Reducing Modal Error Propagation Through Correcting Mismatched Microphone Gains using RAPID

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Abstract

- Spherical microphone arrays are commonly used for capturing higher order soundfields.
- Existing spherical harmonic -based algorithms assume that the conversion from microphone to modes is perfect.
- The error propagation from microphones to modes is not well-understood in literature.
- Error propagation may limit the performance of any spherical harmonic -based algorithms.
- This work investigates modal error propagation and reduce it using a simple and straightforward RAndom PerturbatIons for Diffuse-field (RAPID) calibration.

The Diffuse Field Calibration using RAPID

- RAndom PerturbatIons for Diffuse-field (RAPID), is a novel method for diffuse field calibration.
- Diffuse field response of a microphone array can be obtained in an untreated room by random perturbation and rotation of an array while recording a test signal.
- Requires minimal hardware setup and is shown to match the spatial correlation characteristics of a diffuse field response.
- A video presentation describing RAPID is available at https://vimeo.com/42669671_. Furthermore, a demo of RAPID is available at https://vimeo.com/42668134_

Error Propagation in Modes Caused by Mismatched Microphones Gains

- Consider a spherical microphone array of radius $r$ capable of capturing an order $N$ soundfield, the sound pressure $S$ at $x$ is represented as $S(x) = \sum_{m=0}^{N} \sum_{n=-m}^{m} \frac{A_m^0}{2} e^{i(m+1)x} \sin\left(\frac{n\pi r}{a}\right)
- Sampling in $D$ directions, a matrix of spherical harmonic functions up to order $N$ is written as $Y_{nm}(x) = \left(\frac{4\pi}{a}\right)^{1/2} \frac{\sin\left(\frac{n\pi r}{a}\right)}{\sin\left(\frac{n\pi}{a}\right)} Y_{nm}(x)
- A suitable encoding matrix $E$ satisfies the weighted least-square criteria
- A regularized solution is obtained as $E_{n} = Y_{nm}(x) (Y_{nm}(x)^\dagger Y_{nm}(x))^{-1}
- Let $K$ be a diagonal matrix of arbitrary microphone gains. This produces perturbed transfer functions $H_{m} = K_{m}H_{m}
- From the equations above, ignoring the regularization term, we obtain $E_{n} = Y_{nm}(x) (Y_{nm}(x)^\dagger Y_{nm}(x))^{-1}
- Assuming that there is no microphone gain mismatch, i.e., $K = I$ we obtain $E_{n} = Y_{nm}^0
- Notably, $K$ is not equal to $Y_{nm}$ yields incorrect basic functions.
- Perturbation in just one microphone in the microphone array will result in errors propagation to every mode.

Experimental Evaluation of Spherical Microphone Array Directivity Pattern

- The following apparatus was used in the experiments:
  - A 3D printed two-axis turntable
  - A Dickins Audio 1.8 m radius rhombic triacontrahedron loudspeaker array (DAARRT® 1318)
  - Reference microphone (DBXRTAM)
  - Eigenmike (SN07)
- All experiments were performed in a well-treated room.
- A well-treated environment is not essential for repeatable measurements with RAPID.

Experiment 1: Uncalibrated Directivity Pattern of Eigenmike Obtained using EigenStudio

- Deviations are observed especially at lower frequencies.
- Notably, scattering from the turntable can be observed around 11kHz.

Experiment 2: Calibrated Directivity Pattern of Eigenmike Obtained using RAPID

- Fig. 3 shows the magnitude response offsets of the individual microphones of the em32 from the median response after RAPID.
- Microphone 28 has approximately 5dB error.
- The offset in one microphone was abnormal and not seen on other microphones, but used in this work for demonstrating the value in field testing and calibration.
- Fig. 4 shows FBF's for the calibration versus frequency.
- RAPID provides 6dB improvement in the FBR compared to the uncalibrated case at low frequencies.

Conclusions

- Directivity patterns of a synthesized supercardioid were compared using RAPID and factory calibration.
- The directivity pattern revealed the limitations of the factory calibration in capturing low frequency content with high fidelity.
- Using RAPID for diffuse field calibration extended the measurement capability to lower frequencies.