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Large-Scale Finite Element Micromagnetics Simulations using Open Source Software

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Resume : Continuous down-scaling of semiconductor devices as it is being done for the last decades will come to a halt due to increasing dynamic and stand-by power consumption. Therefore, alternative technologies have to be investigated. Besides charge, the spin is also an inherent property of the electron that can be exploited for digital applications. Magnetic tunnel junctions (MTJ), formed by two ferromagnetic layers separated by a tunnel barrier, are the key element of magnetoresistive random access memory (MRAM). Their parallel and anti-parallel arrangement of the magnetization in the ferromagnetic layers and the corresponding low and high resistivity state make this spin-based technology a feasible energy-efficient and non-volatile alternative to charge-based memories. In order to design these spin-based devices, demanding simulations have to be performed to calculate the magnetization dynamics of the ferromagnetic layers. Large-scale micromagnetics simulations using the finite element method require special care, due to effective field evaluations that have to be performed at every time step. We show how available open source libraries can be used for a highly scalable implementation of the hybrid FEM-BEM approach. Parallelization using distributed-memory techniques and efficient handling of dense matrices using matrix compression are part of the computational machinery to efficiently solve the Landau-Lifshitz-Gilbert equation for the magnetization dynamics.

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Comprehensive Comparison of Switching Models for Perpendicular Spin Transfer Torque MRAM Cells