Karlstad Applied Analysis Seminar (2021)

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An introduction to material distribution topology optimization and its application to the design of a device colloquially called an acoustic diode

Abstract

Topology optimization aims at determining the layout of material(s) within a given design domain Ω so that a given performance measure is extremized. If there are two types of materials, for convenience referred to as material and void, to fill the design domain, then the objective is to find a region $M \subset \Omega$ such that we have material in M and void in the region $V = \Omega \setminus M$. The region M occupied by material is referred to as the design. In practical applications, some regularity on M (and/or V) is typically required. One such regularity constraint is that M exhibits a minimum length scale. In practical applications, the material region is often defined by using a so-called material indicator function, or density, ρ (for now, the characteristic function of M). Material distribution topology optimization problems are generally ill-posed if no restriction or regularization method is used. A standard procedure to treat such a problem is to relax ρ to attain any value in the range $[0, 1]$ in combination with a filtering procedure and some form of penalization to promote binary designs.

This talk comprises two distinct parts. The first part provides an introduction to material distribution topology optimization with an emphasis on a class of non-linear filters (fW-mean filters) that encompasses the vast

majority of currently used in the topology optimization community. This enables a unified analysis of a large class of material distribution methods. In particular, it can be proven that these filters ensure existence of solutions to a continuous version of the filtered and penalized minumum compliance topology optimization problem.

The second part focuses on the application of these methods to the design of a passive acoustic device that allows for one-way flow of sound waves, such a device is often colloquially referred to as an acoustic diode. The Helmholtz equation models the time-harmonic linear wave propagation together with a Dirichlet to Neumann (DtN) type boundary condition and the finite element method is used for discretization. The objective of this study is to maximize the wave propagation in one-direction and minimize the wave propagation in the reverse direction for planar incoming waves. Since a true diode is a non-reciprocal device and here we used a linear acoustic wave model, which is reciprocal; this talk details how it appears to be possible to obtain a one-way waveguiding effect using this linear model.