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

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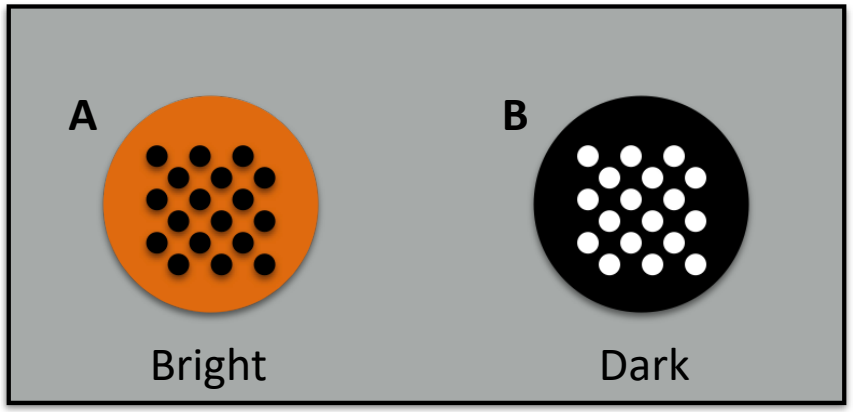
Outline

- 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



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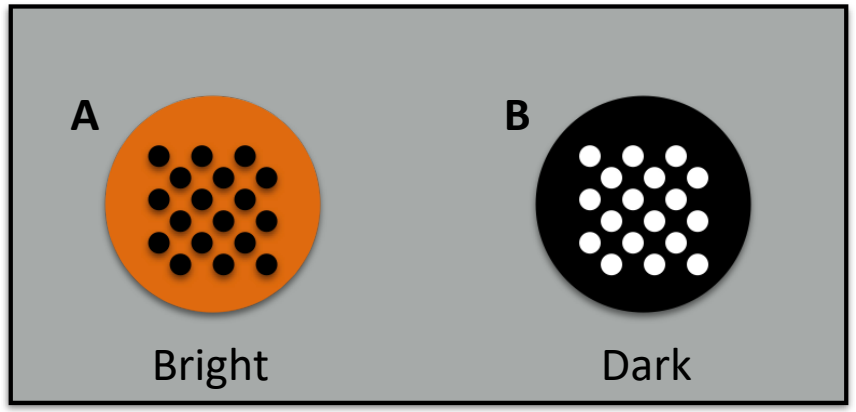
[1] Kirkeby et al., ITASLP, 1998 [2] Choi and Kim, JASA, 2002 [3] Okamoto, ICASSP, 2014

Introduction

- Personal audio with fixed "sweet spots"
  - Performance degradation due to head movements
- Solution for head tracking
  - PM-based[4]
  - SDM-based: aim of the paper



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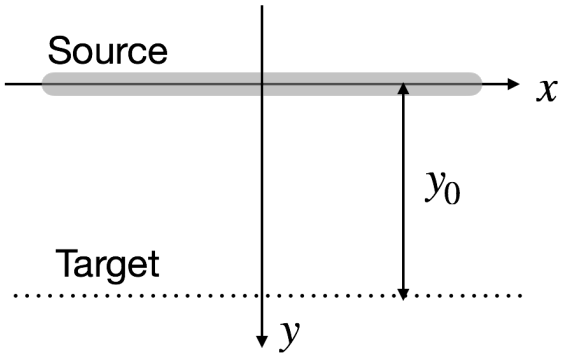
[4] Gálvez et al., JAES, 2019

SDM and Target Shifting

- Spectral Division Method (SDM)[5]



Sound source distribution $D(\boldsymbol{x_0}, \omega)$

Spatial-temporal transfer function $\mathrm{G}(\boldsymbol{x} - \boldsymbol{x_0}, \omega)$

Target sound pressure distribution

$$\mathrm{P_y}(\boldsymbol{x}, \omega) = \int_{-\infty}^{\infty} D(\boldsymbol{x_0}, \omega) G_y(\boldsymbol{x} - \boldsymbol{x_0}, \omega) d\boldsymbol{x_0}$$

Spatial Fourier Transform along the *x*-axis

$$\tilde{P}_y(k_x, y, 0, \omega) = \tilde{D}(k_x, \omega) \cdot \tilde{G}_y(k_x, y, 0, \omega) \longleftrightarrow \tilde{D}(k_x, \omega) = \frac{\tilde{P}_y(k_x, y, 0, \omega)}{\tilde{G}_y(k_x, y, 0, \omega)}$$

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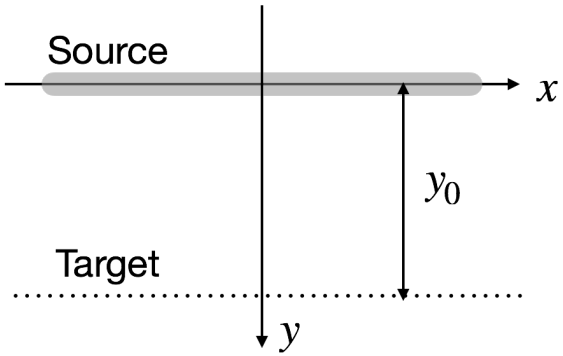
[5] Ahrens and Spors, ITASLP, 2010

SDM and Target Shifting

- Target Shifting



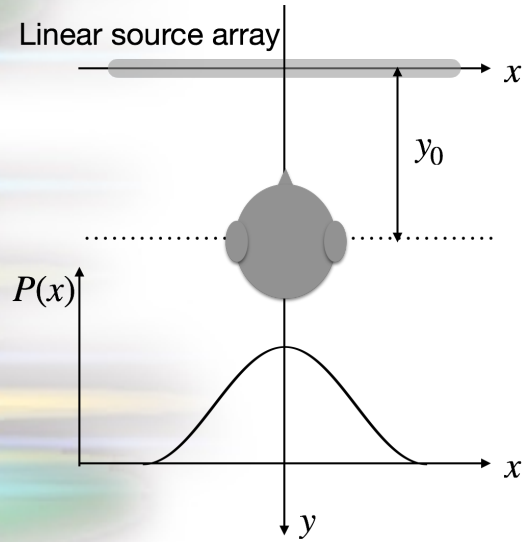
Assuming the listener moves in *x* direction

$$P_{shifted}(x,\omega) = P(x - x_0,\omega) \quad \xleftrightarrow{\text{Spatial Fourier Transform}} \quad \tilde{P}_{shifted}(\mathrm{k_x},\omega) = e^{-jk_x x_0}\tilde{P}(k_x,\omega)$$

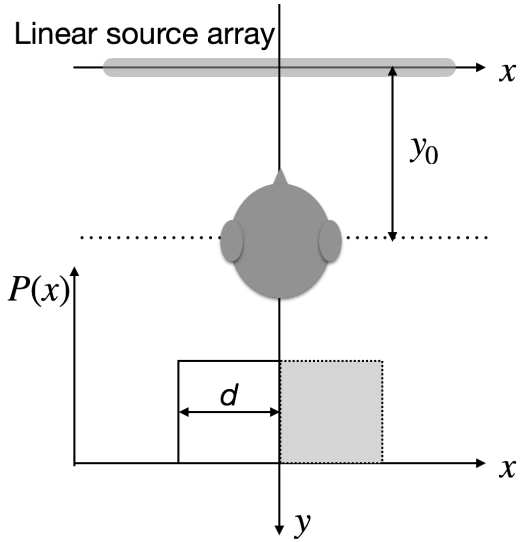
Shifting operation is achieved through multiplication in real time

Practical Implementation

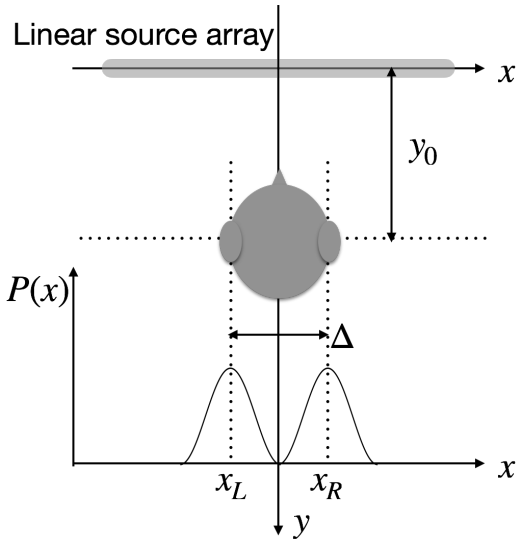
- Specifying spatial window



Single Hanning[6]



Double Rectangular[7]



Double Hanning

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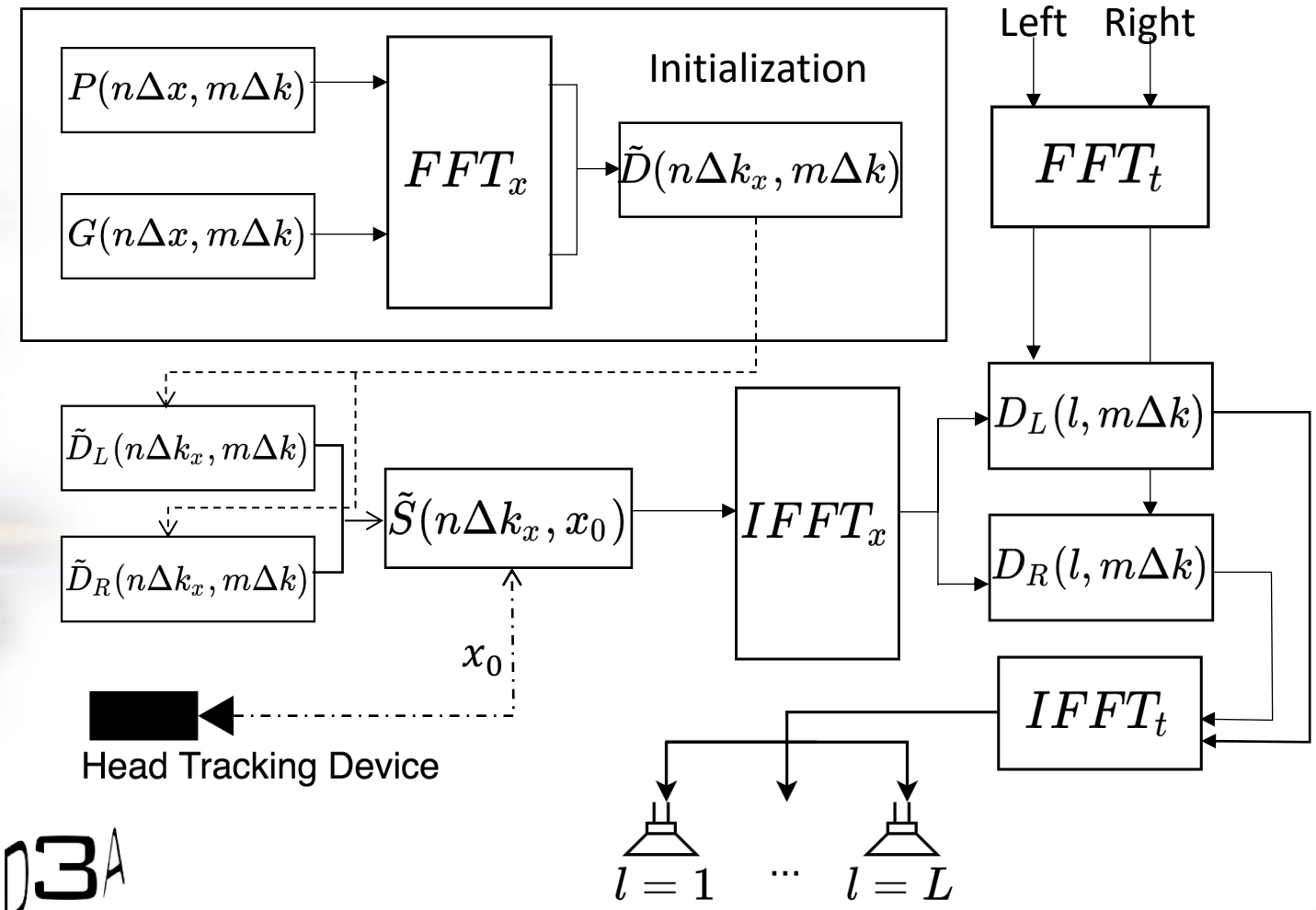
[6] Okamoto and Sakaguchi, JASA, 2017 [7] Ahrens et al., WASPAA, 2013

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[8]
  - Varying specified spatial window for more flexible design

[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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[8] Ahrens et al., WASPAA, 2013.

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