

# Utilization of COMSOL Multiphysics' JAVA API for the Implementation of a Micromagnetic Modeling and Simulation Package with a Customized User Interface

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## Abstract

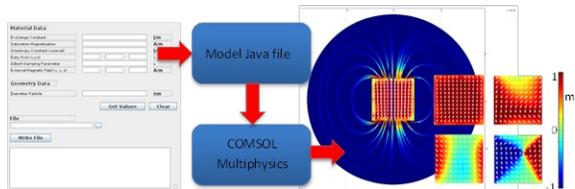
One of the big advantages of COMSOL Multiphysics is the possibility to implement user-defined partial differential equations (PDE) which can be coupled to COMSOL's predefined physics interfaces. However, using the tool's standard user interface requires manual implementation of the PDEs and a multitude of problem-specific parameters. This process is not just error-prone but also very time consuming. As an alternative to this manual implementation one can use COMSOL's Java Application Programming Interface (API) which provides an easy and efficient way to create a user-defined simulation package. Here, we demonstrate the usage of COMSOL's Java API by our implementation of a micromagnetic modeling and simulation package. Micromagnetic Modeling: Nanostructured magnetic materials have recently been focused by many research groups because of their particular properties and potential application in many interesting fields, e.g. data storage, biomedicine and smart materials. In order to calculate the magnetic properties of nano-sized structures hosting only a small number of magnetic moments like magnetic molecules, spin-discrete simulation techniques like quantum and classical Monte Carlo and spin dynamics simulations [1] are well established. Moving on to larger magnetic structures like magnetic nanoparticles or multi-layer systems, the number of atomic moments is growing dramatically. Therefore, spin-discrete modeling techniques have to be replaced by a continuous description of the magnetic moment in these cases. The orientation of the continuous magnetic moment within a micromagnetic description is determined by competing energy contributions, such as the exchange energy, the Zeeman energy, the demagnetization energy, and the anisotropy energy. Minimizing the total energy leads to the well-known Landau-Lifshitz-Gilbert equation (LLG) [2] which describes the precessional motion of magnetic moments. The LLG is coupled to Maxwell's equations via the stray field. This set of equations can be transformed into a weak formulation which allows us to implement them directly in COMSOL Multiphysics [3]. JMicomag: For the efficient usage of our newly implemented micromagnetic modelling features in COMSOL Multiphysics, the customized user interface "JMicomag" has been developed, taking advantage of COMSOL's JAVA API. Within "JMicomag" all necessary material parameters and geometry options can be specified in a user-friendly way. The interface itself generates the simulation's input file with all parameters, equations and problem specific settings. As a consequence, frequent errors during the modeling process can be avoided. Moreover, the time and effort required for setting up a micromagnetic simulation file, is

decreased to a great extent. Conclusion: We have created a micromagnetic simulation package by implementing the weak formulation of the Landau-Lifshitz-Gilbert equation and its coupling to Maxwell's equation within COMSOL Multiphysics. Furthermore, we have developed the specialized user interface "JMicomag" which allows the user to perform micromagnetic simulations in a very efficient and user-friendly way. With these enhancements, COMSOL Multiphysics can be used to simulate and evaluate micromagnetic problems for arbitrary geometries and materials.

## Reference

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2. W.F. Brown, Jr., Micromagnetics. New York: Wiley. ISBN: 0-88275-665-6 (1963).
3. A. Weddemann et al., Detection of magnetic particles by magnetoresistive sensors. Milan: COMSOL Conference 2009. (2009).

## Figures used in the abstract



**Figure 1:** JMicomag user interface: First, all necessary geometry and material parameters are specified by the user. Using this input data JMicomag generates the Model Java file which already contains the micromagnetic equations and their coupling to Maxwell's equations along with additional conditions, parameters and solver settings. The Model Java file can easily be imported into COMSOL Multiphysics, where the actual simulation can be started.