Time-parallel algorithms for chaotic systems

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Supercomputers today can have millions of cores, but traditional methods for solving differential equations can only use space parallelisation effectively up to a few thousand cores. Parallelisation across time appears to be a promising way to provide more parallelism. Chaos makes this hard: small errors grow exponentially, causing nearby paths to diverge. In this talk, we'll show a new framework for understanding how time-parallel algorithms work on nonlinear problems. Building on this, we'll present the moving-window (MoWi) algorithm, which splits long simulations into shorter, overlapping windows. Within each window, we use time parallelisation, but between windows we carefully control errors using a weighted measure that accounts for chaos. This lets MoWi sample paths from the system's attractor while keeping the right statistics and achieving parallel speedup. We'll outline the conditions under which this method can outperform standard implementations of time-parallel methods like Parareal for long simulations of turbulent systems, and present adaptive strategies that change parameters based on local behaviour.