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Review of Soft Computing Techniques: Exploring Scope

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Abstract: Soft Computing is the science of reasoning, thinking and deductions. The idea behind soft computing is to model cognitive behavior of human mind. Soft computing is foundation of conceptual intelligence in machines. Unlike hard computing, soft computing is tolerant of imprecision, uncertainty, partial truth and approximation. The role model for soft computing is the human mind. The guiding principle of soft computing is: Exploit the tolerance for imprecision, uncertainty and partial truth to achieve tractability, robustness and low solution cost. The main techniques in soft computing are evolutionary computing, artificial neural networks, fuzzy logic and Bayesian statistics. Each technique can be used separately, but a powerful advantage of soft computing is the complementary nature of the techniques. Used together they can produce solutions to problems that are too complex or inherently noisy to tackle with conventional mathematical methods. The applications of soft computing have proved two main advantages: first, it made solving non-linear problems, in which mathematical models are not available or possible and second, it introduced the human knowledge such as cognition, recognition, understanding, learning and others into the fields of computing. This resulted in the possibility of constructing intelligent systems such as autonomous self-tuning systems, and automated designed systems. This paper highlights various techniques of soft computing paradigm. Aim of this paper is to explore possibilities of applying soft computing techniques to the problems associated with various domains.

Keywords: Soft Computing, Artificial Neural Network, Fuzzy Logic, Evolutionary Computing, Machine Learning.

I. INTRODUCTION

Soft computing could be seen as a series of techniques and methods so that real practical situations could be dealt with in the same way as humans deal with them, i.e. on the basis of intelligence, common sense, consideration of analogies, approaches etc. In this sense, soft computingis a family of problem-resolution methods headed by approximate reasoning and functional and optimization approximation methods, including search methods.

Soft computing is therefore the theoretical basis for the area of intelligent systems and it is evident that the difference between the area of artificial intelligence and that of intelligent systems is that the first is based on hard computing and the second on soft computing.

This paper looks into soft computing methodologies that have been utilized in building computer aided diagnosis. The purpose of this review is to select the most suitable soft computing methodology to build a disease decision making system with high accuracy. Artificial Neural network, fuzzy logic and genetic algorithm are soft computing methodologies that can be combined to form hybrid systems to developcomputer aided diagnosis.

II. WHAT IS SOFT COMPUTING?

According to L.A. Zadeh, Soft computing differs from conventional (hard) computing in that, unlike hard computing, it is tolerant of imprecision, uncertainty, partial truth, and approximation. Role model for soft computing is the human mind. The guiding principle of soft computing is: Exploit the tolerance for imprecision, uncertainty, partial truth, and approximation to achieve tractability, robustness and low solution cost.

The basic ideas underlying soft computing in its current incarnation have links to many earlier influences, among them Zadeh's 1965 paper on fuzzy sets; the 1973 paper on the analysis of complex systems and decision processes; and the 1979 report (1981 paper) on possibility theory and soft data analysis. The inclusion of neural computing and genetic computing in soft computing came at a later point.

The principal constituents of Soft Computing (SC) are Fuzzy Logic (FL), Neural Computing (NC), Evolutionary Computation (EC) Machine Learning (ML) and Probabilistic Reasoning (PR). What is important to note is that soft computing is not collection of these techniques; rather, it is a partnership in which each of the partners contributes a distinct methodology for addressing problems in its domain. In this perspective, the principal constituent methodologies in SC are complementary rather than competitive. Furthermore, soft computing may be viewed as a foundation component for the emerging field of conceptual intelligence.

A. What is fuzzy logic?

Fuzzy logic is a superset of conventional (Boolean) logic that has been extended to handle the concept of partial truth -- truth values between "completely true" and "completely false". It was introduced by Dr. LotfiZadeh of UC/Berkeley in the 1960's as a means to model the uncertainty of natural language.

Zadeh says that rather than regarding fuzzy theory as a single theory, we should regard the process of “fuzzification” as a methodology to generalize ANY specific theory from a crisp (discrete) to a continuous

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(fuzzy) form [2]. Thus recently researchers have also introduced "fuzzy calculus", "fuzzy differential equations", and so on [7].

Fuzzy Subsets:

Just as there is a strong relationship between Boolean logic and the concept of a subset, there is a similar strong relationship between fuzzy logic and fuzzy subset theory.
In classical set theory, a subset U of a set S can be defined as a mapping from the elements of S to the elements of the set {0, 1},

U: S --> {0, 1}

This mapping may be represented as a set of ordered pairs, with exactly one ordered pair present for each element of S. The first element of the ordered pair is an element of the set S, and the second element is an element of the set {0, 1}. The value zero is used to represent non-membership, and the value one is used to represent membership. The truth or falsity of the statement

x is in U

is determined by finding the ordered pair whose first element is x. The statement is true if the second element of the ordered pair is 1, and the statement is false if it is 0.
Similarly, a fuzzy subset F of a set S can be defined as a set of ordered pairs, each with the first element from S, and the second element from the interval [0,1], with exactly one ordered pair present for each element of S. This defines a mapping between elements of the set S and values in the interval [0,1].

The value zero is used to represent complete non-membership, the value one is used to represent complete membership, and values in between are used to represent intermediate DEGREES OF MEMBERSHIP. The set S is referred to as the UNIVERSE OF DISCOURSE for the fuzzy subset F. Frequently, the mapping is described as a function, the MEMBERSHIP FUNCTION of F. The degree to which the statement

x is in F

is true is determined by finding the ordered pair whose first element is x. The DEGREE OF TRUTH of the statement is the second element of the ordered pair.

In practice, the terms "membership function" and fuzzy subset get used interchangeably.

Fuzzy expert systems are the most common use of fuzzy logic. They are used in several wide-ranging fields, including:

- Linear and Nonlinear Control
- Pattern Recognition
- Financial Systems
- Operation Research
- Data Analysis

B. Neural Networks

An Artificial Neural Network (ANN) is an information processing paradigm that is inspired by the way biological nervous systems, such as the brain, process information. The key element of this paradigm is the novel structure of the information processing system. It is composed of a large number of highly interconnected processing elements (neurones) working in unison to solve specific problems. ANNs, like people, learn by example.
An ANN is configured for a specific application, such as pattern recognition or data classification, through a learning process. Learning in biological systems involves adjustments to the synaptic connections that exist between the neurons. This is true of ANNs as well.

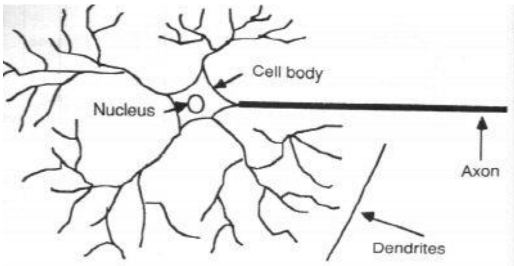

Fig 1: Components of a neuron

Computational neurobiologists have constructed very elaborate computer models of neurons in order to run detailed simulations of particular circuits in the brain.

As Computer Scientists, we are more interested in the general properties of neural networks, independent of how they are actually "implemented" in the brain. This means that we can use much simpler, abstract "neurons", which (hopefully) capture the essence of neural computation even if they leave out much of the details of how biological neurons work.

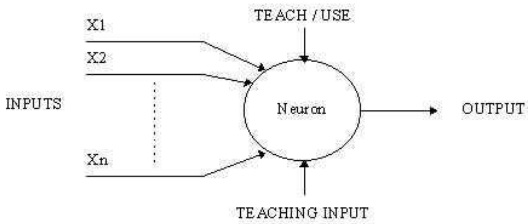

Figure 2: A simple neuron

We conduct these neural networks by first trying to deduce the essential features of neurones and their interconnections. We then typically program a computer to simulate these features.

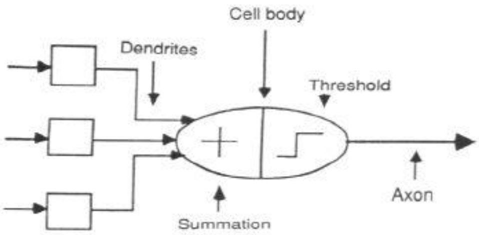

Figure 3: The neuron model

An artificial neuron is a device with many inputs and one output. The neuron has two modes of operation; the training mode and the using mode. In the training mode, the neuron can be trained to fire (or not), for particular input patterns. In the using mode, when a taught input pattern is detected at the input, its associated output becomes the current output. If the input pattern does not belong in the taught list of input patterns, the firing rule is used to determine whether to fire or not.

Our basic computational element (model neuron) is often called a **node** or **unit**. It receives input from some other units, or perhaps from an external source. Each input has an associated **weight** *w*, which can be modified so as to model synaptic learning. The unit computes some function *f* of the weighted sum of its inputs:

$$y_i = f(\sum_j w_{ij} y_j)$$

Its output, in turn, can serve as input to other units.

- The weighted sum $\sum_j w_{ij} y_j$ is called the **net input** to unit *i*, often written net_i.
- Note that w_{ij} refers to the weight from unit *j* to unit *i* (not the other way around).

The function *f* is the unit's **activation function**. In the simplest case, *f* is the identity function, and the unit's output is just its net input. This is called a **linear unit**.

Neural networks are typically organized in layers. Layers are made up of a number of interconnected 'nodes' which contain an 'activation function'. Patterns are presented to the network via the 'input layer', which communicates to one or more 'hidden layers' where the actual processing is done via a system of weighted 'connections'.

Most ANNs contain some form of 'learning rule' which modifies the weights of the connections according to the input patterns that it is presented with. In a sense, ANNs learn by example as do their biological counterparts; a child learns to recognize dogs from examples of dogs.

Neural networks, with their remarkable ability to derive meaning from complicated or imprecise data, can be used to extract patterns and detect trends that are too complex to be noticed by either humans or other computer techniques. A trained neural network can be thought of as an "expert" in the category of information it has been given to analyze. This expert can then be used to provide projections given new situations of interest and answer "what if" questions.

Other advantages include:

1. Adaptive learning: An ability to learn how to do tasks based on the data given for training or initial experience.
2. Self-Organization: An ANN can create its own organization or representation of the information it receives during learning time.
3. Real Time Operation: ANN computations may be carried out in parallel, and special hardware devices are being designed and manufactured which take advantage of this capability.
4. Fault Tolerance via Redundant Information Coding: Partial destruction of a network leads to the corresponding degradation of performance.

However, some network capabilities may be retained even with major network damage.

C. Evolutionary Computing

Evolutionary Computing is the collective name for a range of problem-solving techniques based on principles of biological evolution, such as natural selection and genetic inheritance. These techniques are being increasingly widely applied to a variety of problems, ranging from practical applications in industry and commerce to leading-edge scientific research.

EC refers to computer-based problem solving system that uses computational models of evolutionary processes such as Natural Selection, Survival of the fittest, Reproduction as the fundamental component of such computational system. The theory of natural selection purposes that the plants and animals that exist today are the result of millions of years of adaptation to the demands of environment. Fitness of an organism is measured by success of the organism in adapting to its environment.

Survival of fitness: individual that are more fit have more chances to survive longer hence more chances to reproduce and propagate there genotype to future generation[1].

It is the study of computational systems which use ideas and get inspirations from natural evolution. Evolutionary computation (EC) techniques can be used in optimization; learning and design.EC techniques do not require rich domain knowledge to use. However, domain knowledge can be incorporated into EC techniques. One of the principles borrowed is survival of the fittest.

Few of the EC techniques can be listed as below:

- Evolutionary algorithms
- Gene expression programming
- Genetic algorithm
- Genetic programming
- Evolutionary programming
- Evolution strategy
- Differential evolution
- Swarm intelligence
- Ant colony optimization
- Particle swarm optimization
- Artificial Bee Colony Algorithm
- Bees algorithm
- Artificial life (also see digital organism)
- Artificial immune systems
- Cultural algorithms
- Harmony search
- Learning classifier systems

D. Machine Learning

Machine learning is a branch of artificial intelligence that employs a variety of statistical, probabilistic and optimization techniques that allows computers to “learn” from past examples and to detect hard-to-discern patterns from large, noisy or complex data sets.

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Machine learning is usually divided into two main types. In the **predictive or supervised learning approach**, the goal is to learn a mapping from inputs x to outputs y, given a labeled set of input-output pairs $D = \{(x_i, y_i)\}^N_{i=1}$. Here D is called the **training set**, and N is the number of training examples.

In the simplest setting, each training input x_i is a D-dimensional vector of numbers, representing, say, the height and weight of a person. These are called **features**, **attributes or covariates**. In general, however, x_i could be a complex structured object, such as an image, a sentence, an email message, a time series, a molecular shape, a graph, etc.

Similarly the form of the output or response variable can in principle be anything, but most methods assume that y_i is a **categorical** or **nominal** variable from some finite set, $y_i \in \{1,...,C\}$ (such as male or female), or that y_i is a real-valued scalar (such as income level). When y_i is categorical, the problem is known as **classification** or **pattern recognition**, and when y_i is real-valued, the problem is known as **regression**. Another variant, known as **ordinal regression**, occurs where label space Y has some natural ordering, such as grades A–F.

The second main type of machine learning is the **descriptive** or **unsupervised learning approach**. Here we are only given inputs, $D = \{x_i\}^N_{i=1}$, and the goal is to find "interesting patterns" in the data. This is sometimes called **knowledge discovery**. This is a much less well-defined problem, since we are not told what kinds of patterns to look for, and there is no obvious error metric to use (unlike supervised learning, where we can compare our prediction of y for a given x to the observed value).

III. EXPLORING SCOPE

1. AEROSPACE APPLICATIONS:

Soft computing(neuro, fuzzy, and evolutionary computing) is used for aerospace systems because of the high degrees of nonlinearity, uncertainty, and complexity of these problems and because of the involvement of human beings [18].

Calise proposed the use of **neural networks** for flight control of an aircraft. One network is used to obtain inverse dynamic models off-line, and another neural network is used on-line to behave as an inverse controller. Napolitano et al. constructed a neural and fuzzy virtual flight recorder that could record aircraft control surface deflections.

Berenji proposed the application of soft computing to NASA space projects such as the orbital operations of the space shuttle, including attitude control and rendezvous/docking operations.

Alvarez et al. used **fuzzy approaches** for continuous driving of long-range autonomous planetary micro-rovers, which required maximization of the range and number of interesting scientific sites visited during a limited lifetime. They used a complete set of techniques including fuzzy-based control, real-time reasoning, and fast and robust rover position estimation based on odometry, angular rate sensing, and efficient stereo vision.

2. COMMUNICATIONS SYSTEMS

Since communication systems involve human beings, soft computing can be effectively applied to such systems. Soft computing enables solutions to be obtained for problems that have not been able to be solved satisfactorily by hard computing methods.

Soft computing is used mainly in Communication Networks and Data Communications in communications systems.

Neuro-fuzzy approaches are utilized for equalizers and data compression. Network topologies are determined using evolutionary computation. Soft computing is also expected to play an important role in the development of wireless communication systems[18].

Kolumban et al. applied chaos computation to a synchronized coherent receiver, which has advantages over non coherent ones in terms of noise performance and bandwidth efficiency.

Patra et al. developed a fuzzy implemented channel equalizer that showed performance close to that of an optimal equalizer with a substantial reduction in computational complexity.

Jou et al. proposed an online lossless data compression method using an adaptive fuzzy-tuning modeler with fuzzy inference. The performance was better than that of other lossless coding schemes and satisfactory for various types ofsource data

3. CONSUMER APPLIANCES

The field of consumer or home appliances is not apopular research area in the academic community. Almostall such research activities are related to practical product development.

There is a great potential of fuzzy logic, neural networks (NN), and chaos computing (CC) which have already brought machine intelligence in consumer appliances.

There is a clear demand in developed countries, specifically, in Asia for intelligent, human-like, and user-friendly control features. More recently, evolutionary computation (EC) has also shown considerable potential in this heterogeneous application field.

These techniques are used for various cooling and heating applications like air-conditioners, gas heaters, refrigerators, washing, and food preparation appliances.

4. ELECTRIC POWER SYSTEMS

Neural networks were applied already in the early 1990sto electric power systems. The first conference on applicationof artificial neural networks to power systems was heldin 1991. In the mid-1990s, fuzzy logic was applied to powersystem applications [19] such as control, operation, and planning.

Soft computing was applied to power systems in themid-1990s as reported in [20], which describes in detail themethods for applying SC to various power system problems.

Recently, EC has been used mainly to solve, control operation,and planning problems of power systems, since powersystems are typically large-scale and complex.

Data mining technology, which essentially involves searching for stable, meaningful, and easily interpretable patterns in databases using soft computing [21] has recently become popular, and this new technology may be used to solve certain power system problems in the near future [23].

Software for data mining in a power generation station, e.g., power station performance optimization (reducing energy consumption, identifying measures to reduce operating costs) is now commercially available [22].

5. Manufacturing Automation and Robotics

The term intelligence has been frequently used in this field since robotic technologies that mimic human think ingand behavior of bio-systems have been developed. Contemporary intelligence is sometimes considered to be interactive information processing among human beings, environment, and artificial objects [30]. Intelligence is defined as human-like information processing [28] and adaptation to environment by leaning, evolution, and prediction inorder to survive [29]. The use of structured intelligence by soft computing for intelligent robots has been considered[24]. However, the interaction with human beings is also important. Recently, emotional robots that interact with human beings have attracted much interest by researchers[27]. KANSEI (emotion, feeling) information processinghas become popular in Japan [26]. This technology isneeded for the development of human-friendly robots.

Other technologies, e.g., fuzzy associative memory andchaotic computation have also been used for developinghuman-friendly robots (intelligent robots, welfare robots)[25]. Soft computing is widely used in this field.

6. Transportation

Transportation is a large field with diverse and challenging problems to solve. Since the field of transportation mostly serves ordinary people, passengers, human-orientation and safety in various controls, fault diagnosis, and logistics operations are of considerable importance. Since the early 1990s soft computing has attracted intelligent automobile researchers. FL and EC are often used in state-of-the-art elevator control systems.

Soft computing is an efficient means for constructing intelligent vehicles, since the machine, driver, and the driving environment are interacting with each other.

Intelligent vehicle control requires the following functions:

- recognition of the driving environment;
- planning of driving based on the recognized environment; and
- planning of driving that is easily acceptable for drivers.

7. Healthcare

Healthcare environment is becoming more and more reliant on computer technology, the use of soft computing methods can provide useful aids to assist the physician in many cases, eliminate issues associated with human fatigue and habituation, provide rapid identification of abnormalities and enable diagnosis in real time.

Soft computing techniques are used by various medical applications, such as Medical Image Registration Using Genetic Algorithm, Machine Learning (ML) techniques and tools to solve diagnostic and prognostic problems in a variety of medical domains, Artificial Neural Networks in Medical Diagnosis, Neural Network in diagnosing cancer disease and Fuzzy logic and Anesthetics

IV. FUTURE SCOPE

The successful applications of soft computing (SC)suggest that SC will have increasingly greater impact in the coming years. Soft computing is already playing an important role both in science and engineering.

In many ways, soft computing represents a significant paradigm shift (breakthrough) in the aim of computing, a shift that reflects the fact that the human mind, unlike state-of-the-art computers, possesses a remarkable ability to store and process information, which is pervasively imprecise, uncertain, and lacking in categoricity [31].

Soft computing can be extended to include computing not only from human thinking aspects (mind and brain) but also from bio-informatic aspects [29]. In other words, cognitive and reactive distributed artificial intelligence will be developed and applied to large-scale and complex industrial systems.

In fuzzy systems, computation with words will be investigated increasingly [28] and also evolutionary computation will be emerging [29]. It is expected that these techniques will be applied to the development of more advanced intelligent systems.

V. CONCLUSION

In the current scenario, soft computing has become a major area of academic research. Though, the concept is still evolving, and new methodologies, e.g., chaos computing and immune networks are nowadays considered to belong to SC. While this field is evolving, the number of successful soft computing-based products is increasing concurrently. In the majority of such products, SC is hidden inside systems or subsystems, and the end user does not necessarily know that soft computing methods are used in control, diagnosis, pattern recognition, signal processing, etc. SC is mainly used for improving the performance of conventional hard computing algorithms or even replacing them. Soft computing is very effective when it is applied to real-world problems that are not able to be solved by traditional hard computing. Another class of products that is using soft computing is for implementing novel intelligent and user-friendly features.

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On the whole, soft computing has ability in dealing with uncertain and imprecise problems. We believe that if the quality of studies continues to improve, it is likely that the use of soft computing techniques will become much more commonplace in many varied applications.

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