS

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ABSTRACT

Space-time finite element methods treat time as an additional dimension of the finite element discretization, rather than marching forward from time step to time step, allowing to solve the full space-time domain at once or in a slab-wise fashion. This perspective offers a natural framework for problems with evolving domains and topologies, adaptive resolution in both space and time, and formulations with attractive stability and conservation properties – while also overcoming the limitation of being inherently sequential in time that classical time-marching schemes face in parallelization, opening the door to scalable space-time solvers on HPC and exascale systems. Realizing this potential in practice, however, depends on a step that is often taken for granted in three spatial dimensions but becomes a genuine research problem in four: mesh generation for the space-time domain. While different mesh types are used throughout the space-time finite element community, unstructured simplex meshes are of particular interest for boundary-fitted geometry representations. Robust, efficient, and parallel algorithms for their generation, together with adaptation, refinement, error estimation, and mesh deformation strategies, remain active areas of development at the interface of computational geometry and numerical analysis.

This invited session aims to foster interdisciplinary exchange between researchers working on the mathematical and algorithmic foundations of space-time meshing and those developing and applying space-time finite element formulations to real-world problems in engineering and applied mathematics – moving space-time finite elements from an elegant mathematical framework toward a mature, broadly applicable simulation technology. We invite contributions spanning the full pipeline *from mesh to product*:

- Space-time mesh generation and visualization workflows, in particular unstructured simplex meshing in 4D
- Mesh adaptation and a posteriori error estimation
- Stabilized space-time finite element formulations
- Applications in fluid & solid mechanics, and multiphysics, including fluid-structure interaction, free-surface flows, and other evolving-domain problems
- Deployment of space-time methods in HPC and exascale settings, including parallelization and domain decomposition
- Case studies motivated by specific problems and application domains