Timestepping for Barely Coupled Multiphysics

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ABSTRACT

Over the last five decades computational mechanics has matured rapidly. In each of the core disciplines -fluid dynamics, structural dynamics, combustion, heat transfer, acoustics, electromagnetics, mass transfer, control, etc.- robust and efficient numerical techniques have been developed, and a large code base of academic, open source and commercial codes is available. The acquisition of many of these commercial codes by the leading CAD-vendors attests to the desire to streamline the typical computational mechanics workflow (CAD, boundary conditions, loads, physical parameter, solution with possibly mesh adaptation, post-processing) by integrating all parts into a single application.

The ability to obtain accurate and timely results in each of the core disciplines or metiers has prompted the desire to reach the same degree of simplicity in computing multi-physics problems.

A large class of coupled problems exhibits large disparity of timescales. Examples include evaporative cooling (where the flowfield may be established in seconds while the temperature field requires minutes), sedimentation of rivers and estuaries (where the flowfield is established in seconds while the filling up of a channel takes weeks), deposition of cholesterol in arteries (where the flowfield is established after two heartbeats while the deposition can take years), the wear of semi-autogenous grinding (SAG) mills (where the movement of steel balls and mineral-rich rocks and mud is established in minutes while the wear of the liners can take hours), and many others. We denote this class of problems as `barely coupled'. In each of these cases a coupling is clearly present. However, due to physics and nonlinear effects one can not simply run with a fully coupled time discretization using very large timesteps. This would lead to incorrect results. It then becomes very costly to run in a strictly time-accurate manner. The recourse advocated here is to run each problem to a quasi steady-state, and to couple the different disciplines in a loose manner taking into account error measures.

The talk will describe in detail the techniques used, some fundamental results regarding stability and convergence, and show several examples.