

MADEO: An LLM-Enhanced Tool for Superconducting Magnet Design and Optimization

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The Superconducting Magnet Division (SMD) at Brookhaven National Laboratory (BNL) has the unique capability of developing direct wind magnets, such as those that are being developed for the Electron-Ion Collider (EIC). MADEO (Modeler and Analyzer for Direct-wind Electromagnetic Optimization) is a new program that we have developed to make improvements on the legacy Fortran code that has previously been used for magnet design and development. MADEO was initially developed by hand as a small terminal-based program, after which large-language model (LLM)-assisted development was used to rapidly expand the program's capabilities. This allowed us to improve user experience by easily adding in a graphical user interface (GUI), better visualization tools, and a suite of magnet calculation tools. We were able to verify the numerical accuracy of this program by comparing results from MADEO to those of the legacy Fortran code for multiple single-parameter optimization problems in different magnet types. These comparisons produced identical results between the programs, validating the numerical accuracy of MADEO. MADEO is entirely built in Python, making it highly modular and allowing developers and physicists to integrate multiple modules natively within a single programmatic framework. It is designed to interface with modern scientific computing libraries including SciPy, C++ wrapped frameworks like Minuit, and a custom C# based geometric modeler to name a few. MADEO will allow magnet designers at the SMD at BNL to design magnets in a faster and more user-friendly way, with better visualizations of the actual magnet designs. More broadly, this work demonstrates how LLM-assisted development can accelerate the modernization of specialized scientific software from terminal based programs to user friendly GUI based modular platforms, while preserving the overall scientific functionality.