Beamforming using a spherical microphone array based on legacy microphone characteristics

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Abstract

We present an approach for projecting frequency-dependent directivity pattern of classic recording microphones onto steerable beams created with a spherical microphone array.

In an anechoic chamber, the spatial and timbral characteristics of a classic recording microphone and the characteristics of a novel 120-channel spherical microphone array is measured.

Using a least-square matching approach, these impulse responses were used to derive the set of filters that synthesize the desired legacy recording microphone characteristic from the spherical microphone array.

Motivation

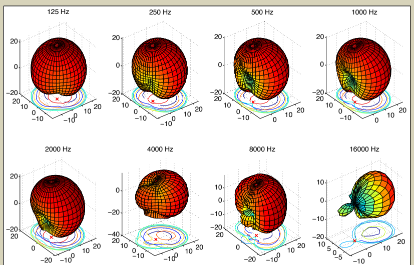
1. Recording and post-production processes could be simplified through flexible beamforming technology offered by spherical microphone arrays.

2. Tonmeister often reject spherical microphone arrays and prefer classic (legacy) recording microphones

3. This might be due to a preference for distinct spatial and timbral characteristics of different microphone types and brands.

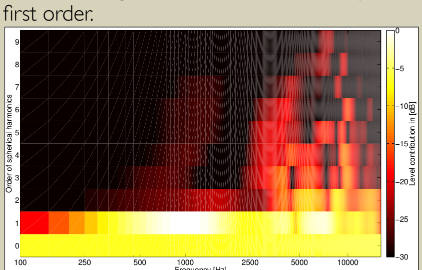
A recording microphone

We measured the frequency response of a mid-price cardioid recording microphone in an anechoic chamber.



Directivity plot of the measured recording microphone

The spherical harmonics decomposition reveals contribution of higher orders harmonics, not just zero and first order.



Frequency dependent contribution of spherical harmonics to the overall microphone directivity

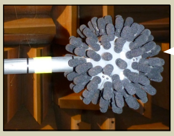
The SAM-array

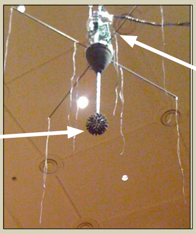
The **S**pheric**A**l **M**icrophone array is a co-development of CNMAT and Meyer Sound and consists of 144 microphones.

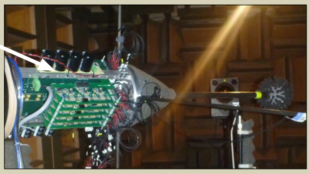
<u>Sphere:</u>
Sensors:
120 x DPA 4080 cardioid capsules
Radius: 6.9 cm
Theoretical spatial resolution: > 9
Rigid body:
Icosahedron
Radius: 4.5 cm

<u>Outriggers:</u>
24 x DPA 4060 omnidirectional capsules
3 sensors per outrigger
spherical layout with three diameters

<u>Onboard electronics:</u>
Mic-amps and AD converter
96kHz / 24 bit
Wordclock sync
Audio Network I/O [2]
FPGA



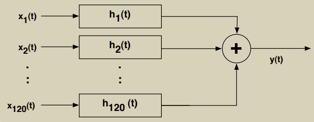




Least-Square Approach

To synthesize the measured recording microphone, we adopted the least-square approach [1] to our needs. The idea is to create the set of FIR filters (*h*) that filters the microphone signals of the spherical microphone array so that the sum of all microphone signals x_n creates a signal *y* which approximates the desired target directivity pattern *q*.

SAM



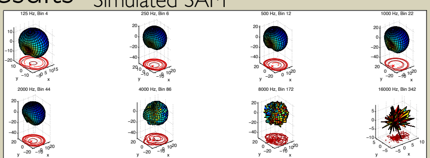
Anonymus recording microphone

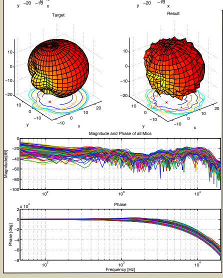
$$[H_k]_{M\times V} = \frac{[C_k]^*_{M\times D}\cdot W_{M\times M}\cdot [Q_k]_D \cdot e^{-j\pi k}}{[C_k]^*_{M\times D}\cdot W_{M\times M}\cdot [C_k]_{D\times M} + \beta_k \cdot [I]_{M\times M}}$$

$[C_k]_{D\times M}$ ...Matrix of 576 x 120 SAM frequency responses measured from 36 x 16 directions, bin *k*
$[Q_k]_D$ ...Frequency response of the anonymus recording microphone, measured from 36 x 16 directions, bin *k*
$W_{M\times M}$ ...Weighting matrix to equalize sampling grid (10 degrees in azimuth and elevation)
β_k ...Frequency-dependent regularization parameter, for frequency bin *k*

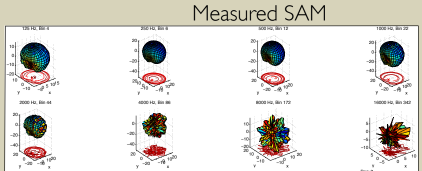
Results

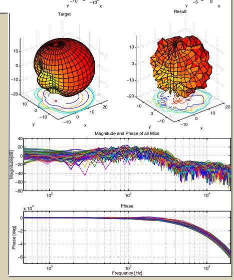
Simulated SAM

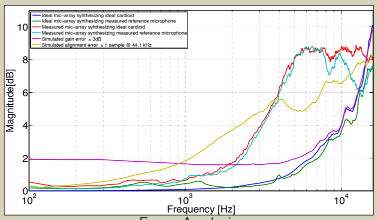




Measured SAM







Error Analysis

Conclusion

- Good results for low and mid frequencies
- Non-optimal results above 3kHz
- Challenges:
  phase alignment of SAM measurements, noise

Future work

- To measure and match other legacy recording microphones, dummy-heads and surround mic setups
- Modeling nonlinear behaviors of microphones
- Subjective evaluation (e.g., ABx listening test)
- Real-time implementation

Acknowledgments

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References

[1] A. Farina, A. Capra, L. Chiesi, and L. Scopece. A spherical microphone array for synthesizing virtual directive microphones in live broadcasting and in post production. In *Proc. of the AES 40th International Conference*, Tokyo, Japan, 2010.

[2] R. Avizienis, A. Freed, T. Suzuki, and D. Wessel. Scalable connectivity processor for computer music performance systems. In *International Computer Music Conference*, pages 523–526, 2000.