Iterative Solvers in Industry : A Case Study

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Linear algebra plays an important role behind the scenes of large scale scientific and engineering simulation. Systems of equations, linear and nonlinear, need to be solved many times in a given simulation, and can take a sizeable fraction of the total time. Iterative methods are widely used to solve the linear systems.

We look at one large simulation package, LS-DYNA, and survey the applications that use iterative methods. Multiphysics is increasingly more common in simulation, so when we speak of the areas of thermal, acoustic, electromagnetic, fluids and mechanics, we will discuss combinations, e.g., coupling thermal-mechanics, fluid-structure-thermal, electro-mechanics, etc.

Constraints enter the definition of the problem in differing degrees. The manners in which the constraints are handled are diverse and influential. Constraints can be imposed exactly, or approximated, e.g., using a penalty method to impose the constraints.

The first part of the talk will be a survey of five application areas : thermal, acoustics, electromagnetics, fluids, and mechanical. The discussions for each will include stating the problem (from the perspective of the engineer developer), translating into linear algebra, solution technique and preconditioner.

In the case of multiphysics, there may be a second layer of solvers, iterating on the coupling of different physical components. This coupling ranges from monolithic, e.g., fluid and thermal variables and their constraints are handled all together, to loosely coupled, e.g., where there may be dozens of mechanical timesteps to solve followed by a thermal solve.

The second part of the talk will address the role of linear algebra in the context of a large simulation code. The strongest trend in simulation is towards more and more complex models and analysis, more coupling of modules, and more complicated internal physics, and therefore need for linear algebra will increase as the simulation functionality grows. We will give the perspective of a linear algebraist embedded in a group of physicists and engineers.

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