ABSTRACT

VISUALIZATION, MEASUREMENT, AND INTERPOLATION OF
HEAD-RELATED TRANSFER FUNCTIONS (HRTF'S)
WITH APPLICATIONS IN ELECTRO-ACOUSTIC MUSIC

by

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Head-Related Transfer Functions (HRTF's) describe the directionally dependent acoustic filtering properties of the head, torso, and external ear. HRTF's are typically measured at a finite number of spatial locations at a fixed radius from the head using various acoustic system identification techniques. Since HRTF's presumably contain all of the psychoacoustic cues needed to synthesize spatial sound, these functions can be used to simulate virtual or "3-D" sound for auditory displays.

The purpose of this thesis is to investigate the structure of HRTF data with novel 2- and 3- dimensional visualization techniques. We show how simply "looking" at HRTF's in these different ways can suggest how HRTF's can be analyzed and processed in innovative ways for both engineering and musical purposes.

We first provide a comparative visualization study of HRTF data in the time, frequency, space, and volume domains. We demonstrate how elevation effects produced by the pinna and diffraction effects produced by head shadowing can be found in all four domains.

We then show that visualizing HRTF data sets with spatial and volumetric methods exposes some artifacts introduced into HRTF's during the measurement procedure. We develop an analytical model for this procedure, show how the model accounts for these artifacts, and illustrate how these artifacts can be found in HRTF's measured by the author and HRTF's reported elsewhere in the literature.

Visualizing HRTF's with spatial techniques shows that HRTF data resembles responses produced by spatially distributed sensor arrays, or beamformers. We develop an adaptive extension to an existing beamformer model for HRTF's and use the model to investigate some dymanic and cognitive phenomena associated with directional hearing.

Finally, we show how interpolation methods used to create spatial domain visualizations can be exploited to compute interpolated HRTF's corresponding to arbitrary spatial locations. We describe a listening experiment designed to evaluate the perceptual quality of the interpolation algorithm. To demonstrate how interpolated HRTF's can be put to creative use, we discuss compositional techniques developed for *Fishbowl*, an original, binaural composition of electro-acoustic music containing moving sound sources synthesized from interpolated HRTF's. Sound examples can be found on the accompanying CD.