

An Introduction to Soft Computing Techniques in Water Resources System

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Abstract—The field of engineering is a creative one. The problems encountered in this field are generally unstructured, imprecise and influenced by intuitions and past experiences of a designer. The conventional methods of computing, relying on analytical or empirical relations, become time consuming and labor intensive when posed with real life problems. To study, model and analyze such problems, approximate computer based Soft Computing techniques inspired by the reasoning, intuition, consciousness and wisdom possessed by human beings are employed. In contrast to conventional computing techniques, which rely on exact solutions, soft computing aims at exploiting given tolerance of imprecision, the trivial and uncertain nature of the problem to yield an approximate solution to a problem in quick time. Soft Computing being a multi-disciplinary field uses a variety of statistical, probabilistic and optimization tools which complement each other to produce its three main branches viz. Neural Networks, Genetic Algorithms and Fuzzy Logic. The applications of two major soft computing techniques viz. , Artificial Neural Networks and Genetic Algorithms, has replaced, to some extent, the time consuming conventional techniques of computing with intelligent and time saving computing tools in the field of Civil Engineering. In simple understanding, by using soft computing techniques, some solution, less than the perfect solution, can be arrived at; which may be quite close to the desired solution or lie within the acceptable limits of error. The field of water resources has a lot of potential application of soft computing. Various such techniques have been used to model pollution transport in streams, optimum water allocation, and others.

IndexTerms—Artificial Neural Network, Fuzzy Logic, Genetic Algorithm, Soft Computing

I. INTRODUCTION

Water is the most essential natural resource for life on earth. There is ever increasing demand for the supply of fresh water to the various sectors of human needs. The United Nations projections indicate that the global water demands will exceed the available water supply by the year 2050. This has given rise to the problem of optimal management of water resources potential on all parts of the world, more so, in a developing country like India, where the distribution of the water resource is highly uneven both in space and time. In the recent years, many advanced technologies have been evolved in engineering field such as remote sensing, GIS, artificial neural networks, genetic algorithms, etc. along with the other optimization techniques. Solution to most of the engineering problems, have become easier by application of these technologies. Water Resources is the thrust area where we need advance technologies for overall management. For efficient management of water resources, prediction of various hydrological events such as rainfall-runoff correlation, forecasting of inflow into a reservoir, forecasting of rainfall, forecasting of evaporation, forecasting of maximum flood and optimum reservoir operation policy etc are required. Soft computing techniques are very effective for forecast of complex water resources system behavior.

II. HISTORICAL BACKGROUND

Soft Computing is a term used in computer science to refer to problems in computer science whose solutions are unpredictable, uncertain and between 0 and 1. Soft Computing became a formal area of study in Computer Science in the early 1990s. Earlier computational approaches could model and precisely analyze only relatively simple systems. Soft computing deals with imprecision, uncertainty, partial truth, and approximation to achieve practicability, robustness and low solution cost. As such it forms the basis of a considerable amount of machine learning techniques. Recent trends tend to involve evolutionary and swarm intelligence based algorithms and bio-inspired computation.

III.SOFT COMPUTING TECHNIQUES

Soft computing is a set of “inexact” computing techniques, which are able to model and analyze very complex problems, more conventional methods have not been able to produce cost-effective, analytical or complete solutions(Huang, 2010). These techniques offer the solution with a tolerance of imprecision, uncertainty, partial truth and approximation. There is a main difference between soft computing and possibility. Possibility is used when we don't have enough information to solve a problem but soft computing is used when we don't have enough information about the problem itself. These kinds of problems originate in the human mind with all its doubts, subjectivity and emotions; an example can be determining a suitable temperature for a room to make people feel comfortable.

Generally speaking, soft computing techniques resemble biological processes more closely than traditional techniques, which are largely based on formal logical systems, such as sentential logic and predicate logic, or rely heavily on computer-aided numerical analysis (as in finite element analysis). Soft computing techniques are intended to complement each other.

Unlike hard computing schemes, which strive for exactness and full truth, soft computing techniques exploit the given tolerance of imprecision, partial truth, and uncertainty for a particular problem. Another common contrast comes from the observation that inductive reasoning plays a larger role in soft computing than in hard computing. Soft computing is a term applied to a field within computer science which is characterized by the use of inexact solutions to computationally hard tasks such as the solution of Non Polynomial-complete problems, for which there is no known algorithm that can compute an exact solution in polynomial time. Soft computing differs from conventional (hard) computing in that, unlike hard computing, it is tolerant of imprecision, uncertainty, partial truth, and approximation. In effect, the role model for soft computing is the human mind.

IV. VARIOUS TECHNIQUES OF SOFT COMPUTING

Some of the Soft Computing Methods may be following in isolation or combination.

- Evolutionary computation (EC), including:
 - Evolutionary algorithms
 - Genetic algorithms
 - Differential evolution
 - Metaheuristic and Swarm Intelligence
 - Ant colony optimization
 - Particle swarm optimization
 - Firefly algorithm
 - Cuckoo search
- Genetic Programming
- Neural Network based Learning Methods
 - Perceptron
- Support Vector Machines
- Model Trees
- Fuzzy Logic
- Data Mining
- Knowledge based Decision Support Systems
- Multi-criterion Decision Making
- Ideas about probability including:
 - Bayesian network
- Chaos theory

V. COMPONENT

Components of soft computing include:

- Data in suitable format
- Computational Algorithm
- Decision Rules
- Output in understandable and useful forms

VI. APPLICATIONS OF SOFT COMPUTING TECHNIQUES IN WATER RESOURCES SYSTEM

- Reservoir Operation
- River Basin Management
- Water Distribution Systems
- Ground Water Management
- Watershed Management
- Irrigation Water Management
- Rainfall Runoff Modeling
- Urban Hydrology
- Modelling Hydrologic Extremes
- Impact of Climate Change on Water Resources
- Environmental Hydraulics
- Analysis of groundwater table fluctuation
- Water Treatment System
- Longitudinal Dispersion Coefficient in Natural Channels

Soft computing has been applied to these predominant general fields of water resources engineering with varying success. Pursuit of higher accuracy has further lead to application in combination of more than one technique. The most commonly used techniques are Fuzzy Logic, ANN and GA. Newer variation to these have also been tested with fair results. For e.g. Fuzzy Inference System (FIS), Adaptive-Neuro Fuzzy Inference System (ANFIS), etc.

VII. COMPARISONS AND LIMITATIONS

There are various limitations of soft computing techniques in theoretical study and practical application. Tikk et al.(2001) studied the approximation behavior of soft computing techniques. The authors point out that these techniques have common approximation behavior in the sense that an arbitrary function from the certain set of functions can be approximated with arbitrary accuracy on a compact domain. Compared to classical logic, FL is not always accurate because the results are often perceived as an estimate. Also, fuzzy systems typically require the time consuming process of knowledge acquisition, although they provide the understandable form of knowledge representation.

ANNs are black box in nature. If the problem is to specifically identify causal-effect relationship between input and output, ANNs have only limited ability to do it compared with conventional statistical methods. With too much training time, too many hidden nodes, or too large training data set, the network will over-fit the data and have a poor generalization, i.e. high accuracy for training data set but poor interpolation of testing data.

GAs work on their own internal rules and are good for complex or loosely defined problems using their inductive nature without the need to know any rules of the problem. However, with this inductive ability alone, the algorithms do not necessarily evolve to the optimal solution. GAs, always have a risk finding a suboptimal solution.

VIII. SUMMARY AND DISCUSSION

The application of optimization techniques is most challenging task in water resources systems area, due to the large number of decision variables involved, stochastic nature of the inputs and multiple objectives. Though soft computing techniques offer a feasible solution with little compromise on precision yet, each soft computing technique has its own limitations. The fusion of two or three of these techniques will continue to be one of the major trends in soft computing engineering applications. Fuzzy and Neuro-fuzzy systems represent knowledge in an explicit form, such as fuzzy rules, rather than in an implicit form as ANN alone.

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