Machine-Learning-Driven Discovery of Novel Acoustic Metamaterials for Broadband Noise Mitigation

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Noise pollution is the second largest environmental hazard to human health, yet it is often overlooked. Hundreds of millions Americans are at risk of noise-induced diseases and dementia, while millions have already suffered permanent hearing damage from excessive noise exposure. Noise-related costs range in the billions of dollars annually, and continue to worsen with societal development. Current soundproofing measures rely on reflection and porous sound absorption, restricting application across different environments. A promising alternative is acoustic metamaterials that employ resonant sound absorption. However, their reliance on internal structures with complex parameters makes optimization through empirical methods time-consuming and prototyping impractical. This work pioneers a machine-learning-driven approach, supported by COMSOL simulation data and additive manufacturing, for the efficient development of periodic, scalable acoustic metamaterials. My research first simulated the sound absorption of metamaterial designs with nine parameters using COMSOL Multiphysics. This generated an initial dataset for integration with ML, and the Extremely Randomized Trees algorithm yielded the best predictive model. On this basis, the annealing algorithm then achieved structural optimization. Real-world testing of my 3D-printed metamaterial presents a one-inch broadband noise reduction coefficient (NRC) and sound transmission class (STC) of 1.07 and 74.6, respectively. Both values exceed those of traditional Class A acoustic absorbers, while the metamaterial itself presents a novel, 3D-printer-friendly fiber pattern. This research demonstrates the potential of integrating computer simulation, ML, and additive manufacturing for noise mitigation and materials development.