

Modeling of Pinna Related Transfer Functions (PRTF) Using the Finite Element Method (FEM)

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Abstract

Abstract: Pinna Related Transfer Functions (PRTFs) are signal processing models that represent the modifications undergone by the acoustic signal as it interacts with the listener's pinna (outer ear). PRTFs can be used to generate binaural sound elevation effects as they contain most of the information about the sound source's elevation. Pinna-Related Impulse Responses (PRIRs), which are a part of Head Related Impulse Responses (HRIRs), are used in signal processing to synthesize spatialized audio that is used in a variety of applications, from virtual computer games to aids for the visually impaired. HRIRs and HRTFs (Head Related Transfer Functions) represent the transformation undergone by the sound signals, as they travel from their source to both of the listener's eardrums. This transformation is due to the interaction of sound waves with the torso, shoulder, head, and outer ear of a listener. The outer ear (pinna) is a complex shaped organ responsible for shaping much of the HRTF in the higher frequencies. The two components of these HRTF or PRTF pairs (left and right) are typically different from each other, and pairs corresponding to sound sources at different locations around the listener are different. Moreover, since the physical elements that determine the transformation of the sounds reaching the listener's eardrums (i.e., the listener's head, torso, and pinnae), are somewhat different for different listeners, so should be their HRTF and PRTF sets. For a listener to perceive synthesized 3D sound cues correctly, the synthesized cues must be similar to the listener's own PRTFs. One can measure individual PRTFs using specialized recording systems; however, these systems are prohibitively expensive and restrict the portability of the 3D sound system. PRTF-based systems also face several computational challenges.

This research provides an alternative to real PRTF measurement, where the 3D images of human ears are used to generate the pinna related transfer functions - which is a simpler, efficient, accurate, and cost effective way. The images can be obtained using a hand held scanner or any other type of 3D scanner. These images are used in a COMSOL Multiphysics® simulation that uses the finite element method to solve the related partial differential equations (PDE). The synthesized PRTFs are compared, using MATLAB®, with the real PRTFs measured at Florida International University's DSP lab (FIU HRTF database). The comparison shows a percentage match and cross correlation higher than 80% (Figure 1). An artificial ear is used for the measurement of PRTFs. A graphical user interface (GUI) is also created in MATLAB® to perform the comparison and error analysis.

Figures used in the abstract

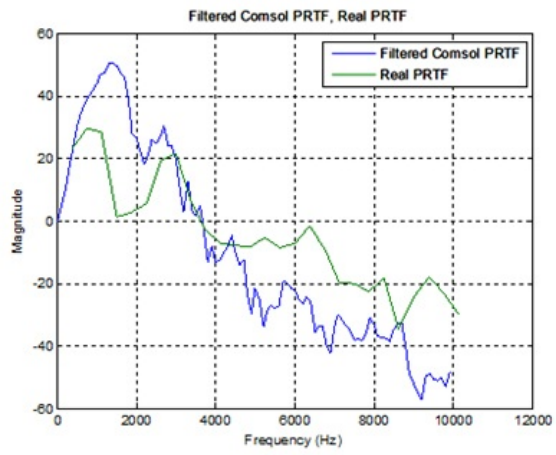


Figure 1: Comparison of the real PRTF vs. COMSOL generated PRTF.