Parallel-In-Time Integration of the LLG With the Parallel Full Approximation Scheme in Time and Space

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Speeding up computationally expensive problems, such as simulations of large micromagnetic systems, requires efficient use of parallel computing infrastructure. While parallelism across space is commonly exploited in micromagnetics, this strategy is only effective down to a minimum number of degrees of freedom per core. First attempts to additionally parallelize the solution of partial differential equations in the temporal domain date back almost 60 years, but many specialized algorithms for the so-called parallel-in-time integration have only been developed recently [1]. This work investigates the Parallel Full Approximation Scheme in Space and Time (PFASST) [2] as a space- and time-parallel solver for the Landau-Lifshitz-Gilbert equation (LLG). Said scheme is based on Spectral Deferred Correction (SDC) [3] methods, which on their own already provide an interesting prospective timestepping method for solving the LLG, especially at higher accuracies. Prototyping was done with the pySDC [4] python library, but this work uses a custom SDC/PFASST implementation developed as an extension to the magnum.pi [5] micromagnetic simulation software package. Figure 1 shows the performance of the algorithm when simulating a $1000 \times 1000 \times 20$ nm rectangular domain without an external field for 20 ns, starting from the initial state $\boldsymbol{m} = (0, 0, 1)$, with material parameters similar to permalloy and on an airbox mesh with 264264 elements in total. All results meet the same accuracy target in the form of a relative residual tolerance at every timestep.

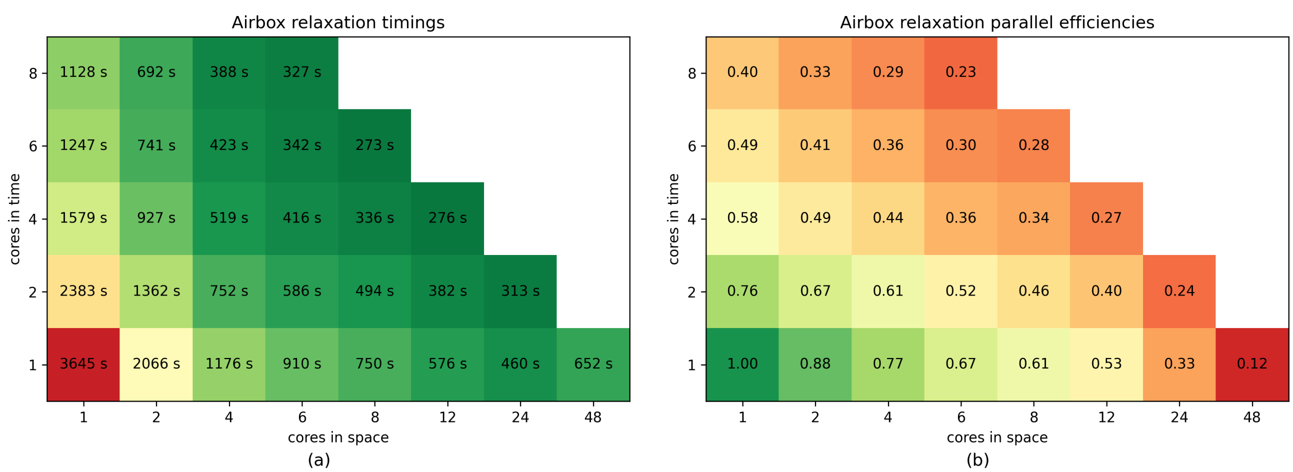

Figure 1: Simulating the relaxation process of a rectangular mesh in parallel. Timings (a) and parallel efficiencies (b), where parallel efficiency is understood as achieved speedup divided by number of threads.

References

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