Two Dimensional Short Time Hartley Transforms

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ABSTRACT: The Hartley transform, as in the case of the Fourier transform, is not suitably applicable to non-stationary representations of signals whose statistical properties change as a function of time. Hence, different versions of 2-D short time Hartley transforms (STHT) are given in comparison with the short time Fourier transform (STFT). Although the two different versions of STHT defined here with their inverses are equally applicable, one of them is mathematically incorrect/incompatible due to the incorrect definition of the 2-D Hartley transform in literature. These definitions of STHTs can easily be extended to multi-dimensions. Computations of the STFT and the two versions of STHTs are illustrated based on 32 channels (traces) of synthetic seismic data consisting of 256 samples in each trace. Salient features of STHTs are incorporated.

Keywords: Fourier transform; Hartley transform; Wavelet transform; Time; Frequency and Window.

تحويلات هارتلي ثنائية الأبعاد للزمن القصير

نارسيمان ساندرارجان و علاءالدين ابراهيمي ناناباراجا فاسودا

الملخص: ان تحويل هارتلي كما هو الحال بالنسبة لتحويل فورييه، لا ينطبق بشكل مناسب للتمثيل غير الثابت للإشارات التي خصائصها الإحصائية تتغير كدالة في زمن. بالتالي إصدارات مختلفة من تحويلات هارتلي للزمن ثنائي الأبعاد للزمن القصير (STHT) تقارن مع تحويل فورييه للزمن القصير (STFT). بالرغم من وجود إصدارين مختلفين من STHT المعرفة هنا مع معكوسها الذين مشاريان في التطبيق، فإن احدهما غير صحيح/ متوافقه رياضيا بسبب التعريف الغير صحيح لتحويل هارتلي للبعدين ثنائي أبعاد متعددة وقد تم توضيح حسابات STFT و تعريف الإصدارين لـ STHTs بالاستناد الى قناة 32 (اثر) من البيانات السيزمية المولفة تتألف من 256 عينة في كل اثر . كما تم دمج الخصائص البارزة لـ STHTs.

الكلمات المفتاحية: تحويل فورييه، تحويل هارتلي،تحويل الموجات،الزمن، فريكونسي والنافذه.

1. Introduction

It is well known that the elegant mathematical tools, the Fourier transform (FT) and Hartley transforms (HT), were invented in 1807 and 1942 respectively. Subsequently, the theory of spectral analysis began with the breakthrough of Tukey in 1949 [1]. However, the computational feasibility of the FT was a reality only when the great breakthrough occurred in the form of the fast Fourier transform (FFT) algorithm that was brought out in 1965 by Cooley and Tukey [2].

In general, the FT gives the spectral content of the signal, devoid of any information regarding the time at which those spectral components appear. Such a result is appreciable only for stationary signals [3], whose frequency content does not change with time. In most of the cases, a particular spectral component occurring at a specific time instant can be more useful and interesting, as in the case of seismological data which is non-stationary, and in which the frequency of the signal varies with time. Mathematicians and researchers are aware that the Fourier transform is best suited to process stationary signals; however, most of the information and data we come across in our day to day life are not stationary. To achieve time localization of frequency of a non-stationary signal while using the FT, it is necessary that the signal be subjected to narrow windows, narrow enough that the portion of the signal seen from these windows is indeed stationary. This approach is called the short time Fourier transform (STFT), which is a modified version of the FT. In the STFT, the given signal is divided into small segments, such that each segment of the signal can be assumed to be stationary. For this purpose, a window function is chosen, so that the width of the window is equal to the segment of the signal, in which its stationarity is valid. Thus, the one dimensional STFT can be defined as [4–6]:

$$STFT(\tau, w) = \int_{-\infty}^{\infty} f(t) g(t-\tau) e^{-j2\pi wt} dt \tag{1}$$

Hartley Transforms

Gintautas Dzemyda,Jolita Bernatavičienė,Janusz Kacprzyk

Hartley Transforms:

   Transforms and Applications Handbook Alexander D. Poularikas,2018-09-03 Updating the original Transforms and Applications Handbook Third Edition solidifies its place as the complete resource on those mathematical transforms most frequently used by engineers scientists and mathematicians Highlighting the use of transforms and their properties this latest edition of the bestseller begins with a solid introduction to signals and systems including properties of the delta function and some classical orthogonal functions It then goes on to detail different transforms including lapped Mellin wavelet and Hartley varieties Written by top experts each chapter provides numerous examples and applications that clearly demonstrate the unique purpose and properties of each type The material is presented in a way that makes it easy for readers from different backgrounds to familiarize themselves with the wide range of transform applications Revisiting transforms previously covered this book adds information on other important ones including Finite Hankel Legendre Jacobi Gengenbauer Laguerre and Hermite Fraction Fourier Zak Continuous and discrete Chirp Fourier Multidimensional discrete unitary Hilbert Huang Most comparable books cover only a few of the transforms addressed here making this text by far the most useful for anyone involved in signal processing including electrical and communication engineers mathematicians and any other scientist working in this field   *Multidimensional Discrete Unitary Transforms* Artyom M. Grigoryan,Sos S. Agaian,2003-07-31 This reference presents a more efficient flexible and manageable approach to unitary transform calculation and examines novel concepts in the design classification and management of fast algorithms for different transforms in one two and multidimensional cases Illustrating methods to construct new unitary transforms for best algorithm selection and development in real world applications the book contains a wide range of examples to compare the efficacy of different algorithms in a variety of one two and three dimensional cases Multidimensional Discrete Unitary Transforms builds progressively from simple representative cases to higher levels of generalization   *Transforms and Fast Algorithms for Signal Analysis and Representations* Guoan Bi,Yonghong Zeng,2012-12-06 that is what learning is You suddenly understand something you ve un derstood all your life but in a new way Various transforms have been widely used in diverse applications of science engineering and technology New transforms are emerging to solve many problems which may have been left unsolved in the past or newly created by modern science or technologies Various meth ods have been continuously reported to improve the implementation of these transforms Early developments of fast algorithms for discrete transforms have significantly stimulated the advance of digital signal processing technologies More than 40 years after fast Fourier transform algorithms became known several discrete transforms including the discrete Hart ley transform and discrete cosine transform were proposed and widely used for numerous applications Although they all are related to the discrete Fourier transform different fast algorithms and their implementations have to be separately developed to minimize compu tational complexity and implementation costs In spite of the tremendous increase in the speed of computers or

processors the demands for higher processing throughout seemingly never ends Fast algorithms have become more important than ever for modern applications to become a reality Many new algorithms recently reported in the literature have led to important improvements upon a number of issues which will be addressed in this book Some discrete transforms are not suitable for signals that have time varying frequency components Although several approaches are available for such applications various inher ent problems still remain unsolved   The Regularized Fast Hartley Transform Keith Jones,2010-03-10 Most real world spectrum analysis problems involve the computation of the real data discrete Fourier transform DFT a unitary transform that maps elements N of the linear space of real valued N tuples R to elements of its complex valued N counterpart C and when carried out in hardware it is conventionally achieved via a real from complex strategy using a complex data version of the fast Fourier transform FFT the generic name given to the class of fast algorithms used for the ef cient computation of the DFT Such algorithms are typically derived by explo ing the property of symmetry whether it exists just in the transform kernel or in certain circumstances in the input data and or output data as well In order to make effective use of a complex data FFT however via the chosen real from complex N strategy the input data to the DFT must rst be converted from elements of R to N elements of C The reason for choosing the computational domain of real data problems such N N as this to be C rather than R is due in part to the fact that computing equ ment manufacturers have invested so heavily in producing digital signal processing DSP devices built around the design of the complex data fast multiplier and accumulator MAC an arithmetic unit ideally suited to the implementation of the complex data radix 2 butter y the computational unit used by the familiar class of recursive radix 2 FFT algorithms   The Hartley Transform Ronald Newbold Bracewell,1986 The author describes the fast algorithm he discovered for spectral analysis and indeed any purpose to which Fourier Transforms and the Fast Fourier Transform are normally applied   **Advanced Biomedical Image Analysis** Mark Haidekker,2011-03-29 A comprehensive reference of cutting edge advanced techniques for quantitative image processing and analysis Medical diagnostics and intervention and biomedical research rely progressively on imaging techniques namely the ability to capture store analyze and display images at the organ tissue cellular and molecular level These tasks are supported by increasingly powerful computer methods to process and analyze images This text serves as an authoritative resource and self study guide explaining sophisticated techniques of quantitative image analysis with a focus on biomedical applications It offers both theory and practical examples for immediate application of the topics as well as for in depth study Advanced Biomedical Image Analysis presents methods in the four major areas of image processing image enhancement and restoration image segmentation image quantification and classification and image visualization In each instance the theory mathematical foundation and basic description of an image processing operator is provided as well as a discussion of performance features advantages and limitations Key algorithms are provided in pseudo code to help with implementation and biomedical examples are included in each chapter Image registration storage transport

and compression are also covered and there is a review of image analysis and visualization software Members of the academic community involved in image related research as well as members of the professional R D sector will rely on this volume It is also well suited as a textbook for graduate level image processing classes in the computer science and engineering fields   *Introduction to Digital Image Processing* William K. Pratt,2013-09-13 The subject of digital image processing has migrated from a graduate to a junior or senior level course as students become more proficient in mathematical background earlier in their college education With that in mind Introduction to Digital Image Processing is simpler in terms of mathematical derivations and eliminates derivations of advanced s   **Fourier Transforms** Robert M. Gray,Joseph W. Goodman,2012-12-06 The Fourier transform is one of the most important mathematical tools in a wide variety of fields in science and engineering In the abstract it can be viewed as the transformation of a signal in one domain typically time or space into another domain the frequency domain Applications of Fourier transforms often called Fourier analysis or harmonic analysis provide useful decompositions of signals into fundamental or primitive components provide shortcuts to the computation of complicated sums and integrals and often reveal hidden structure in data Fourier analysis lies at the base of many theories of science and plays a fundamental role in practical engineering design The origins of Fourier analysis in science can be found in Ptolemy s decomposing celestial orbits into cycles and epicycles and Pythagorus de composing music into consonances Its modern history began with the eighteenth century work of Bernoulli Euler and Gauss on what later came to be known as Fourier series J Fourier in his 1822 Theorie analytique de la Chaleur 16 still available as a Dover reprint was the first to claim that arbitrary periodic functions could be expanded in a trigonometric later called a Fourier series a claim that was eventually shown to be incorrect although not too far from the truth It is an amusing historical sidelight that this work won a prize from the French Academy in spite of serious concerns expressed by the judges Laplace Lagrange and Legendre re garding Fourier s lack of rigor   *Data Analysis and Signal Processing in Chromatography* A. Felinger,1998-05-19 This book gives an overview of the numerical data analysis and signal treatment techniques that are used in chromatography and related separation techniques Emphasis is given to the description of the symmetrical and asymmetrical chromatographic peak shape models Both theoretical and empirical models are discussed The fundamentals of data acquisition types and effect of baseline noise and methods of improving the signal to noise ratio either in time or in frequency and wavelet domain are thoroughly discussed Resolution enhancement techniques such as curve fitting deconvolution by Fourier and wavelet transforms iterative deconvolution Kalman filtering and multivariate methods of curve resolution are all discussed with several chromatographic examples Quantitative analysis by peak area of peak height measurement the precision and accuracy of the quantitation of stand alone or overlapping and symmetrical or asymmetrical peaks are treated In a separate chapter guidelines are given for the use of transform techniques for the analysis of chromatograms A statistical description of peak overlap is given in the final chapters Since the concept of resolution has to

be reconsidered when one separates complex mixtures the problem of resolution and overlap is quantitatively discussed by means of statistical methods and by using Fourier analysis of the complex chromatogram Features of this book The ultimate source of numerical techniques to enhance chromatographic data Gives a detailed description of signal and resolution enhancement techniques in a manner applicable for enhancing not only chromatography but also spectroscopic and other analytical signals The first book with a thorough overview of the statistics of peak overlap This is the first volume to encompass both the simple and more sophisticated methods for the numerical treatment of chromatograms It is therefore the fundamental resource of numerical analysis methods for every analyst   Feature Extraction & Image Processing Mark Nixon,2008-01-08 Whilst other books cover a broad range of topics Feature Extraction and Image Processing takes one of the prime targets of applied computer vision feature extraction and uses it to provide an essential guide to the implementation of image processing and computer vision techniques Acting as both a source of reference and a student text the book explains techniques and fundamentals in a clear and concise manner and helps readers to develop working techniques with usable code provided throughout The new edition is updated throughout in line with developments in the field and is revised to focus on mathematical programming in Matlab Essential reading for engineers and students working in this cutting edge field Ideal module text and background reference for courses in image processing and computer vision   **Data Science: New Issues, Challenges and Applications** Gintautas Dzemyda,Jolita Bernatavičienė,Janusz Kacprzyk,2020-02-13 This book contains 16 chapters by researchers working in various fields of data science They focus on theory and applications in language technologies optimization computational thinking intelligent decision support systems decomposition of signals model driven development methodologies interoperability of enterprise applications anomaly detection in financial markets 3D virtual reality monitoring of environmental data convolutional neural networks knowledge storage data stream classification and security in social networking The respective papers highlight a wealth of issues in and applications of data science Modern technologies allow us to store and transfer large amounts of data quickly They can be very diverse images numbers streaming related to human behavior and physiological parameters etc Whether the data is just raw numbers crude images or will help solve current problems and predict future developments depends on whether we can effectively process and analyze it Data science is evolving rapidly However it is still a very young field In particular data science is concerned with visualizations statistics pattern recognition neurocomputing image analysis machine learning artificial intelligence databases and data processing data mining big data analytics and knowledge discovery in databases It also has many interfaces with optimization block chaining cyber social and cyber physical systems Internet of Things IoT social computing high performance computing in memory key value stores cloud computing social computing data feeds overlay networks cognitive computing crowdsource analysis log analysis container based virtualization and lifetime value modeling Again all of these areas are highly interrelated In addition data science is now expanding to new fields of application chemical

engineering biotechnology building energy management materials microscopy geographic research learning analytics radiology metal design ecosystem homeostasis investigation and many others **Handbook of Function and Generalized Function Transformations** Ahmed I. Zayed,2019-08-21 Function transformations which include linear integral transformations are some of the most important mathematical tools for solving problems in all areas of engineering and the physical sciences They allow one to quickly solve a problem by breaking it down into a series of smaller more manageable problems The author has compiled the most important and widely used of these function transforms in applied mathematics and electrical engineering In addition to classical transforms newer transforms such as wavelets Zak and Radon are included The book is neither a table of transforms nor a textbook but it is a source book that provides quick and easy access to the most important properties and formulas of function and generalized function transformations The DFT William L. Briggs,Van Emden Henson,1995-01-01 This book explores both the practical and theoretical aspects of the Discrete Fourier Transform one of the most widely used tools in science engineering and computational mathematics Designed to be accessible to an audience with diverse interests and mathematical backgrounds the book is written in an informal style and is supported by many examples figures and problems Conceived as an owner s manual this comprehensive book covers such topics as the history of the DFT derivations and properties of the DFT comprehensive error analysis issues concerning the implementation of the DFT in one and several dimensions symmetric DFTs a sample of DFT applications and an overview of the FFT *Fast Fourier Transform - Algorithms and Applications* K.R. Rao,Do Nyeon Kim,Jae Jeong Hwang,2011-02-21 This book presents an introduction to the principles of the fast Fourier transform This book covers FFTs frequency domain filtering and applications to video and audio signal processing As fields like communications speech and image processing and related areas are rapidly developing the FFT as one of essential parts in digital signal processing has been widely used Thus there is a pressing need from instructors and students for a book dealing with the latest FFT topics This book provides thorough and detailed explanation of important or up to date FFTs It also has adopted modern approaches like MATLAB examples and projects for better understanding of diverse FFTs **Digital Image Processing** Bernd Jähne,2005-04-07 This long established and well received monograph offers an integral view of image processing from image acquisition to the extraction of the data of interest written by a physical scientists for other scientists Supplements discussion of the general concepts is supplemented with examples from applications on PC based image processing systems and ready to use implementations of important algorithms Completely revised and extended the most notable extensions being a detailed discussion on random variables and fields 3 D imaging techniques and a unified approach to regularized parameter estimation *A First Course in Fourier Analysis* David W. Kammler,2008-01-17 This book provides a meaningful resource for applied mathematics through Fourier analysis It develops a unified theory of discrete and continuous univariate Fourier analysis the fast Fourier transform and a powerful elementary theory of generalized functions and shows how these

mathematical ideas can be used to study sampling theory PDEs probability diffraction musical tones and wavelets The book contains an unusually complete presentation of the Fourier transform calculus It uses concepts from calculus to present an elementary theory of generalized functions FT calculus and generalized functions are then used to study the wave equation diffusion equation and diffraction equation Real world applications of Fourier analysis are described in the chapter on musical tones A valuable reference on Fourier analysis for a variety of students and scientific professionals including mathematicians physicists chemists geologists electrical engineers mechanical engineers and others *Handbook of Formulas and Tables for Signal Processing* Alexander D. Poularikas,2018-10-08 Signal processing is a broad and timeless area The term signal includes audio video speech image communication geophysical sonar radar medical and more Signal processing applies to the theory and application of filtering coding transmitting estimating detecting analyzing recognizing synthesizing recording and reproducing signals Handbook of Formulas and Tables for Signal Processing a must have reference for all engineering professionals involved in signal and image processing Collecting the most useful formulas and tables such as integral tables formulas of algebra formulas of trigonometry the text includes Material for the deterministic and statistical signal processing areas Examples explaining the use of the given formula Numerous definitions Many figures that have been added to special chapters Handbook of Formulas and Tables for Signal Processing brings together in one textbook all the equations necessary for signal and image processing for professionals transforming anything from a physical to a manipulated form creating a new standard for any person starting a future in the broad extensive area of research

Computational Frameworks for the Fast Fourier Transform Charles Van Loan,1992-01-01 The author captures the interplay between mathematics and the design of effective numerical algorithms **Feature Extraction and Image Processing for Computer Vision** Mark Nixon,2012-12-18 Feature Extraction and Image Processing for Computer Vision is an essential guide to the implementation of image processing and computer vision techniques with tutorial introductions and sample code in Matlab Algorithms are presented and fully explained to enable complete understanding of the methods and techniques demonstrated As one reviewer noted The main strength of the proposed book is the exemplar code of the algorithms Fully updated with the latest developments in feature extraction including expanded tutorials and new techniques this new edition contains extensive new material on Haar wavelets Viola Jones bilateral filtering SURF PCA SIFT moving object detection and tracking development of symmetry operators LBP texture analysis Adaboost and a new appendix on color models Coverage of distance measures feature detectors wavelets level sets and texture tutorials has been extended Named a 2012 Notable Computer Book for Computing Methodologies by Computing Reviews Essential reading for engineers and students working in this cutting edge field Ideal module text and background reference for courses in image processing and computer vision The only currently available text to concentrate on feature extraction with working implementation and worked through derivation *Fourier Analysis and Imaging* Ronald Bracewell,2012-12-06 As Lord Kelvin said Fourier s

theorem is not only one of the most beautiful results of modern analysis but it may be said to furnish an indispensable instrument in the treatment of nearly every recondite question in modern physics This has remained durable knowledge for a century and has extended its applicability to topics as diverse as medical imaging CT scanning the presentation of images on screens and their digital transmission remote sensing geophysical exploration and many branches of engineering Fourier Analysis and Imaging is based on years of teaching a course on the Fourier Transform at the senior or early graduate level as well as on Prof Bracewell s 1995 text Two Dimensional Imaging It is an excellent textbook and will also be a welcome addition to the reference library of those many professionals whose daily activities involve Fourier analysis in its many guises

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