

Preface

This book presents an introduction to the principles of the fast Fourier transform (FFT). It 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 the 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 a 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.

Fast Fourier transform (FFT) is an efficient implementation of the discrete Fourier transform (DFT). Of all the discrete transforms, DFT is most widely used in digital signal processing. The DFT maps a sequence either in the time domain or in the spatial domain into the frequency domain. The development of the DFT originally by Cooley and Tukey [A1] followed by various enhancements/modifications by other researchers has provided the incentive and the impetus for its rapid and widespread utilization in a number of diverse disciplines. Independent of the Cooley-Tukey approach, several algorithms such as prime factor, split radix, vector radix, split vector radix, Winograd Fourier transform, and integer FFT have been developed. The emphasis of this book is on various FFTs such as the decimation-in-time FFT, decimation-in-frequency FFT algorithms, integer FFT, prime factor DFT, etc.

In some applications such as dual-tone multi-frequency detection and certain pattern recognition, their spectra are skewed to some regions that are not uniformly distributed. With this basic concept we briefly introduce the nonuniform DFT (NDFT), dealing with arbitrarily spaced samples in the Z-plane, while the DFT deals with equally spaced samples on the unit circle with the center at the origin in the Z-plane.

A number of companies provide software for implementing FFT and related basic applications such as convolution/correlation, filtering, spectral analysis, etc. on various platforms. Also general-purpose DSP chips can be programmed to implement the FFT and other discrete transforms.

This book is designed for senior undergraduate and graduate students, faculty, engineers, and scientists in the field, and self-learners to understand FFTs and directly apply them to their fields, efficiently. It is designed to be both a text and a reference. Thus examples, projects and problems all tied with MATLAB, are provided for grasping the concepts concretely. It also includes references to books and review papers and lists of applications, hardware/software, and useful websites. By including many figures, tables, block diagrams and graphs, this book helps the reader understand the concepts of fast algorithms readily and intuitively. It provides new MATLAB functions and MATLAB source codes.

The material in this book is presented without assuming any prior knowledge of FFT. This book is for any professional who wants to have a basic understanding of the latest developments in and applications of FFT. It provides a good reference for any engineer planning to work in this field, either in basic implementation or in research and development.

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Organization of the Book

Chapter 1 introduces various applications of the discrete Fourier transform. Chapter 2 is devoted to introductory material on the properties of the DFT for the equally spaced samples. Chapter 3 presents fast algorithms to be mainly categorized as decimation-in-time (DIT) or decimation-in-frequency (DIF) approaches. Based on these, it introduces fast algorithms like split-radix, Winograd algorithm and others. Chapter 4 is devoted to integer FFT which approximates the discrete Fourier transform. One-dimensional DFT is extended to the two-dimensional signal and then to the multi-dimensional signal in Chapter 5. Applications to filtering are presented in this chapter. Variance distribution in the DFT domain is covered. It also introduces how we can diagonalize a circulant matrix using the DFT matrix. Fast algorithms for the 2-D DFT are covered in Chapter 6. Chapter 7 is devoted to introductory material on the properties of nonuniform DFT (NDFT) for the non-equally spaced samples. Numerous applications of the FFT are presented in Chapter 8. Appendix A covers performance comparison of discrete transforms. Appendix B covers spectral distance measures of image quality. Appendix C covers Integer DCTs. DCTs and DSTs are derived in Appendix D (DCT – discrete cosine transform, DST – discrete sine transform). Kronecker products and separability are briefly covered in Appendix E. Appendix F describes mathematical relations. Appendices G and H include MATLAB basics and M files. The bibliography contains lists of references to books and review papers, software/hardware, and websites. Numerous problems and projects are listed at the end of each chapter.

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