FINITE ELEMENT SIMULATION OF MICROMAGNETISM

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OUTLINE

This project will study the physics of magnetic materials by numerical simulations. Magnetic materials are increasingly used in industry and widely applied in the construction of different items, for instance magnetic cores of transformers, motors, generators, etc. They are used to construct recording devices such as a Magnetoresistive Random-Access Memory (MRAM), see the left panel of Figure 1. The ferromagnetic layer is divided in a grid of cells, where by magnetizing the core of the cell they are designed to hold a bit information 0 or 1 with respect to the directions of the magnetic fields. There are numerous advantages of MRAM against the traditional flash drives and hard disc drives and it is believed that MRAM will become a universal computer memory in the future. However much development is still needed in order to make the magnetic memories to be competitive with traditional devices that are used today.

Figure 1. The structure of MRAM (left) and a schematic representation of a magnetic domain wall (right)

PROJECT DESCRIPTION

Experimental analysis of the magnetic devices are usually expensive, therefore mathematical models of the magnetization processes are developed. The so-called Landau-Lifshitz-Gilbert (LLG) equation is introduced by Landau and Lifshitz in 1935 and by Gilbert in 1955. The LLG equation is used to model the magnetisation dynamics in ferromagnetic materials. The equation is highly nonlinear and analytical solutions can only be obtained in a few particular cases. Finding a suitable numerical scheme, which respects various physical properties and performs well in complex geometries, poses a challenge from a numerical viewpoint.

Magnetization dynamics occur in different spatial and temporal scales. In a computation, different resolutions are required to capture these variations. As an example, the so-called domain wall, see the right panel of Figure 1, is a very sudden change in the magnetization direction and it may happen over a few nanometer length-scale. Typical regime of interest, however, is on the micro-meter scales. Traditional numerical schemes
will have to use mesh sizes dictated by the size of the domain wall, everywhere in the domain. This makes the simulation of the magnetization dynamics unpractical. If the exact position of the domain walls are known a priori, one can adapt the mesh so that smaller mesh sizes are used only around the sharp transition and much coarser mesh sizes are used in the rest of the domain; the so-called adaptivity. The location of these fast local variations, however, typically are not known a priori.

One of the aims of this project is to develop finite element methods to automatically identify the position of such singularities. The idea is to develop a goal oriented adaptivity, which effectively uses information about the approximate solution to construct a proper refinement around singularities. Another part of the plan is to combine the adaptivity with novel atomistic-continuum strategies where atomistic models are used locally to further increase the computational accuracy.

Qualification

A suitable background for this position would be a Master of Science in Mathematics, Physics or Engineering, with a specialization in numerical analysis and with experience in scientific computation. It is expected that the applicant has sufficient programming knowledge in C/C++/Fortran or Python. A good knowledge in finite element analysis counts as a merit.

Moreover, applicants must be strongly motivated for doctoral studies, possess the ability to work independently and perform critical analysis as well as possessing good levels of cooperative and communicative abilities.

Contacts

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