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Finite Volumes Discretization of Topology Optimization Problems

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Utilizing control in the coefficients of partial differential equations (PDEs) for the purpose of optimal design, or topology optimization, is a well established technique in both academia and industry. Advantages of using control in the coefficients for optimal design purposes include the flexibility of the induced parametrization of the design space that allows optimization algorithms to efficiently explore it, and the ease of integration with existing computational codes in a variety of application areas, the simplicity and efficiency of sensitivity analyses—all stemming from the use of the same grid throughout the optimization procedure. As topology optimization is gaining maturity, the method is applied to increasingly more complex coupled multi-physical problems. As a result it becomes vital to utilize robust and mature PDE solvers within a topology optimization framework.

Finite volume methods (FVMs) represent such a mature and versatile technique for discretizing partial differential equations in the form of conservation laws of varying types. Advantages of FVMs include the simplicity of implementation, their local conservation properties, and the ease of coupling various PDEs in a multi-physics setting. In fact, FVMs represent a standard method of discretization within engineering communities dealing with computational fluid dynamics, transport, and convection-reaction problems. Among various flavours of FVMs, cell based approaches, where all variables are associated only with cell centers, are particularly attractive, as all involved PDEs on a given domain are discretized using the same and the lowest possible number of degrees of freedom. In spite of their numerous favourable advantages, FVMs have seen very little adoption within the topology optimization community, where the absolute majority of numerical computations is done using finite element methods (FEMs). Despite some limited recent efforts [1, 2], we have only started to develop our understanding of the interplay between the control in the coefficients and FVMs.

Recent advances in discrete functional analysis allow us to analyze convergence of FVM discretizations of model topology optimization problems. We illustrate the numerical behaviour of a cell based FVM topology optimization algorithm on a series of benchmark examples.

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