

Blind Sound Separation Using Frequency-Domain and Time-Domain Independent Component Analysis for Machines Fault Detection

B.T. Atmaja, D.Arifianto

Laboratory of Acoustic and Vibration

Sepuluh Nopember Institute of Technology, Surabaya

Email :backguys@ep.its.ac.id , dhany@ep.its.ac.id

Abstract—In this paper, we present Independent Component Analysis (ICA) techniques for multiple machinery fault diagnosis using acoustical sound emission of the machines. The sound mixture of fault machines was recorded from an equally spaced microphone array. The main objective is to separate machine sounds from its mixture. In the experiment we used one source and one sensor as the baseline and pair of 2 sensors and 2 sources, 3 sensors and 3 sources and 4 sources and 4 sensors, respectively. The results showed that time-domain ICA (TDICA) performed better than Frequency Domain ICA and Multistage ICA. Separated signal was then analyzed further with instantaneous frequency technique (IF) to determine the exact location of frequency for machinery fault detection.

I. INTRODUCTION

Recent trend in industrial machine maintenance or machine diagnosis is towards predictive maintenance techniques which essentially mean continuous monitoring of the machineries before failure. There are some techniques in predictive maintenance or condition monitoring such as: vibration analysis, thermography, tribology and motor current. The vibration analysis is the most powerful one because it involves direct measurement using attached probe to the enclosure of the machine.

Mechanical vibration of the machine is directly related to the sound emission. Alteration of vibration causes proportional alteration in sound signal. If a normal machine emits certain parameters of sound signal and forms a particular pattern, therefore the change of that specific parameter can be concluded as a result of an abnormality of the machine condition [11]. This signal is bearing signal signatures that observable using time-frequency technique [7].

In the real application, a plant usually uses more

than one machinery, combined in a way to complete a specific process goal. The sound signals emitted by these machines are mixed and it is difficult to separate the machine sound from this mixture to identify which machine emits what kind of sound.

Blind source separation (BSS) is method to separate mixed source without prior knowledge (blind) of source and mixing process [9, 10]. It exploits the statistically independent nature of source. The method to solve blind source separation problem is commonly called independent component analysis (ICA). The authors of [2, 3, 4] reported the time-domain ICA (TDICA), frequency-domain ICA (FDICA) and multi-stage ICA for speech signal. However, these techniques, to the best of our knowledge, have not been implemented for lower frequency in rotating machinery (lower than 100Hz).

In this paper, we propose ICA-based techniques to separate mixture of 2, 3 and 4 machines using 2, 3, and 4 sensors. We evaluated time-domain ICA, frequency-domain ICA and multistage ICA to investigate the suitable technique for sound separation of lower frequency than speech. This paper will briefly present some backgrounds, followed by algorithm to estimate the separation matrices. In the later section, the experimental set-up and discussion of the results will be elaborated.

II. THEORY

A. Theory of ICA

Independent events occur when an event doesn't have any relation with another event. It is statistically a stronger measure than uncorrelated. Mathematically, probability function of those events can be formulated as follows,

$$P(Y_1, Y_2) = P(Y_1) \cdot P(Y_2) \dots (1)$$

The probability functions of those events are the multiplication of each other. Let's define x_j is measured signal by j -th sensor. The x_j is j -th sources that statistically independent to each other which implies any event observed from one

Blind Source Separation Using Frequency Independent Component Analysis

Ganesh R. Naik, Wenwu Wang



Blind Source Separation Using Frequency Independent Component Analysis:

Blind Source Separation Using Frequency Independent Component Analysis Gozie Okwelume, Anayo K.

Ezeude, 2010-07 The need for speech enhancement is very important because of the acoustic environment we are living in which is composed of noise and other atmospheric disturbances and this makes it almost impossible to record a speech signal in pure form. In most of the mixed signals there is usually no information about each source. In such a situation, the estimates of the original source signals are done based on the information of the received mixed signals; therefore, the approach to be adopted in such cases to separate the signals must be one that does it blindly. Thus, the method Blind Source Separation is used in this work. Our thesis work focuses on Frequency domain Blind Source Separation (BSS) in which the received mixed signals are converted into the frequency domain and Independent Component Analysis (ICA) is applied at each frequency bin. Our main target in this project is to solve the permutation and scaling ambiguities in real time applications using the method proposed by Minje et al. in [12]. Our results show that this method works better in offline mixtures than in real time and lastly we gave some suggestions to improve the results.

Handbook of Blind Source Separation Pierre Comon, Christian Jutten, 2010-02-17 Edited by the people who were forerunners in creating the field together with contributions from 34 leading international experts, this handbook provides the definitive reference on Blind Source Separation, giving a broad and comprehensive description of all the core principles and methods, numerical algorithms and major applications in the fields of telecommunications, biomedical engineering and audio/acoustic and speech processing. Going beyond a machine learning perspective, the book reflects recent results in signal processing and numerical analysis and includes topics such as optimization criteria, mathematical tools, the design of numerical algorithms, convolutive mixtures and time-frequency approaches. This Handbook is an ideal reference for university researchers. R. algebraic identification of underdetermined mixtures, time-frequency methods, Bayesian approaches, blind identification under non-negativity, approaches, semi-blind methods for communications. Shows the applications of the methods to key application areas such as telecommunications, biomedical engineering, speech/acoustic audio and music processing while also giving a general method for developing applications.

Blind Source Separation Ganesh R. Naik, Wenwu Wang, 2014-05-21 Blind Source Separation intends to report the new results of the efforts on the study of Blind Source Separation (BSS). The book collects novel research ideas and some training in BSS, independent component analysis (ICA), artificial intelligence and signal processing applications. Furthermore, the research results previously scattered in many journals and conferences worldwide are methodically edited and presented in a unified form. The book is likely to be of interest to university researchers. R. Dr. Wenwu Wang works at University of Surrey, UK.

Independent Component Analysis and Signal Separation Mike E. Davies, Christopher C. James, Samer A. Abdallah, Mark D. Plumbley, 2007-08-28 This book constitutes the refereed proceedings of the 7th International Conference on Independent Component Analysis and Blind Source Separation (ICA 2007) held in London, UK, in September 2007. It covers

algorithms and architectures applications medical applications speech and signal processing theory and visual and sensory processing

Independent Component Analysis and Signal Separation Tulay Adali, Christian Jutten, Joao Marcos Travassos Romano, Allan Kardec Barros, 2009-02-25 This book constitutes the refereed proceedings of the 8th International Conference on Independent Component Analysis and Signal Separation ICA 2009 held in Paraty Brazil in March 2009 The 97 revised papers presented were carefully reviewed and selected from 137 submissions The papers are organized in topical sections on theory algorithms and architectures biomedical applications image processing speech and audio processing other applications as well as a special session on evaluation

Independent Component Analysis for Audio and Biosignal Applications Ganesh R. Naik, 2012-10-10 Independent Component Analysis ICA is a signal processing method to extract independent sources given only observed data that are mixtures of the unknown sources Recently Blind Source Separation BSS by ICA has received considerable attention because of its potential signal processing applications such as speech enhancement systems image processing telecommunications medical signal processing and several data mining issues This book brings the state of the art of some of the most important current research of ICA related to Audio and Biomedical signal processing applications The book is partly a textbook and partly a monograph It is a textbook because it gives a detailed introduction to ICA applications It is simultaneously a monograph because it presents several new results concepts and further developments which are brought together and published in the book

Independent Component Analysis and Blind Signal Separation Justinian Rosca, Deniz Erdogmus, Jose C. Principe, Simon Haykin, 2006-02-27 This book constitutes the refereed proceedings of the 6th International Conference on Independent Component Analysis and Blind Source Separation ICA 2006 held in Charleston SC USA in March 2006 The 120 revised papers presented were carefully reviewed and selected from 183 submissions The papers are organized in topical sections on algorithms and architectures applications medical applications speech and signal processing theory and visual and sensory processing

Audio Signal Separation Using Blind Source Separation Techniques, 1999 Techniques developed so far are based on 1 Constant modulus algorithm CMA Independent component analysis ICA polyspectra and time frequency Examples of ICA Frequency domain JADE ICA JADE ICA on Each Frequency Bin With Port Deswapping and Normalization Spectrograms of Speech Signal Mixtures ICA Separated Frequency Components Inverse Spectrogram Transform Separated Speech Signals 16 tap random channel and cross channel filters and mixing matrix

Independent Component Analysis and Blind Signal Separation Carlos G. Puntonet, 2004-09-17 In many situations found both in Nature and in human built systems a set of mixed signals is observed frequently also with noise and it is of great scientific and technological relevance to be able to isolate or separate them so that the information in each of the signals can be utilized Blind source separation BSS research is one of the more interesting emerging fields nowadays in the field of signal processing It deals with the algorithms that allow the recovery of the original sources from a set of mixtures only The adjective blind is applied because the purpose is to estimate the

original sources without any a priori knowledge about either the sources or the mixing system. Most of the models employed in BSS assume the hypothesis about the independence of the original sources. Under this hypothesis, a BSS problem can be considered as a particular case of independent component analysis (ICA), a linear transformation technique that, starting from a multivariate representation of the data, minimizes the statistical dependence between the components of the representation. It can be claimed that most of the advances in ICA have been motivated by the search for solutions to the BSS problem, and the other way around: advances in ICA have been immediately applied to BSS. ICA and BSS algorithms start from a mixture model whose parameters are estimated from the observed mixtures. Separation is achieved by applying the inverse mixture model to the observed signals, separating or unmixing the model. Mixture models usually fall into three broad categories: instantaneous linear models, convolutive models, and nonlinear models, the first being the simplest but in general not near realistic applications. The development and test of the algorithms can be accomplished through synthetic data or with real world data. Obviously, the most important aim and most difficult is the separation of real world mixtures. BSS and ICA have strong relations also apart from signal processing, with other fields such as statistics and artificial neural networks. As long as we can find a system that emits signals propagated through a medium and those signals are received by a set of sensors, and there is an interest in recovering the original sources, we have a potential field of application for BSS and ICA. Inside that wider range of applications, we can find, for instance, noise reduction applications, biomedical applications, audio systems, telecommunications, and many others. This volume comes out just 20 years after the first contributions in ICA and BSS [1] appeared. Thereafter, the number of research groups working in ICA and BSS has been constantly growing, so that nowadays we can estimate that far more than 100 groups are researching in these fields. As proof of their recognition among the scientific community, ICA and BSS developments there have been numerous special sessions and special issues in several well-known journals. J. Herault, B. Ans, "Circuits neuronaux synapses modifiables d'encodage de messages complexes pour l'apprentissage non supervisé," *C. R. de l'Académie des Sciences*, vol. 299, no. III, pp. 525-528, 1984. *Independent Component Analysis and Blind Signal Separation*, 2004. **Blind Speech Separation**, Shoji Makino, Te-Won Lee, Hiroshi Sawada, 2007-09-07. We are surrounded by sounds. Such a noisy environment makes it difficult to obtain desired speech, and it is difficult to converse comfortably there. This makes it important to be able to separate and extract a target speech signal from noisy observations for both man-machine and human-human communication. Blind source separation (BSS) is an approach for estimating source signals using only information about their mixtures observed in each input channel. The estimation is performed without possessing information on each source such as its frequency characteristics and location, or on how the sources are mixed. The use of BSS in the development of comfortable acoustic communication channels between humans and machines is widely accepted. Some books have been published on BSS, independent component analysis (ICA), and related subjects. There, ICA-based BSS has been well studied in the statistics and information theory fields for applications to a variety of disciplines, including wireless communication and biomedicine. However, as speech

and audio signal mixtures in a real reverberant environment are generally convolutive mixtures they involve a structurally much more challenging task than instantaneous mixtures which are prevalent in many other applications

Independent Component Analysis and Blind Source Separation, 2007 Blind Source Separation Yong Xiang, Dezhong Peng, Zuyuan Yang, 2014-09-16 This book provides readers a complete and self contained set of knowledge about dependent source separation including the latest development in this field The book gives an overview on blind source separation where three promising blind separation techniques that can tackle mutually correlated sources are presented The book further focuses on the non negativity based methods the time frequency analysis based methods and the pre coding based methods respectively

Efficient Blind Speech Signal Separation Using Independent Component Analysis Qiongfeng Pan, 2006 **Blind Signal Processing** Xizhi Shi, 2011-12-28 Blind Signal Processing Theory and Practice not only introduces related fundamental mathematics but also reflects the numerous advances in the field such as probability density estimation based processing algorithms underdetermined models complex value methods uncertainty of order in the separation of convolutive mixtures in frequency domains and feature extraction using Independent Component Analysis ICA At the end of the book results from a study conducted at Shanghai Jiao Tong University in the areas of speech signal processing underwater signals image feature extraction data compression and the like are discussed This book will be of particular interest to advanced undergraduate students graduate students university instructors and research scientists in related disciplines Xizhi Shi is a Professor at Shanghai Jiao Tong University Advanced Research on Industry, Information System and Material Engineering, IISME2011 Helen Zhang, Gang Shen, David Jin, 2011-02-21 Selected peer reviewed papers from the 2011 International Conference on Industry Information System and Material Engineering IISME 2011 April 16 17 2011 Guangzhou China Independent Component Analysis for Audio and Biosignal Applications Ganesh R. Naik, 2012-10-10 Independent Component Analysis ICA is a signal processing method to extract independent sources given only observed data that are mixtures of the unknown sources Recently Blind Source Separation BSS by ICA has received considerable attention because of its potential signal processing applications such as speech enhancement systems image processing telecommunications medical signal processing and several data mining issues This book brings the state of the art of some of the most important current research of ICA related to Audio and Biomedical signal processing applications The book is partly a textbook and partly a monograph It is a textbook because it gives a detailed introduction to ICA applications It is simultaneously a monograph because it presents several new results concepts and further developments which are brought together and published in the book *Independent Component Analyses, Wavelets, Unsupervised Nano-biomimetic Sensors, and Neural Networks V* Harold H. Szu, Jack Agee, 2007 Proceedings of SPIE present the original research papers presented at SPIE conferences and other high quality conferences in the broad ranging fields of optics and photonics These books provide prompt access to the latest innovations in research and technology in their respective fields Proceedings of SPIE are among

the most cited references in patent literature *Blind Source Separation* Xianchuan Yu, Dan Hu, Jindong Xu, 2013-12-13 A systematic exploration of both classic and contemporary algorithms in blind source separation with practical case studies The book presents an overview of Blind Source Separation a relatively new signal processing method Due to the multidisciplinary nature of the subject the book has been written so as to appeal to an audience from very different backgrounds Basic mathematical skills e g on matrix algebra and foundations of probability theory are essential in order to understand the algorithms although the book is written in an introductory accessible style This book offers a general overview of the basics of Blind Source Separation important solutions and algorithms and in depth coverage of applications in image feature extraction remote sensing image fusion mixed pixel decomposition of SAR images image object recognition fMRI medical image processing geochemical and geophysical data mining mineral resources prediction and geoanomalies information recognition Firstly the background and theory basics of blind source separation are introduced which provides the foundation for the following work Matrix operation foundations of probability theory and information theory basics are included here There follows the fundamental mathematical model and fairly new but relatively established blind source separation algorithms such as Independent Component Analysis ICA and its improved algorithms Fast ICA Maximum Likelihood ICA Overcomplete ICA Kernel ICA Flexible ICA Non negative ICA Constrained ICA Optimised ICA The last part of the book considers the very recent algorithms in BSS e g Sparse Component Analysis SCA and Non negative Matrix Factorization NMF Meanwhile in depth cases are presented for each algorithm in order to help the reader understand the algorithm and its application field A systematic exploration of both classic and contemporary algorithms in blind source separation with practical case studies Presents new improved algorithms aimed at different applications such as image feature extraction remote sensing image fusion mixed pixel decomposition of SAR images image object recognition and MRI medical image processing With applications in geochemical and geophysical data mining mineral resources prediction and geoanomalies information recognition Written by an expert team with accredited innovations in blind source separation and its applications in natural science Accompanying website includes a software system providing codes for most of the algorithms mentioned in the book enhancing the learning experience Essential reading for postgraduate students and researchers engaged in the area of signal processing data mining image processing and recognition information geosciences life sciences **Independent Component Analysis with Applications to Blind Source Separation** Frank Herrmann, University of Liverpool, 2000

Blind Source Separation Using Frequency Independent Component Analysis Book Review: Unveiling the Power of Words

In some sort of driven by information and connectivity, the energy of words has be much more evident than ever. They have the ability to inspire, provoke, and ignite change. Such is the essence of the book **Blind Source Separation Using Frequency Independent Component Analysis**, a literary masterpiece that delves deep to the significance of words and their affect our lives. Compiled by a renowned author, this captivating work takes readers on a transformative journey, unraveling the secrets and potential behind every word. In this review, we shall explore the book is key themes, examine its writing style, and analyze its overall impact on readers.

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