Finite Hex Element Adaptive Mesh Refinement of Demagnetizing Field Computation

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Micromagnetic simulations is a field of computing the behavior of magnetic materials. Computationally answering the question how the magnetization - the magnet's magnetic configuration - is changing under the influence of external magnetic field sources or under the influence of the magnets own emitted stray-field, also called demagnetizing field. In this work we introduce an early stage of a micromagnetic code implementation within PyMFEM, an open-source, lightweight, scalable C++ library for finite element methods [1]. The library supports higher-order finite element spaces, allowing us to test quadratic mesh elements for the discretization of the investigated sample space of an artificial magnet cube. In order to accurately compute the magnetic state later the accurate computation of the magnets demagnetizing field is required. Within this work we demonstrate the computation of the demagnetizing field while using the Zienkiewicz-Zhu residuum approximation [2] to trigger an adaptive mesh refinement process at elements with a local error above 70 percent of the maximum error. An additional local error goal has been defined such that it does not exceed 0.01 anywhere. The magnetic cubes discretization resolution was initialized with a mesh size of 2 nm. The magnet is surrounded by an air box. The total computational domain is 11 times larger than the ferromagnetic cube. The size of the finite elements of the initial mesh increases by a factor of 10 when moving from the magnet's surface towards to boundary of the computational domain. The airbox is used to mimick the zero field boundary conditions at infinity. We focus on the computation of the demagnetizing field therefore the initial magnetization of the cube is kept static and is a vector with length one pointing in positive z-direction. Because the of singularity of the demagnetizing field near the edge, the error will never reach zero. However, in micromagnetics we may stop refinement if mesh size reaches half of the exchange length. This research was funded in whole or in part by the Austrian Science Fund (FWF) I 5712.

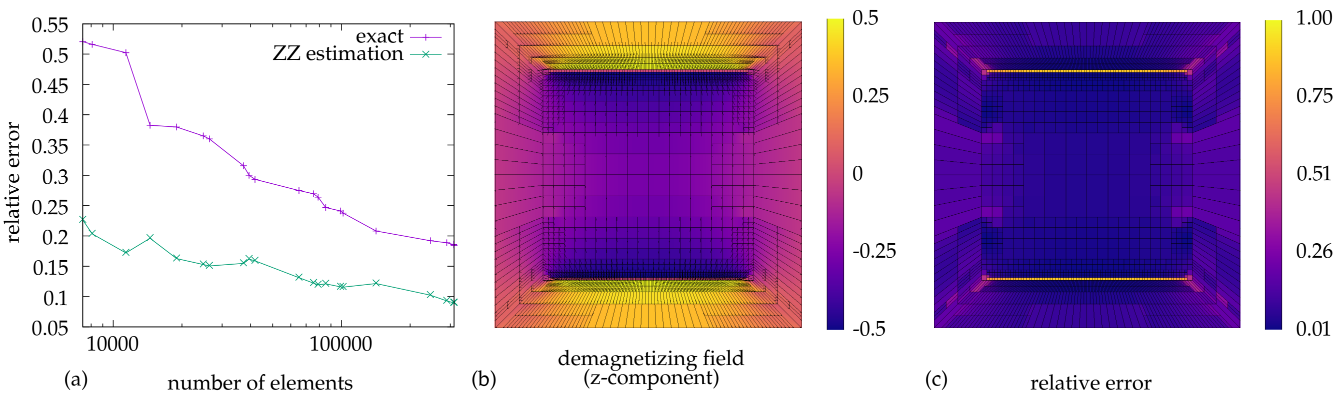

Figure 1: (a) The relative errors over the number of finite elements, the difference to the exact solution and the error estimation. (b) shows the z-component of computed demagnetizing field interpolated onto the mesh nodes at the refinement step 20 with a total of $3 \cdot 10^5$ finite elements, (c) shows the relative error per finite element at the same refinement stage.

References

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