Regularized Spherical Fourier Transform for Room Impulse Response Interpolation

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I. Introduction

Room impulse response (RIR)

- Room response to sound propagation between a source and a receiver
- Key tool in architectural acoustics and spatial sound for virtual reality
I. Introduction

Room impulse response (RIR)

- RIR is sound pressure measured in a reverberant room with an impulse
- Directional RIR can be measured with a spherical microphone array
I. Introduction

RIR interpolation

- Either because of the low number of microphones or limited computational capacity, there is a need to interpolate RIRs.
I. Introduction

Proposal for RIR interpolation
II. Formulation of the regularized SFT

Continuous spherical Fourier transform (SFT) and inverse spherical Fourier transform (ISFT)

- The SFT and ISFT allows to express the RIRs as a linear combination of orthonormal basis functions on the sphere (e.g., spherical harmonics)

Continuous sound pressure: $\psi$

Infinite spherical harmonics

Infinite SFT coefficients

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II. Formulation of the regularized SFT

*Spherical discretization*

- Sample of sparse RIR
- Sample of dense RIR

**Discrete SFT**

- Frequency limit
- Uniform distribution: Interpolation error ✓
- No-uniform distribution: Interpolation error ✗❗

**ISFT**

**RIR interpolation**

$L$ microphones

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II. Formulation of the regularized SFT

*Regularized SFT*

- Frequency limit.
- Uniform distribution: Interpolation error ✓
- No-uniform distribution: Interpolation error ✓
- **Random distribution**: Interpolation error ✓
III. Evaluation of RIR interpolation

Initial Conditions

Room dimensions
4.62m wide, 3.84m long, 3m high.
Reverberation time: 0.2 s.
Sampling frequency: 16 kHz.
Number of samples in time: 3200.

Sparse grid
Radius: $r = 8$ cm
Random distribution, $L = 49, 16$.

Dense grid
Icosphere distribution, 162 microphones
III. Evaluation of RIR interpolation

RIR energy comparison

- In both cases, the energy remains concentrated within the first 100 ms
- Envelopes are very similar in the region of interest

Energy of the target RIRs

Energy of the interpolated RIRs
III. Evaluation of RIR

Interpolation error

\[ \lambda = 0 : \text{non-regularized} \]

\[ \lambda > 0 : \text{regularized} \]

Simulated RIRs

- Sparse RIR (initial data)
- Dense RIR (target data)

\[ \psi_{\text{sparse}} \]
\[ \psi_{\text{dense}} \]

Low-pass filter

SFT

ISFT

Interpolated RIR

\[ \hat{\psi}_{\text{dense}} \]

Calculation of the interpolation error

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III. Evaluation of RIR interpolation

Interpolation error

Number of microphones: $L = 49$
Max order: $N_{\text{max}} = 6$

Number of microphones: $L = 16$
Max order: $N_{\text{max}} = 3$
IV. Conclusions

- Regularized SFT based interpolation maintained the errors bounded at high-energy values in time.

- Extensions to this work might include physics-based frameworks for the reconstruction of sound pressure fields.

- Open-source library available at: https://github.com/AlarconGanoza/sphericalAcoustic

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We invite you to use our library