

Preface

Computational intelligence-based techniques have firmly established themselves as viable, alternate, mathematical tools for more than a decade now. These techniques have been extensively employed in many systems and application domains, e.g., signal processing, automatic control, industrial and consumer electronics, robotics, finance, manufacturing systems, electric power systems, power electronics and drives, etc. Image processing is also an extremely potent area which has attracted the attention of many researchers interested in the development of new computational intelligence-based techniques and their suitable applications, in both research problems and in real-world problems. Initially, most of the attention and, hence, research efforts, were focused on developing conventional fuzzy systems, neural networks, and genetic algorithm-based solutions. But, as time elapsed, more sophisticated and complicated variations of these systems and newer branches of stochastic optimization algorithms have been proposed for providing solutions for a wide variety of image processing algorithms. As image processing essentially deals with multidimensional nonlinear mathematical problems, these computational intelligence-based techniques lend themselves perfectly to provide a solution platform for these problems. The interest in this area among researchers and developers is increasing day by day and this is visible in the form of huge volumes of research works that get published in leading international journals and in international conference proceedings.

When the idea of this book was first conceived, the goal was to mainly expose the readers to the cutting-edge research and applications that are going on across the domain of image processing where contemporary computational intelligence techniques can be and have been successfully employed. The result of the spirit behind this original idea and its fruitful implementation in terms of contributions from leading researchers across the globe, in varied related fields, is in front of you: a book containing 15 such chapters. A wide cross-section of image processing problems is covered within the purview of this book. They include problems in the domains of image enhancement, image segmentation, image analysis, image compression, image retrieval, image classification and clustering, image registration, etc.

The book focuses on the solution of these problems using state-of-the-art fuzzy systems, neuro-fuzzy systems, fractals, and stochastic optimization techniques. Among fuzzy systems and neuro-fuzzy systems, several chapters demonstrate how type-2 neuro-fuzzy systems, fuzzy transforms, fuzzy vector quantization, the concept of fuzzy entropy, etc., can be suitably utilized for solving these problems. Several chapters are also dedicated to the solution of image processing problems using contemporary stochastic optimization techniques. These include several modern bio- and nature-inspired global optimization algorithms like bacterial foraging optimization, biogeography-based optimization, genetic programming (GP), along with other popular stochastic optimization strategies, namely, multi-objective particle swarm optimization techniques and differential evolution algorithms. It is our sincere belief that this book will serve as a unified destination where interested readers will get detailed descriptions of many of these modern computational intelligence techniques and they will also obtain fairly good exposure to the modern image processing problem domains where such techniques can be successfully applied.

This book has been divided into four parts. Part I concentrates on discussion of several image preprocessing algorithms. Part II broadly covers image compression algorithms. Part III demonstrates how computational intelligence-based techniques can be effectively utilized for image analysis purposes, and Part IV elucidates how pattern recognition, classification, and clustering-based techniques can be developed for the purpose of image inferencing.

Part I: Image Preprocessing Algorithms

This section of the book presents representative samples of how state-of-the-art computational intelligence-based techniques can be utilized for image preprocessing purposes, e.g., for image enhancement, image filtering, and image segmentation.

[Chapter 1](#) by Yüksel and Baştürk shows how type-2 neuro-fuzzy systems can be utilized for developing image enhancement operators. Type-2 fuzzy systems are considered as improvements over the conventional type-1 fuzzy systems, where type-2 fuzzy systems utilize ‘fuzzy-fuzzy sets’, as opposed to the conventional ‘fuzzy sets’ utilized by the type-1 fuzzy systems. Type-2 fuzzy systems have specifically come into existence to handle data uncertainties in a better manner. This chapter shows how such general-purpose operators can be developed for a variety of image enhancement purposes. The chapter also specifically concentrates on the development of suitable new noise filters and noise detectors based on the above-mentioned methodology.

[Chapter 2](#) by Kwok, Ha, Fang, Wang, and Chen focuses on the problem of contrast enhancement by employing a local intensity equalization strategy. The method shows how an image can be subdivided into sectors and each such sector can be independently equalized. The method employs a particle swarm

optimization algorithm-based technique that determines a suitable Gaussian weighting factor-based methodology for reduction of discontinuities along sector boundaries.

Chapter 3 by Boussaïd, Chatterjee, Siarry, and Ahmed-Nacer shows how intelligent hybridization of biogeography-based optimization with differential evolution can be utilized to solve multilevel thresholding problems for image segmentation purposes, utilizing the concept of fuzzy entropy. The objective here is to incorporate diversity in the biogeography-based optimization (BBO) algorithm to solve three-level thresholding problems in a more efficient manner and to provide better uniformity for the segmented image. The utility of the proposed schemes is demonstrated for a series of benchmark images, widely utilized by the researchers within this community.

Chapter 4 by Perlin and Lopes demonstrates how GP approaches can be utilized for the development of image segmentation algorithms. This chapter shows how the image segmentation problem can be viewed as a classification problem and how GP can use a set of terminals and non-terminals to arrive at the final segmented image. The method demonstrates how suitable fitness functions can be defined and how a penalty term can be utilized to obtain a fair division of an original image into its reasonable, constituent parts, in an automated manner. The performance of the algorithm has been extensively evaluated on the basis of a set of images.

Part II: Image Compression Algorithms

Image compression techniques are becoming more and more important in recent times because the race for transmission of huge volumes of image data in real time for a wide variety of applications like Internet-based transmission, mobile communication, live transmission of television events, medical imaging, etc., is well and truly on. The main objective is to simultaneously achieve two competing requirements, i.e., to achieve very high rates of compression ratio and yet there should not be any perceptible degradation in the reconstructed image at the viewer end. This section of the book presents a collection of such modern techniques which primarily aim to solve this problem as efficiently as possible.

Chapter 5 by Tsekouras and Tsolakis describes how fuzzy clustering-based vector quantization techniques can be utilized to solve these problems. This chapter first presents a systematic overview of existing fuzzy clustering-based vector quantization techniques and then it presents a new effective fuzzy clustering-based image compression algorithm that tackles two contentious issues: (i) achieving performance independent of initialization and (ii) reducing the computational cost. The method demonstrates how hybrid clusters can be formed containing crisp and fuzzy areas.

Chapter 6 by Di Martino and Sessa demonstrates how recently proposed fuzzy transforms (F-transforms) can be utilized for layer image compression and reconstruction and then proposes a new modification. The chapter discusses how

an image can be viewed as a fuzzy matrix, comprising several square submatrices, and how direct F-transforms can be suitably applied on each such image block for the compression purpose. The chapter also demonstrates how inverse F-transforms can be utilized for image reconstruction purposes at the viewer end.

Chapter 7 by Sanyal, Chatterjee, and Munshi introduces how the modified bacterial foraging optimization (BFO) algorithm can be suitably used to solve vector quantization-based image compression algorithms. This chapter shows how a nearly optimal codebook can be designed for this purpose with a high peak signal-to-noise ratio (PSNR) in the reconstructed image. The chapter also demonstrates how improvements in the chemotaxis procedure of the BFO algorithm can be useful in achieving high PSNR at the output. The utility of this algorithm is demonstrated by employing it for a variety of benchmark images.

Part III: Image Analysis Algorithms

An important research domain within the broader category of image processing is to analyze an image, captured by a suitable sensor system, for a variety of applications. Such image analysis algorithms may be solely guided by the requirement of the output of the system. In this section of the book, five chapters are included to expose the readers to five different problem domains where different aspects of image analyses are required.

Chapter 8 by Mandal, Halder, Konar, and Nagar discusses how template matching problems in a dynamic image sequence can be solved by fuzzy condition-sensitive algorithms. This chapter shows how a decision-tree-based approach can be utilized to determine the matching(s) of a given template in an entire image. A new hierarchical algorithm has been developed for this purpose and the conditions are induced with fuzzy measurements of the features. The utility of this method has been aptly demonstrated by implementing this algorithm for template matching of human eyes in facial images, under different emotional conditions.

Chapter 9 by Di Martino and Sessa presents another important application which will show how watermarking for tamper detection can be carried out for images compressed by fuzzy relation equations. This method makes use of the well-known encrypting alphabetic text Vigenère algorithm. They have used a novel, interesting method of embedding a varying binary watermark matrix in every fuzzy relation.

Chapter 10 by Bhattacharya and Das makes a detailed, systematic study on how evolutionary algorithms can be utilized for human brain registration processes, that can be useful for the purpose of brain mapping, treatment planning, image guided therapies of nervous system, etc. A new system has been developed for MR and CT image registration of human brain sections, utilizing similarity measures, for both intensity- and gradient-based images. A fuzzy c-means clustering technique has been utilized for extraction of the region of interest in each image. Any degeneracy or abnormality in human brains can be detected by utilizing this

similarity metric, utilized to test the alignment between two images. These similarity metric-based objective functions are nonconvex in nature and do not lend themselves naturally for solution by conventional optimization algorithms. Hence this problem has been solved using a genetic algorithm.

Chapter 11 by Broilo and De Natale discusses how stochastic optimization algorithms can be utilized for another important image processing-based application domain, i.e., image retrieval problems. The chapter first presents an overview of the motivations behind utilizing these methods for image retrieval and several interesting methods that have so far evolved in this domain. Detailed discussions on the setting and tuning of free parameters in traditional retrieval tools as well as direct classification of images in a dataset, based on these competing stochastic algorithms, are presented. A systematic analysis on the relative merits and demerits of these methods has been presented in the context of several application examples.

Chapter 12 by Battiato, Farinella, Guarnera, Messina, and Ravì discusses an important present-day research topic in image processing, removal of red-eye artifacts in images, caused by the flash light reflected from a human retina. While the conventional preflash approaches suffer from unacceptable power consumption problems, the software-based post-acquisition correction procedures may require substantial user interaction. Many contemporary research efforts in this problem area focus on the development of suitable red eye removal techniques with as minimum visual error as possible. This chapter discusses how boosting algorithm aided classifiers can be designed for red eye recognition utilizing the concept of gray codes feature space.

Part IV: Image Inferencing Algorithms

The last section of the book presents several chapters on how modern pattern recognition-based techniques, especially those directed toward classification and clustering objectives, can be utilized for the purpose of image inferencing.

Chapter 13 by Huang, Lee, and Lin presents how fractal analysis can be useful for the purpose of pathological prostate image classification. Very recently, the use of fractal geometry for effective analysis of pathological architecture and growth of tumors has gained prominence. This chapter demonstrates how fractal dimension can be suitably utilized along with other multicategories for feature extraction from texture features, e.g., multiwavelets, Gabor filters, gray-level co-occurrence matrix, etc. These feature extraction methodologies have been coupled with several candidate classifiers, e.g., k-NN and SVM classifiers, to evaluate their relative effectiveness in classifying such prostate images. The chapter demonstrates that, in different types of classifiers developed, each time the best correct classification rates are obtained only when the feature sets include fractal dimensions. Hence the authors have justified the importance and utility of including fractal dimension-based features in prostate image classification.

[Chapter 14](#) by Melgani and Pasolli discusses the development of multiobjective PSO algorithms for hyperspectral image clustering problems. Hyperspectral remote sensing images are quite rich in information content and they can simultaneously capture a large number of contiguous spectra from a wide range of the electromagnetic spectrum. Development of hyperspectral image classification schemes to achieve accurate data class in an unsupervised context is widely known as a challenging research problem. This chapter demonstrates how such an unsupervised clustering problem can be solved by formulating it as a multiobjective optimization problem and how a multiobjective PSO can be suitably utilized for this purpose. The authors have implemented three different statistical criteria for this purpose, i.e., the log-likelihood function, the Bhattacharyya distance, and the minimum description length. Several experimentations clearly validate the utility of the particle swarm optimizers for automated, unsupervised analysis of hyperspectral remote sensing images.

[Chapter 15](#) by Halder, Shaw, Orea, Bhowmik, Chakraborty, and Konar details a new computational intelligence-based approach for emotion recognition from the outer lip-contour of a subject. This approach shows how the lip region of a face image can be segmented and subsequently utilized for determining the emotion. This method demonstrates how a lip-contour model can be suitably utilized for this problem and an effective hybridization of differential evolution-based optimization and support vector machine-based classification techniques have been carried out to draw the final inference. Experimental studies on a large database of human subjects have been carried out to establish the utility of the approach.

Last but not least, we would like to take this opportunity to acknowledge the contribution made by Ilhem Boussaïd, who is a faculty member in the University of Science and Technology Houari Boumediene (USTHB), Algiers, Algeria, in preparing this book in its final form. Ilhem is pursuing her own Ph.D. at the moment, performs her regular duties in her University, is the lead author of [Chap. 3](#) of this book, and, in addition to all these, performed all LaTeX-related activities in integrating this book. We have no words left to express our gratitude to her in this matter.

Finally, the book is in its published form in front of all the readers, worldwide. We do hope that you will find this volume interesting and thought provoking. Enjoy!

Kolkata, India, August 2011
Paris, France, August 2011

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Computational Intelligence in Image Processing

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2013, XII, 304 p., Hardcover

ISBN: 978-3-642-30620-4