Preface

Digital image processing is a popular, rapidly growing area of electrical and computer engineering. Digital image processing has enabled various intelligent applications such as face recognition, signature recognition, iris recognition, forensics, automobile detection, and military vision applications. Its growth is leveraged by technological innovations in the fields of computer processing, digital imaging, and mass storage devices. Traditional analog imaging applications are now switching to digital systems to utilize their usability and affordability. Important examples include photography, medicine, video production, remote sensing, and security monitoring. These sources produce a huge volume of digital image data every day. Theoretically, image processing can be considered as the processing of a two-dimensional image using a digital computer. The outcome of image processing could be an image, a set of features, or characteristics related to the image. Most image processing methods treat an image as a two-dimensional signal and implement standard signal processing techniques.

Many image processing techniques were of only academic interest because of their computational complexity. However, recent advances in processing and memory technology made image processing a vital and cost-effective technology in a host of applications. Multi-scale image transformations, such as Fourier transform, wavelet transform, complex wavelet transform, quaternion wavelet transform, ridgelet transform, contourlet transform, curvelet transform, and shearlet transform, play an extremely crucial role in image compression, image denoising, image restoration, image enhancement, and super-resolution. Fourier transform is a powerful tool that has been available to signal and image analysis for many years. However, the problem with using Fourier transform is frequency analysis cannot offer high frequency and time resolution at the same time. To overcome this problem, windowed Fourier transform or short-time Fourier transform was introduced. Although the short-time Fourier transform has the ability to provide time information, a complete multiresolution analysis is not possible. Wavelet is a solution to the multiresolution problem. A wavelet has the important property of not having a fixed-width sampling window. The wavelet transform can be classified into (i) continuous wavelet transform and (ii) discrete wavelet transform. The discrete wavelet transform (DWT) algorithms have a firm position in processing of images in many areas of research and industry.

The main focus of classical wavelets includes compression and efficient representation. Important features which play a role in analysis of functions in two variables are dilation, translation, spatial and frequency localization, and singularity orientation. Singularities of functions in more than one variable vary in dimensionality. Important singularities in one dimension are simply points. In two dimensions, zero- and one-dimensional singularities are important. A smooth singularity in two dimensions may be a one-dimensional smooth manifold. Smooth singularities in two-dimensional images often occur as boundaries of physical objects. Efficient representation in two dimensions is a hard problem. To overcome this problem, new multi-scale transformations such as ridgelet transform, contourlet transform, curvelet transform, and shearlet transform were introduced. Recently, these multi-scale transforms have become increasingly important in image processing.

In this book, we will provide a complete introduction of multi-scale image transformations followed by their applications to various image processing algorithms including image denoising, image restoration, image enhancement, and super-resolution. The book is mainly divided into three parts. The readers will learn about the basic introduction of image processing in the first part in Chaps. 1 and 2. The second part starts with Fourier transform followed by wavelet transform and new multi-scale constructions. The third part deals with applications of the multi-scale transform in image processing.

The chapters of the present book consist of both tutorial and advanced theory. Therefore, the book is intended to be a reference for graduate students and researchers to obtain state-of-the-art knowledge on multi-scale image processing applications. The technique of solving problems in the transform domain is common in applied mathematics as used in research and industry, but we do not devote as much time to it as we should in the undergraduate curriculum. Also, the book is intended to be used as a reference manual for scientists who are engaged in image processing research, developers of image processing hardware and software systems, and practicing engineers and scientists who use image processing as a tool in their applications.

Appendices summarize mostly used mathematical background in the book.

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