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Hybrid Intelligent Systems for Pattern Recognition Using Soft Computing

An Evolutionary Approach for Neural Networks and Fuzzy Systems

Springer

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Preface

We describe in this book, new methods for intelligent pattern recognition using soft computing techniques. Soft Computing (SC) consists of several computing paradigms, including fuzzy logic, neural networks, and genetic algorithms, which can be used to produce powerful hybrid intelligent systems for pattern recognition. Hybrid intelligent systems that combine several SC techniques are needed due to the complexity and high dimensionality of pattern recognition problems. Hybrid intelligent systems can have different architectures, which have an impact on the efficiency and accuracy of pattern recognition systems, for this reason it is very important to optimize architecture design. The architectures can combine, in different ways, neural networks, fuzzy logic and genetic algorithms, to achieve the ultimate goal of pattern recognition. This book also shows results of the application of hybrid intelligent systems to real-world problems of face, fingerprint, and voice recognition.

As a prelude, we provide a brief overview of the existing methodologies in Soft Computing. We then describe our own approach in dealing with the problems in pattern recognition. Our particular point of view is that to really achieve intelligent pattern recognition in real-world applications we need to use SC techniques. As consequence, we will describe several real-world applications, in which the reader will be able to appreciate that the use of these techniques really helps in achieving the goals of intelligent pattern recognition. In these applications, we will always compare with the traditional approaches to make clear the advantages of using SC techniques.

This book is intended to be a major reference for scientists and engineers interested in applying new computational and mathematical tools to achieve intelligent pattern recognition. This book can also be used as a textbook or major reference for graduate courses like the following: soft computing, intelligent pattern recognition, computer vision, applied artificial intelligence, and similar ones. We consider that this book can also be used to get novel ideas for new lines of research, or to continue the lines of research proposed by the authors of the book.

In Chap. 1, we begin by giving a brief introduction to the main problems in achieving intelligent pattern recognition in real-world applications. We discuss the importance of the concept of intelligent pattern recognition. We motivate the need for using SC techniques for solving problems of face, fingerprint, and voice recognition. We also outline the real-world applications to be considered in the book.

We describe in Chap. 2 the main ideas underlying type-1 fuzzy logic, and the application of this powerful computational theory to the problems of modeling and pattern recognition. We discuss in some detail type-1 fuzzy set theory, fuzzy reasoning, and fuzzy inference systems. At the end, we also give some general guidelines for the process of fuzzy modeling. We illustrate these concepts with several examples that show the applicability of type-1 fuzzy logic. The importance of type-1 fuzzy logic as a basis for developing intelligent systems in pattern recognition has been recognized in several areas of application. For this reason, we consider this chapter essential to understand the new methods for intelligent pattern recognition that are described in subsequent chapters.

We describe in Chap. 3 the basic concepts, notation, and theory of type-2 fuzzy logic, and intuitionistic fuzzy logic, which are generalizations of type-1 fuzzy logic. Type-2 fuzzy logic enables the management of uncertainty in a more complete way. This is due to the fact that in type-2 membership functions we also consider that there is uncertainty in the form of the functions, unlike type-1 membership functions in which the functions are considered to be fixed and not uncertain. We describe type-2 fuzzy set theory, type-2 fuzzy reasoning, and type-2 fuzzy systems. We also give examples to illustrate these ideas to the reader of the book. Finally, we briefly describe the basic concepts and theory of intuitionistic fuzzy logic and illustrate their applicability with examples.

We describe in Chap. 4 the basic concepts, notation and the learning algorithms for supervised neural networks. We discuss in some detail feedforward neural networks, radial basis neural networks, and adaptive neuro-fuzzy inference systems. First, we give a brief review of the basic concepts of neural networks and the back-propagation learning algorithm. We then continue with a general description of radial basis neural networks. Finally, we end the chapter with a description of the adaptive neuro-fuzzy inference system (ANFIS) method and some examples of application. The importance of supervised neural networks as a computational tool to achieve "intelligence" for software systems has been well recognized in the literature of the area. For this reason, supervised neural networks have been applied for solving complex problems of modeling, identification, and pattern recognition.

We describe in Chap. 5 the basic concepts, notation and learning algorithms for unsupervised neural networks. This type of neural network only receives input data and not output data, unlike supervised neural networks, which receive input-output training data. We describe in some detail competitive neural networks, Kohonen sef-organizing maps, Learning Vector

Quantization (LVQ) neural networks, and Hopfield neural networks. We describe each of this type of neural networks and give examples to illustrate their applicability. Unsupervised neural networks are very important for classification, pattern recognition and clustering applications. For this reason, we consider this chapter very important for understanding some of the applications that are described in later chapters of the book.

We describe in Chap. 6 the basic concepts, theory and algorithms of modular and ensemble neural networks. We will also give particular attention to the problem of response integration, which is very important because response integration is responsible for combining all the outputs of the modules. Basically, a modular or ensemble neural network uses several monolithic neural networks to solve a specific problem. The basic idea is that combining the results of several simple neural networks we will achieve a better overall result in terms of accuracy and also learning can be done faster. For pattern recognition problems, which have great complexity and are defined over high dimensional spaces, modular neural networks are a great alternative for achieving the level of accuracy and efficiency needed for real-time applications. This chapter will serve as a basis for the modular architectures that will be proposed in later chapters for specific pattern recognition problems.

We describe in Chap. 7 the basic concepts and notation of genetic algorithms. We also describe the application of genetic algorithms for evolving neural networks, and fuzzy systems. Genetic algorithms are basic search methodologies that can be used for system optimization. Since genetic algorithms can be considered as a general-purpose optimization methodology, we can use it to find the model, which minimizes the fitting error for a specific data set. As genetic algorithms are based on the ideas of natural evolution, we can use this methodology to evolve a neural network or a fuzzy system for a particular application. The problem of finding the best architecture of a neural network is very important because there are no theoretical results on this, and in many cases we are forced to trial and error unless we use a genetic algorithm to automate this process. A similar thing occurs in finding out the optimal number of rules and membership functions of a fuzzy system for a particular application, here a genetic algorithm can also help us avoid time consuming trial and error.

We describe in Chap. 8 clustering with intelligent techniques, like fuzzy logic and neural networks. Cluster analysis is a technique for grouping data and finding structures in data. The most common application of clustering methods is to partition a data set into clusters or classes, where similar data are assigned to the same cluster whereas dissimilar data should belong to different clusters. In real-world applications there is very often no clear boundary between clusters so that fuzzy clustering is often a good alternative to use. Membership degrees between zero and one are used in fuzzy clustering instead of crisp assignments of the data to clusters. Pattern recognition techniques can be classified into two broad categories: *unsupervised* techniques and *supervised* techniques. An unsupervised technique does not use a given set of

unclassified data points, whereas a supervised technique uses a data set with known classifications. These two types of techniques are complementary. For example, unsupervised clustering can be used to produce classification information needed by a supervised pattern recognition technique. In this chapter, we first give the basics of unsupervised clustering. The Fuzzy C-Means algorithm (FCM), which is the best known unsupervised fuzzy clustering algorithm is then described in detail. Supervised pattern recognition using fuzzy logic will also be mentioned. Finally, we describe the use of neural networks for unsupervised clustering and hybrid approaches.

We describe in Chap. 9 a new approach for face recognition using modular neural networks with a fuzzy logic method for response integration. We describe a new architecture for modular neural networks for achieving pattern recognition in the particular case of human faces. Also, the method for achieving response integration is based on the fuzzy Sugeno integral. Response integration is required to combine the outputs of all the modules in the modular network. We have applied the new approach for face recognition with a real database of faces from students and professors of our institution. Recognition rates with the modular approach were compared against the monolithic single neural network approach, to measure the improvement. The results of the new modular neural network approach gives excellent performance overall and also in comparison with the monolithic approach. The chapter is divided as follows: first we give a brief introduction to the problem of face recognition, second we describe the proposed architecture for achieving face recognition, third, we describe the fuzzy method for response integration, and finally we show a summary of the results and conclusions.

We describe in Chap. 10 a new approach for fingerprint recognition using modular neural networks with a fuzzy logic method for response integration. We describe a new architecture for modular neural networks for achieving pattern recognition in the particular case of human fingerprints. Also, the method for achieving response integration is based on the fuzzy Sugeno integral. Response integration is required to combine the outputs of all the modules in the modular network. We have applied the new approach for fingerprint recognition with a real database of fingerprints obtained from students of our institution.

We describe in Chap. 11 the use of neural networks, fuzzy logic and genetic algorithms for voice recognition. In particular, we consider the case of speaker recognition by analyzing the sound signals with the help of intelligent techniques, such as the neural networks and fuzzy systems. We use the neural networks for analyzing the sound signal of an unknown speaker, and after this first step, a set of type-2 fuzzy rules is used for decision making. We need to use fuzzy logic due to the uncertainty of the decision process. We also use genetic algorithms to optimize the architecture of the neural networks. We illustrate our approach with a sample of sound signals from real speakers in our institution.

We describe in Chap. 12 a new approach for human recognition using as information the face, fingerprint, and voice of a person. We have described in the previous chapters the use of intelligent techniques for achieving face recognition, fingerprint recognition, and voice identification. Now in this chapter we are considering the integration of these three biometric measures to improve the accuracy of human recognition. The new approach will integrate the information from three main modules, one for each of the three biometric measures. The new approach consists in a modular architecture that contains three basic modules: face, fingerprint, and voice. The final decision is based on the results of the three modules and uses fuzzy logic to take into account the uncertainty of the outputs of the modules.

We end this preface of the book by giving thanks to all the people who have help or encourage us during the writing of this book. First of all, we would like to thank our colleague and friend Prof. Janusz Kacprzyk for always supporting our work, and for motivating us to write our research work. We would also like to thank our colleagues working in Soft Computing, which are too many to mention each by their name. Of course, we need to thank our supporting agencies, CONACYT and COSNET, in our country for their help during this project. We have to thank our institution, Tijuana Institute of Technology, for always supporting our projects. Finally, we thank our families for their continuous support during the time that we spend in this project.

Mexico *Patricia Melin*
January 2005 *Oscar Castillo*

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