Soft Computing Techniques: A Review

Rohin Gupta* and Dr. S.S. Gill**
*Dept. of Electronics and Communication Engineering, Guru Nanak Dev Engineering College, Ludhiana, India
engg.rohin@gmail.com
**Dept. of Electronics and Communication Engineering, Guru Nanak Dev Engineering College, Ludhiana, India
ssg@gndec.ac.in

Abstract: This review paper describes a computation technique known as Soft Computing that is based on natural as well as artificial ideas. This includes various techniques such as Fuzzy Logic, Neural Network, Support Vector Machines, Evolutionary Computation, Machine Learning, Probabilistic Reasoning etc. The paper presents some of the soft computing techniques that include Artificial Neural Networks, Fuzzy Logic and Evolutionary Computing; its applications and future scope.

Keywords: Soft computing, heuristics, neural networks, fuzzy logic, evolutionary computing.

Introduction

Computing is the systematic study of algorithmic processes that describe and transform information: their theory, analysis, design, efficiency, implementation, and application. Computing and computers are used in all disciplines of science and technology and as well in social sciences and humanities. Computing and computers are used to find exact solutions of scientific problems on the basis of two-valued logic and classical mathematics. However not all problems can be resolved by the use of conventional mathematics. There are two types of computing that includes: Hard Computing and Soft Computing.

Hard computing or conventional computing requires a precisely stated analytic model and often a lot of computation time. It is based on binary logic, crisp systems, numerical analysis and crisp software. It requires programs to be written which is deterministic and requires exact input data, strictly sequential and produces precise answers.

Soft Computing

The idea of soft computing was given by L. A. Zadeh in 1981 when he defined soft computing in one multidisciplinary system which is combination of the fields of Fuzzy Logic, Neuro-computing, evolutionary, Genetic computing and probabilistic computing. According to L.A. Zadeh, " Soft Computing is an emerging approach to computing which parallel the remarkable ability of the human mind to reason and learn in an environment of uncertainity and imprecision". Soft computing (SC) solutions are unpredictable, uncertain and between 0 and 1. Soft Computing became a formal area of study in Computer Science in the early 1990s [1]. It is the fusion of technologies which are designed to find solutions of the real world problems which are too difficult to find it by the usual mathematics. Its aim is to exploit the tolerance for imprecision, uncertainity, approximate reasoning, partial truth in order to achieve close resemblance with human like decision making. Soft computing development history is shown in figure 1.

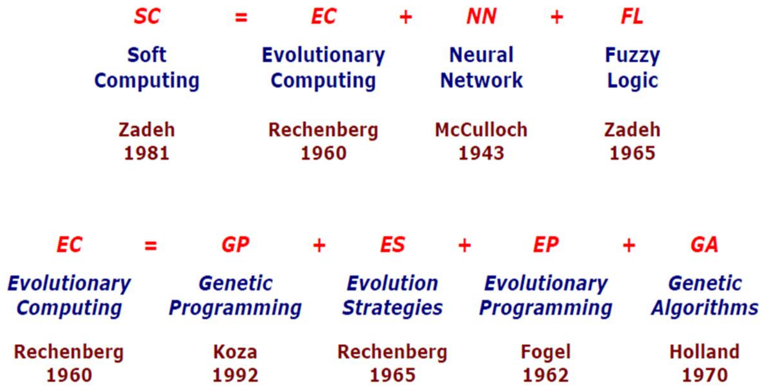

Figure1. Soft Computing development history. (Courtesy: RC Chakraborty)

It do have potential applications in almost every field of engineering which includes: Remote sensing, data analysis, data mining, web mining, GPS, Medical Imaging, forensic applications, optical character recognition, signature verification, multimedia, target recognition, face recognition, communication engineering etc. It differs from hard computing in a number of points which includes:

1. Soft Computing is based on fuzzy logic, neural sets, and probabilistic reasoning whereas Hard Computing is based on binary logic, crisp system, numerical analysis and crisp software.
2. Soft Computing is tolerant of imprecision, uncertainty, partial truth and approximation whereas Hard Computing requires a precisely state analytic model.
3. Soft computing can evolve its own programs whereas hard computing requires programs to be written.
4. Soft computing can deal with ambiguous and noisy data whereas Hard computing requires exact input data.
5. Soft computing allows parallel computations whereas Hard computing is strictly sequential.
6. Soft computing can yield approximate answers whereas Hard computing produces precise answers.

More complex systems arising in biology, medicine, the humanities, management sciences, and similar fields often remained intractable to conventional mathematical and analytical methods. These complex systems can be approximated with the help of Soft Computing.

Some of the components of soft computing include:

1. Neural networks (NN)
2. Fuzzy logic (FL)
3. Evolutionary computation (EC)

Neural Networks (NN)

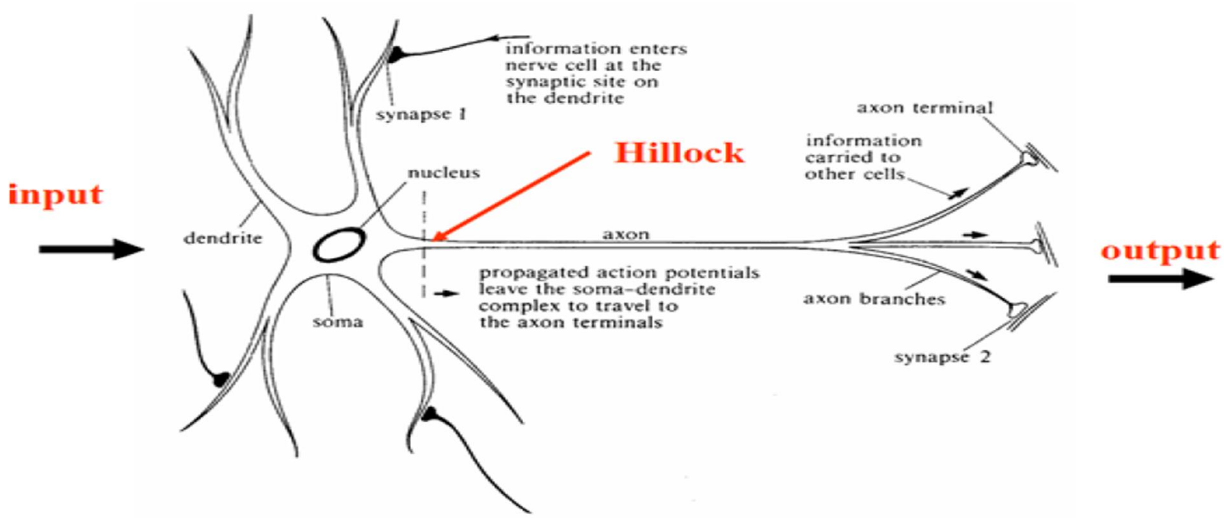

Figure 2. Propagation of information of neural cell in human brain.(Courtesy: RC Chakraborty)

Structure of a neural cell with the flow of information inside the body of a human is shown in figure 2. Here dendrites on the neural cell receive the signals from other neurons. These signals are processed by soma in the cell and after processing, give its output signal. The output signal by soma is transmitted through axons which act as transmission lines. Synapses act as contacts between the signals carried out by axons and other neurons.

Based on the biological neural networks, McCulloch-pits introduced Artificial Neural Networks (ANN) model in year 1943. This model works in parallel to biological Neural Network. ANN is a computing system made up of a number of simple, highly interconnected processing elements, which process information by their dynamic state response to external inputs.

A simplified model of McCulloch-pits artificial neuron which is mimicking the biological neuron is given in figure 3. In this a set of inputs from other neurons are taken by the input node layers. Hidden node layers sums up the signals and process it. Then the signal is transmitted to other artificial neurons. The cell can again start building and process the signals.

Hence artificial neural networks learn through examples and it can be defined as a computational model based on the structure and functions of biological neural networks. Information that flows through the network affects the structure of the ANN because a neural network changes - or learns, in a sense - based on that input and output. The greatest advantage of ANNs is their capability to be used as approximation mechanism that learns from observed data [2].

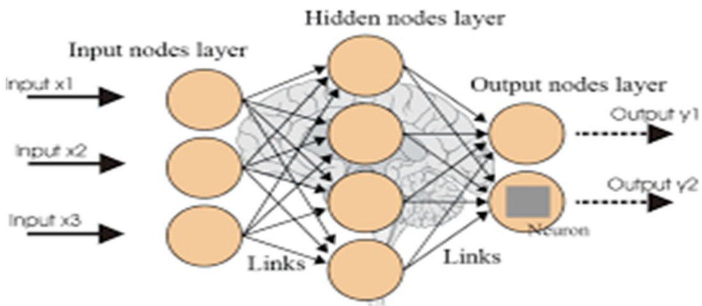

Figure 3. Simplified model of Signal flow in artificial neurons

Some of the applications of Neural Networks include Clustering, Classification, character recognition, Image compression, Function approximations, Prediction systems, medicine, security etc.

Fuzzy Logic

Fuzzy logic was introduced with the 1965 proposal of fuzzy set theory by Lotfi Zadeh [3]. Fuzzy knowledge is vague, imprecise, uncertain, ambiguous, inexact or probabilistic in nature. It is a form of knowledge representation suitable for notions that cannot be defined precisely, but which depend upon their context. Fuzzy technology enables computerized devices to reason more like humans. Fuzzy logic deals in more than simple true and false values [4]. It can be represented with degrees of truthfulness and falsehood. It has proved to be particularly useful in expert system and other artificial intelligence applications. It is also used in some spell checkers to suggest a list of probable words to replace a misspelled one. Fuzzy logic doesn't deal in extremes as shown in figure 4. In this example three parameters are shown viz. Speed, Acceleration and Distance. In speed other than extremes that is too slow and too fast, many other values are present showing the concept of fuzziness. Same is the case in acceleration and distance.

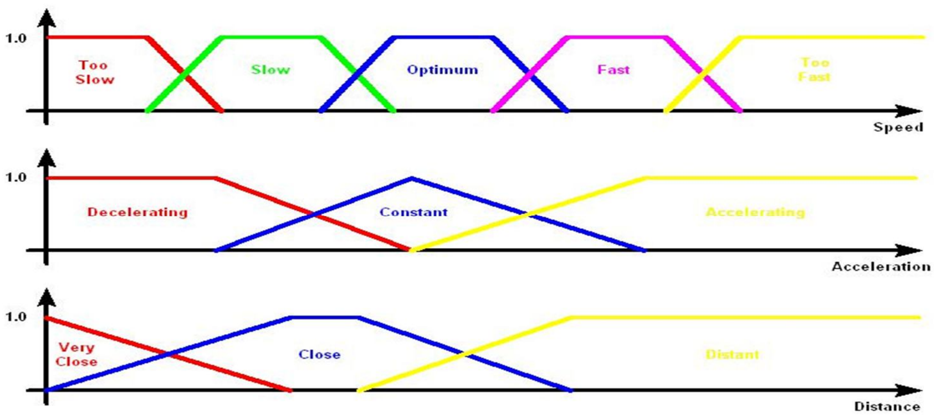

Figure 4. Fuzzy logic example showing vague values other than extremes

Evolutionary Computation

Heuristic can be any approach to problem solving, learning, or discovery that employs a practical method not guaranteed to be optimal or perfect, but sufficient for the immediate goals. Heuristics are shortcuts that ease the cognitive load of making a decision and speed up the process of finding a satisfactory solution. It doesn't always give the best answer to the problem. Metaheuristic is a higher-level procedure or heuristic designed to find, generate, or select a heuristic (partial search algorithm) that may provide a sufficiently good solution to an optimization problem, especially with incomplete or imperfect information or limited computation capacity [5]. Metaheuristic is able to employ heuristics methods by guiding them over the search space in order to exploit its best capabilities to achieve better solutions. Its classification is summarized in figure 5.
Evolutionary computation is a family of algorithms for global optimization inspired by biological evolution, and the subfield of artificial intelligence and soft computing studying these algorithms. In evolutionary computation, an initial set of candidate solutions is generated and iteratively updated. Each new generation is produced by stochastically removing less desired solutions, and introducing small random changes. There are many evolutionary computational techniques. Some of these are:

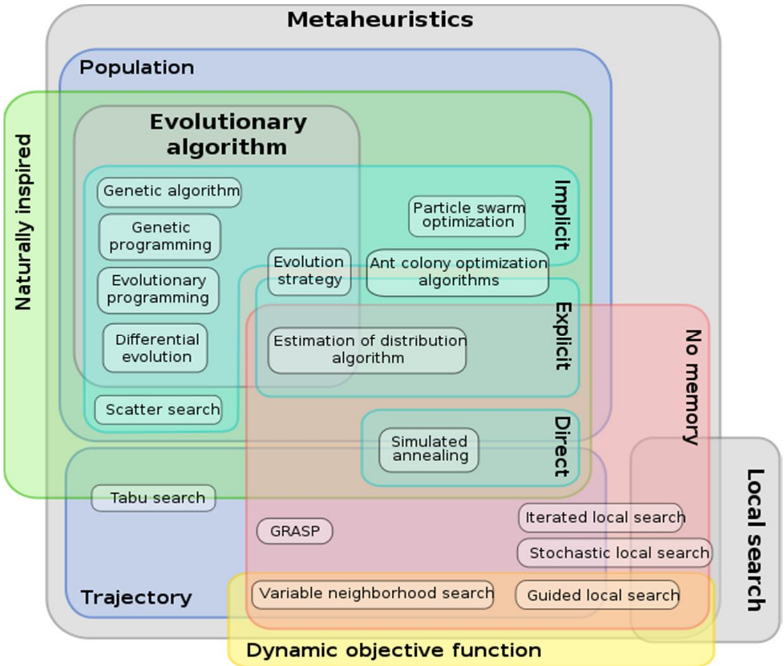

Figure 5. Heuristics classification (courtesy: Jahann, metaheuristics classification)

1. Genetic Algorithm
2. Particle Swarm Optimization
3. Ant Colony Optimization
4. Artificial Bee Colony Algorithm
5. Differential Evolution
6. Harmony Search Algorithm
7. Swarm Intelligence

and many more. Many new techniques are also invented with new algorithms including bioinspired algorihms [6].
Genetic algorithm (GA) is a metaheuristic technique based on the process of natural selection that belongs to the larger class of evolutionary algorithms (EA). Genetic algorithms are commonly used to generate high-quality solutions to optimization and search problems by relying on bio-inspired operators such as mutation, crossover and selection. It suggests that more than two "parents" generate higher quality chromosomes [7][8]. It can be applied on both constrained and unconstrained optimization problems. This algorithm repeatedly modifies a population of individual solutions. At each step, the genetic algorithm randomly selects individuals from the current population and uses them as parents to produce the children for the next generation. Some of the processes involved in genetic algorithms are as shown in figure 6.

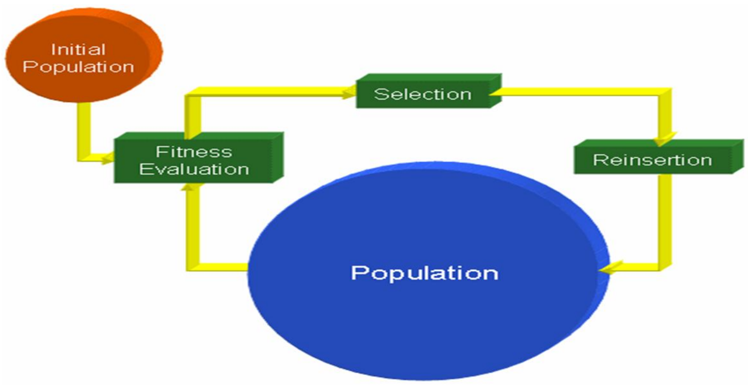

Figure 6. A simple Genetic Algorithm cycle

It is based on random sampling and is non deterministic, hence it yields different results to different calculations. The use of a population (sample solutions) of solutions helps the evolutionary algorithm avoid becoming "trapped" at a local optimum, when an even better optimum may be found outside the vicinity of the current solution. Mutation sometimes used in the algorithm process to generate some distinct population and create a wider search space. The process of mutation may or may not be successful all the time. An evolutionary algorithm attempts to combine elements of existing solutions in order to create a new solution, with some of the features of each parent (previous solutions). Hence it works on the principal of survival of the fittest.

Conclusion and Future Scope

Soft computing is widely used in today's engineering era. It has changed the definition of computing which was precise before. It has been a shift from strict solutions to a process in which computation can mimic the learning. Hence the future scope of soft computing is immense especially in the field of artificial thinking having its impact on almost every field of engineering from robotics, computers to automation.

This review paper is good introduction about soft computing to readers and researchers who want to pursue their career or research in this field.

References

[1] L. A. Zadeh, "Fuzzy Logic, Neural Networks, and Soft Computing," Communications of the ACM, Volume 37, Issue 3, 1994, Pages 77-84.

[2] S. Mittal, "A Survey Of Techniques for Approximate Computing", Communications of the ACM, Volume 48, Issue 4, 2016.

[3] L.A. Zadeh, "Fuzzy sets", Information and Control, Elsevier, Volume 8, Issue 3, 1965, Pages 338–353.

[4] V. Novák, I. Perfilieva, and J. Močkoř, "Mathematical principles of fuzzy logic", International Series in Engineering and Computer Science, Springer Series, Volume 517, 1999.

[5] L. Bianchi, M. Dorigo, L. M. Gambardella and W. J. Gutjahr, "A survey on metaheuristics for stochastic combinatorial optimization". Natural Computing: an international journal. Volume 8, Issue 2, 2009, Pages 239-287.

[6] D. K. Chaturvedi, "Soft Computing: Techniques and Its Applications in Electrical Engineering", Springer, 2008.

[7] A. E. Eiben, P-E Raue and Z. Ruttkay, "Genetic algorithms with multi-parent recombination", Proceedings of the International Conference on Evolutionary Computation, Nature, 1994, Pages 78–87.

[8] C-K Ting, "On the Mean Convergence Time of Multi-parent Genetic Algorithms Without Selection", Advances in Artificial Life, 2005, Pages 403–412.