# Towards real time computation of 3D magnetic field in parametrized Polyhelix magnets using a reduced basis Biot-Savart model

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We present our work on model reduction for the computation of 3D magnetic field, as part of our collaboration with the Laboratoire National des Champs Magntiques Intenses (LNCMI), large-scale equipment of CNRS. LNCMI designs, builds and operates electromagnets that produce high-intensity magnetic field, up to 37T for several hours. These electromagnets are then used by researchers and companies to do experiments under these magnetic fields. To reach this intensity level, the magnets are made of advanced copper alloy materials which then dissipates enormous amounts of energy due to Joule effect and are cooled down by water. From the modeling point of view, to design these magnets, a parametrized thermoelectric problem, with material properties depending on temperature, needs to be solved to retrieve the electrical current. Then, we use the Biot-Savart law, away from the conductor, to compute the magnetic field, in the central part of the magnet, called the user field. The thermoelectric problem is, in fact, non-linear and thus expensive to solve. To solve the parametrized design problem with an affordable cost, we proposed to use the reduced basis method and the well-known Empirical Interpolation Method (EIM) [2] within the Simultaneous EIM Reduced basis (SER) [3] algorithm.
We extend this work, and we propose a strategy to use the reduced potential directly into the Biot-Savart law. It allows, in the presence of physical parameters (conductivity, current density, etc.) to compute in real time the user field when changing these parameters. It enables, then, extremely fast uncertainty quantification, sensitivity analysis or optimization studies.
In the presence of geometrical parameters, we propose a non-standard, but well-adapted, parametrization for such complex geometries. Unfortunately, we can no longer apply the standard Empirical Interpolation, but rather a so-called discrete variation [1] to recover the affine decomposition. Although this method reduces significantly the time needed for the computation of the magnetic field, it no longer allows achieving real-time calculation.

As an illustration, we present two applications from LNCMI: the geometrical optimization of a real magnet to improve the homogeneity of the magnetic field, and the identification of cooling parameters to be as close as possible as the experiments.

### Références

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