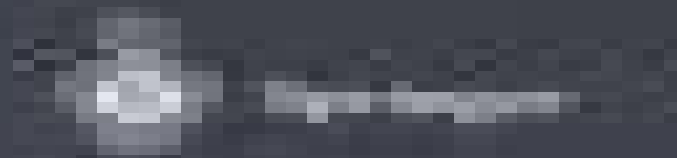


Microphone Arrays



**Microphone Arrays Signal Processing Techniques And
Applications Digital Signal Processing By Michael
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Michael Brandstein, Darren Ward



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Microphone Arrays Michael Brandstein, Darren Ward, 2013-04-17 The study and implementation of microphone arrays originated over 20 years ago Thanks to the research and experimental developments pursued to the present day the field has matured to the point that array based technology now has immediate applicability to a number of current systems and a vast potential for the improvement of existing products and the creation of future devices In putting this book together our goal was to provide for the first time a single complete reference on microphone arrays We invited the top researchers in the field to contribute articles addressing their specific topics of study The reception we received from our colleagues was quite enthusiastic and very encouraging There was the general consensus that a work of this kind was well overdue The results provided in this collection cover the current state of the art in microphone array research development and technological application This text is organized into four sections which roughly follow the major areas of microphone array research today Parts I and II are primarily theoretical in nature and emphasize the use of microphone arrays for speech enhancement and source localization respectively Part III presents a number of specific applications of array based technology Part IV addresses some open questions and explores the future of the field

Microphone Array Signal Processing Jacob Benesty, Jingdong Chen, Yiteng Huang, 2008-03-11 In the past few years we have written and edited several books in the area of acoustic and speech signal processing The reason behind this endeavor is that there were almost no books available in the literature when we first started while there was and still is a real need to publish manuscripts summarizing the most useful ideas concepts results and state of the art algorithms in this important area of research According to all the feedback we have received so far we can say that we were right in doing this Recently several other researchers have followed us in this journey and have published interesting books with their own visions and perspectives The idea of writing a book on Microphone Array Signal Processing comes from discussions we have had with many colleagues and friends As a consequence of these discussions we came up with the conclusion that again there is an urgent need for a monograph that carefully explains the theory and implementation of microphone arrays While there are many manuscripts on antenna arrays from a narrowband perspective narrowband signals and narrowband processing the literature is quite scarce when it comes to sensor arrays explained from a truly broadband perspective Many algorithms for speech applications were simply borrowed from narrowband antenna arrays However a direct application of narrowband ideas to broadband speech processing may not be necessarily appropriate and can lead to many misunderstandings

Acoustic Signal Processing for Telecommunication Steven L. Gay, Jacob Benesty, 2012-12-06 158 2 Wiener Filtering 159 3 Speech Enhancement by Short Time Spectral Modification 3 1 Short Time Fourier Analysis and Synthesis 159 160 3 2 Short Time Wiener Filter 161 3 3 Power Subtraction 3 4 Magnitude Subtraction 162 3 5 Parametric Wiener Filtering 163 164 3 6 Review and Discussion Averaging Techniques

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Theory and Applications of Spherical Microphone Array Processing Daniel P. Jarrett, Emanuel A.P. Habets, Patrick A. Naylor, 2016-08-26 This book presents the signal processing algorithms that have been developed to process the signals acquired by a spherical microphone array Spherical microphone arrays can be used to capture the sound field in three dimensions and have received significant interest from researchers and audio engineers Algorithms for spherical array processing are different to corresponding algorithms already known in the literature of linear and planar arrays because the spherical geometry can be exploited to great beneficial effect The authors aim to advance the field of spherical array processing by helping those new to the field to study it efficiently and from a single source as well as by offering a way for more experienced researchers and engineers to consolidate their understanding adding either or both of breadth and depth The level of the presentation corresponds to graduate studies at MSc and PhD level This book begins with a presentation of some of the essential mathematical and physical theory relevant to spherical microphone arrays and of an acoustic impulse response simulation method which can be used to comprehensively evaluate spherical array processing algorithms in reverberant environments The chapter on acoustic parameter estimation describes the way in which useful descriptions of acoustic scenes can be parameterized and the signal processing algorithms that can be used to estimate the parameter values using spherical microphone arrays Subsequent chapters exploit these parameters including in particular measures of direction of arrival and of diffuseness of a sound field The array processing algorithms are then classified into two main classes each described in a separate chapter These are signal dependent and signal independent beamforming algorithms Although signal dependent beamforming algorithms are in theory able to provide better performance compared to the signal independent algorithms they are currently rarely used in practice The main reason for this is that the statistical information required by these algorithms is difficult to estimate In a subsequent chapter it is shown how the estimated acoustic parameters can be used in the design of signal dependent beamforming algorithms This final step closes at least in

part the gap between theory and practice **Study and Design of Differential Microphone Arrays** Jacob Benesty, Chen Jingdong, 2012-10-23 Microphone arrays have attracted a lot of interest over the last few decades since they have the potential to solve many important problems such as noise reduction speech enhancement source separation dereverberation spatial sound recording and source localization tracking to name a few However the design and implementation of microphone arrays with beamforming algorithms is not a trivial task when it comes to processing broadband signals such as speech Indeed in most sensor arrangements the beamformer output tends to have a frequency dependent response One exception perhaps is the family of differential microphone arrays DMAs who have the promise to form frequency independent responses Moreover they have the potential to attain high directional gains with small and compact apertures As a result this type of microphone arrays has drawn much research and development attention recently This book is intended to provide a systematic study of DMAs from a signal processing perspective The primary objective is to develop a rigorous but yet simple theory for the design implementation and performance analysis of DMAs The theory includes some signal processing techniques for the design of commonly used first order second order third order and also the general Nth order DMAs For each order particular examples are given on how to form standard directional patterns such as the dipole cardioid supercardioid hypercardioid subcardioid and quadrupole The study demonstrates the performance of the different order DMAs in terms of beam pattern directivity factor white noise gain and gain for point sources The inherent relationship between differential processing and adaptive beamforming is discussed which provides a better understanding of DMAs and why they can achieve high directional gain Finally we show how to design DMAs that can be robust against white noise amplification *Microphone Arrays* Jacob Benesty, Gongping Huang, Jingdong Chen, Ningning Pan, 2023-08-09 This book explains the motivation for using microphone arrays as opposed to using a single sensor for sound acquisition The book then goes on to summarize the most useful ideas concepts results and new algorithms therein The material presented in this work includes analysis of the advantages of using microphone arrays including dimensionality reduction to remove the redundancy while preserving the variability of the array signals using the principal component analysis PCA The authors also discuss benefits such as beamforming with low rank approximations fixed adaptive and robust distortionless beamforming differential beamforming and a new form of binaural beamforming that takes advantage of both beamforming and human binaural hearing properties to improve speech intelligibility The book makes the microphone array signal processing theory and applications available in a complete and self contained text The authors attempt to explain the main ideas in a clear and rigorous way so that the reader can easily capture the potentials opportunities challenges and limitations of microphone array signal processing This book is written for those who work on the topics of microphone arrays noise reduction speech enhancement speech communication and human machine speech interfaces *Audio Signal Processing for Next-Generation Multimedia Communication Systems* Yiteng (Arden) Huang, Jacob Benesty, 2004-03-31 Audio Signal Processing for Next

Generation Multimedia Communication Systems presents cutting edge digital signal processing theory and implementation techniques for problems including speech acquisition and enhancement using microphone arrays new adaptive filtering algorithms multichannel acoustic echo cancellation sound source tracking and separation audio coding and realistic sound stage reproduction This book s focus is almost exclusively on the processing transmission and presentation of audio and acoustic signals in multimedia communications for telecollaboration where immersive acoustics will play a great role in the near future

Study and Design of Differential Microphone Arrays Jacob Benesty, Chen Jingdong, 2012-10-23 Microphone arrays have attracted a lot of interest over the last few decades since they have the potential to solve many important problems such as noise reduction speech enhancement source separation dereverberation spatial sound recording and source localization tracking to name a few However the design and implementation of microphone arrays with beamforming algorithms is not a trivial task when it comes to processing broadband signals such as speech Indeed in most sensor arrangements the beamformer output tends to have a frequency dependent response One exception perhaps is the family of differential microphone arrays DMAs who have the promise to form frequency independent responses Moreover they have the potential to attain high directional gains with small and compact apertures As a result this type of microphone arrays has drawn much research and development attention recently This book is intended to provide a systematic study of DMAs from a signal processing perspective The primary objective is to develop a rigorous but yet simple theory for the design implementation and performance analysis of DMAs The theory includes some signal processing techniques for the design of commonly used first order second order third order and also the general Nth order DMAs For each order particular examples are given on how to form standard directional patterns such as the dipole cardioid supercardioid hypercardioid subcardioid and quadrupole The study demonstrates the performance of the different order DMAs in terms of beam pattern directivity factor white noise gain and gain for point sources The inherent relationship between differential processing and adaptive beamforming is discussed which provides a better understanding of DMAs and why they can achieve high directional gain Finally we show how to design DMAs that can be robust against white noise amplification

Design of Circular

Differential Microphone Arrays Jacob Benesty, Jingdong Chen, Israel Cohen, 2015-01-24 Recently we proposed a completely novel and efficient way to design differential beamforming algorithms for linear microphone arrays Thanks to this very flexible approach any order of differential arrays can be designed Moreover they can be made robust against white noise amplification which is the main inconvenience in these types of arrays The other well known problem with linear arrays is that electronic steering is not really feasible In this book we extend all these fundamental ideas to circular microphone arrays and show that we can design small and compact differential arrays of any order that can be electronically steered in many different directions and offer a good degree of control of the white noise amplification problem high directional gain and frequency independent response We also present a number of practical examples demonstrating that differential

beamforming with circular microphone arrays is likely one of the best candidates for applications involving speech enhancement i.e noise reduction and dereverberation Nearly all of the material presented is new and will be of great interest to engineers students and researchers working with microphone arrays and their applications in all types of telecommunications security and surveillance contexts

Digital Audio Signal Processing Udo Zölzer, 2022-02-24 Digital Audio Signal Processing The fully revised new edition of the popular textbook featuring additional MATLAB exercises and new algorithms for processing digital audio signals Digital Audio Signal Processing DASP techniques are used in a variety of applications ranging from audio streaming and computer generated music to real time signal processing and virtual sound processing Digital Audio Signal Processing provides clear and accessible coverage of the fundamental principles and practical applications of digital audio processing and coding Throughout the book the authors explain a wide range of basic audio processing techniques and highlight new directions for automatic tuning of different algorithms and discuss state of the art DASP approaches Now in its third edition this popular guide is fully updated with the latest signal processing algorithms for audio processing Entirely new chapters cover nonlinear processing Machine Learning ML for audio applications distortion soft hard clipping overdrive equalizers and delay effects sampling and reconstruction and more Covers the fundamentals of quantization filters dynamic range control room simulation sampling rate conversion and audio coding Describes DASP techniques their theoretical foundations and their practical applications Discusses modern studio technology digital transmission systems storage media and home entertainment audio components Features a new introductory chapter and extensively revised content throughout Provides updated application examples and computer based activities supported with MATLAB exercises and interactive JavaScript applets via an author hosted companion website Balancing essential concepts and technological topics Digital Audio Signal Processing Third Edition remains the ideal textbook for advanced music technology and engineering students in audio signal processing courses It is also an invaluable reference for audio engineers hardware and software developers and researchers in both academia and industry

Fundamentals of Spherical Array Processing Boaz Rafaely, 2015-02-18 This book provides a comprehensive introduction to the theory and practice of spherical microphone arrays It is written for graduate students researchers and engineers who work with spherical microphone arrays in a wide range of applications The first two chapters provide the reader with the necessary mathematical and physical background including an introduction to the spherical Fourier transform and the formulation of plane wave sound fields in the spherical harmonic domain The third chapter covers the theory of spatial sampling employed when selecting the positions of microphones to sample sound pressure functions in space Subsequent chapters present various spherical array configurations including the popular rigid sphere based configuration Beamforming spatial filtering in the spherical harmonics domain including axis symmetric beamforming and the performance measures of directivity index and white noise gain are introduced and a range of optimal beamformers for

spherical arrays including beamformers that achieve maximum directivity and maximum robustness and the Dolph Chebyshev beamformer are developed The final chapter discusses more advanced beamformers such as MVDR and LCMV which are tailored to the measured sound field

Applications of Digital Signal Processing to Audio and Acoustics Mark Kahrs, Karlheinz Brandenburg, 1998-03-31 With the advent of multimedia digital signal processing DSP of sound has emerged from the shadow of bandwidth limited speech processing to become a research field of its own To date most research in DSP applied to sound has been concentrated on speech which is bandwidth limited to about 4 kilohertz Speech processing is also limited by the low fidelity typically expected in the telephone network Today the main applications of audio DSP are high quality audio coding and the digital generation and manipulation of music signals They share common research topics including perceptual measurement techniques and analysis synthesis methods Additional important topics are hearing aids using signal processing technology and hardware architectures for digital signal processing of audio In all these areas the last decade has seen a significant amount of application oriented research The frequency range of wideband audio has an upper limit of 20 kilohertz and the resulting difference in frequency range and Signal to Noise Ratio SNR due to sample size must be taken into account when designing DSP algorithms There are whole classes of algorithms that the speech community is not interested in pursuing or using These algorithms and techniques are revealed in this book This book is suitable for advanced level courses and serves as a valuable reference for researchers in the field Interested and informed engineers will also find the book useful in their work

Directivity Based Multichannel Audio Signal Processing For Microphones in Noisy Acoustic Environments Simon Grimm, 2019-01-28 Simon Grimm examines new multi microphone signal processing strategies that aim to achieve noise reduction and dereverberation Therefore narrow band signal enhancement approaches are combined with broad band processing in terms of directivity based beamforming Previously introduced formulations of the multichannel Wiener filter rely on the second order statistics of the speech and noise signals The author analyses how additional knowledge about the location of a speaker as well as the microphone arrangement can be used to achieve further noise reduction and dereverberation

Modal Array Signal Processing: Principles and Applications of Acoustic Wavefield Decomposition Heinz Teutsch, 2009-09-02 This book deals with the problem of detecting and localizing multiple simultaneously active wideband acoustic sources by applying the notion of wavefield decomposition using circular and spherical microphone arrays A rigorous derivation of modal array signal processing algorithms for unambiguous source detection and localization as well as performance evaluations by means of measurements using an actual real time capable implementation are discussed

Sound Capture and Processing Ivan Jelev Tashev, 2009-07-01 Provides state of the art algorithms for sound capture processing and enhancement Sound Capture and Processing Practical Approaches covers the digital signal processing algorithms and devices for capturing sounds mostly human speech It explores the devices and technologies used to capture enhance and process sound for the needs of communication and speech recognition in modern

computers and communication devices This book gives a comprehensive introduction to basic acoustics and microphones with coverage of algorithms for noise reduction acoustic echo cancellation dereverberation and microphone arrays charting the progress of such technologies from their evolution to present day standard Sound Capture and Processing Practical Approaches Brings together the state of the art algorithms for sound capture processing and enhancement in one easily accessible volume Provides invaluable implementation techniques required to process algorithms for real life applications and devices Covers a number of advanced sound processing techniques such as multichannel acoustic echo cancellation dereverberation and source separation Generously illustrated with figures and charts to demonstrate how sound capture and audio processing systems work An accompanying website containing Matlab code to illustrate the algorithms This invaluable guide will provide audio R D and software engineers in the industry of building systems or computer peripherals for speech enhancement with a comprehensive overview of the technologies devices and algorithms required for modern computers and communication devices Graduate students studying electrical engineering and computer science and researchers in multimedia cell phones interactive systems and acousticians will also benefit from this book

Acoustic Field Analysis in Small Microphone Arrays Roman Scharrer, 2013 In this work the possibilities of an acoustic field analysis in small microphone arrays are investigated With the increased use of mobile communication devices such as smartphones and hearing aids and the increase in the number of microphones in such devices multi channel signal processing has gained popularity Apart from the definite signal processing this thesis evaluates what information on the acoustic sound field and environment can be gained from the signal of such small microphone arrays For this purpose an innovative sound field classification was developed that determines the energies of the single sound field components The method is based on spatial coherences of two or more acoustical The method was successfully verified with a set of simulated and measured input signals An adaptive automatic sensor mismatch compensation was created which proved able to fully compensate any slow sensor drift after an initial training Further a new method for the blind estimation of the reverberation time based on the dependency of the coherence estimate on the evaluation parameters was proposed The method determines the reverberation time of a room from the spatial coherence between two or more acoustic sensors

Digital Signal Processing Zahir M. Hussain, Amin Z. Sadik, Peter O'Shea, 2011-02-28 In three parts this book contributes to the advancement of engineering education and that serves as a general reference on digital signal processing Part I presents the basics of analog and digital signals and systems in the time and frequency domain It covers the core topics convolution transforms filters and random signal analysis It also treats important applications including signal detection in noise radar range estimation for airborne targets binary communication systems channel estimation banking and financial applications and audio effects production Part II considers selected signal processing systems and techniques Core topics covered are the Hilbert transformer binary signal transmission phase locked loops sigma delta modulation noise shaping quantization adaptive filters

and non stationary signal analysis Part III presents some selected advanced DSP topics *Speech and Audio Signal Processing* Ben Gold,Nelson Morgan,Dan Ellis,2011-08-23 When *Speech and Audio Signal Processing* published in 1999 it stood out from its competition in its breadth of coverage and its accessible intuition based style This book was aimed at individual students and engineers excited about the broad span of audio processing and curious to understand the available techniques Since then with the advent of the iPod in 2001 the field of digital audio and music has exploded leading to a much greater interest in the technical aspects of audio processing This Second Edition will update and revise the original book to augment it with new material describing both the enabling technologies of digital music distribution most significantly the MP3 and a range of exciting new research areas in automatic music content processing such as automatic transcription music similarity etc that have emerged in the past five years driven by the digital music revolution New chapter topics include Psychoacoustic Audio Coding describing MP3 and related audio coding schemes based on psychoacoustic masking of quantization noise Music Transcription including automatically deriving notes beats and chords from music signals Music Information Retrieval primarily focusing on audio based genre classification artist style identification and similarity estimation Audio Source Separation including multi microphone beamforming blind source separation and the perception inspired techniques usually referred to as Computational Auditory Scene Analysis CASA **Microphone Arrays for Stereo and Multichannel Sound Recordings: a variable two channel microphone array ; The training of the ear : experimental recording and listening tests ; More on microphones : a short tutorial** Michael Williams,2004 **A Study into the Design of Steerable Microphone Arrays** Chiong Ching Lai,Sven Erik Nordholm,Yee Hong Leung,2016-08-13 The book covers the design formulations for broadband beamformer targeting nearfield and farfield sources The book content includes background information on the acoustic environment including propagation medium the array geometries signal models and basic beamformer designs Subsequently it introduces design formulation for nearfield farfield and mixed nearfield farfield beamformers and extends the design formulation into electronically steerable beamformers In addition a robust formulation is introduced for all the designs mentioned

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