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# Topology optimization of 2D lattice structures for target band gaps with continuity conditions

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## Abstract

Excessive vibrations in engineering systems can lead to significant challenges, including structural failure and decreased operational efficiency. This research addresses these issues by developing an innovative topology optimization algorithm to design 2D lattice structures that exhibit band gaps around a specified target frequency, specified by the user. Band gaps are frequency ranges within which wave propagation is prohibited, making them essential in vibration control and wave filtering applications. The methodology relies on analyzing a single unit cell using the Bloch-Floquet theorem, which significantly reduces computational complexity. The optimization employs the innovative method Floating Projection Topology Optimization (FPTO) method, considering material and voids (design variables equal to 1 and 0, respectively). The implicit floating projection constraint in the FPTO method numerically simulates 0/1 constraints of the design variables so that even a linear material interpolation scheme can be employed (penalty not required). By gradually tightening 0/1 constraints, more and more design variables are pushed to 0/1 until an optimized element-based design with a clear topology can be accurately represented by a smooth design. One of the key innovations in this work is the introduction of a novel objective function that focuses exclusively on natural frequencies nearest to the target frequency, independent of their relationship to the fundamental frequency. This approach minimizes computational costs by reducing the range of frequency analysis while improving the robustness of the optimization process, the frequencies adapting to changes in material distribution, ensuring that they cover the target frequency throughout the optimization process.

The algorithm was rigorously tested on lattice structures composed of periodically repeated unit cells in both one-dimensional (1D-CR) and two-dimensional (2D-CR) configurations, incorporating continuity conditions by means of thermal conduction homogenization techniques, thus avoiding the appearance in the unit cell of material geometries surrounded by void (which would not be possible to manufacture, since it loses the continuity of the entire lattice).

F. Gómez-Silva acknowledges support from MCIN/ AEI /10.13039/501100011033 under Grant numbers PID2021-123294OB-I00 and TED2021-129709B-I00, from FEDER, UE and from the European Union Next Generation EU/PRTR.

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