Real-time Implementation of the Spectral Division Method for Binaural Personal Audio Delivery with Head Tracking

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Outline

• Introduction
• SDM Method and Target Shifting
• Practical Implementation
• Discussion
• Conclusion
Introduction

• Personal Audio Delivery
• Filter Design Approaches
  • Pressure Matching (PM)\[^1\], Acoustic Contrast Control (ACC)\[^2\]
    • Regularization required
  • Spectral Division Method (SDM) Based\[^3\]
    • Spatial window configuration

Introduction

• Personal audio with fixed “sweet spots”
  • Performance degradation due to head movements
• Solution for head tracking
  • PM-based\textsuperscript{[4]}
  • SDM-based: aim of the paper

\textsuperscript{[4]} Gálvez et al., JAES, 2019
SDM and Target Shifting

- Spectral Division Method (SDM)\cite{5}

\begin{align*}
\text{Sound source distribution } D(x_0, \omega) \\
\text{Spatial-temporal transfer function } G(x - x_0, \omega) \\
\text{Target sound pressure distribution } P_y(x, \omega) &= \int_{-\infty}^{\infty} D(x_0, \omega) G_y(x - x_0, \omega) dx_0 \\
\text{Spatial Fourier Transform along the } x\text{-axis}\end{align*}

\[ \tilde{P}_y(k_x, y, 0, \omega) = \tilde{D}(k_x, \omega) \cdot \tilde{G}_y(k_x, y, 0, \omega) \]

\[ \tilde{D}(k_x, \omega) = \frac{\tilde{P}_y(k_x, y, 0, \omega)}{\tilde{G}_y(k_x, y, 0, \omega)} \]

\cite{5} Ahrens and Spors, ITASLP, 2010
SDM and Target Shifting

• Target Shifting

Assuming the listener moves in $x$ direction

$$P_{shifted}(x, \omega) = P(x - x_0, \omega)$$

Spatial Fourier Transform

$$\tilde{P}_{shifted}(k_x, \omega) = e^{-j k_x x_0} \tilde{P}(k_x, \omega)$$

Shifting operation is achieved through multiplication in real time
Practical Implementation

• Specifying spatial window

Practical Implementation

- Proposed scheme
Discussion

• Potential Advantages
  • Cascading other audio filters designed for the center position
  • Using measured spatial-temporal transfer functions to improve performance\cite{8}
  • Varying specified spatial window for more flexible design

\cite{8} Ahrens et al., WASPAA, 2013.
Conclusion

• We proposed a scheme for implementing SDM in real time for binaural personal audio delivery
• Shifting of the target sound field is done through simple multiplications in the wavenumber domain
• Binaural sound image is preserved regardless of head movements
• Future Work
  • Optimizing the filter calculation process\[8\]
  • Numerical simulation and physical experiments for evaluation

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