Soft Computing: Concepts and Techniques

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SOFT COMPUTING:
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FOREWORD

Mrutyunjaya Panda is an experienced teacher as well as a scientist, does a lot of research work in the field of soft computing and network security. He has contributed many things in this book which are outcome of his teaching experience and research work so that Neuro-Fuzzy and soft computing demonstrates his knowledge in this field, his mastery and insightfulness with expository skills. His coauthor Dr. Manas Ranjan Patra has made an important contribution in writing the text using his extensive experience in dealing with real world problems.

The soft computing concepts and techniques are aimed at an accommodation with the pervasive imprecision of the real world problems so as to exploit the tolerance for imprecision, uncertainty, and robustness. However, the real role model for soft computing is the Human brain.

This book *Soft Computing: Concepts and Techniques* has been designed for undergraduate students computer science and other branches of engineering. The book is enriched with a wealth of information which is lucidly presented, well organized and illustrated by many examples. This will help the reader to acquire the needed background in soft computing for further work in designing many efficient intelligent systems.

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PREFACE

Soft computing (SC), is an innovative approach to computing which parallels the remarkable ability of the human mind to reason and learn in an environment of uncertainty and imprecision. Soft computing techniques having the roots in artificial intelligence (AI) consist of fuzzy logic (FL) neural network (NN) and evolutionary algorithms (EA).

There are many potential applications of soft computing methodologies, which includes pattern recognition, adaptive control system, robotics, data mining, and so on.

This book has been written for undergraduate students and others, who are interested in using soft computing techniques. It has been developed as a textbook for one semester course at university for students pursing computer science and in almost all other branches of engineering. During the course of teaching soft computing, I found that no textbook covers the complete syllabi of the soft computing. In this book, we have attempted to cover all the syllabi along with many examples and their applications to pattern recognition and control.

The text is divided into 4 chapters. Chapter 1 gives an overview of artificial intelligence with their Pros and Cons, followed by the various tools of soft computing needed to understand the concept. Non-Linear error surface and optimization techniques are also discussed to understand the usefulness of these in soft computing.

Chapter 2 covers the fundamentals of fuzzy logic. It discusses some insights to the fuzzy relations, fuzzy inferencing along with examples that describes the real world applications. It also discusses about the various defuzzification methods.

Chapter 3 introduces neural networks. It basically discusses various neural network architectures, such as feed-forward (FFNN), backpropagation (BPN), radial basis function (RBF), self-organizing maps (SOM), linear vector quantization (LVQ) and hybrid neuro-fuzzy system (ANFIS), with many solved examples to understand the concept of soft computing.

Finally, in Chapter 4, fundamentals of genetic algorithms (GAs) and genetic programming (GP) are covered with several examples. It presents different types of genetic representation, crossover operators and selection mechanism, along with various optimization methods like simulated annealing (SA), hill climbing (HL), etc. The chapter concludes with possible applications to robotics, data mining, and pattern recognitions.

—Authors

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—Authors

1

ARTIFICIAL INTELLIGENT SYSTEM: AN INTRODUCTION

1.1 INTRODUCTION

Artificial intelligence, or AI for short, is a combination of computer science, physiology, and philosophy. AI is a broad topic, consisting of different fields, form machine vision to expert systems. The elements that the fields of AI have in common is the creation of machines that can "think".

In order to classify machines as "thinking", it is necessary to define intelligence. Research into the areas of learning, of language, and of sensory perception have aided researchers in building intelligent machines. One of the most challenging approaches facing experts is building system that mimic the behaviour of the human brain, made up of billions of neurons, and arguably the most complex matter in the universe. As per Alan tuning, a British computer scientist, a computer would deserves to be called intelligent if it could deceive a human into believing that it was human.

The beginning of AI started from an eminent mathematician "Boole" and others; theorizing on principles that were used as the foundation of AI logic. AI has always been on the pioneering end of computer science. Advanced level computer languages, as well as computer interfaces and word-processors owe their existence to the research into artificial intelligence, which will set the trend in the future of computing.

As a prelude, we shall provide a bird's-eye-view of relevant intelligent system approaches, along with bits of their history and discuss the features of soft computing paradigms.

1.2 HISTORY OF AI

Evidence of artificial intelligence folklore can be traced back to ancient Egypt, but the technology finally became available to create machine intelligence, after the development of the electronic computer in 1941. Through its short modern history, advancement in the fields of AI have been slower that first estimated, progress continues to be made. From its birth 5 decades ago, there have been a variety of AI programs, which have impacted other technological advancements. The history of AI is shown below in Figure 1.1.

Year	History of AI	Comments
1941	First Electronic computer	—
1949	First commercial, stored program computer	The birth of AI
1956	Dartmouth conference and logic theorist developed	

1958	LISP language developed	—
1963	Start of DOD's advanced Research Projects	
1968	Microworld program, SHRDLU created.	—
1970	First expert system	—
1972	PROLOG language revealed	—
1986	AI based hardware sells US $ 425 million to companies	—
1991	AI system beats human chess master	—

Fig. 1.1 The history of artificial intelligence

1.3 PROS AND CONS OF AI

Pros of AI : Emotions that often intercept rational thinking of a human being are not a hindrance for artificial thinkers. Lacking the emotional side, robots can think logically and take the right decisions. Sentiments are associated with moods that affect human efficiency. This is not the case with machines with artificial intelligence.

Thus artificial intelligence can be utilized in the completion of repetitive and time-consuming tasks efficiently. Intelligent machines can be used to perform certain dangerous tasks. Machines equipped with AI can be mode to thoughtfully plan towards the fulfilment of tasks and accordingly adjust their parameters such as speed and time. They can be made to act quickly, unaffected by anything like emotion and take the tasks toward perfection.

Cons of AI : The first concern regarding the application of AI is about ethics and moral values. Is it ethically correct to create replicas of human beings? Do our moral values allow us to recreate intelligence? Intelligence is after all a gift of nature. It may not be right to install it into a machine to make it work for our benefit.

Secondly, imagine robots working in hospitals. Do you picture them showing care and concern towards the patients? Human beings are emotional intellectuals. They think and feel. Their feelings guide their thoughts.

Eventually, it is up to us whether to stand by AI or warn ourselves of the likely disaster that it may lead to. In our opinion, there is no ideal replacement for human beings. AI can help alleviate the difficulties faced by man but can never be "human".

1.4 BASIC TOOLS OF SOFT COMPUTING

Soft computing is considered to be an important tool to perform several computing operations that include neural networks, fuzzy logic, models, approximate reasoning, and evolutionary algorithms such as genetic algorithms and simulated annealing. The soft computing allows to incorporate human knowledge effectively, deal with uncertainty, imprecision, and learns to adapt to unknown or changing environment for better performance. As soft computing does not perform much symbolic manipulations, we can therefore view it as a new discipline that complements conventional artificial intelligence (AI) approaches, and vice-versa.

1.4.1 Basics of Neural Network

The human brain is a collection of about 10 billion interconnected neurons. Each neuron is a cell that uses biochemical reactions to receive, process, and transmit information.

Inspired by the biological nervous system, a novel non algorithmic approach such as artificial neural networks; have been explored by many scientist and researchers for information processing. Thus, artificial neural network is an information processing paradigm which attempts to simulate the functionality of human brain and model non linear statistical data.

Then the question arises: "what is the need to simulate human brain when we have computers which can perform millions of numerical calculations within a fraction of second?"

The answer to this is, even though a computer can store a huge amount of data and can perform numerical calculations efficiently, there are some problems which it struggles to solve.

Let us take an example, we have text based search engines that are capable of searching millions of files across the internet for a text key. Thinking in similar lines, imagine an image searching application, where the user is given some space to draw an image and the application should search and show all images similar to the one drawn. If the user draws a tree, the search engine should return all images having a tree.

This image search belongs to a broad class of similar problems, called "Pattern Recognitions" problems. Optical character recognition, hand writing recognition, face recognition, speech recognition, image processing, signature recognition and speaker recognition are different forms of pattern recognition.

Though a computer can store huge amounts of data, it does not know how to identify, organize, understand and interpret the data. On the other hand, human brain is incredibly efficient in identifying patterns. Just by looking at one's face, we can recognize who the person is (if we know him), but it is not so easy for a computer. This is because, there is no algorithm to map a picture (or a video) accurately to a person's identity. It is not possible mathematically to model these kinds of problems. This makes it impossible to solve such problems using conventional problem solving techniques. If we want to solve pattern recognition, we have to somehow simulate human brain. The concept of artificial neural network is an attempt to the same.

Artificial neural networks take a different problem solving approach than that of conventional computers. They connot be programmed to solve a specific problem. They learn by example. This gives them a remarkable property of deriving meaningful information from complicated data and allows them to extract patterns and detect trends that are too complex to be noticed by other computing techniques.

1.4.1.1 Applications

Artificial neural networks are extensively used in applications involving:

(*i*) Function Modelling
(*ii*) Biometric Pattern Recognition
(*iii*) Classification
(*iv*) Prediction
(*v*) Forecasting , and
(*vi*) Data clustering problems.

1.4.2 Fuzzy Logic

Consider the following statement, which is the base on which fuzzy logic is built:

"As the complexity of a system increases, it becomes more difficult and eventually impossible to make a precise statement about its behaviour, eventually arriving at a point of complexity where the fuzzy logic method borns in humans is the only way to get at the problem". (Originally identified by Lofti A. Zadeh, Ph.D, University of California, Berkeley).

Fuzzy logic is used in system control and analysis design, because it shortens the time for engineering development and sometimes, in the case of highly complex system, is the only way to solve the problem.

Human beings have the ability to take in and evaluate all sorts of information from the physical world they are in contact with and to mentally analyze, average and summarize all this input data into an optimum course of action. All living things do this, but human do it more and do it better and have become the dominant species of the planet.

If we think about it, much of the information you take in is not very precisely defined, such as evaluation of the behaviour of a vehicle entering form a side of the street and the likelihood of the vehicle pulling in front of you. We call this as fuzzy input. However, some of our "input" is reasonably precise and non-fuzzy such as speedometer readings. The processing of all these informations are not very precisely definable. We call this fuzzy processing. Fuzzy Logic theorists would call it using fuzzy algorithms (algorithm is another word for procedure or program, as in a computer program). So, fuzzy logic is the way the human brain works, and we can mimic this in machines, to perform somewhat like humans, not to be confused with artificial intelligence, where the so far unattainable goal is for machines to perform EXACTLY like humans (see Forbes magazine, December 2009, digital tools , "why computer can't mimic the Brain: our gray matter is far too complex for machine to simulate".

1.4.2.1 The Fuzzy Logic Method

Fuzzy logic control and analysis systems may be electromechanical in nature, or concerned only with data, for example economic data, in all cases guided by "if- then" rules stated in human language.

Therefore, the fuzzy logic analysis and control method is:

(*a*) Receiving of one or a large number of measurements or other assessment of conditions existing in some system we wish to analyze or control.

(*b*) Processing all these inputs according to human based, fuzzy "IF-THEN" rules, which can be expressed in plain language words.

(*c*) Averaging and weighting the resulting outputs form all the individual rules into one single output decision or signal which decides what to do or tells a controlled system what to do. The output signal eventually arrived at, is a precise appearing, defuzzified "crisp" value. The details about the fuzzy logic and fuzzy set theory are described in Chapter-2 .

1.4.3 Evolutionary Computation

Evolutionary Computation is an area of research within computer science, which draws inspiration from the process of natural evolution. Evolutionary computation offers practical advantages to the researchers facing difficult optimization problems. These advantages are multi-fold, including the simplicity of the approach, its robust response to changing circumstances, its flexibility and many other facets. The evolutionary approach can be applied to problems where heuristic solutions are not available or generally led to unsatisfactory results. Thus evolutionary computing is needed for developing automated problem solvers, where the most powerful natural problem solvers are human brain and evolutionary process (that created the human brain). Designing the problem solvers based on human brain leads to the field of "neuro computing", while the second one leads to "evolutionary computing". The algorithms involved in evolutionary computing are termed as evolutionary algorithms (EA).

The various applications of evolutionary computing may include:

(*a*) Bio Informatics
(*b*) Numerical Combinatorial Optimization
(*c*) System Modeling and Identification
(*d*) Planning and Control
(*e*) Engineering Design
(*f*) Data Mining
(*g*) Machine Learning, and
(*h*) Artificial Life

More discussion about EA is provided in chapter-4.

1.5 APPROXIMATIONS OF MULTIVARIATE FUNCTIONS

1.5.1 Univariate Functions

Problems with a single variable are called univariate. The univariate optimum for $Y = f(X)$ occurs at points where the first derivative of $f(X)$ with respect to x (*i.e.*, $f'(X)$) equals to zero. However, points which have zero first derivatives do not necessarily constitute a minimum or maximum. The second derivative is used to discover character of a point. Points at which a relative minimum occurs have a positive second derivative at that point, while relative maximum occurs at points with a negative second derivative. Zero second derivatives are in conclusive.

It is also important to distinguish between local and global optima. A local optimum arises when one finds a point whose value in the case of a maximum exceeds that of all surrounding points but may not exceed that of distant points. The second derivative indicates the shape of functions and is useful in indicating whether the optimum is local a global. The second derivative is the rate of change in the first derivative. If the second derivative is always negative (or positive) that implies that any maximum (or minimum) found is a global result.

Consider a maximization problem, with a negative second derivative for which $f'(X^*) = 0$. This means the first derivative was > 0 for $X < X^*$ and was < 0, for $X > X^*$. The function can never rise when moving away from X^* because of the sign of the second derivative. An everywhere positive second derivative indicates a global minimum, will be found if $f'(X^*) = 0$, while a negative indicates a global maximum.

1.5.2 Multivariate Functions

The univariate optimization results have multivariate analogues. In the multivariate case, partial derivatives are used, and a set of simultaneous conditions is established. The first and second derivatives are again key to the optimization process, excepting now that a vector of first derivatives and a matrix of second derivatives is involved.

There are several terms to consider in this case. First, the gradient vector, $\Lambda_x f(X_E)$, is the vector of first order partial derivatives of a multivariate function w.r.t. each of the variables evaluated at the point X_E.

$$\nabla f(X_k^*) = \left[\frac{\partial f(X^*)}{\partial X_k}\right],$$

where $\dfrac{\partial f(X_E)}{\partial X_K}$ stands for the partial derivatives of $f(X)$ w.r.t. X_k evaluated at X_E, and X_E depicts $X_{IE}, X_{2E}, \ldots, X_{mE}$. The second derivatives constitute the Hessian matrix,