Inverse-design micromagnetic simulation solver based on PyTorch framework

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Spin waves, the collective excitation of the electron spin system, are known to be a promising candidate for the information carriers in the novel type of data processing units. Over the years, various designs have been proposed that exploit such magnetic phenomena [1]. However, the increasing demands for miniaturisation and speed of the logic devices require innovative and more advanced numerical methods for the design of these units.

The concept of structure optimisation by inverse design is extensively used in photonics research and has recently been adapted for magnetic systems. In this approach, numerical simulations of the magnetic properties are combined with feedback-based machine-learning algorithms to obtain the device design [2,3].

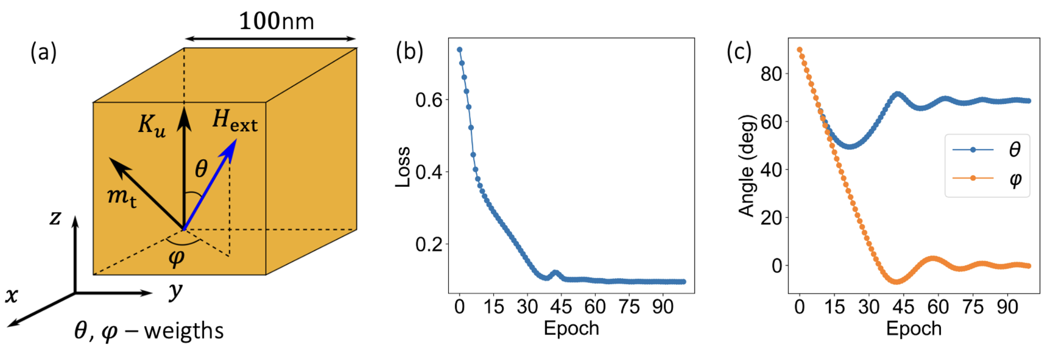

Figure 1: (a) The schematic representation of the simulated inverse design problem; (b) The loss function defined as the absolute value of the difference between the magnetisation of the cube and the target magnetisation m_{t}; (c) The optimisation of the spherical coordinates (φ and θ) of the external magnetic field.

The current research aims to develop a versatile simulation tool that uses the advanced computational algorithms of the open-source machine learning framework PyTorch. The computations for the inverse design are based on the novel finite-difference micromagnetic solver magnum.np [4] where computational speed is significantly increased by the use of GPUs and the implementation of the adjoint solver makes it possible to reduce the memory consumption to a minimum.

The effectiveness of the proposed simulation software was tested using the micromagnetic problem shown in Figure 1. The task for the inverse design solver here is to find an optimal orientation of the external magnetic field H_{ext} so that the magnetisation of the cube is aligned at an angle of 45° in the xz-plane (m_{t}) in the presence of the strong uniaxial anisotropy K_u along the z-direction (Figure 1a). At the same time, the amplitude of the external magnetic field is preserved. The strong decrease of the loss function (Figure 1b) and the decaying oscillation of the angles of the external field towards the optimal value (Figure 1c) prove the validity and robustness of the software.

The proposed algorithm greatly facilitates the design of the applied devices and is a useful tool, especially for spin-wave computing elements.

References

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