Metamaterial Design using Reduced Basis Method and Interior-Point Methods

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Abstract: Metametarials are scientifically engineered materials that are designed to interact with and control mechanical and electromagnetic waves in ways that cannot be achieved with conventional materials. For instance, metamaterials can be designed to bend electromagnetic waves around an object so that the object appears invisible to surrounding observers, focus light to create a subwavelength image of a source, and mitigate blast waves to protect structures and humans from explosion. These and other novel applications have attracted considerable interest in designing and fabricating metamaterials. Typically, metamaterials are fabricated by embedding small inclusions in a homogeneous host medium. This provides us with a large set of independent parameters with which to engineer metamaterials, including the properties of the host medium, as well as the size, shape, composition, and arrangement of the inclusions. All of these design parameters can play an important role in the performance of the metamaterial.

Fundamental challenges abound about the design of metamaterials using formal optimization constrained by partial differential equations (PDEs). First, the optimization problem is in general *nonlinear* and *nonconvex* due to an implicit dependence of the objective function on the design variables through the underlying PDEs. Second, the problem is *large-scale* since the discretization of the PDEs leads to a very large number of constraints. Lastly but not least, the issue of fabrication is particularly important in practical applications involving metamaterials since the desired length scales are often at the limit of our fabrication capability and hence geometric design tolerances (in relative scale) need to be larger.

In this talk, we discuss a numerical approach to address the above-mentioned challenges. The proposed approach combines the reduced basis method with contemporary interior-point methods. We present our recent results on the design of photonic crystals and negative-coefficient materials to illustrate the potential of the proposed approach.

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