Sensitivity Analysis in the Level Set Method for Electromagnetic Problems

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Abstract

Interest in electromagnetic design problems has been recently refuelled as structural optimization rapidly propagates to other scientific and technological fields. Undertaking a sensitivity analysis of an objective function with respect to topology changes is a critical (and usually the most technical) step in any gradient-based topology optimization study. These types of analyses have been well documented for the density-based (SIMP) optimization methods, however clear instruction for the level set method is still scarce in the literature. As we will show, the level set method is a powerful alternative to the gradient-based methods, and has been shown to be superior in regard to some recent problems, such as the design of electromagnetic metamaterials and plasmonic devices.

This study will explain the steps required in a level set sensitivity analysis. We will begin by describing the level set method in detail and how one can use it to represent and transform a topology. We will continue by explaining the so-called shape gradient and derive some key formulas for its use. We will then show how to transform the governing PDE equations of a general engineering problem to a "level set method"-friendly form, and show how discrete methods can be used to evolve a topology toward optima.

We will conclude by applying the described steps to a number of example electromagnetic problems which have been solved previously by density methods in order to demonstrate the generality of the level set method and compare the results. We will also suggest some current problems which may require the level set method in order to be solved.