Parallel multigrid in time for chaos with timescale-independent convergence

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Despite the growing importance of parallel-in-time (PinT) algorithms, there are currently no known practical methods which scale well with the length of the time-domain for chaotic problems, due to exponential dependence of the condition number on the fastest chaotic time-scale. While most prior works applying multigrid-in-time (MGinT) to chaotic systems focus on the coarse grid equation, we demonstrate that the commonly used fine-grid relaxation is inadequate. We present the novel Local Shadowing Relaxation (LSR), a convergent, PinT relaxation scheme for chaotic systems. Promising analytical results and numerical experiments with a coupled Lorenz system indicate that LSR, when used as a smoother in MGinT, yields an optimally scaling PinT algorithm for chaotic systems, potentially allowing efficient space-time parallelization of turbulent computational fluid dynamics.