Computational Mathematics Colloquium

When the mesh is important: The role of anisotropic mesh adaptation in numerical modeling, from crack propagation to topology optimization

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Abstract: Anisotropic mesh adaptation has been proved to be a powerful strategy for improving the quality and the efficiency of numerical modeling. Anisotropic phenomena occur in many applications, ranging from shocks in compressible flows, steep boundary or internal layers in viscous flows around bodies, fronts of different nature to be sharply tracked. These problems typically require advanced methods of scientific computing that rely on a tessellation or mesh of the region of interest. The intrinsic directionalities of these dynamics call for an accurate control of the shape, the size and the orientation of mesh elements in contrast to standard isotropic meshes where the only parameter to choose is the element size. Metric-based techniques usually drive anisotropic mesh adaptation, the metric being derived by either heuristic or theoretical approaches. In the former case, the metric is identified by a numerical approximation of the Hessian or of the gradient of the discrete solution, coupled with an a priori error estimator. More rigorous - theoretically based - approaches move from a posteriori error analyses, i.e., from an explicit control of the discretization error or in more sophisticated cases of a functional of the error. This control is enhanced by an appropriate inclusion of the main directional features of the problem at hand.

In this presentation, we focus on both heuristic and rigorous anisotropic error estimators. We present some theoretical aspects and applications to a variety of problems relevant for different fields, (i) propagation of cracks in brittle materials, (ii) topology optimization of structures for aerospace engineering (in collaboration with Thales Alenia Space) and (iii) medical image segmentation.

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