

Preface

In this information era, processing of noisy and noise-free images and multimedia data for faithful analysis and retrieval of useful information has assumed utmost importance. One of the main tenets of this image processing task is the extraction of relevant features through segmentation of the data under consideration. Proper analysis of image data for relevant object specific information requires efficient extraction and segmentation techniques. Faithful detection of image edges for this purpose is also a grave matter of concern for researchers. Handling of image data in the binary domain may be a trivial task but it becomes severe when it comes to the gray scale or color intensity gamut. This is purely due to the enormity and variety of the underlying data under consideration. If one is required to handle only two (0 or 255) values in the binary domain, in the gray scale it is 256 shades of gray. The situation becomes more difficult in the color domain where there are $16,777,216 (=256 \times 256 \times 256)$ colors to deal with. Add to it the processing overhead involved in handling multimedia data, where each and every image frame within a video sequence needs to be processed. To be precise, the entire process is too time-complex.

Several classical approaches for processing images and multimedia data exist in the literature. Among the score of intelligent approaches in this direction, the *soft computing* paradigm is equipped with several tools and techniques, which incorporate intelligent concepts and principles. Artificial neural networks, fuzzy sets and fuzzy logic, rough sets and evolutionary computation form the backbone of this intelligent computing framework. Out of the several components of the *soft computing* paradigm, these four components either operate independently or in synergy.

Artificial neural networks are electrical analogues of biological neurons in the human brain. These operate on numeric data and are well known for their learning, generalization and approximation capabilities. The constituent neurons are prone to graceful degradation. These neurons remain densely interconnected with neighboring neurons following the architecture of biological neurons by means of some interconnection strengths (or *weights*). When real-world data is incident on these neurons, they generate a weighted sum of the incident inputs. They also

impress an activation of the input data and pass it on to the connected neurons via the interconnection weights. Artificial neural networks figure in different topologies. They operate in both supervised and unsupervised forms. In the supervised type of models, the network is trained with an input–output relationship. In unsupervised learning, the network does not require such training. On the contrary, it adapts to the ground conditions.

Fuzzy sets and systems deals with ambiguity, imprecision, vagueness and uncertainty observed in real-world situations. These systems resort to fuzzy logical connectives for modeling human reasoning and operate in a linguistic framework. Their strength lies in their capability to perform approximate reasoning. While the crisp set contains its members with either a membership of 1 or 0, a fuzzy set includes all elements of the universal set of the domain but with varying degrees of membership in the interval $[0, 1]$.

Rough set theory has come up of late, as a new mathematical approach to model imperfect knowledge. It presents another attempt to handle real-world uncertainties. The rough set theoretic approach seems to be of fundamental importance to artificial intelligence and cognitive sciences, especially in the areas of machine learning, knowledge acquisition, decision analysis, knowledge discovery from databases, expert systems, inductive reasoning and pattern recognition. The main advantage of rough set theory in data analysis is that it does not need any preliminary or additional information about data—unlike probability in statistics, or basic probability assignment in Dempster–Shafer theory, grade of membership or the value of possibility in fuzzy set theory.

The evolutionary computation and metaheuristic search techniques provide powerful search and optimization methodologies. These are based on a pool of trial solutions/individuals (*population*) in the search space to start with. Several in-built operators are applied on the individuals of the population to derive better solutions. The suitability of a particular individual in the population in a particular generation is determined by a *fitness function* also referred to as the *objective function*. Once the suitability of the individuals in the population in a particular generation is measured, the operators are applied to generate a newer population for the next generation. Typical examples of these techniques include genetic algorithms, ant colony optimization, particle swarm optimization, the differential evolutionary algorithm, and simulated annealing, to name a few. These techniques have been lately used with multiple conflicting objectives. These versions of these techniques, referred to as multiobjective evolutionary techniques, deal with multiple conflicting objectives in that a set of solutions is finally obtained out of the search procedure. Typical examples include the multiobjective genetic algorithm (MOGA), the multiobjective differential evolutionary algorithm (MODE), the multiobjective simulated annealing (MOSA), to name a few.

This book is aimed at addressing the problem of image segmentation, object extraction and edge detection using a *soft computing* framework. The main aspect of this effort lies in removing the inherent limitations in the existing neural network topologies as revealed by theoretical investigations. Newer topologies have been

presented taking into cognizance the space- and time-complexity of the existing methods.

Chapter 1 of the book throws light on the different tenets of the *soft computing* paradigm. It first discusses the anatomical characteristics of the human brain along with synaptic learning, transmission, storage and processing of information in the human brain. Furthermore, it draws an analogy between the artificial neural network and the human brain. Next, it discusses the different learning methodologies of artificial neural networks. It explores the topology and functions of both supervised and unsupervised models of artificial neural networks. Fuzzy sets and fuzzy logic are also touched upon in this chapter. Next, the mathematical prerequisites of rough set theory relevant to this book are elucidated. The rest of the chapter deals with the optimization problems and solution techniques in existence. These include genetic algorithms, the classical differential evolutionary algorithm, simulated annealing, and their multiobjective counterparts. The chapter also throws some light on particle swarm optimization.

Chapter 2 focusses on the image recognition and transformation detection capabilities of a trained multilayer perceptron (MLP) architecture. The generalization and approximation capabilities of an MLP architecture are also illustrated in this chapter with the help of suitable examples.

Chapter 3 presents an application of a multilayer perceptron (MLP) for detecting and controlling the lighting conditions in an illuminated scene. Here also the generalization and approximation capabilities of the multilayer perceptron (MLP) come into play.

A *soft computing* technique for tracking of high-speed objects in real-life video sequences is presented in Chap. 4. The underlying principle of the approach is to segment the optical flow field regions computed between the successive image frames of real-life video sequences into coherent and incoherent flow regions. The examples illustrated in this chapter apply fuzzy hostility index-based segmentation of the flow regions.

In Chap. 5 the limitations of the multilayer self-organizing neural network architecture (MLSONN), in terms of its transfer characteristics, thresholding mechanism and the error adjustment methodology, are discussed and addressed. A three-layer bidirectional self-organizing neural network (BDSONN) architecture applicable for real-time image processing applications is presented. The architecture uses counter-propagation of network states for self-organizing input information into outputs. The network dynamics and operation are discussed. The network uses an adaptive fuzzy context-sensitive thresholding (CONSENT) mechanism for the processing task, which enhances the generalization capabilities of the network architecture. This is because the network takes into cognizance the inherent heterogeneities in the input images. The network interconnection weights are assigned and updated by the relative fuzzy memberships of the representative pixels in the image information, rather than through backpropagation strategies. The efficiency of the proposed network architecture over its MLSONN counterpart using a bilevel sigmoidal and a beta function is reported with regards to immunity to different types of noise. The improvement of the quality of the extracted objects is also demonstrated with

suitable examples which signify the shape-restoring capability of the architecture as well. The reduced time complexity of the object extraction process ensures its operation in real time.

The requirement of a multilevel sigmoidal (MUSIG) activation function for the purpose of multilevel image segmentation is discussed in Chap. 6. The thresholding aspects of the MUSIG activation function are explored using five different pixel intensity-based adaptive thresholding techniques so as to incorporate the image context information in the thresholding process. A study of the performances of these thresholding approaches in segmenting multilevel images has been reported with an MLSONN architecture and a Pyramidal Network (PyraNet) architecture. In addition, the performance of a bidirectional self-organizing neural network (BDSONN) architecture for a self-supervised segmentation of multilevel images is also presented and the role of embedded CONSENT parameters in its transfer characteristics is also demonstrated. The efficiency of the BDSONN architecture is also demonstrated using four segmentation quality evaluation measures.

The flaws and failings of a parallel self-organizing neural network (PSONN) architecture as regards its fixed and uniform thresholding mechanism are addressed by introducing different image intensity adaptive thresholding mechanisms in Chap. 7. A novel parallel bidirectional self-organizing neural network (PBDSONN) architecture with embedded CONSENT parameters, which improves upon the extraction performance of PSONN, is presented. PBDSONN also outperforms PSONN in terms of computational overhead.

Methods for finding the edges in multilevel images using pixel roughness and rough pixel neighborhood hostility indices are presented in Chap. 8. The underlying heterogeneities in image neighborhoods are also determined using a proposed rough pixel neighborhood hostility index. The results indicate superior performance over the fuzzy pixel neighborhood hostility index.

The present volume is an attempt dedicated to object extraction, image segmentation and edge detection using *soft computing* techniques with extensive real-life application to image and multimedia data. The volume, which is unique in its character, will be useful to graduate students and researchers in computer science, electrical engineering, system science, and information technology both as a text and reference book for some parts of the curriculum. Researchers and practitioners both in industry and research and development laboratories working in the fields of system design, pattern recognition, image processing and *soft computing* will also benefit.

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