Differentiable Coil Optimization

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In magnetic confinement fusion, one of the most promising approaches that allow steady state operation with no disruptions is the stellarator. The stellarator consists of electromagnetic coils that create a twisted magnetic field that needs to be optimized to confine a high-performing plasma. Such optimization is performed over a large set of parameters, typically of the order of several hundred or more. Furthermore, the target magnetic field is usually a fixed one, that has been previously obtained using another optimization based on the ideal MHD equations. With this work, we trace particles directly in the corresponding Biot-Savart magnetic fields stemming from a set of coils and optimize them to yield a small fraction of lost particles outside of the confinement region. Furthermore, to replace the need for hundreds of simulations per optimization step, we make use of automatic differentiation by implementing the guiding-center equations, magnetic field solver, and optimization routines in JAX. This allows us to streamline optimization efforts, and create a specialized, but very fast, numerical tool, to optimize force-free stellarator equilibria. As force-free equilibria are usually the first step in determining the viability of a device, such optimizations will be able to guide future designs based on ideal MHD equilibria.