

Novel nodal finite-difference micromagnetic code for distributed systems

Ruslan Allayarov¹, Florian Bruckner¹, Dieter Suess¹, Claas Abert¹

¹Faculty of Physics, University of Vienna, Vienna, Austria

In recent years, there has been a trend towards the use of graphics processing units (GPUs) for scientific computing. This trend has been implemented in both finite element and finite difference micromagnetics (e.g., mumax [1] and tetramag [2]). Besides the use of existing numerical algorithms, the development of improved numerical algorithms has always been a focus of micromagnetics research.

Despite the massive increase in computing power, the high number of unknowns in micromagnetic systems even of moderate size remains to be one of the main challenges. Another challenge is the accurate numerical description of material interfaces with rapid changes of material parameters. Finite-difference micromagnetics is well suited for the handling of large problems due to its highly efficient FFT accelerated demagnetization field computation. However, the correct handling of interface effects is very cumbersome due to the degrees of freedom lying in the centers of the discretization cells [3, 4]. On the other hand, the finite-element method provides an elegant description for interface effects by means of a variational approach [5], while being computationally heavier on the demagnetization field calculation.

In this work we propose a new discretization scheme that aims to combine the advantages of finite-element and finite-difference micromagnetics – the nodal finite-difference discretization scheme. In this scheme, we use the finite-element method on a regular hexahedral mesh with the magnetization being defined on the nodes of the mesh and the material parameters being piece-wise constant functions defined in each cell. Due to the regular grid we can use matrix-free methods. Moreover, it allows to simplify numerical approximation of differential operations and to use the efficient FFT-formulation for the demagnetization field.

As a framework we use the modern tensor library Pytorch [6]. We consider all magnetic parameters as well as magnetization as multidimensional tensors. To check the correct handling of interface effects between the materials we tested the new method with the standard problem of domain wall pinning [4] (see Figure 1, right) and obtained a good agreement with the theoretical model. The performance of the new code is comparable to mumax (see Figure 1, left).

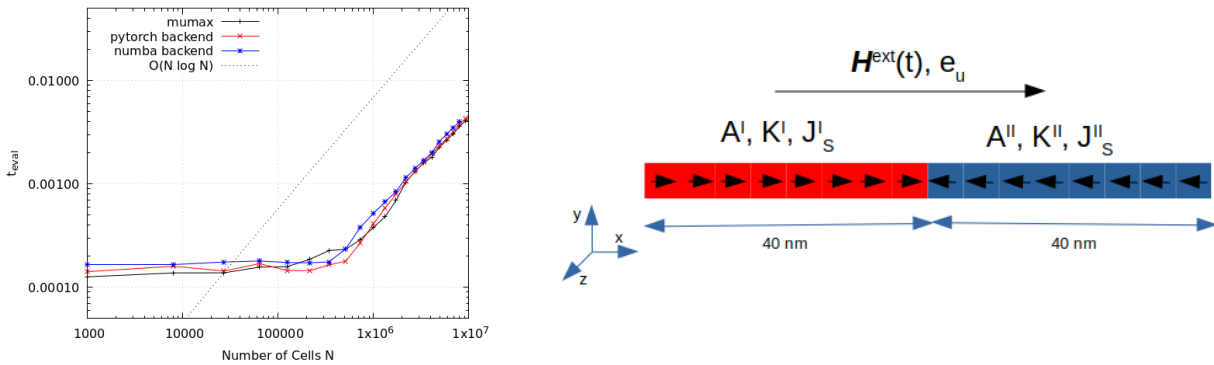


Figure 1. Performance comparison between mumax, Pytorch and numba backends for exchange field calculations (left) and description of the standard problem with domain wall pinning (right).

References

- [1] <https://mumax.github.io/api.html>
- [2] <https://www.ipcms.fr/en/equipe/spintronic-basics/micromagnetism-tetramag/>
- [3] D. Suess, et al.: Accurate finite-difference micromagnetics of magnets including RKKY interaction--analytical solution and comparison to standard micromagnetic codes. arXiv preprint arXiv:2206.11063 (2022).
- [4] Paul Heistracher, et al.: Proposal for a micromagnetic standard problem: Domain wall pinning at phase boundaries. Journal of Magnetism and Magnetic Materials, 548, 168875 (2022).
- [5] Claas Abert: Micromagnetics and spintronics: models and numerical methods. Eur. Phys. J. B, 92, 120 (2019).
- [6] www.pytorch.org