Abstract

Loudspeakers are an integral part of modern-day society, and their applications are many. It is a technology that has matured over many decades and is used in a wide range of products with diverse use cases. The maturity of the technology also means that there are no obvious improvements to be made to the existing technology in most instances. Therefore, this work is centered around utilizing numerical optimization techniques, as they can generate new designs, ideas, or concepts that have yet to be introduced by more conventional design methods.

Firstly, the thesis concerns the modeling aspect of loudspeakers. Here, a hybrid approach is developed where a fully coupled finite element model is coupled to a lumped parameter model. The model is able to mimic a reference model of a full loudspeaker, even at very high frequencies.

Subsequently, the work is centered around improving the quality of sound radiated from loudspeaker drivers and compact speakers. The design problems considered are formulated to be applicable in broad frequency ranges. This thesis investigates the positive influence on the frequency response and directivity that can be gained from optimizing the material layout in the speaker diaphragm and surround. The design of the material layout is determined with a density-based optimization approach. A generic 5-inch loudspeaker unit is considered in a target frequency range of 600 Hz up to 10 kHz; here, a completely flat on-axis response is achieved with the proposed optimization method. It is also shown that the method can be used to control the directivity of the loudspeaker unit to obtain a wider listening window where both the on-axis and off-axis response is reasonably flat and aligned. The method is also applied to determine the homogeneous material properties of a passive radiator to enhance the low frequency performance of a smart speaker significantly. Furthermore, the application of shape optimization relying on the principles of free form deformation with nonlinear element constraints is developed. The suggested approach uses element constraints to ensure that the quality of the mesh is not degraded during the optimization. The design problem considers a compact speaker consisting of a down-firing woofer and an acoustic lens. The suggested approach can produce smooth and uncomplicated designs that are able to yield a well-behaved horizontal frequency response in the frequency range from 90 Hz to 10 kHz.