Source Rendering on Dynamic Audio Displays

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Motivation for Research

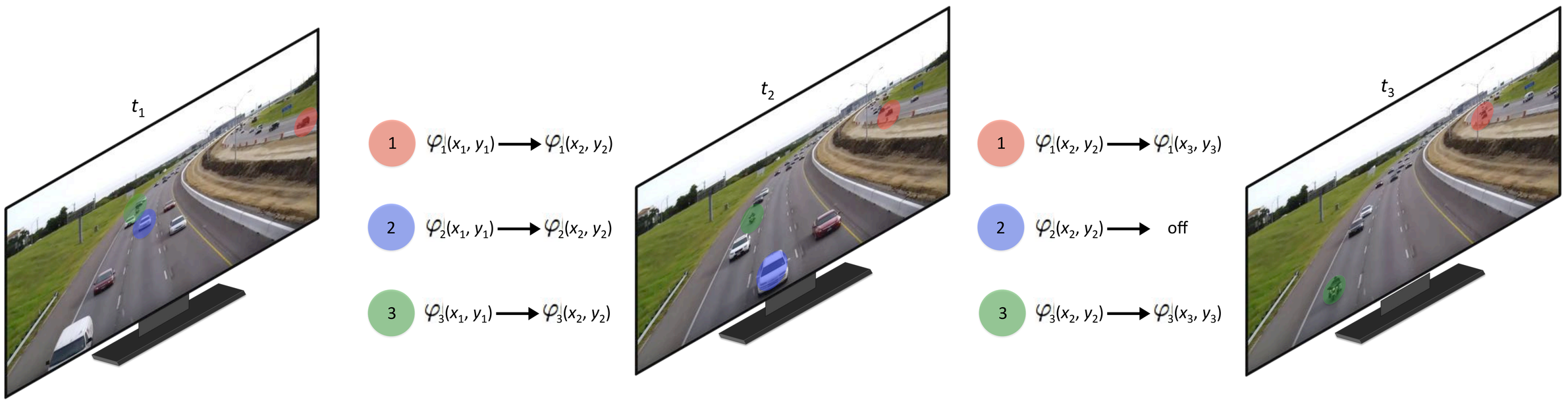
Display technology has seen great changes in the past twenty years. Displays have become equipped with touch sensitive interfaces, seen improvements in visual resolution, gained portability, and have become more compact and thin. On the other hand, loudspeaker devices have undergone relatively few fundamental changes since their inception in the early 20th century. The traditional loudspeaker has become difficult to integrate into space-constrained devices such as smartphones, tablets, computer displays, and television screens. As a result, audio quality is often sacrificed to accommodate the improvements in visual quality as displays become thinner and more compact, oftentimes requiring the consumer to purchase additional sound bar or subwoofer units to bypass the internal speakers of the device.

What is an Audio Display?

An audio display employs an array of force exciters to induce sound-producing bending waves on the screen of a display. The exciter array can be used to render localized sound sources at specific locations on the display screen. These localized sound sources have the potential for a number of intriguing multimodal functions including stereo imaging, the ability to dynamically align audio sources with video images, and steady-state haptic vibration rendering for touch feedback on mobile devices.

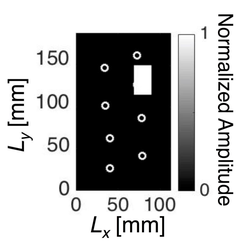
Mapping Audio Objects to Positions on the Screen

Define a position function $\varphi_i(x_t, y_t)$ on the surface of the panel for each audio object *i* at each instant in time *t*.



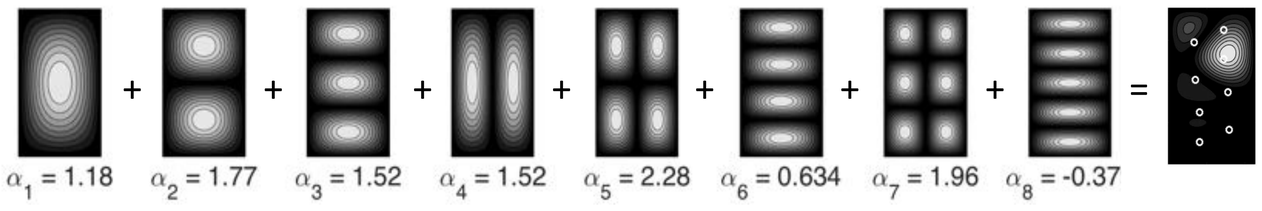
Rendering Sources at the Object Position

Define a target source vibration function $\varphi(x.y)$.



Determine band-limited Fourier series representation of $\varphi(x, y)$ using the set of bending modes as a basis.

$$\alpha_r = \frac{4}{S}\int_0^{L_x}\int_0^{L_y} \varphi(x,y)\Phi_r(x,y)\,dy\,dx$$

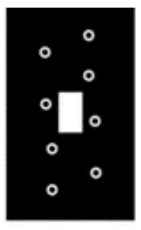


Dynamically Moving Rendered Sources

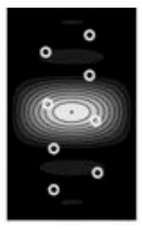
A unique set of spatial Fourier series coefficients is required to render a source at each new position. The efficiency of this computation may be improved by applying a shifting algorithm to the spatial Fourier coefficients for a predetermined source position. The new set of spatial Fourier coefficients may be used to construct the translated version of the rendered source

Coordinates of Shifted Source Position (x_1, y_1)

Initial Source Position at (x_0, y_0)



Band-Limited Reconstruction



Initial Fourier Coefficients

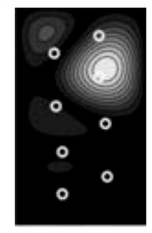
$$\mathbf{A} = \begin{bmatrix} \alpha_1 \\ \alpha_2 \\ \vdots \\ \alpha_N \end{bmatrix}$$

Shifting Algorithm for Spatial Fourier Series

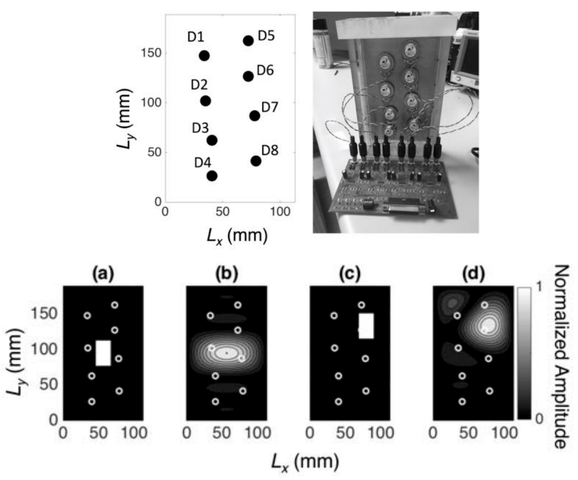
Fourier Coefficients of Shifted Source

$$\mathbf{Z} = \begin{bmatrix} Z_1 \\ Z_2 \\ \vdots \\ Z_N \end{bmatrix}$$

Rendered Shifted Source



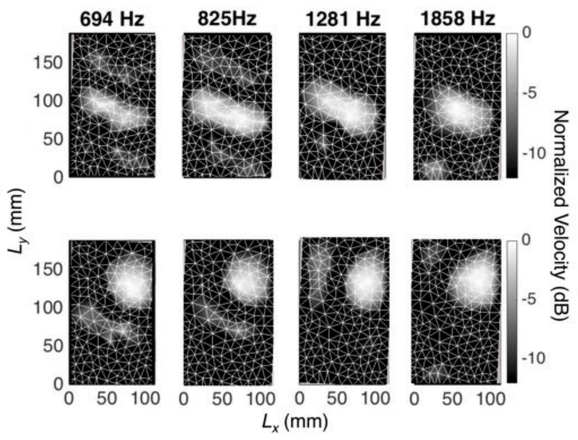
Experimental Results



(Top Left) - Actuator array layout and panel.

(Bottom Left) - Audio objects positioned in the middle and upper right corner of the panel.

(Right) - Laser vibrometer scans of the panel with a source rendered in the center, and the translation of the source to the upper right corner.



Future Work

- Perceptual tests to explore how source vibration rendering influences a listeners ability to localize the source position.
- Employing audio source separation/recognition techniques for video/audio image pairing on screen
- Adapting wave field synthesis techniques to render virtual acoustic sources off screen