

Springer Topics in Signal Processing

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# Theory and Applications of Spherical Microphone Array Processing

 Springer

# Microphone Array Signal Processing Springer Topics In Signal Processing

**Simon Haykin, K. J. Ray Liu**



## **Microphone Array Signal Processing Springer Topics In Signal Processing:**

**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.

**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 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

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

Handbook of Signal Processing in Acoustics David Havelock,2008 Mathematical Modeling and Signal Processing in Speech and Hearing Sciences Jack Xin,Yingyong Qi,2014-04-14 The aim of the book is to give an accessible introduction of mathematical models and signal processing methods in speech and hearing sciences for senior undergraduate and beginning graduate students with basic knowledge of linear algebra differential equations numerical analysis and probability Speech and hearing sciences are fundamental to numerous technological advances of the digital world in the past decade from music compression in MP3 to digital hearing aids from network based voice enabled services to speech interaction with mobile phones Mathematics and computation are intimately related to these leaps and bounds On the other hand speech and hearing are strongly interdisciplinary areas where dissimilar scientific and engineering publications and approaches often coexist and make it difficult for newcomers to enter **Automation Control Theory Perspectives in Intelligent Systems** Radek Silhavy,Roman Senkerik,Zuzana Kominkova Oplatkova,Petr Silhavy,Zdenka Prokopova,2016-04-26 The volume

Automation Control Theory Perspectives in Intelligent Systems presents new approaches and methods to real world problems and in particular exploratory research that describes novel approaches in the field of cybernetics and automation control theory Particular emphasis is laid on modern trends in intelligent information technology system monitoring and proactive management of complex objects The 5th Computer Science On line Conference CSOC2016 is intended to provide an international forum for discussions on the latest high quality research results in all areas related to Computer Science The addressed topics are the theoretical aspects and applications of Computer Science Artificial Intelligences Cybernetics Automation Control Theory and Software Engineering *Array Processing* Jacob Benesty, Israel Cohen, Jingdong

Chen, 2019-02-28 The focus of this book is on array processing and beamforming with Kronecker products It considers a large family of sensor arrays that allow the steering vector to be decomposed as a Kronecker product of two steering vectors of smaller virtual arrays Instead of directly designing a global beamformer for the original array once the steering vector has been decomposed smaller virtual beamformers are designed and separately optimized for each virtual array This means the matrices that need to be inverted are smaller which increases the robustness of the beamformers and reduces the size of the observations The book explains how to perform beamforming with Kronecker product filters using an unconventional approach It shows how the Kronecker product formulation can be used to derive fixed adaptive and differential beamformers with remarkable flexibility Furthermore it demonstrates how fixed and adaptive beamformers can be intelligently combined optimally exploiting the advantages of both The problem of spatiotemporal signal enhancement is also addressed and readers will learn how to perform Kronecker product filtering in this context **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  $N$ th 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. [Springer Handbook of Speech Processing](#) Jacob Benesty, M. M. Sondhi, Yiteng Huang, 2007-11-22 This handbook plays a fundamental role in sustainable progress in speech research and development. With an accessible format and with accompanying DVD Rom it targets three categories of readers: graduate students, professors and active researchers in academia and engineers in industry who need to understand or implement some specific algorithms for their speech related products. It is a superb source of application oriented, authoritative and comprehensive information about these technologies. This work combines the established knowledge derived from research in such fast evolving disciplines as Signal Processing and Communications Acoustics.

Computer Science and Linguistics      **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      *Parametric Time-Frequency Domain Spatial Audio* Ville Pulkki, Symeon Delikaris-Manias, Archontis Politis, 2017-12-26 A comprehensive guide that addresses the theory and practice of spatial audio This book provides readers with the principles and best practices in spatial audio signal processing It describes how sound fields and their perceptual attributes are captured and analyzed within the time frequency domain how essential representation parameters are coded and how such signals are efficiently reproduced for practical applications The book is split into four parts starting with an overview of the fundamentals It then goes on to explain the reproduction of spatial sound before offering an examination of signal dependent spatial filtering The book finishes with coverage of both current and future applications and the direction that spatial audio research is heading in Parametric Time frequency Domain Spatial Audio focuses on applications in entertainment audio including music home cinema and gaming covering the capturing and reproduction of spatial sound as well as its generation transduction representation transmission and perception This book will teach readers the tools needed for such processing and provides an overview to existing research It also shows recent up to date projects and commercial applications built on top of the systems Provides an in depth presentation of the principles past developments state of the art methods and future research directions of spatial audio technologies Includes contributions from leading researchers in the field Offers MATLAB codes with selected chapters An advanced book aimed at readers who are capable of digesting mathematical expressions about digital signal processing and sound field analysis Parametric Time frequency Domain Spatial Audio is best suited for researchers in academia and in the audio industry      Automotive Acoustics Conference 2015 Wolfgang Siebenpfeiffer, 2019-08-28 Elektrofahrzeuge sind f r Entwickler der Fahrzeugakustik ebenso eine Herausforderung wie eine h here NVH Performance durch Leichtbaustrukturen und kleinere Motoren mit Turbolader Die Automobilforschung muss das Akustikmanagement im Fahrzeug neu denken Die

internationale Automotive Acoustics Conference bietet dazu als Fachtagung das notwendige Expertenwissen um die künftigen Anforderungen an Antriebsstrang Antriebssysteme und Fahrzeugarchitekturen zu erfüllen Simulationsprozesse und Verfahren der Multiphysik sind dabei essenziell um Ruhe in die Passagierkabine zu bringen Die Konferenz zur car acoustics bietet dazu neuestes Expertenwissen *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

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>

Acoustic Array Systems Mingsian R. Bai, Jeong-Guon Ih, Jacob Benesty, 2013-03-07 Presents a unified framework of far field and near field array techniques for noise source identification and sound field visualization from theory to application *Acoustic Array Systems Theory Implementation and Application* provides an overview of microphone array technology with applications in noise source identification and sound field visualization In the comprehensive treatment of microphone arrays the topics covered include an introduction to the theory far field and near field array signal processing algorithms practical

implementations and common applications vehicles computing and communications equipment compressors fans and household appliances and hands free speech The author concludes with other emerging techniques and innovative algorithms Encompasses theoretical background implementation considerations and application know how Shows how to tackle broader problems in signal processing control and transducers Covers both farfield and nearfield techniques in a balanced way Introduces innovative algorithms including equivalent source imaging NESI and high resolution nearfield arrays Selected code examples available for download for readers to practice on their own Presentation slides available for instructor use A valuable resource for Postgraduates and researchers in acoustics noise control engineering audio engineering and signal processing

**Topics in Acoustic Echo and Noise Control** Eberhard Häsler, Gerhard Schmidt, 2006-08-26 This book treats important topics in Acoustic Echo and Noise Control and reports the latest developments Methods for enhancing the quality of transmitted speech signals are gaining growing attention in universities and in industrial development laboratories This book written by an international team of highly qualified experts concentrates on the modern and advanced methods

**Digital Human Modeling and Applications in Health, Safety, Ergonomics and Risk Management. Human Communication, Organization and Work** Vincent G. Duffy, 2020-07-10 This two volume set LNCS 12198 and 12199 constitutes the thoroughly refereed proceedings of the 11th International Conference on Digital Human Modeling and Applications in Health Safety Ergonomics and Risk Management DHM 2020 which was supposed to be held as part of the 22st HCI International Conference HCII 2020 in Copenhagen Denmark in July 2020 The conference was held virtually due to the COVID 19 pandemic A total of 1439 papers and 238 posters have been carefully reviewed and accepted for publication in HCII 2020 DHM 2020 includes a total of 77 papers they were organized in topical sections named Part I Posture Motion and Health Posture and motion modelling in design ergonomics and occupational health applications for exercising physical therapy and rehabilitation health services DHM for aging support Part II Human Communication Organization and Work Modelling human communication modelling work collaboration and the human environment addressing ethical and societal challenges new research issues and approaches in digital human modelling

**Frontiers in Signal Processing Editors' Choice 2022** Augusto Sarti, Sri Krishnan, Frederic Dufaux, Fulvio Gini, Wenwu Wang, Yonghui Li, Dirk Slock, Asoke Nandi, 2023-04-05

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