Wavelet Theory and Its Application to Pattern Recognition

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We dedicate this book to
our parents, wives, children
and all members of the families

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Preface

This book aims at attacking a challenging research topic that is related to both areas of wavelet theory and pattern recognition.

Wavelet analysis and its applications have become one of the fastest growing research areas in recent years. This is in part attributed to the pioneering work by the researchers as well as practitioners in the fields of mathematics and signal processing. Wavelet theory has been employed in many fields and applications, such as signal and image processing, communication systems, biomedical imaging, radar, air acoustics, theoretical mathematics, control system, and endless other areas. However, the research on applying the wavelets to pattern recognition is still too weak; only a few publications deal with this topic at the present. This book focuses on this challenging research topic.

The most fascinating area of signal/image processing with practical applications is pattern recognition. Making computers see and recognize objects like humans has captured the attention of many scientists in different disciplines. Indeed, machine recognition of different patterns such as printed and handwritten characters, fingerprints, biomedical images, etc. has been intensively and extensively researched by scientists in different countries around the world. The area of pattern recognition, after over four decades of continued development, is now definitely playing a very major role in advanced automation as we enter the 21st century. Although a lot of achievements have been made in the area of pattern recognition, many problems still have to be solved. The goal of this book is to, through mathematically sound derivations and experiments, develop some new application-oriented techniques in wavelet theory, and thereafter, ap-

ply these new techniques to solve some particular problems in the area of pattern recognition.

This book is organized into two groups, namely, Chapters 1 - 4 extend wavelet theory, while Chapter 5 through Chapter 9 deal with the application of the wavelet theory to pattern recognition, which is the core of this book. Considering the major readers of this book are scientists and engineers, thus, in some sections, we give up the exactness in mathematics temporarily.

Initially, in Chapter 1, a brief description of wavelet theory is introduced, and a comparison between the wavelet and Fourier transforms is discussed along with several pictorial examples. This chapter reviews established applications of the wavelet theory to pattern recognition. The review is not detailed, since this book concentrates on the novel research results developed by the authors. However, the references are cited if additional details are desired.

Throughout Chapters 2 and 3, both the wavelet transform and wavelet bases are of critical concerns, which formulate the basic wavelet theory. In Chapter 2, the general theory of the continuous wavelet transform is addressed, and its major properties are investigated including the characterization of Lipschitz regularity of signals by the wavelet transform. Chapter 2 also primarily examines an important property by relating the processing to matched filtering concepts. Chapter 3 considers multiresolution analysis (MRA) and wavelet bases, where the basic concepts of the both are presented as well as the construction of them. As an important algorithm for implementing the discrete wavelet transform, Mallat algorithm is introduced.

After studying these basic concepts of the wavelet theory, some typical wavelet bases including the orthonormal and nonorthonormal bases are provided in Chapter 4. They benefit the application of the wavelet theory to the engineering, such as pattern recognition, image processing, etc.

By formulating the above wavelet theory and the general applications with wavelet theory, the second group of this book (Chapters 5 - 9) demonstrates more detailed applications, which become the core chapters. All of these applications were made by our research group recently. Chapter 5 develops a novel method to identify different structures of the edges and design an algorithm to detect the step-structure edges. This technique can be employed to contour extraction in document processing as well as 2-D object recognition. Chapter 6 presents a new approach to feature extraction. In this way, the wavelet decomposition was used to produce wavelet

sub-patterns, and thereafter, the fractal divider dimensions were utilized to find the numerical features from these sub-patterns. Chapter 7 applies 2-D multiresolution analysis (MRA) and Mallat algorithm to form document analysis. The HL and LH sub-images were utilized to find the reference lines in a form document, furthermore, the useful information can be extracted in accordance with these reference lines. This application is verified by several concrete examples of bank checks. Chapter 8 uses B-spline wavelet for Chinese computing, which consists of three operations, namely, (1) compression of Chinese characters, (2) enlargement of type size with arbitrary scales, and (3) generation of type styles of Chinese fonts. Chapter 9 deals with the classification of patterns with wavelet theory. In this way, the orthogonal wavelet series are used for the probability density estimation in the classifier design.

The main components of this book are the achievements in our research group with visiting scholars. The professors from various universities and the graduate students at Hong Kong Baptist University have made contributions to this book:

- Professor P. C. Yuen at Hong Kong Baptist University, and Professor Seong-Whan Lee at Korea University of Korea presented their research results in Chapter 1.
- Professors Yi Dong, Zeng Li and N. W. Strathy, and Ms. Tang Yan joined us to modify Chapters 1 - 4.
- Some material in Chapter 4 were supported by Professor Chen Zhikui.
- The origin of the application of wavelet theory to Chinese character processing was provided by Professor Yang Feng, and is covered in Chapter 8. Professor Chen Zhikui and Ms. Tang Yan made some contributions to this chapter.

To review the established applications of the wavelet theory to pattern recognition, in Chapter 1, we quoted some materials including figures from the published papers. We would like to thank the following authors to release the copyrights to us:

- S. H. Yoon, J. H. Kim, W. E. Alexander, S. M. Park and K. H. Sohn: [Yoon et al., 1998],
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