DK Seminar

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University of Vienna,
Oskar-Morgenstern-Platz 1, HS 2.

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Coupling and numerical integration of the Landau-Lifshitz-Gilbert equation

Time-dependent micromagnetic phenomena are usually described by the LandauLifshitzGilbert (LLG) equation. The numerical integration of the LLG equation poses several challenges: strong nonlinearities, a nonconvex pointwise constraint, an intrinsic energy law, as well as the presence of nonlocal field contributions, which prescribe the coupling with other partial differential equations (PDEs). We discuss the numerical analysis of a tangent plane integrator for the LLG equation. The method is based on an equivalent reformulation of the equation in the tangent space, which is discretized by first-order finite elements and requires only the solution of one linear system per time-step.

The pointwise constraint is enforced at the discrete level by applying the nodal projection mapping to the computed solution at each time-step. We prove that the sequence of discrete approximations converges towards a weak solution of the problem. Under appropriate assumptions, the convergence is unconditional, i.e., the numerical analysis does not require to impose any CFL-type condition on the time-step size and the spatial mesh size. Moreover, we show that a fully linear projection-free variant of the method preserves the (unconditional) convergence result. One particular focus is on the efficient treatment of coupled systems, for which we show that an approach based on the decoupling of the time integration of the LLG equation and the coupled PDE is very attractive in terms of computational cost and still leads to time-marching algorithms that are unconditionally convergent. As an application of the abstract theory, we analyze the nonlinear coupling of the LLG equation with a diffusion equation describing the evolution of the spin accumulation in the presence of spin-polarized currents. Numerical experiments support our theoretical findings and demonstrate the applicability of the method for the simulation of practically relevant problem sizes.