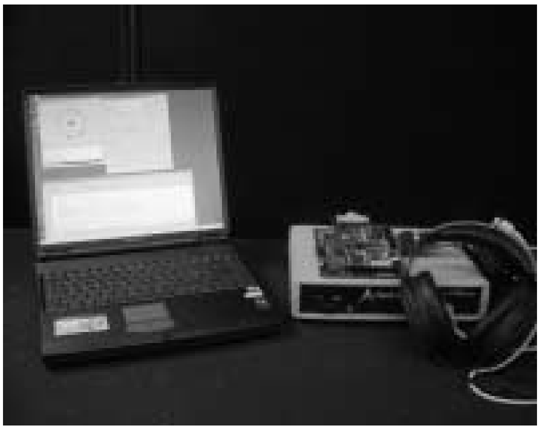
3D Ambisonic based Binaural Sound Reproduction System

Project Manager: Robert Höldrich (robert.hoeldrich@kug.ac.at)
Contributors: Markus Noisternig
Alois Sontacchi
Thomas Musil
Piotr Majdak

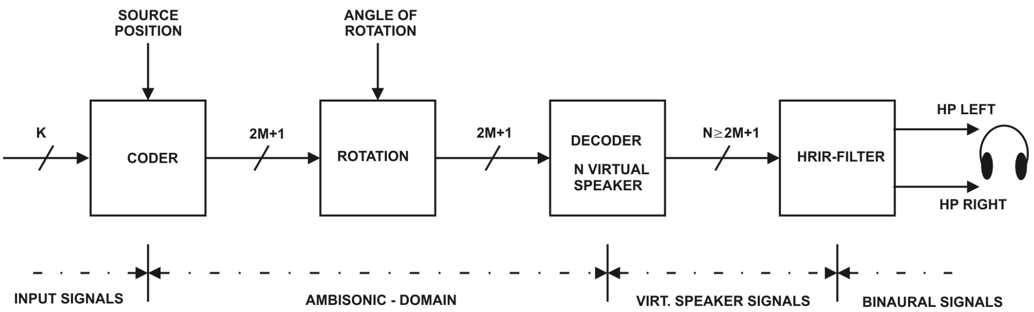
Abstract:

A 3D real time rendering engine for sound reproduction via headphones is presented. Binaural sound reproduction requires filtering of virtual sources with head related transfer functions (HRTFs). To improve source localization capabilities head tracking as well as room simulation have to be incorporated. This yields the problem of high-quality time-varying interpolation between different HRTFs. The proposed solution uses a virtual ambisonic approach that results in time invariant HRTF filter.



Revise:

A review of perceptual literature states that humans are able to locate the position of a sound source with remarkable accuracy using a variety of acoustic cues. Referring to the duplex theory of sound source localization the main cues are the interaural time difference (ITD) and the interaural level difference (ILD) caused by wave propagation time difference and shadowing effects of the head. Due to the relative symmetry of the head points of equal ITD or equal ILD occur, described by the so called “cones of confusion”. This effect yields ambiguities in the perceived vertical position of the sound source and front-back confusions. Also audible artifacts like localization errors and externalization errors caused by distortion of the localization cues through the binaural system occur. The head related transfer functions (HRTFs) capture both, the frequency domain and time domain aspects of the listening cues to a sound position. Binaural sound reproduction using



headphones requires filtering of virtual sources with HRTFs. Using nonindividualized (generic) HRTFs as opposed to individualized HRTFs yields degrading localization accuracy, decreasing externalization and increasing reversal errors. Regarding hearing in natural sound fields humans are able to improve source localization capabilities due to small head movements. To benefit from this phenomenon in virtual reality (VR) applications head tracking has to be incorporated. In time-varying binaural sound reproduction systems this yields the problem of high-quality time-varying interpolation between different HRTFs. The proposed system solves this problem using a virtual ambisonic approach that results in time-invariant HRTF filters. The influence of the head position is taken into account with cheap time-variant rotation matrices in the ambisonic domain using three degrees of freedom. To improve the perceived externity (out of head localization) of the virtual sound sources a realistic reverberent context has to be taken into account as well. First early reflections are incorporated using a simple geometrical approach calculating mirror sources depending to the enclosing walls. Now its possible to characterize mirror sources by their position and their time delay relative to the direct sound. The time difference is taken into account using simple delay lines. To embrace absorption caused by the reflections at the walls additional low pass filter are implemented. Because of the exponentially increase of the number of mirror sources over time its important to reduce the computationally cost of encoding. Therefore the mirror sources are combined to several regions of influence. Henceforth mirror sources dedicated to the same region of influence are merged and encoded to the binaural system depending to the regions main position. Secondly a realistic representation of the diffuse reverberent sound field is calculated using algorithms presented by David Griesinger and Jon Dattoro. These late reverberations are significant to simulate spaciousness.

The proposed system is implemented on a standard notebook using PD. PD stands for Pure Data, a graphically based open source computer music software for real time applications originally written by Miller Puckette.

Simulation Results: