## Introduction

Soft computing, as opposed to traditional computing, deals with approximate models and gives solutions to complex real-life problems. Unlike hard computing, soft computing is tolerant of imprecision, uncertainty, partial truth, and approximations. In effect, the role model for soft computing is the human mind. Soft computing is based on techniques such as fuzzy logic, genetic algorithms, artificial neural networks, machine learning, and expert systems. Although soft computing theory and techniques were first introduced in 1980s, it has now become a major research and study area in automatic control engineering. The techniques of soft computing are nowadays being used successfully in many domestic, commercial, and industrial applications.

One of the problems in traditional control systems is that complex plants cannot be accurately described by mathematical models, and are therefore difficult to control using such existing methods. Soft computing on the other hand deals with partial truth, uncertainty, and approximation to solve complex problems. Dr. Zadeh who is the pioneer of fuzzy logic quoted that "the guiding principle of soft computing is to exploit the tolerance for imprecision, uncertainty, and partial truth to achieve tractability, robustness, low solution cost, better rapport with reality".

It is becoming difficult to control the growing complexity of modern machinery using traditional control systems techniques. For example, many nonlinear and time-variant plants with large time delays cannot easily be controlled and stabilized using traditional techniques. One of the reasons for this difficulty is the lack of an accurate model that describes the plant. Soft computing is proving to be an efficient way of controlling such complex plants.

Zadeh pointed out that soft computing is not a single method, but instead it is a combination of several methods, such as fuzzy logic, neural networks, and genetic algorithms. All these methods are not competitive, but are complimentary to each other and can be used together to solve a given problem4. It can be said that soft computing aims to solve complex problems by exploiting the imprecision and uncertainty in decision making processes. Fig. 1 shows the conventional and soft computing based problem solution principle as suggested by Gupta and Kulkarni. The left diagram shows the traditional hard computing approach where an exact model of the plant under investigation is available and traditional mathematical methods are used to solve the problem. The right diagram shows soft computing approach where only an approximate model of the plant may be available, and the solution depends upon approximate reasoning techniques.

Fuzzy control has been in use for over two decades to solve complex control problems. In addition, many instrumentation problems are being solved using fuzzy logic principles. Neural networks, although a newer concept, have also been used by many people to solve complex automatic control problems, including the demanding servo problems8. In addition to solving automatic control problems, soft computing has also been used in diverse applications such as in intelligent speech recognition, communications, fields of signal processing, heavy current systems, design and manufacturing, pattern recognition, and many more applications.

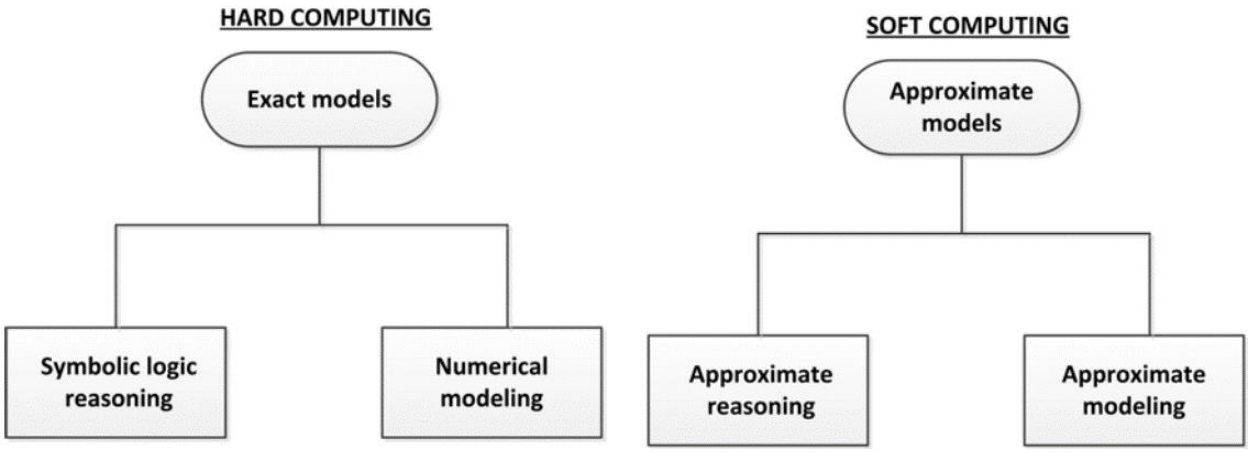


*Figure 1: Problem-solving approach*

## 1. Fuzzy logic

The concept of fuzz logic was introduced by Zadeh as a method for representing human knowledge that is imprecise by nature. Fig. 2 shows the basic configuration of a fuzzy logic system. The fuzzification interface transforms the crisp input value into a fuzzy linguistic value. The fuzzification is always necessary in a fuzzy logic system since the input values from existing sensors are always crisp numerical values. The inference engine takes the fuzzy input and the fuzzy rule base and generates fuzzy outputs. The fuzzy rule base is in the form of "IF-THEN" rules involving linguistic variables. The last processing element of a fuzzy logic system is the defuzzification which has the task of producing crisp output actions. Perhaps one of the biggest advantage of fuzzy logic is that it offers a practical way for designing nonlinear control systems which are difficult to design and stabilize using traditional methods.

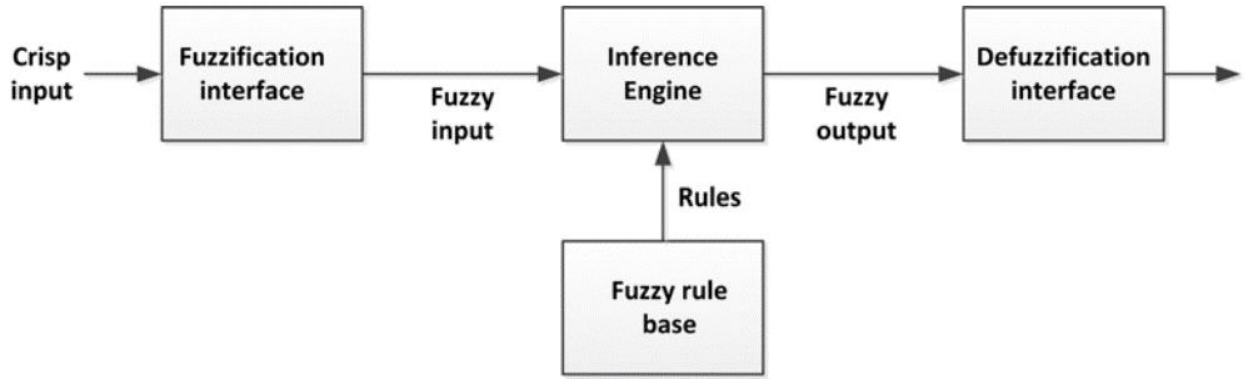


*Figure 2: Architecture of a fuzzy logic system.*

## 2. Artificial neural networks Artificial

Artificial neural networks (ANN), or neural computing is one of the rapidly growing fields of research, attracting researchers from a wide variety of engineering disciplines, such as electronic engineering, control engineering, and software engineering.

ANNs are information processing systems that are inspired by the way biological nervous system and the brain works. ANNs are usually configured for specific applications, such as pattern recognition, data recognition, image processing, stock market prediction, weather prediction, image compression, and security and loan applications. Neural networks aim to bring the traditional computers a little closer to the way human brain works. ANNS work best if the relationship between the inputs and outputs are highly non-linear. ANNs are highly suitable for solving problems where there are no algorithms or specific set of rules to be followed in order to solve the problem.

A neural network is a large network of interconnected elements, inspired by the human neurons. Each neuron performs a little operations and the overall operation is the weighted sum of these operations.

A neural network has to be trained so that a known set of inputs produces the desired outputs. Training is usually done by feeding teaching patterns to the network and letting the network to change its weighting function according to some previously defined learning rules. The learning can either be supervised, or unsupervised. In supervised learning the network under investigation is trained by giving it inputs and matching output patterns. i.e. the outcomes are known for specific inputs. In unsupervised learning the output of the network is trained to respond to input patterns.

Some of the advantages and disadvantages of neural networks are:

- ANNs are not universal tools for solving problems as there is no methodology for training and verifying an ANN.
- The result of an ANN depends upon the accuracy of the available data
- Excessive training may be required in complex ANN systems
- ANNs can deal with incomplete data sets
- ANNs are successful in prediction and forecasting applications.

An ANN is basically composed of three layers: input, hidden layer, and output, where each layer can have number of nodes. Backpropagation algorithm is used in most ANN networks as a method to train the network. Here, output of the neural network is evaluated against desired output, and if the results are not as expected, the weights between layers are modified and the process is repeated until a very small error remains.

### 3. Genetic algorithms

Genetic algorithms are parts of artificial intelligence and fuzzy computing and they are mainly used to solve various optimization problems encountered in real-life applications. The basic idea of a genetic algorithm is to mimic the natural selection in nature in order to find a good selection for an application. Genetic algorithm is basically a model of machine learning inspired by the process of evolution in nature. A genetic algorithm can be used for finding solutions complex search problems found in engineering applications. For example, they can search through various designs and components to find the best combination that will result in overall better and cheaper design.

Genetic algorithms are used in many diverse fields nowadays, such as climatology, biomedical engineering, code-breaking, control engineering, games theory, electronic design, and automated manufacturing and design.

The basic processes in genetic algorithms are:

- Initialization, where an initial population is created randomly.
- Evaluation, where each member of the population is evaluated and the fitness of the individuals are assessed based on how well they fit the desired requirements.
- Selection, where only the ones that fit the desired requirements are selected.
- Crossover, where new individual are created by combining best aspects of the existing individuals. At the end of this it is expected to create individuals that are closer to the desired requirements. The process is repeated from the second step until a termination condition is finally reached.

## 4. Hybrid Systems

Each system discussed above has some advantages and some disadvantages. In hybrid systems, we try to mix the existing systems, with the aim of combining the advantages of various systems into a single, more complex system that gives better performances. Many hybrid systems have been proposed, and many models have been made to better cater to the data. One of the best examples is the fusion of ANNs and Fuzzy systems to make fuzzy-neuro systems. In this hybrid model, a fuzzy system is built over ANN architecture and is then trained using the back propagation algorithm (BPA). These hybrid systems are highly beneficial in real life applications, such as in controllers. These controllers primarily use the fuzzy logic approach, but optimization of the various parameters is done using ANN training. This combination makes the systems perform with a very high degree of precision.

## References and Further reading:

[1] Ibrahim, D. (2016). An overview of soft computing. *Procedia Computer Science*, *102*, 34-38.

[2] Shukla, A., Tiwari, R., & Kala, R. (2010). *Real life applications of soft computing*. CRC press.