

Apurba Das

# Guide to Signals and Patterns in Image Processing

Foundations, Methods and Applications



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*To  
Angana*

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## Preface

We, humans, generally called as *Homo sapiens*, are the most superior species in the globe. Probably the most complex part of human body is the vision system which is the combination of the two eyes, the brain, and perception. Our vision system is probably the most accurate sensor among the other five, to create an illustration of the nature around us onto our brain in terms of perception. Hence the eye rather the entire vision system is not only one image-capturing device like a camera, but also a complex processing device of the captured image. The processing includes detection, identification, recognition, analysis, synthesis, and modeling.

In today's digital world, everything including some abstract concepts like emotions is expressed in terms of digital logic. The basic rule of digitization is finiteness and discreteness in the expression of any kind of data. The natural image can have infinite number of shades against each of the infinite number of colors. The variation of color along the space is also continuous and the precision of change of intensity in natural image might be infinitesimally small. Hence, in digital representation of image we must have to go for some kind of approximation in terms of primary colors, spatial samples, and quantized intensities.

Any system, whether a computing system or psycho-visual system, infers images in terms of a highly correlated signal. The aforementioned correlation is not necessarily neighborhood spatial correlation always. There can be a correlation in an image in terms of a repetitive texture, frequency component, shape, template, and many more. For any kind of object recognition from captured image we generally see that image from two different angles namely, local texture and holistic pattern.

This book illustrates the subject digital image processing from two different viewpoints. The first viewpoint is the signal processing perspective where each of the separation (primary color) of the image can be expressed as a two-dimensional (2D) matrix of discrete points representing intensities. These intensities must follow the aforementioned rule of digitization having finite upper limit, lower limit, and minimum step between adjacent levels. The second viewpoint is the pattern perspective where we discuss identification/selection, extraction, and reduction of suitable features from images, based on different applications and domains. Hence, the primary motivation of this book is to illustrate the wonderful subject of digital image processing from two different perspectives namely, signal processing and pattern recognition. The guide to the journey through the discipline of image processing would be "signals" and "patterns". Wayne Wheeler, Sr. Editor of Springer,

UK has proposed the title of this book as “Guides to Signals and Patterns in Image Processing—Foundations, Methods and Applications”. I believe this is the most appropriate title depicting the motivation of this text.

Even though the subject digital image processing has been evolved through years and requires background of mathematics, physics, computer science, statistics, and information theory, I have tried to describe the concepts in a lucid way. Wherever signal processing or background of statistics or information theory is required, I have mentioned the prerequisites briefly at the beginning of the chapter or as an appendix. Like all my other books, specially the last two books published by Springer, I started the chapters considering almost zero prerequisite and discussed the application levels and research scope in that particular area in depth after introducing the chapter of interest formally. Hence I believe this book would not only be a good text and reference book on image processing, but also a good teaching material for the teachers.

The chapter on the “Introduction to Digital Image” starts with formation of images in nature. Any naturally formed image is an analog image. The principle of pin-hole camera is discussed to illustrate the theory of image formation. Next, the concept of digital image has been described in terms of sampling (to ensure the number of samples in a defined space to be finite) and quantization (to ensure number of intensity levels to be finite). The concept of formation of picture element (or pixel) has been described. The basic geometric transformations are discussed here. Finally, the two basic operations of image processing, convolution and correlation are discussed along with suitable applications.

The second chapter “Image Enhancement in Spatial Domain” discusses different intensity transformations and image enhancement techniques in spatial domain. The histogram equalization technique is depicted in terms of an algorithm through which we get an enhanced image with improved information content. Here the concept of information theory (entropy) is discussed briefly as a prerequisite. The interpolation techniques are also discussed to be used for image resampling and quality improvement of geometrically transformed images.

It is comparatively easier to understand the concept of frequency and phase in time domain representation of single dimensional signal than that of a spatial representation of a two-dimensional image. It is really difficult to realize frequency and phase from a given image without understanding the concepts physically. I have tried to hit that area in the chapter of “Interpretation and Processing of Image in Frequency Domain”.

The fourth chapter “Color Science and Color Technology” starts with the physics of light. Different kinds of devices are described from the color perspective. A number of device dependent and independent color spaces and models are discussed along with their mathematical interrelations and applicability. The psycho-visual color system and its inclusion in CIE based color model are also described. The concept of halftone screening and color management are also discussed mentioning the industry and research scopes.

Understanding of the concept of frequency in images has been walked forward through the next chapter “Wavelets: Multi-resolution Image Processing”. Here we have described the method and idea of wavelet decomposition in detail. The dis-

crete wavelet transform and its applications in image enhancement and image compression have been described.

The sixth chapter “Compression and Encoding of Image: Image Formats” is especially important for any kind of application development in image processing. The lossless and lossy compression methodology with trade-off has been described in the first half of this chapter. Second half of the chapter describes the process and algorithm of encoding the raw and compressed image formats. We have presented one C++ code for reading 24-bit BMP image. The code is available in the supplementary electronic material (CD) also. The two popular compressed image formats, JPEG and GIF are also discussed and the required code snippets are presented.

The seventh chapter “Morphology-Based Image Processing” is the bridge between the signal and pattern perspective of image processing. Processing binary images with respect to their shape through basic set theory-based operations have been presented in this chapter. Next, a number of applications of basic morphology-based image processing, like erosion, dilation, opening, closing, pruning, filling, and skeletonization are presented.

The eighth chapter “Patterns in Images and its Applications” formally defines the pattern and feature. Next the method of feature extraction, selection, and reduction are presented. We have described many state-of-the-art applications against each of the pattern recognition techniques discussed in this chapter.

The ninth chapter “Psycho-visual Pattern Recognition: Computer Vision” describes the vision system of human brain in terms of object recognition. The three-level image processing by visual cortex has been modeled through 2D signal processing filters. The response of different illusions to our vision system is studied and 2D filters generating equivalent responses are synthesized. The designed filter next has been used in computerized image enhancement and recognition of objects through patterns in images.

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## Salient Features

1. The subject is introduced from the very basic understanding of analog and digital image and the entire gamut is explored in an elegant way.
2. The application areas included in this volume are rich and state-of-art trend of industry and fundamental research.
3. Supplementary electronic material for this book is available from <http://www.springer.com/978-3-319-14171-8> which includes a number of *codes* in *MATLAB* and *C++*, with uncommon and common applications for better understanding of the subject.
4. A couple of power point presentation materials are included in the supplementary electronic material (<http://www.springer.com/978-3-319-14171-8>) which would be useful for the teachers to present the abstract concepts like color and frequency in images through slides, as and when required.
5. Two GUI-based modules have also been supplied with the other supplementary electronic materials. The first one is Fourier Synthesis module (Version 1.1) to



illustrate the synthesized waveform by tuning the amplitudes of the *sine* and *cosine* Fourier coefficients. The second one is image crop tool from 4-plane (CMYK) tiff image and creating images of different primary color separations with respect to selected region in the image. Readers can play with the tools for better understanding of the subject.

6. Elegant worked out numerical problems are designed in such a way that, the readers can get the flavor of the subject and get attracted towards the future scopes of research and development in the domain of signal processing, image processing, and pattern recognition.
7. Depending on the relationship and interdependencies between the nine chapters and three appendices, two distinct study flows are presented. Readers can choose their appropriate study flow according to their areas of interest, understanding the interdependencies.

This volume is intended to fulfill the expectations of students as well as the teachers. I hope this book is not only a favorite study material for the students but also a nice resource for teaching. In my career, I have been engaged in full-time teaching, faculty upgradation training, and served both government R&D and hardcore private industry. Therefore I can feel the requirements of each and every sector closely. I expect detailed feedback from the readers of this book. My sincere efforts would be successful, if this volume meets the requirements and expectations of all the students, teachers, researchers, and professionals in the domain of image processing and pattern recognition.



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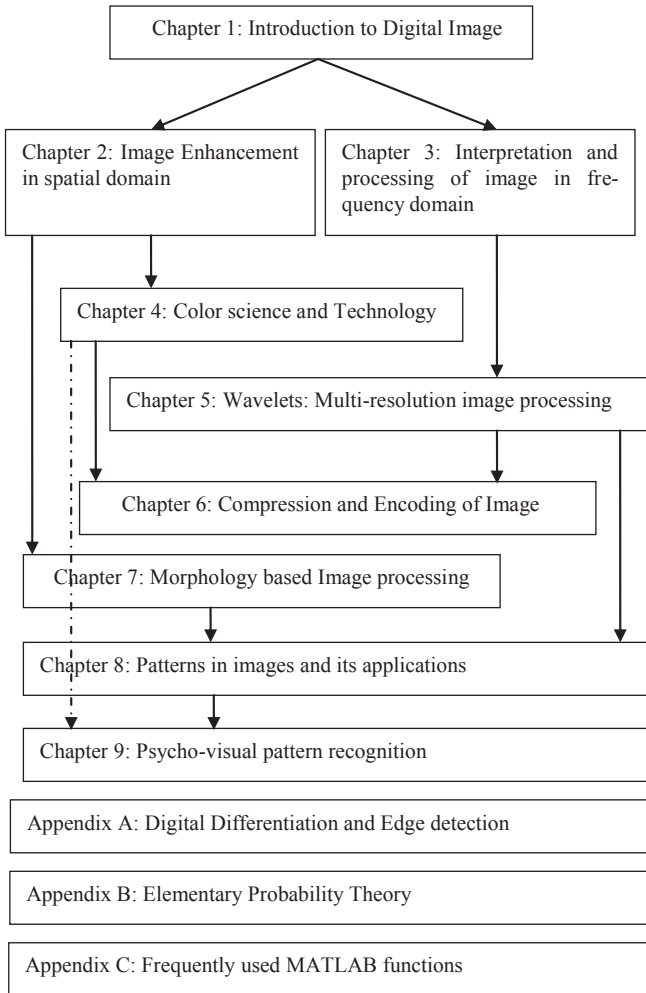
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## The Flow of Study

Depending on the relationships and interdependencies between the nine chapters and three appendices, three distinct study flows are presented. It is now up to the readers to choose the most suitable and convenient study flow according to their field of interest.



1<sup>st</sup> Study Flow: Chapter Relationships