Multi-Level-hp-Adaptivity: High-Order Mesh Adaptivity without the Difficulties of Constraining Hanging Nodes

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The efficient numerical simulation of complex physical problems demands for a local refinement in domains of interest. The hp-version of the finite element method (hp-FEM) is well suited for this need as it features both, a variable element size h and polynomial degree p. With this combination, exponential convergence can be achieved also in the presence of singularities. However, despite its high computational power, the hp-FEM approach is not the standard method in engineering applications. One main reason lies in the high implementational effort of the discretization kernel, which partially originates from the handling of the hanging nodes.

Figure 1: Connectional idea of multi-level hp-FEM
In the current work, this challenge is addressed using the recently introduced multi-level hp-formulation of the Finite Element Method [1]. The essential idea of this novel discretization scheme is to increase the approximation accuracy not by replacing coarse elements but by superposing a finer overlay mesh instead (see Figure 1). In this way, hp-FEM like meshes can be created without the difficulties associated with hanging nodes. This allows to define a flexible data structure, which also greatly simplifies the change of the discretization in a transient simulation (see Figure 2). It is demonstrated that the proposed multi-level hp-refinement achieves exponential convergence for problems with non-smooth solutions and can be combined successfully with residual-based error estimators. Furthermore, we show that the dynamic discretization provided by this scheme also captures moving stress concentrations accurately on a fixed background mesh. This is of particular advantage in applications featuring travelling loads or propagating cracks.

References