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Material distribution-based topology optimization for wave propagation problems

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Abstract
This thesis employs material distribution-based topology optimization for wave propagation problems. In the material distribution approach, we define a material indicator function that models the presence and absence of material in a design domain. By placing material inside the design domain, the aim is to design a device that maximizes the output power or transmission of the system. The time-harmonic linear wave propagation problem is modeled using the Helmholtz equation. The governing equation is solved using the finite element method, and an artificial boundary condition is used to truncate the domain. Moreover, a gradient-based algorithm, the method of moving asymptotes by Svanberg, is used to solve the optimization problem. An adjoint method efficiently computes the gradients of the objective function with respect to design variables.

This thesis considers two types of wave propagation problems: acoustic (Papers I-III) and electromagnetic wave propagation (Papers IV-V). In Papers I-II, we consider a bandpass design of a subwoofer. The aim of Paper I is to reduce the computational time required to evaluate the performance of a given subwoofer layout. To accomplish this, we develop a computationally efficient hybrid 2D-3D model. A full 3D model as well as a lumped model validate the hybrid model's results. Paper II focuses on optimizing the topology of a subwoofer using the computationally efficient hybrid model from Paper I for single as well multiple frequencies. In Paper III, we design a highly efficient uni-directional linear acoustic waveguide. Moreover, we also challenge the use of the term *acoustic diode* for such uni-directional linear acoustic waveguides in literature. Paper IV deals with the design of a microwave frequency dividing multiplexer, which splits the incoming signals into two frequency bands and delivers them to their respective output ports. In Paper V, we use the adjoint method to perform the sensitivity analysis of a coupled plasmonic problem where a Helmholtz equation is coupled to the Poisson equation. We validate the sensitivities computed using the adjoint method with the finite difference approach.

Keywords
topology optimization, material distribution, wave propagation problems, Helmholtz equation, acoustics, electromagnetics, plasmonics

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