SOFT COMPUTING APPROACH TO PATTERN RECOGNITION AND IMAGE PROCESSING

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To the participants of

2002 *CIMPA-UNESCO-INDIA School*, Kolkata.

Preface

Pattern recognition and image analysis form a major area of research and development that encompasses the processing of pictorial, numeric and non-numeric data obtained from nature. The main motivation behind this spurt of activity is the idea of designing and making intelligent machines that can carry out certain tasks as we human beings do. In order to posses human like behavior, the system model should have at least the following characteristics:

- capability of handling uncertainties in different stages arising out of measurement errors and/or deficiency in input information,
- flexibility (adaptivity) to incorporate changes in its functionalities depending on the data characteristics,
- capability for parallel and distributed computing with close interaction among the processing elements, and
- robustness/ruggedness with respect to distortion, noise/failure of components.

In addition, it is desirable that the computational paradigm be capable of approximate reasoning, efficient searching and handling non-numeric inputs. This has become particularly useful in addressing the current need of Internet technology for mining (discovering patterns/ knowledge) voluminous, both in size and dimension, heterogeneous data sets.

Soft computing, which has emerged in the last decade as an efficient tool, is a consortium of methodologies that works synergistically and offers the aforesaid characteristics to a reasonable extent for handling real life ambiguous situations. Its aim is to exploit the tolerance for imprecision, uncertainty, approximate reasoning, and partial truth in order to achieve

tractability, robustness, low cost solution and close resemblance with human like decision-making. The relevance of soft computing for pattern recognition and image analysis is established with potential applications in areas like data mining, web mining, bioinformatics, remotely sensed data analysis, medical image analysis, forensic sciences, optical character recognition, signature verification, target recognition, face recognition, multimedia, and man machine communication. Its principal components, at this juncture, are fuzzy logic (FL), neural computing (NC), evolutionary computing (EC) and rough sets (RS). FL is mainly concerned with providing algorithms for dealing with imprecision and approximate reasoning, and for computing with words. NC provides the machinery for adaptive learning and identification. RS is for knowledge encoding and EC for efficient search and optimization. All these partners of soft computing are complimentary rather than competitive.

The present volume provides a collection of sixteen articles containing new material, and demonstrating the significance of soft computing to pattern recognition, image processing & vision, granular computing, data mining and bioinformatics with recent developments and applications. These articles are written by leading experts from different countries. It is shown how the different soft computing tools can be utilized, both in individual and integrated manner, in various ways to develop efficient and intelligent systems. The collection ranges from chapters providing insight into the theories, developing algorithms, to demonstrating their success to various real life problems. These are divided into four categories, namely, pattern recognition (Chapters 1-4), image processing and vision (Chapters 5-10), granular computing and case based reasoning (Chapters 11-13) and real life applications (Chapters 14-16).

Multiple classifier systems address a serious drawback of the classical approach to designing a pattern recognition system, and offer a means for enhancing its performance. Its design involves the problem of classifier fusion which represents one of the significant advances, over the last decade, in pattern recognition. The volume begins with a critical review on this issue written by Kittler, a pioneering researcher in the area of pattern recognition, in Chapter 1. This includes the theoretical framework for classifier combination, recent developments in multiple expert fusion, and fusion system architectures. In Chapter 2, Kargupta considers the problem of construction of a decision tree from the Fourier spectrum of an ensemble model within a user-defined range of errors. This approach is effectively used for building ensemble-based classifiers from both static data sets and

data streams for mobile data mining problems.

Chapter 3, written by Narasimha Murty, provides an excellent review on the problem of clustering large data sets which is an important task encountered in several pattern recognition and data mining applications. Various methods of clustering are described in the frameworks of fuzzy set theory, neurocomputing, evolutionary computing and rough set theory, together with their related merits and features. Some of the emerging directions for clustering large data sets are illustrated. In Chapter 4, Bandyopadhyay, Srivastava and Pal describe a non-parametric genetic classifier based on variable string length chromosomes and multi-object fitness function. Its superiority over other related methods is demonstrated both qualitatively and quantitatively on remotely sensed images for classifying in different landcover regions.

The image processing and vision section of the book starts with the article of Rosenfeld, the grandfather of image processing, and his co-author Bhutani. Here, in Chapter 5, they propose two dissimilarity measures between fuzzy subsets of a finite set S, and it is shown that both measures are metrics. These measures are also generalized to fuzzy structures, such as fuzzy graphs, defined on S. These are useful in fuzzy image processing. The next chapter (Chapter 6) by Gesu presents an overview of soft approaches to vision problems with an emphasis on integrated methods. Algorithms for edge detection, image segmentation, and different morphological operations on gray level images are discussed, and results are analyzed. In Chapter 7, Ghosh and Sen explain a neuro-fuzzy self-organizing multilayer neural network for multi-level (multi-class) image segmentation. Each pixel in the image is represented by a set of C neurons in each layer, corresponding to C classes. Measures of fuzziness are used to model the error (instability of the network) of the system. A pixel is assigned to a class to which it has the maximum membership value. Tang, Feng, Sun and Wang present in Chapter 8 a novel, low cost approach to geometric transformation, which can be modelled by a partial differential equation with boundary conditions. The algorithm is based on moment method and wavelet matrix. The performance is evaluated through image processing experiments.

Chapters 9-10 deal with motion picture analysis. In Chapter 9, Acharya and Kim describe a fast motion estimation algorithm that uses 'Context Adaptive Search' windows. They also present a simple, fast and accurate rate control algorithm using nonlinear regression that plays a central role in estimation theory. Results are found to be superior to MPEG-4 standard. The next chapter (Chapter 10) by Chaudhury, Jadon and Biswas provides

an evolutionary learning based fuzzy set theoretic approach for classifying video sequences into generic categories. This categorization is based on features like shot durations, editing style, camera work and shot activity which characterize the presentation style of video.

Granular computing (GC) has drawn recently the attention of researchers for its potential application in knowledge discovery and data mining. Since it involves representation of information in the form of some aggregates (i.e., clumps or granules) and their processing through computation on granules themselves, it provides significant computational gain. Moreover, GC in fuzzy set theoretic framework (i.e., the concept of fuzzy-granularity) plays a key role in the Computational Theory of Perceptions (CTP), recently explained by Zadeh, which promises to have substantial impact on formulating and solving pattern recognition problems in the near future. Chapters 11 and 12, which are from two leading scientists in this area, address respectively, the theoretical and application aspects of granular computing. In Chapter 11, Skowron presents an outline of foundations for information granule calculi and methods for inducing relevant information granule constructions from data and background knowledge for approximate reasoning schemes. A methodology of approximate reasoning has been developed for solving complex problems in areas such as identification of objects by autonomous systems, web mining or sensor fusion. Role of rough-neuro computing is also discussed. Pedrycz explains, in Chapter 12, the fundamentals of granular computing and relates them to the paradigm of pattern recognition by identifying their knowledge-intensive facets. Different notions of granules are explained through examples. In Chapter 13, another novel artificial intelligence problem-solving paradigm, called case-based reasoning, is considered in the light of soft computing. Here, Shiu deals with the problem of case-base maintenance and provides a brief overview. The use of fuzzy set theory, rough set theory and fuzzy integral for maintaining a distributed case-based reasoning system is demonstrated, along with some experimental results using an example case base in the travel domain.

The applications section has three articles. Chapter 14 deals with the problems of speech and face recognition using neural networks. Here, Yegnanarayana, Gangashetty and Palanivel discuss some special properties of autoassociative neural network (AANN) models which can be exploited for pattern recognition tasks in speech and image processing. In particular, they discuss three important properties of AANN models, namely, distribution capturing, data compression, and extraction of higher order correlation.

Bioinformatics is a newly emerging interdisciplinary research area involving an interface between biological and computational sciences. Structure of proteins (which is a sequence of amino acids), and DNA microarray data analysis are two important aspects of biological data mining. Prediction of secondary and tertiary protein structures from the primary amino acid sequences is a challenging task. Chapter 15 of Mitra, Ghosh and Phukan highlights the use of soft computing tools, particularly artificial neural networks and genetic algorithms, for this purpose. The learning ability of neural networks and the searching potential of genetic algorithms are utilized in this process. In the last chapter (Chapter 16) Cho introduces a sophisticated classification architecture for better performance in biological data mining. The experimental results with a leukemia data set indicate that the sophisticated classifier is promising for better gene expression analysis.

We take this opportunity to thank all the contributors for agreeing to write for this book. While most of the contributions are taken from the lectures to be delivered at the *CIMPA-UNESCO-INDIA School* on *Soft Computing Approach to Pattern Recognition and Image Processing* during December 2-13, 2002, at Indian Statistical Institute, Kolkata, the remaining few are included to bridge the gap and to make the volume cohesive. We gratefully acknowledge the financial assistance provided by the CIMPA (International Centre for Pure and Applied Mathematics, France), DST (Department of Science and Technology), Government of India, and Indian Statistical Institute, and the co-sponsorship of the IAPR (International Association for Pattern Recognition) and UNESCO. The co-operation extended by our colleagues of MIU, particularly the secretarial assistance of Mr. S. K. Das, Mr. I. Dutta and Ms. M. Dey is also acknowledged.

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