

Talk announcement

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On Parallel-in-Time Methods for Fractional Diffusion

Diffusion describes the collective effect of the microscopic motion of large ensembles of particles. Classical diffusion models based on Brownian motion are not capable to reproduce experimental data observed in field like sub-surface flow or viscoelastic phase separation. This motivates the use fractional diffusion equations featuring non-local operators with temporal memory. Discretizing these memory-dependent operators breaks the sparse, block-triangular structure of standard diffusion matrices, presenting severe computational bottlenecks.

In this talk, we discuss parallel-in-time (PinT) methods to overcome these limitations. We give a gentle introduction to fractional derivatives starting from a time periodic setting and then extend their definition to the causal setting. We introduce fractional derivatives in Fourier space and derive their consistent time representations. Discretization in time leads to a discrete fractional calculus which mimicks the analytical formulas obtained on the continuous level. The causal convolution form of fractional derivatives is encoded in a lower triangular Toeplitz structure of the resulting linear systems. We recall Bini's approximate-circulant embedding which allows to solve lower triangular Toeplitz systems in $O(N \log N)$ complexity, and with $O(\log N)$ steps on N parallel computers. Via tensorization, these method can be applied to fractional diffusion problems in multiple space dimensions, leading to very efficient parallel-in-time solvers.