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Preface

Soft Computing for Pattern Recognition

The aim of soft computing is to exploit the tolerance for imprecision and uncertainty to achieve tractability, robustness and low cost [4]. It may be viewed as a consortium of different computing tools to deal with real-world problems efficiently. Often, it attempts to find an approximate solution to a precisely or imprecisely formulated problem. Neurocomputing (NC) is one of the major components of soft computing. The other two important constituents are fuzzy logic (FL) and probabilistic reasoning, which subsumes belief networks, genetic algorithms (GAs) and chaotic systems. FL is mainly concerned with providing a machinery for dealing with imprecision and approximate reasoning. NC deals with learning and curve fitting. Probabilistic reasoning, on the other hand, deals with probabilistic uncertainty, propagation of belief, etc.

Often, to solve a fairly complex real world problem a single computational tool may not be adequate. For such cases integration of more than one tool to solve the given problem may be more effective. Let us illustrate it with some examples. A feed-forward multilayer network can recognize patterns, but the way it arrives at a decision is difficult to interpret. Neural networks (NNs) attempt to model the way brain computes/works; they have the generic advantages of parallelism, fault tolerance and robustness. Fuzzy logic, on the other hand, can model, to a reasonable extent, the vagueness present in a system and reason or explain happenings. Thus, a judicious integration of the two approaches may lead to a system having the benefits of both paradigms. Sometimes such an integration may result in some application specific advantages in addition to their generic merits. GAs are parallel stochastic search techniques which have, to a reasonable extent, the capability of both exploration and exploitation, while many fuzzy or neural systems require finding the optimal values of a set of parameters to realize good performance. Therefore, GAs can be inserted into the development path of a fuzzy or neural system to devise a better system for solving a given problem. Thus, the integration of any two or all the three promises high potentiality to develop more (artificial) intelligent systems having all the generic advantages of each tool, and in some cases system specific advantages [3].

Such integrations have resulted in hybrid systems known as neuro-fuzzy, fuzzy-neural, neuro-genetic, fuzzy-genetic systems and so on. A detailed discussion on these issues can be found in [3].

With this introduction to soft computing let us consider how it can help to solve pattern recognition problems. Duda and Hart [2] defined pattern recognition (PR) as a field concerned with machine recognition of meaningful regularities in a noisy or complex environment, while according to Bezdek [1] pattern recognition is the search for structure in data. Irrespective of the way PR is defined, it primarily deals with three important tasks: feature analysis, clustering and classification. A brief discussion on these three main facets of PR is presented in the article by Pal.

It is almost impossible to think of any real world intelligent decision making system that does not do pattern recognition in some form or other. It is an essential and important part of realizing intelligent systems for solving real world problems. It was the idea of Prof. Takeshi Yamakawa, who, during IIZUKA'96 conference, suggested me to guest edit this special issue on this very important area of *Soft Computing for Pattern recognition*. He also suggested to write an

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expository article so that readers get a comprehensive overview of the subject. The first article of the special issue is written keeping this in mind. Although the initial intention was to cover all three aspects of PR, to restrict the size of the paper from being excessively large, we concentrated only on feature analysis. Of the three, feature analysis is chosen because the success of clustering and classification depends heavily on the features used.

For this special issue we got a large number of articles from the contributors to the IIZUKA'96. Each paper was thoroughly reviewed by at least three referees. The revised versions are also re-reviewed as and when required and finally, we could select twelve papers for the special issue. The topics covered by the special issue range from classifier design, image processing, image analysis, genetic algorithms, genetic programming, and some hybrid systems. The papers can be logically organized into three groups: pattern recognition, image analysis and hybrid systems (note that pattern recognition includes image processing, but image processing, because of the spatial organization of the pixels, often requires special treatments).

The first article by Pal is on soft computing for feature analysis. With an introduction to soft computing he explains the relevance and importance of soft computing to different tasks of pattern recognition. Then with some illustrative methods he discusses how neural networks can be used for feature ranking and selection. A few connectionist schemes for efficient structure preserving dimensionality reduction are then presented. This is followed by some fuzzy set theoretic methods for feature analysis and finally, how genetic algorithms can be used for feature selection is presented. Most of the methods discussed are illustrated with simulation results.

The next article by Ishibuchi et al. presents some fuzzy rule-based systems for pattern classification. They consider two kinds of voting schemes: the first one is based on voting by multiple fuzzy if–then rules in a single fuzzy rule-based classification system and in the other scheme voting is done by multiple fuzzy rule-based classification systems. Under voting by multiple fuzzy rule-based classification systems, three voting strategies, namely, perfect unison rule, majority rule and weighted voting rule are considered. In this regard the authors also discuss how the fuzzy if–then rules can be learnt. The performance of the proposed schemes is compared with neural net and statistical techniques using some well known data sets.

The article by Chen and Wang is on optimization of fuzzy membership functions using clustering results. This is an important step for identification of fuzzy rule-based systems. Chen and Wang propose a heuristic method to obtain a desirable value of the fuzzy exponent used in Bezdek's fuzzy c-means (FCM) clustering algorithm. The authors then present a hybrid learning scheme for the parameters of the rule based system. The effectiveness of the proposed scheme is established by comparing its performance with the equalized universe method and the subtractive clustering.

The fourth article by Hattori and Furuhashi presents a new concept on association of patterns and symbols using neural networks. They propose an interesting network for inference using patterns and symbols. The patterns are spatial distribution of feature vectors made from input images while symbols are labels given to the patterns. The network is designed with a view to learning concepts and inferring meanings of the original images. The proposed network is a three layer associative memory net with one input and two symbol layers. The characteristics of the network is such that association from a pattern to another pattern, from a symbol to another symbol, and inference from patterns to symbols and vice versa can be done.

We now focus on a group of six papers on different aspects of image processing and analysis.

Russo proposed the fuzzy inference ruled by else-action (FIRE) operators and applied it in different image processing applications. FIRE operators are non-linear operators driven by fuzzy reasoning. In his paper, he discusses the use of FIRE operators for non-linear filtering of noisy images and for edge detection. An interesting aspect of the algorithm is that it enables him to achieve both noise cancellation and details preservation. A GA-based method for rule generation is also presented (so this is a hybridization of fuzzy logic and genetic algorithms). Following this a new class of noise-protected edge detection operator is explained. The excellent performance of the proposed schemes are demonstrated with several simulation results.

The article by Wang et al. is also on fuzzy reasoning but for a different image processing problem, image compression. Wang et al. present an image

compression method named adaptive patch adjustment (APA). The method adaptively adjusts the three-dimensional position of triangular plane patches that approximates the corresponding luminance curved surface of the original image. Such adjustments take into account the influence of all pixels contained in the projection of the patch. They empirically established that such a strategy can significantly reduce the average distortion between the reconstructed image and the original one, avoiding excess block splitting and hence resulting in high data compression.

Chen et al. in their paper describe a method for restoration of gray images in the presence of noise using genetic algorithms with Laplacian constraint. This investigation explores the possibility of using GAs in image restoration. In this regard they discuss *uniform R/C crossover* which performs a local small-scale exchange of information, *random R/C crossover* that performs a large-scale exchange of information, *uniform arithmetic crossover* and *non-uniform arithmetic crossover*. Various mutations operators relevant in the present context are also discussed. The simulation results presented are encouraging.

Ali et al. first discuss two methods for the reconstruction of two-dimensional CT images from a small number of projection data. The first technique uses simulated annealing while the other one is based on back-propagation algorithm. The structure of the Boltzmann machine is realized by a grid of neuro-nodes. For the back-prop technique the input and output layers correspond to the projections of the original and the reconstructed image, respectively, while the hidden layer represents the reconstructed image itself. The two techniques are compared with *algebraic reconstruction techniques* (*ART*). Simulation results demonstrate the effectiveness of the two techniques compared to ART.

The next paper by Koppen and Nickolay presents a new technique for designing image processing algorithms based on the concept of image exploring agents. The image exploring agents iteratively run a *sense-compute-act* loop. Although the loop operations are performed locally, the trace of the agent is claimed to be a global image property. The idea is to solve a global problem based on local computation. The proposed scheme is then applied to design image processing algorithms for different problems including crack detection.

With all these image processing background we now switch to the task of image interpretation. Figue et al. propose a method for analysis of still images based on fusion of information obtained from different complementary processing channels. Each channel has three distinct stages: segmentation of the image into informative regions called cues; characterization of the cues by computing a set of attributes and then interpretation of the attributes by fuzzy rules which represent a loose model of the objects that may be present in the image. Processing in each channel is done so as to extract the semantic content of the image. Once the interpretation task is completed by each channel, the final aggregation of results obtained from all channels is done by another set of fuzzy rules. They demonstrate the effectiveness of the proposed paradigm to the problem of face characterization from black and white identity photographs.

Of the first ten papers discussed so far, except Russo, all other authors primarily used only one of the soft computing tools to solve some pattern recognition problems. The next two papers integrate more than one soft computing tool to solve a given problem. The paper by Cho discusses a hybrid method that combines multiple neural network classifiers by genetic algorithms. The outputs of different networks are multiplied by some weights and then aggregated. These weights are learnt by genetic algorithms. The proposed scheme is applied to the recognition of totally unconstrained handwritten numerals and found to exhibit results superior to some of the conventional methods.

The last paper Kasabov et al. presents some hybrid systems for phoneme and word recognition. The authors discuss the problem of adaptation in automatic speech recognition system and suggest several strategies, in a modular architecture, for speech recognition. The architecture is such that each module can be adapted individually based on its own performance and the performance of the whole system. Two realizations of the architecture are presented. The first one is a hybrid neuro-fuzzy recognition system with neural networks for recognizing phonemes and fuzzy systems for modeling acoustic and linguistic knowledge. The second system is also a hybrid system that uses fuzzy neural networks to accommodate both a prior linguistic knowledge and data from speech corpus. Authors also present a method for on-line adaptation of the fuzzy neural networks.

To summarize, as it has been revealed by the previous discussion, the twelve papers published in this issue span a wide spectrum of both soft computing and pattern recognition.

Before I conclude I would like to express my sincere thanks to Prof. Yamakawa, *Fuzzy Logic Systems Institute*, Fukuoka, Japan for giving me an opportunity to guest edit this nice special issue on this very important subject. Thanks are also due to Prof. Zimmermann, Editor-in-chief, *Fuzzy Sets and Systems*, for his cooperation and help on many occasions while working on this special issue. I also take this opportunity to express my sincere gratitude to the referees without whose help successful completion of this special issue would not have been possible. Finally, I like to thank all authors who submitted papers for this special issue.

References

[1] J.C. Bezdek, Pattern Recognition with Fuzzy Objective Function Algorithms, Plenum Press, New York, 1981.

[2] R.O. Duda, P.E. Hart, Pattern Classification and Scene Analysis, Wiley, New York, 1973.

[3] S.K. Pal, N.R. Pal, Soft computing: goals, tools and feasibility, J. IETE 42 (4–5) (1996) 195–204.

[4] L.A. Zadeh, Fuzzy logic and soft computing: issues, contention and perspectives, Proc. 3rd Int. Conf. on Fuzzy Logic, Neural Nets and Soft Computing, IIZUKA, 1994, Japan, pp. 1–2.

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