Immersive Audiovisual Production Enhancement based on 3D Audio PhD Research Proposal

Andrés Pérez López

September 8, 2017

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Outline

Introduction

Context & Motivation Ambisonics

Scientific Background

Sound Source Localization Blind Source Separation Multimodal Enhancement for BSS Machine Learning for BSS Summary

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Research Proposal

Goals & Contributions Methodology Schedule & Dissemination

Outline for Section 1

Introduction

Context & Motivation Ambisonics

Scientific Background

Sound Source Localization Blind Source Separation Multimodal Enhancement for BSS Machine Learning for BSS Summary

Research Proposal

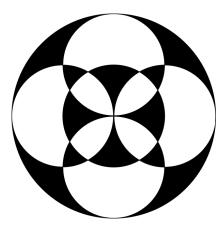
Goals & Contributions Methodology Schedule & Dissemination Context

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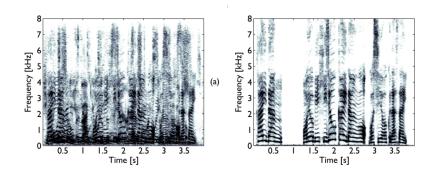


Motivation

Ambisonics



Motivation Blind Source Separation



Adapted from N. Epain et. al., Blind Source Separation using Independent Componen Analysis in the Spherical Harmonics Domain, 2010 $\langle \Box \rangle \vee \langle \Box \rangle \vee \langle \Box \rangle \vee \langle \Xi \rangle = \langle \Xi \rangle = \Xi$

Motivation Idea

Multichannel spatial information contained in Ambisonics audio might be exploited by Blind Source Separation algorithms.

Outline for Section 1

Introduction

Context & Motivation Ambisonics

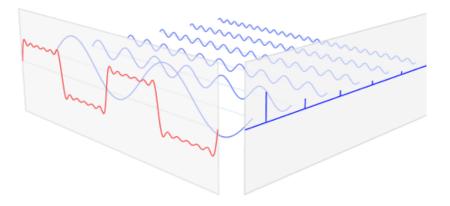
Scientific Background

Sound Source Localization Blind Source Separation Multimodal Enhancement for BSS Machine Learning for BSS Summary

Research Proposal

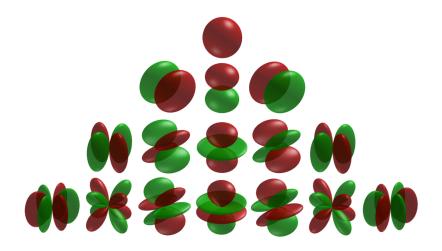
Goals & Contributions Methodology Schedule & Dissemination

Theory

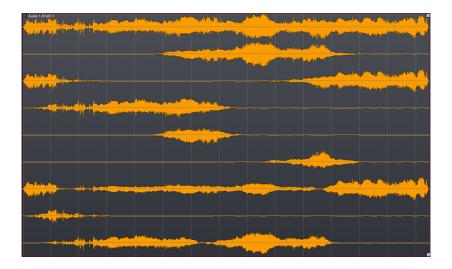


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Theory

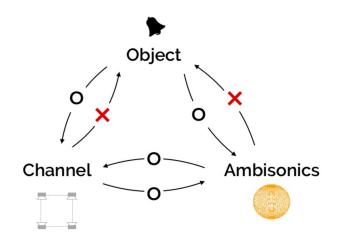


Theory



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Formats



Ambisonics HRTF - Binaural



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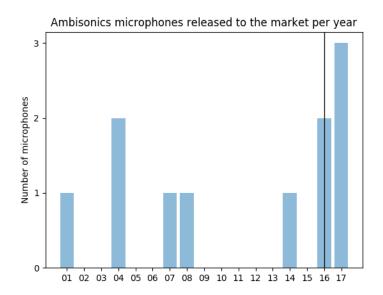
NoiseMakers, Ambi Head

Recording



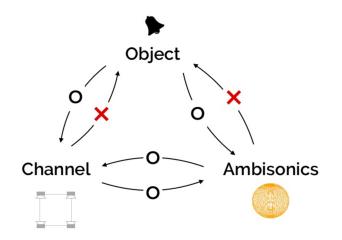
From E. Bates et. al., Comparing Ambisonics Microphones - Part 2, 2017 🗆 > (🖶 > (🚊 > (🪊 >) 🚊

Why?



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Ambisonics Why?



Outline for Section 2

Introduction

Context & Motivation Ambisonics

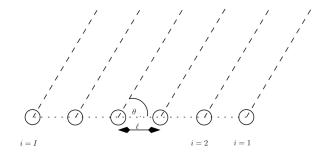
Scientific Background

Sound Source Localization Blind Source Separation Multimodal Enhancement for BSS Machine Learning for BSS Summary

Research Proposal

Goals & Contributions Methodology Schedule & Dissemination

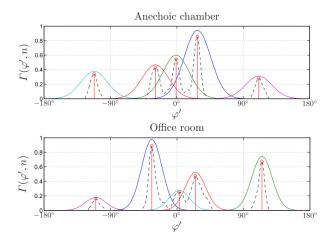
Linear Arrays - TDoA



Ambisonics Intensity Vector Analysis

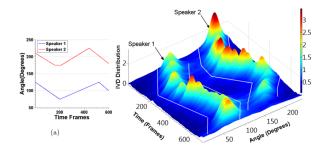
Adapted from O. Thiergart et. al., Localization of Sound Sources in Reverberant Environments Based on Directional Audio Coding Parameters, 2009

B-Format Intensity Vector Analysis



From O. Thiergart et. al., Localization of Sound Sources in Reverberant Environments Based on Directional Audio Coding Parameters, 2009

B-Format Intensity Vector Analysis



From A. Riaz, Adaptive Blind Source Separation Based on Intensity Vector: Statistics, 2015 🖹 🕨 4 🗄 🖉 🗠 🔍

Ambisonics-SSL review

Article	Method	Ambisonics Order	Microphone	Number of Capsules	
Pulkki07 [19]	IV	1	-	-	
Thiergart09 [21]	IV + GMM	1 horizontal	Custom circular	4	
Tervo09 [22]	IV + vonMises MM	1 horizontal	Custom circular	4	
Pavlidi15 [23]	IV + SSZ	1	Custom spherical	32	
Pulkki13 ²⁴	Sectorial IV	HOA	-	-	
He17 [25]	IV + local DOA + ac-curacy + FOSDA	1 horizontal	Custom circular	4	
Ding17 [26]	IV + local DOA + ac-curacy + KMeans	1 horizontal	Custom circular	4	
Jarret10 [27]	PIV	HOA	Eigenmike	32	
Evers14 [28]	PIV + K-Means	HOA	Custom spherical	32	
Moore15 [29]	PIV + DPD	HOA	Custom spherical	32	
Nadiri14 [30]	PWD + SCM + DPD	HOA	Eigenmike	32	
Berge10 [31]	Harpex	1	-	-	
Thiergart12 [32]	Harpex	1	-	-	
Dimoulas07 [34]	A-EBL	1	SoundField	4	
Dimoulas09 [35]	(DWT/SWT)-JTF- A-EBL	1	SoundField	4	

Outline for Section 2

Introduction

Context & Motivation Ambisonics

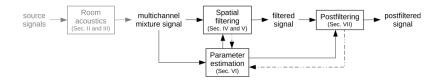
Scientific Background

Sound Source Localization Blind Source Separation Multimodal Enhancement for BSS Machine Learning for BSS Summary

Research Proposal

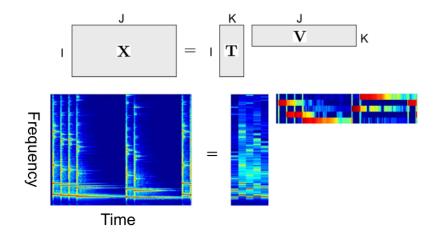
Goals & Contributions Methodology Schedule & Dissemination

Multichannel



From S. Gannot et. al., A Consolidated Perspective on Multi-Microphone Speech Enhancement and Source Separation, 2017

Multichannel

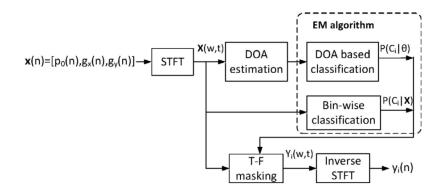


From H. Sawada et. al., Multichannel Extensions of Non-negative Matrix Factorization with Complex-valued Data, 2013

Multichannel BSS review

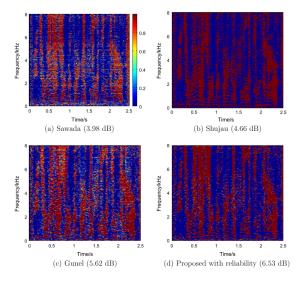
Article	Method	Microphone Array		Target Sound	Dataset	Evaluation Metrics
Epain10 [40]	ICA	Custom spherical	2	Speech	custom	PESQ
Baque16 [41]	ICA (ERBM)	Custom spherical	2	Speech	custom	SDR, DOA
Ozerov09 [42]	NMF	Linear array	-	Music	SiSEC08	SDR, ISR, SIR, SAR
Duong11 [44]	Gaussian SCM + ML	Linear array	-	Speech	custom	SDR, ISR, SIR, SAR
Arberet 11 [46]	Gaussian SCM + NMF	Linear array	-	Music	custom	SDR
Sawada13 [38]	Spatial CNMF	Linear array	-	Music	SiSEC11	SDR

Blind Source Separation Ambisonics SSL-BSS



From X. Chen et. al., Reverberant speech separation with probabilistic time-frequency masking for B-format recordings, 2015

Blind Source Separation Ambisonics SSL-BSS



From X. Chen et. al., Reverberant speech separation with probabilistic time-frequency masking for B-format recordings, 2015 $\triangleleft \square \vdash \triangleleft \bigcirc \square \vdash \triangleleft \bigcirc \square \vdash \triangleleft \bigcirc \square \vdash \triangleleft \bigcirc \square$

Ambisonics SSL-BSS review

Article	Method	Ambisonics Microphone	L	Target Sound	Dataset	Evaluatio Metrics
Gunel08 [49]	IV + vonMises MM + Softmask	SoundField	1 h	Speech	Music for Archimedes	SDR, SIR
Riaz15 [50]	Gunel + Mic Correc- tion + Adaptive Fil- ter + Location Esti- mation	SoundField	1 h	Speech, Music	Music for Archimedes	SDR, ISR, SIR, SAR
Shujau11 [51]	IV + VAD + DOA Clustering + Binary Mask	AVS	1 h	Speech	TIMIT	SDR, ISR, PESQ- MOS
Chen15 [53]	IV + MV + Softmask	SoundField	1 h	Speech	TIMIT	SDR, ISR, PESQ- MOS

Outline for Section 2

Introduction

Context & Motivation Ambisonics

Scientific Background

Sound Source Localization Blind Source Separation Multimodal Enhancement for BSS Machine Learning for BSS Summary

Research Proposal

Goals & Contributions Methodology Schedule & Dissemination

Multimodal Enhancement for BSS



- (a) green: audio, blue: visual
- (b) correct detection

(c) observations

(d) bad detection

Multimodal Enhancement for BSS

Multimodal SSL/BSS review

Article	Localization Method	Separation Method	Target	Mic	Camera
Khalidov11 [55]	Conjugate GMM	-	Speech	2 omni	2
Gebru14 [56]	Weighted-Data	-	Speech	Binaural	1
	GMM			head	
Khan13 [57]	MCMC-PF	GMM-EM	Speech	Binaural	2
				head	

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Outline for Section 2

Introduction

Context & Motivation Ambisonics

Scientific Background

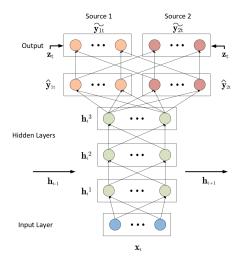
Sound Source Localization Blind Source Separation Multimodal Enhancement for BSS Machine Learning for BSS Summary

Research Proposal

Goals & Contributions Methodology Schedule & Dissemination

Machine Learning for BSS

Monophonic Musical BSS



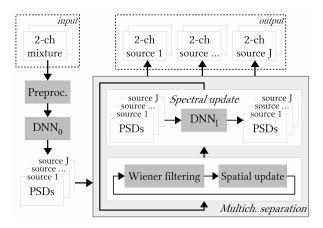
From P. Huang et. al., Singing-Voice Separation from Monaural Recordings using Deep Recurrent Neural Networks, 2014

Machine Learning for BSS

Monophonic Musical DNN for BSS review

Article	DNN Architec- ture	Target	Dataset	Evaluation Metrics
Huang14 [58]	DNN, DRNN, sRNN	Singing Voice	MIR-1k	SDR, SIR, SAR
Uhlich15 [59]	ReLU DNNU	Predefined In- strument	TRIOS	SDR, SIR, SAR
Uhlich17 [60]	Feed-Forward, Bi-LSTM	Vocal, Bass, Drum, other	DSD100	SDR,R
Sebastian16 [61]	MOD-GD DRNN	Singing Voice, Vocal-Violin	MIR-1k	SDR, SIR, SAR
Chandna17 [62]	DNN, 2 convolu- tional layers	Vocal, Bass, Drum, other	DSD100, MSD100	SDR, SIR, SAR, ISR

Machine Learning for BSS Multichannel BSS

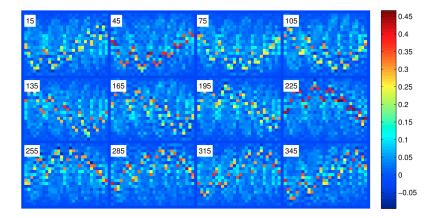


From A. Nugraha et. al., Multichannel music separation with deep neural networks, 2016 (🚊) () 🚊 () ()

Multichannel DNN for BSS review

Article	Method	Microph Array	ione	#Mics	Target Sound	Dataset	Evaluation Metrics
Nugraha16 [63]	DNN-PSD + SCM	Custom ear	lin-	2	Vocals	DSD100	SDR, SIR, ISR, SAR
Nugraha16(2) [64]	DNN-PSD + SCM	Custom ear	lin-	6	Speech	CHiME-3	SDR, SIR, ISR, SAR
Wisdom16 [65]	DMCGMM	Custom cular	cir-	8	Speech	WSJCAM0 REVERB	SDR
Erruz17 [66]	ILD-CNN	-		2	Music	DSD100	SDR, SIR, ISR, SAR

Sound Source Localization

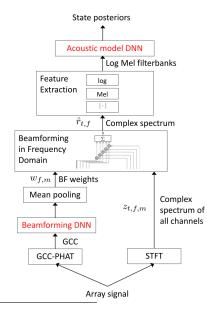


From X. Xiao et. al., A learning-based approach to direction of arrival estimation in noisy and reverberant environments, 2015

Multichannel DNN for SSL review

Article	Method	Microphone Array	#Mics	Target Sound	Dataset	Evaluation Metrics
Xiao15 [67]	MLP GCC- PHAT	Custom cir- cular	8	Speech	WSJCAM0	DOA RMSE, MAE
Chakrabarty17 [68]	phase spec- trogram CNN	Custom lin- ear	4	Speech	Synthesized Noise	SDR

Multichannel SSL-BSS



From X. Xiao et. al., Deep Beamforming Networks for Multi-Channel Speech Recognition, 2016 < 🚊 🛛 🖓 🔍 (~

Multichannel DNN for SSL-BSS review

Article	Method	Microphone Array	#Mics	Target Sound	Dataset	Evaluation Metrics
Araki15 [69]	ITD, ILD DAE	Binaural	2	Speech	PASCAL CHiME	SSNR, CD
Jiang14 [70]	ITD, ILD, GFCC DNN	Binaural	2	Speech	Custom speech, ROOM- SIM	HIT, FA, HIT-FA, SNR
Xiao16 [71]	FF GCC- PHAT, LSTM AM	Custom cir- cular	8	Speech	WSJCAM0, REVERB	WER

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Outline for Section 2

Introduction

Context & Motivation Ambisonics

Scientific Background

Sound Source Localization Blind Source Separation Multimodal Enhancement for BSS Machine Learning for BSS Summary

Research Proposal

Goals & Contributions Methodology Schedule & Dissemination

Summary Euler Diagram

	NN	I	MULTICHANNEL SSL-NN	AMBISONIC SSL-NN	AMBISONIC SSL	AUDIOVISUAL MULTICHANNEL SSL
BSS			MULTICHANNEL BSS-SSL-NN	AMBISONIC BSS-SSL-NN	AMBISONIC BSS-SSL	MULTIMODAL AUDIOVISUAL MULTICHANNEL BSS-SSL
		MONO BSS-NN MUSIC	MULTICHANNEL BSS-SSL-NN MUSIC	AMBISONIC BSS-SSL-NN MUSIC	AMBISONIC BSS-SSL MUSIC	MULTICHANNEL BSS-SSL MUSIC
		MUSIC	MULTICHANNEL BSS-NN MUSIC	AMBISONIC BSS-NN MUSIC	AMBISONIC BSS MUSIC	MULTICHANNEL BSS MUSIC
			MULTICHANNEL BSS-NN	AMBISONIC BSS-NN	AMBISONIC BSS AMBISONIC	MULTICHANNEL BSS
		MONO			MULTI	CHANNEL

Summary Euler Diagram

	NN		П				
				MULTICHANNEL SSL-NN 2.5.2.2 2.9	AMBISONIC SSL-NN	AMBISONIC SSL 2.2.2 2.3	AUDIOVISUAL MULTICHANNEL SSL MULTIMODAL
SS				MULTICHANNEL BSS-SSL-NN	AMBISONIC BSS-SSL-NN	AMBISONIC BSS-SSL2.3.2.2 2.5	AUDIOVISUAL MULTICHANNEL BSS-SSL 2.4.1 2.6
		MONO BSS-NN MUSIC		MULTICHANNEL BSS-SSL-NN MUSIC 2.5.2.3	AMBISONIC BSS-SSL-NN MUSIC	AMBISONIC BSS-SSL MUSIC	MULTICHANNEL BSS-SSL MUSIC
		2.7 MUSIC		MULTICHANNEL BSS-NN MUSIC	AMBISONIC BSS-NN MUSIC	AMBISONIC BSS MUSIC	MULTICHANNEL BSS MUSIC
				MULTICHANNEL BSS-NN 2.5.2.1 2.8	AMBISONIC BSS-NN	AMBISONIC BSS AMBISONIC	MULTICHANNEL BSS 2.3.2.1 2.4
		MONO					CHANNEL

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Outline for Section 3

Introduction

Context & Motivation Ambisonics

Scientific Background

Sound Source Localization Blind Source Separation Multimodal Enhancement for BSS Machine Learning for BSS Summary

Research Proposal

Goals & Contributions Methodology Schedule & Dissemination

Conclusions

BSS-SSL: stablished, but mostly horizontal FOA and speech

¹A. Gannot et. al., A consolidated perspective on multi-microphone speech enhancement and source separation, 2017 $\langle \Box \rangle + \langle \Box \rangle +$

Conclusions

- BSS-SSL: stablished, but mostly horizontal FOA and speech
- DNN: promising results for SSL/BSS, but mostly mic arrays and speech

Conclusions

- BSS-SSL: stablished, but mostly horizontal FOA and speech
- DNN: promising results for SSL/BSS, but mostly mic arrays and speech
- Multimodal: "the area of audio-visual speech processing remains largely understudied despite its great promise"¹

Conclusions

BSS Guidelines²:

1. Consider number of sources and microphones

²A. Gannot et. al., A consolidated perspective on multi-microphone speech enhancement and source separation, 2017 $\langle \Box \rangle + \langle \Box \rangle + \langle \Box \rangle + \langle \Xi + \langle \Xi \rangle + \langle \Xi + \langle \Xi = \langle \Xi = \langle \Xi + \langle \Xi = \langle$

Conclusions

BSS Guidelines²:

- 1. Consider number of sources and microphones
- 2. Exploit microphone array geometry

²A. Gannot et. al., A consolidated perspective on multi-microphone speech enhancement and source separation, 2017

Conclusions

BSS Guidelines²:

- 1. Consider number of sources and microphones
- 2. Exploit microphone array geometry
- 3. Exploit prior/additional information

²A. Gannot et. al., A consolidated perspective on multi-microphone speech enhancement and source separation, 2017

Research Goal:

 Investigation, adaptation and improvement of existing algorithms of Blind Source Separation for application to Ambisonics, specially focusing on musical applications.

Contributions

Collateral Contributions:

1. Investigate SSL for HOA based on DNNs

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Contributions

Collateral Contributions:

- $1. \ \mbox{Investigate SSL}$ for HOA based on DNNs
- 2. Apply Contribution I to BSS, focusing on music

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Contributions

Collateral Contributions:

- 1. Investigate SSL for HOA based on DNNs
- 2. Apply *Contribution I* to BSS, focusing on music
- 3. Investigate raw multichannel BSS for HOA based on DNNs

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Contributions

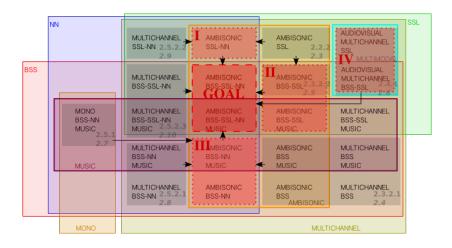
Collateral Contributions:

- 1. Investigate SSL for HOA based on DNNs
- 2. Apply *Contribution I* to BSS, focusing on music
- 3. Investigate raw multichannel BSS for HOA based on DNNs
- 4. New approach to multimodal BSS from immersive audiovisual content

Contributions

	NN						
				TICHANNEL -NN 2.5.2.2 2.9	AMBISONIC SSL-NN	AMBISONIC SSL 2.2.2 2.3	AUDIOVISUAL MULTICHANNEL SSL MULTIMODAL
SS				.TICHANNEL S-SSL-NN	AMBISONIC BSS-SSL-NN	AMBISONIC BSS-SSL ² .3.2.2 2.5	AUDIOVISUAL MULTICHANNEL BSS-SSL 2.4.1 2.6
		MONO BSS-NN MUSIC 2.5.1	BSS	TICHANNEL S-SSL-NN SIC 2.5.2.3	AMBISONIC BSS-SSL-NN MUSIC	AMBISONIC BSS-SSL MUSIC	MULTICHANNEL BSS-SSL MUSIC
		2.7 MUSIC		TICHANNEL S-NN	AMBISONIC BSS-NN MUSIC	AMBISONIC BSS MUSIC	MULTICHANNEL BSS MUSIC
				TICHANNEL S-NN 2.5.2.1 2.8	AMBISONIC BSS-NN	AMBISONIC BSS AMBISONIC	MULTICHANNEL BSS 2.3.2.1 2.4
		MONO				MULTI	CHANNEL

Contributions



Outline for Section 3

Introduction

Context & Motivation Ambisonics

Scientific Background

Sound Source Localization Blind Source Separation Multimodal Enhancement for BSS Machine Learning for BSS Summary

Research Proposal

Goals & Contributions Methodology Schedule & Dissemination

Dataset

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b-format Show advanced search options	Automatic by relevance 💡 search		
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0 comments

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February 5th,

21 downloads

0 comments

2017

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19 sounds



Agotnes_Terminal_B_forma...thinkink lossius

Ambisonics (surround) field recording done at Ågotnes bus terminal at the Sotra Island west of Bergen, Norway. Busses arriving and ...

B-format bus suburbia ambisonics traffic Sotra Norway Aagotnes

• 1 more result in the same pack "Sotra soundscapes"



amb; ext; yard; summer m... think the

Ambisonic **b-format** recording recorded with the Coresound Tetramic in Pittsburgh, PA. *NOTE: you will need to decode this b-format ambisonic ...

b-format background-traffic birds ambience background cicadas exterior atmosphere summer

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- Creative Commons 0 (11)

tags

aspotnes ambiance ambience ambisonic ambience arms atmosphere 5 **b-format** background supportent background supportent support beach birds but are an car-bys anty acade any exterior field-recording format norway ocean software waves

Dataset

Music:

MSD100/DSD100

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MIR-1k

Speech:

- ► TIMIT
- WSJCAM0

Dataset

Ambisonics Impulse Response:

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- SMIR Generator
- OpenAirLib

Dataset

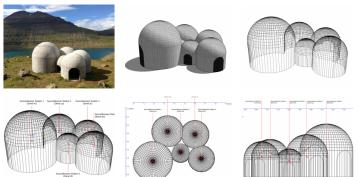


Home	IR Data	Anechoic Data	Resources	About	Log in
		Browse Auraliz	ation Data	Auralizati	on Map

Tvísöngur Sound Sculpture, Iceland (Model)



Photographs and Diagrams:

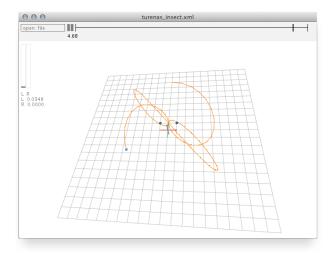


Methodology Dataset Contributions

Collateral Contributions:

- 1. Investigate SSL for HOA based on DNNs
- 2. Apply *Contribution I* to BSS, focusing on music
- 3. Investigate raw multichannel BSS for HOA based on DNNs
- 4. New approach to multimodal BSS from immersive audiovisual content
- 5. New tool for procedural creation of reverberant sound scenes, for training and evaluation purposes

Scene Description: SpatDIF





Ambisonics Microphones Availability:

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- SoundField SPS422B
- EigenMike
- Ambeo
- Zoom H2n

Methodology Experimental Setups



Experimental Setups

YouTube 8M Da	taset E	Explore	Download	Workshop
Vertical Televite Filter Televite Musical (26930) Music of Eritrea (199) Kawai Musical Instruments (185) Shrek The Musical (145) Vertical Music of Eritrea (199) Kawai Musical (145) Musical (145) Mus				

Outline for Section 3

Introduction

Context & Motivation Ambisonics

Scientific Background

Sound Source Localization Blind Source Separation Multimodal Enhancement for BSS Machine Learning for BSS Summary

Research Proposal

Goals & Contributions Methodology Schedule & Dissemination

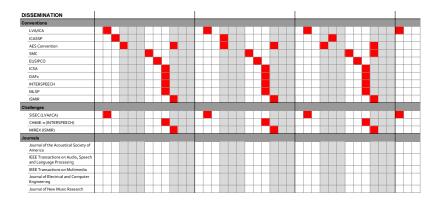
Schedule & Dissemination

Schedule

		2017								2018							2019												2020								
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RESEARCH																																					
Scientific Background																																					
Literature Review																																					
Methodology																																					
Contribution I: SSL																																					
Contribution II : BSS-SSL																																					
Contribution III: DNN																								Τ													
Contribution IV: Multimodal																																					
Contribution V - Dataset																								Τ													
Main Goal								Т		Т													Г	Т													
Writing																																					
Thesis Review and Writing																																					

Schedule & Dissemination

Dissemination



Thank you Questions?