

Denoising Electrical Signal via Empirical Mode Decomposition

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Abstract

Electric signals are affected by numerous factors, random events, and corrupted with noise, making them nonlinear and non-stationary in nature. In recent years, the application of Empirical Mode Decomposition (EMD) technique to analyze nonlinear and non-stationary signals has gained importance. It is an empirical approach to decompose a signal into a set of oscillatory modes known as intrinsic mode functions (IMFs). Based on an empirical energy model of IMFs, the statistically significant information content is established and combined. In this paper, we demonstrate an approach to detect power quality disturbances in noisy conditions. The approach is based on the statistical properties of fractional Gaussian noise (fGn).

1. Introduction

A signal obtained from any system is never a perfect reflection of the actual measurement. Rather, a signal is always corrupted by noise introduced by the device itself or by other means. Therefore, an observed signal is a combination of actual information and noise,

$$x(t) = s(t) + n(t) \quad (1)$$

where $x(t)$ is the observed signal, $s(t)$ is the actual measurement, and $n(t)$ is the noise. The unknown amount and type of noise present in the data can lead to misinterpretation of the phenomena reflected by the signal.

In this paper, we study an electrical power signal corrupted with noise and disturbances. A 50 Hz sinusoidal voltage signal of 2 volts peak to peak amplitude is shown in Fig. 1. A constant supply of normal voltage with less than 10% variations is considered as good power supply quality. With increasing use of solid state switching devices, nonlinear load switching, rectifiers, inverters, and improper load balance, the power quality degrades. Thus, power quality monitoring has gained tremendous importance in recent years [1, 2]. Power disturbances based on effects, duration, and intensity can be divided into five categories, voltage fluctuations, transients, harmonics, power outages, and electrical noises. Among all the

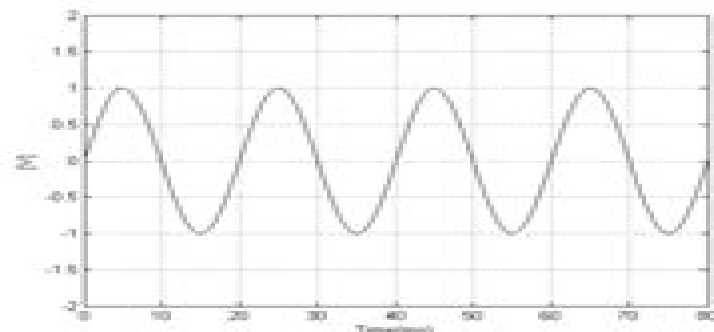


Fig. 1. Normal voltage signal.

disturbances, electrical noise is the most common.

Electrical noise is generally white noise. Consider a signal $z(t)$ of the form,

$$z(t) = s(t) + y(t) \quad (2)$$

where $y(t)$ is the power disturbance. The detection of $y(t)$ in noisy conditions is a challenging task. The application of signal processing tools for noise removal and power quality monitoring is been studied extensively [3-5]. Wu et al. discusses the limitations of various existing denoising approaches in signal processing [6]. Wavelet transform based power quality monitoring received wide attention because of its ability to handle nonlinear and non-stationary signal [7-9]. Santoso et al. detected power disturbances using wavelets and classified them accordingly using pattern recognition techniques [10, 11].

In this paper, we demonstrate the performance of EMD in detecting power disturbance in noisy conditions. The EMD approach originally proposed by Huang et al. is a highly adaptive decomposition technique [12]. It decomposes any complicated signal into a finite set of functions called intrinsic

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Oil and Gas Exploration Said Gaci, Olga Hachay, 2017-02-17 Oil and Gas Exploration Methods and Application presents a summary of new results related to oil and gas prospecting that are useful for theoreticians and practical professionals The study of oil and gas complexes and intrusions occurring in sedimentary basins is crucial for identifying the location of oil and gas fields and for making accurate predictions on oil findings Volume highlights include Advanced geophysical techniques for achieving hydrocarbon exploration efficiency from beneath the Earth Discussion of theoretical and practical approaches in solving problems related to exploring and mining new oil and gas deposits New geological concepts for predicting potential hydrocarbon targets Novel methods of control of the outworking of these deposits using different geophysical methods significant for optimization of mining hydrocarbon and carbonate deposits Estimation of the degree of outworking of oil and gas deposits to facilitate the use of space time monitoring of different kinds of fields Analysis of exploration data by an efficient processing system based on strong methods proven mathematically Oil and Gas Exploration is a valuable resource for exploration geophysicists petroleum engineers geoengineers petrologists mining engineers and economic geologists who will gain insights into exploring new methods involved in finding natural resources from our Earth Read an interview with the editors to find out more <https://eos.org/editors-vox-where-and-how-can-we-find-new-sources-of-oil-and-gas> Advanced Methods in Biomedical Signal Processing and Analysis Kunal Pal, Samit Ari, Arindam Bit, Saugat Bhattacharyya, 2022-09-07 Advanced Methods in Biomedical Signal Processing and Analysis presents state of the art methods in biosignal processing including recurrence quantification analysis heart rate variability analysis of the RRI time series signals joint time frequency analyses wavelet transforms and wavelet packet decomposition empirical mode decomposition modeling of biosignals Gabor Transform empirical mode decomposition The book also gives an understanding of feature extraction feature ranking and feature selection methods while also demonstrating how to apply artificial intelligence and machine learning to biosignal techniques Gives advanced methods in signal processing Includes machine and deep learning methods Presents experimental case studies *Intelligent Systems in Cybernetics and Automation Control Theory* Radek Silhavy, Petr Silhavy, Zdenka Prokopova, 2018-08-28 This book presents real world problems and pioneering research that reflect novel approaches to cybernetics algorithms and software engineering in the context of intelligent systems It gathers the peer reviewed proceedings of the 2nd Computational Methods in Systems and Software 2018 CoMeSySo 2018 a conference that broke down traditional barriers by being held online The goal of the event was to provide an international forum for discussing the latest high quality research results **Signal Processing and Analysis of Electrical Circuit** Adam Glowacz, Grzegorz Królczyk, Jose Alfonso Antonino Daviu, 2020-03-13 This Special Issue with 35 published articles shows the significance of the topic Signal Processing and Analysis of Electrical Circuit This topic has been gaining increasing attention in recent times The presented articles can be categorized into four different areas signal processing and analysis methods of electrical circuits

electrical measurement technology applications of signal processing of electrical equipment fault diagnosis of electrical circuits It is a fact that the development of electrical systems signal processing methods and circuits has been accelerating Electronics applications related to electrical circuits and signal processing methods have gained noticeable attention in recent times The methods of signal processing and electrical circuits are widely used by engineers and scientists all over the world The constituent papers represent a significant contribution to electronics and present applications that can be used in industry Further improvements to the presented approaches are required for realizing their full potential

Proceedings of the First International Conference on Intelligent Computing and Communication Jyotsna Kumar Mandal, Suresh Chandra Satapathy, Manas Kumar Sanyal, Vikrant Bhateja, 2016-11-21 The book covers a wide range of topics in Computer Science and Information Technology including swarm intelligence artificial intelligence evolutionary algorithms and bio inspired algorithms It is a collection of papers presented at the First International Conference on Intelligent Computing and Communication ICIC2 2016 The prime areas of the conference are Intelligent Computing Intelligent Communication Bio informatics Geo informatics Algorithm Graphics and Image Processing Graph Labeling Web Security Privacy and e Commerce Computational Geometry Service Orient Architecture and Data Engineering Machine Intelligence and Signal Analysis M. Tanveer, Ram Bilas Pachori, 2018-08-07 The book covers the most recent developments in machine learning signal analysis and their applications It covers the topics of machine intelligence such as deep learning soft computing approaches support vector machines SVMs least square SVMs LSSVMs and their variants and covers the topics of signal analysis such as biomedical signals including electroencephalogram EEG magnetoencephalography MEG electrocardiogram ECG and electromyogram EMG as well as other signals such as speech signals communication signals vibration signals image and video Further it analyzes normal and abnormal categories of real world signals for example normal and epileptic EEG signals using numerous classification techniques The book is envisioned for researchers and graduate students in Computer Science and Engineering Electrical Engineering Applied Mathematics and Biomedical Signal Processing

Mechanics of Composite, Hybrid & Multi-functional Materials, Volume 5 Vijaya Chalivendra, Frank Gardea, 2025-08-07 Mechanics of Composite Hybrid and Multifunctional Materials Volume 5 of the Proceedings of the 2022 SEM Annual Conference Exposition on Experimental and Applied Mechanics the fifth volume of six from the Conference brings together contributions to this important area of research and engineering The collection presents early findings and case studies on a wide range of areas including Recycled Constituent Composites Damage Detection Advanced Imaging of Composites Multifunctional Materials Composite Interfaces Tunable Composites

Advances in Noise Reduction and Feature Extraction of Acoustic Signal Govind Vashishtha, Rajesh Kumar, 2023-10-11 Acoustic signal is one of the hot topics of research in physics and has been studied by many engineers and scientists in various real world fields including underwater acoustics architectural acoustics engineering acoustics physical acoustics environmental acoustics psychological acoustics and so on Noise

reduction is the foundation of acoustic signal pre processing and the feature extraction for noise reduction signals can obtain useful information from the acoustic signal which is the linchpin for pattern recognition target detection tracking and localization

Artificial Intelligence and Algorithms in Intelligent Systems Radek Silhavy, 2018-05-26 This book presents the latest trends and approaches in artificial intelligence research and its application to intelligent systems It discusses hybridization of algorithms new trends in neural networks optimisation algorithms and real life issues related to the application of artificial methods The book constitutes the second volume of the refereed proceedings of the Artificial Intelligence and Algorithms in Intelligent Systems of the 7th Computer Science On line Conference 2018 CSOC 2018 held online in April 2018

Acoustic Emission Signal Analysis and Damage Mode Identification of Composite Wind Turbine Blades Pengfei Liu, 2023-05-20 Acoustic Emission Signal Analysis and Damage Mode Identification of Composite Wind Turbine Blades covers both the underlying theory and various techniques for effective structural monitoring of composite wind turbine blades via acoustic emission signal analysis helping readers solve critical problems such as noise elimination defect detection damage mode identification and more Author Pengfei Liu introduces techniques for identifying and analyzing progressive failure under tension delamination damage localization adhesive composite joint failure and other degradation phenomena outlining methods such as time difference wavelet machine learning and more including combined methods The disadvantages and advantages of using each method are covered as are techniques for different blade lengths and various blade substructures Piezoelectric sensors are discussed as is experimental analysis of damage source localization The book also takes great lengths to let readers know when techniques and concepts discussed can be applied to composite materials and structures beyond just wind turbine blades Features fundamental acoustic emission theories and techniques for monitoring the structural integrity of wind turbine blades Covers sensor arrangements noise elimination defect detection and dominating damage mode identification using acoustic emission techniques Outlines the wavelet method the time difference defect detection method and damage mode identification techniques using machine learning Discusses how the techniques covered can be extended and adapted for use in other composite structures under complex loads and in different environments

AI-Enabled Smart Healthcare Using Biomedical Signals Chaurasiya, Rahul Kumar, Agrawal, Dheeraj, Pachori, Ram Bilas, 2022-05-27 Technological advancements have enhanced all functions of society and revolutionized the healthcare field Smart healthcare applications and practices have grown within the past decade strengthening overall care Biomedical signals observe physiological activities which provide essential information to healthcare professionals Biomedical signal processing can be optimized through artificial intelligence AI and machine learning ML presenting the next step towards smart healthcare AI Enabled Smart Healthcare Using Biomedical Signals will not only cover the mathematical description of the AI and ML based methods but also analyze and demonstrate the usability of different AI methods for a range of biomedical signals The book covers all types of biomedical signals helpful for smart

healthcare applications Covering topics such as automated diagnosis emotion identification and frequency discrimination techniques this premier reference source is an excellent resource for healthcare administration biomedical engineers medical laboratory technicians medical technology assistants computer scientists libraries students and faculty of higher education researchers and academicians

Testing and Measurement: Techniques and Applications Kennis Chan, 2015-06-11 Testing and Measurement Techniques and Applications is divided into 6 sections Microwave Ultrasonic and Acoustic Measurement and Application Material Performance and Measuring and Testing Technique Laser Optics Fiber and Sensor Industrial Autoimmunization and Measurement Artificial Intelligence and Application and Image Signal and In

Machine Learning, Image Processing, Network Security and Data Sciences Arup Bhattacharjee, Samir Kr. Borgohain, Badal Soni, Gyanendra Verma, Xiao-Zhi Gao, 2020-06-24 This two volume set CCIS 1240 1241 constitutes the refereed proceedings of the Second International Conference on Machine Learning Image Processing Network Security and Data Sciences MIND 2020 held in Silchar India Due to the COVID 19 pandemic the conference has been postponed to July 2020 The 79 full papers and 4 short papers were thoroughly reviewed and selected from 219 submissions The papers are organized according to the following topical sections data science and big data image processing and computer vision machine learning and computational intelligence network and cyber security

Proceedings of International Conference on Computational Intelligence Ritu Tiwari, Mario F. Pavone, Ranjith Ravindranathan Nair, 2022-10-04 The book presents high quality research papers presented at International Conference on Computational Intelligence ICCI 2021 held online during 27 28 December 2021 The topics covered are artificial intelligence neural network deep learning techniques fuzzy theory and systems rough sets self organizing maps machine learning chaotic systems multi agent systems computational optimization ensemble classifiers reinforcement learning decision trees support vector machines hybrid learning statistical learning metaheuristics algorithms evolutionary and swarm based algorithms like genetic algorithms genetic programming differential evolution particle swarm optimization whale optimization spider monkey optimization firefly algorithm memetic algorithms And also machine vision Internet of Things image processing image segmentation data clustering sentiment analysis big data computer networks signal processing supply chain management web and text mining distributed systems bioinformatics embedded systems expert system forecasting pattern recognition planning and scheduling time series analysis human computer interaction web mining natural language processing multimedia systems and quantum computing

Smart Trends in Computing and Communications Tomonobu Senjyu, Chakchai So-In, Amit Joshi, 2025-09-30 This book gathers high quality papers presented at the Ninth International Conference on Smart Trends in Computing and Communications SmartCom 2025 organised by Global Knowledge Research Foundation GR Foundation from 29 to 31 January 2025 in Pune India It covers state of the art and emerging topics in information computer communications and effective strategies for their use in engineering and managerial applications It also explores and discusses the latest technological advances in and future directions for

information and knowledge computing and its applications

Sensing and Signal Processing in Smart Healthcare

Wenbing Zhao, Srinivas Sampalli, 2021-01-29 In the last decade we have witnessed the rapid development of electronic technologies that are transforming our daily lives. Such technologies are often integrated with various sensors that facilitate the collection of human motion and physiological data and are equipped with wireless communication modules such as Bluetooth, radio frequency identification and near field communication. In smart healthcare applications, designing ergonomic and intuitive human computer interfaces is crucial because a system that is not easy to use will create a huge obstacle to adoption and may significantly reduce the efficacy of the solution. Signal and data processing is another important consideration in smart healthcare applications because it must ensure high accuracy with a high level of confidence in order for the applications to be useful for clinicians in making diagnosis and treatment decisions. This Special Issue is a collection of 10 articles selected from a total of 26 contributions. These contributions span the areas of signal processing and smart healthcare systems, mostly contributed by authors from Europe including Italy, Spain, France, Portugal, Romania, Sweden and Netherlands. Authors from China, Korea, Taiwan, Indonesia and Ecuador are also included.

Sensor Signal and Information Processing III Wai Lok Woo, Bin Gao, 2021-02-05 In the current age of information explosion, newly invented technological sensors and software are now tightly integrated with our everyday lives. Many sensor processing algorithms have incorporated some forms of computational intelligence as part of their core framework in problem solving. These algorithms have the capacity to generalize and discover knowledge for themselves and to learn new information whenever unseen data are captured. The primary aim of sensor processing is to develop techniques to interpret, understand and act on information contained in the data. The interest of this book is in developing intelligent signal processing in order to pave the way for smart sensors. This involves the mathematical advancement of nonlinear signal processing theory and its applications that extend far beyond traditional techniques. It bridges the boundary between theory and application, developing novel, theoretically inspired methodologies targeting both longstanding and emergent signal processing applications. The topics range from phishing detection to integration of terrestrial laser scanning and from fault diagnosis to bio-inspired filtering. The book will appeal to established practitioners along with researchers and students in the emerging field of smart sensor signal processing.

Soft Computing and Its Engineering Applications Kanubhai K. Patel, KC Santosh, Gabriel Gomes de Oliveira, Atul Patel, Ashish Ghosh, 2025-05-17 The two volume proceedings set CCIS 2430, 2431 constitutes the revised selected papers of the 6th International Conference on Soft Computing and its Engineering Applications, icSoftComp 2024, held in Bangkok, Thailand during December 10-12, 2024. The 58 full papers and 3 short papers included in this book were carefully reviewed and selected from 501 submissions. They were organized in topical sections as follows: Part I: Theory and Methods; Part II: Theory and Methods; Systems and Applications; Hybrid Techniques; Soft Computing for Smart World.

Advanced Materials and Structural Engineering Jong Wan Hu, 2016-02-03 The ICAMEST 2015 Conference covered

new developments in advanced materials and engineering structural technology Applications in civil mechanical industrial and material science are covered in this book Providing high quality scholarly research addressing developments applications and implications in the field of structural health monitoring construction safety and management sensors and measurements This volume contains new models for nonlinear structural analysis and applications of modeling identification Furthermore advanced chemical materials are discussed with applications in mechanical and civil engineering and for the maintenance of new materials In addition a new system of pressure regulating and water conveyance based on small and middle hydropower stations is discussed An experimental investigation of the ultimate strength and behavior of the three types of steel tubular K joints was presented Furthermore real time and frequency linear and nonlinear modeling performance of materials of structures contents were concluded with the notion of a fully brittle material and this approach is implemented in the book by outlining a finite element method for the prediction of the construction performance and cracking patterns of arbitrary structural concrete forms This book is an ideal reference for practicing engineers in material mechanical and civil engineering and consultants design construction maintenance and can also be used as a reference for students in mechanical and civil engineering courses

CMBEBIH 2021 Almir Badnjevic, Lejla Gurbeta Pokvić, 2021-05-31 This book presents cutting edge research and developments in the field of medical and biological engineering It gathers the proceedings of the International Conference on Medical and Biological Engineering CMBEBIH 2021 held partly virtually partly physically on April 21 24 2021 from and in Mostar Bosnia and Herzegovina Focusing on the goal to Stay Focused contributions report on both basic and applied research in a wide range of related fields such as biomedical signal processing medical physics and imaging biosensors and micro nanotechnologies biomaterials biomechanics and robotics cardiorespiratory endocrine and neural systems engineering Novel models methods and technologies for bio and health informatics as well as applications of machine learning and AI in health care and advances in genetic engineering are also highlighted All in all this book provides academics and professionals with novel practical solutions to solve the current problems in biomedical research and applications and a source of inspiration for improving medicine and health care in the future

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