Department of Mathematics and Statistics Colloquium

Some of the Uses of Temporal Filtering for Fluid-Flow Simulation

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Abstract: There are three ways to study the dynamics of moving fluids (liquids and gases): experiment, theory, and computation. Spectacular advances in computing power and algorithmic efficiency have made the third, computation, increasingly attractive.

Fluid motions are governed by the Navier-Stokes Equations (NSE), a coupled set of nonlinear partial differential equations. In dimensionless form, the NSE are parameterized by Reynolds number, Re, a dimensionless quantity whose value determines whether a given flow is laminar (layered) or turbulent (chaotic). Most flows of engineering interest involve high Reynolds number and hence are turbulent. The computational effort (time) required to solve the full NSE (by direct numerical simulation or DNS for short) scales as Re cubed. Commonly Re > 1,000,000 for engineering flows, rendering DNS prohibitively expensive in most cases, even on today's supercomputers.

Large-eddy simulation (LES), which was introduced in 1963 for weather modeling, offers a computationally tractable alternative to DNS. Whereas the larger scales of motion are computed, the effects of the smaller scales are modeled. Unfortunately, LES has not lived up to its potential, partly because, developed by engineers using ad hoc methodology, it has lacked a firm mathematical foundation. Recent efforts (e.g., Stolz, Adams, and Kleiser, *Phys. Fluids*, 1999, and Pruett et al, *Phys. Fluids*, 2006) have attempted to correct this deficiency.

In general, LES begins by filtering velocity fields with a low-pass filter-either spatial or temporal-to separate large turbulent eddies from smaller ones. This presentation involves filtering in the time domain and leads to a novel approach to LES called temporal LES (TLES). It turns out, however, that temporal filtering has several fluid-flow applications short of full-blown TLES.

The talk will explain what is meant by time-domain filtering and describe four distinct uses of temporal filtering in simulating fluid flows. Some doggerel will be used to motivate the physics, and some nice computer graphics will illustrate the computational technologies, so even those for whom the physics and math are a stretch should come away with intuitive understanding and, hopefully, appreciation for the versatility of the methodology.

Monday, September 10 at 3:50 in Roop 103

Refreshments at 3:30