Springer Topics in Signal Processing

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Design of Circular Differential Microphone Arrays

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Design Of Circular Differential Microphone Arrays Springer Topics In Signal Processing:

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 *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 beampattern 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 **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 beampattern 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 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 acousticandspeechsignalprocessing Thereasonbehindthisendeavoristhat there were almost no books available in the literature when we rst 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 c sequence 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 s sor arrays explained from a truly broadband perspective Many algorithms for speech applications were simply borrowed from narrowband antenna rays However a direct application of narrowband ideas to broadband speech processing may not be necessarily appropriate and can lead to many m understandings 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 re searchers in the field to contribute articles addressing their specific topic s of study The reception we received from our colleagues was quite enthusi astic 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 the oretical in nature and emphasize the use of microphone arrays for speech enhancement and source localization respectively Part III presents a num ber of specific applications of array based technology Part IV addresses some open questions and explores the future of the field **Theory and Applications of Spherical Microphone Array Processing** Daniel P. Jarrett,Emanuël 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 *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 Fundamentals of Spherical Array Processing Boaz Rafaely,2018-09-27 This book provides a comprehensive introduction to the theory and practice of spherical microphone arrays and was written for graduate students researchers and engineers who work with spherical microphone arrays in a wide range of applications The new edition includes additions and modifications and references supplementary Matlab code to provide the reader with a straightforward start for own implementations The book is also accompanied by a Matlab manual which explains how to implement the examples and simulations presented in the book 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 In turn 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 highlight 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 those that achieve maximum directivity and maximum robustness are developed along with the Dolph Chebyshev beamformer The final chapter discusses more advanced beamformers such as MVDR minimum variance distortionless response and LCMV linearly constrained minimum variance types which are tailored to the measured sound field Mathworks kindly distributes the Matlab sources for this book on https www mathworks com matlabcentral fileexchange 68655 fundamentals of spherical array processing **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 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 for Envelope Estimation 169 4 169 4 1 Moving Average 170 4 2 Single Pole Recursion 170 4 3 Two Sided Single Pole Recursion 4 4 Nonlinear Data Processing 171 5 Example Implementation 172 5 1 Subband Filter Bank Architecture 172 173 5 2 A Posteriori SNR Voice Activity Detector 5 3 Example 175 6 Conclusion 175 Part IV Microphone Arrays 10 Superdirectional Microphone Arrays 181 Gary W Elko 1 Introduction 181 2 Differential Microphone Arrays 182 3 Array Directional Gain 192 4 Optimal Arrays for Spherically Isotropic Fields 193 4 1 Maximum Gain for Omnidirectional Microphones 193 4 2 Maximum Directivity Index for Differential Microphones 195 4 3 Maximimum Front to Back Ratio 197 4 4 Minimum Peak Directional Response 200 4 5 Beamwidth 201 5 Design Examples 201 5 1 First Order Designs 202 5 2 Second Order Designs 207 5 3 Third Order Designs 216 5 4 Higher Order designs 221 6 Optimal Arrays for Cylindrically Isotropic Fields 222 6 1 Maximum Gain for Omnidirectional Microphones 222 6 2 Optimal Weights for Maximum Directional Gain 224 6 3 Solution for Optimal Weights for Maximum Front to Back Ratio for Cylindrical Noise 225 7 Sensitivity to Microphone Mismatch and Noise 230 8 *Audio Signal Processing for Next-Generation Multimedia Communication Systems* Yiteng (Arden) Huang,Jacob Benesty,2007-05-08 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 **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 **Signal Processing for Circular Microphone Arrays**

Clara Ferreira Cardoso,2007 Signal Processing for Microphone Arrays with Novel Geometrical Design Khemapat Tontiwattanakul,2016 *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 *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 *A Study of Approaches for Microphone Array Signal Processing* Hniang Za Za,2008 **CMOS 60-GHz and E-band Power Amplifiers and Transmitters** Dixian Zhao,Patrick Reynaert,2015-06-29 This book focuses on the development of design techniques and methodologies for 60 GHz and E band power amplifiers and transmitters at device circuit and layout levels The authors show the recent development of millimeter wave design techniques especially of power amplifiers and transmitters and presents novel design concepts such as power transistor layout and 4 way parallel series power combiner that can enhance the output power and efficiency of power amplifiers in a compact silicon area Five state of the art 60 GHz and E band designs with measured results are demonstrated to prove the effectiveness of the design concepts and hands on methodologies presented This book serves as a valuable reference for circuit designers to develop millimeter wave building blocks for future 5G applications **Adaptive 3D Sound Systems** John Garas,2012-12-06 Adaptive 3D Sound Systems focuses on creating multiple virtual sound sources in 3D reverberant spaces using adaptive filters Adaptive algorithms are introduced and explained including the multiple error filtered x algorithm and the adjoint LMS algorithm The book covers the physical psychoacoustical and signal processing aspects of adaptive and non adaptive 3D sound systems

Included is an introduction to spatial hearing sound localization and reverberation frequency selectivity of the human auditory system the state of the art in HRTF based 3D sound systems binaural synthesis and loudspeaker displays The adaptive approach to HRTF based 3D sound systems is examined in detail for the general case of creating multiple virtual sound sources at the ears of multiple listeners in a reverberant 3D space The derived solution can be applied to other applications such as cross talk cancellation loudspeakers and room equalization concert hall simulation and active sound control Several solutions for the problem of moving listeners are introduced Strategies for enlarging the zones of equalization around the listeners ears correct loudspeakers positioning and using multiresolution filters are proposed Fast multiresolution spectral analysis using non uniform sampling is developed for implementation of multiresolution filters The well focused topics along with implementation details for adaptive algorithms make Adaptive 3D Sound Systems suitable for multimedia applications programmers advanced level students and researchers in audio and signal processing

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