CHAPTER 1

Unit I

Introduction

Syllabus Topic : Introduction

1.1 Introduction

- Soft computing consists of distinct concepts and techniques that help in solving complex real-world problems that are difficult to solve using conventional methodologies.
- This chapter gives an introduction to various soft computing techniques such as artificial neural networks, fuzzy logic and genetic algorithms along with their applications.
- Soft computing is a collection of all the techniques that help us to construct computationally intelligent systems.
- It has been now realized that, real world problems are complex, pervasively imprecise and uncertain. To solve such problems, we require computationally intelligent systems that combine knowledge, techniques and methodologies from various sources.
- There are three main requirements of any intelligent system.
  1. They must possess **human like expertise** within a specific domain.
  2. They should be able to **adapt and learn** to do better in changing environment.
  3. Should be capable of **making decisions** and taking actions accordingly.

Syllabus Topic : Soft Computing Vs. Hard Computing

1.2 Soft Computing Vs. Hard Computing

Hard computing involves the traditional methods of computing that require precisely stated analytical models. They often require more computational time. Examples of hard computing are :

- Solving numerical problems (e.g. roots of polynomial, integration etc.)

- Searching and sorting techniques
- Solving Computational geometry problem etc.

Unlike hard computing, soft computing techniques are tolerant of imprecision, uncertainty, partial truth and approximation that are present in the real world problems. Examples of soft computing techniques are Neural networks, Fuzzy logic, genetic algorithms etc.

Following are differences between hard computing and soft computing.

Sr. No.	Hard computing	Soft computing
1.	Hard computing is a conventional type of computing that requires a precisely stated analytic model.	Soft computing techniques are imprecision, approximation and uncertainty tolerant.
2.	Hard computing requires programs to be written.	Soft computing techniques are model free. They can evolve their own models and programs.
3.	Hard computing is deterministic and uses two-valued logic.	Soft computing is stochastic and uses multi-valued logic such as fuzzy logic.
4.	Hard computing needs exact data to solve a particular problem.	Soft computing can deal with incomplete, uncertain and noisy data.
5.	Hard computing techniques perform sequential computation.	Soft computing allows parallel computations. E.g. Neural networks.
6.	The solution or output of hard computing is precise.	Soft computing can generate approximate output or solution.
7.	Hard computing is based on crisp logic, binary logic and numerical analysis.	Soft computing is based on neural networks, fuzzy logic, and evolutionary computations etc.
8.	Hard computing techniques are not fault tolerant. The reason is conventional programs and algorithms are built in such a way that errors have serious consequences, unless enough redundancy is added into the system.	Soft computing techniques are fault tolerant due to their redundancy, adaptability and reduced precision characteristics.

Syllabus Topic : Various Types of Soft Computing Techniques

1.3 Various Types of Soft Computing Techniques

- Soft Computing is the fusion of different techniques that were designed to model and enable solutions to complex real world problems, which are not modeled or too difficult to model, mathematically. Soft computing consist several computing paradigms mainly are :
  - Neural Network
  - Fuzzy Logic
  - Evolutionary Algorithms such as Genetic algorithm
- Every paradigm of soft computing mentioned above has its own strength. In order to build a computationally intelligent system, we may integrate multiple techniques or methodologies to take advantage of the strengths of each of them. Such systems are called **Hybrid soft computing systems.**
- Table 1.3.1 summarizes the soft computing methodologies and their strengths.

Table 1.3.1 : Soft computing constituents and their strengths

Sr. No.	Methodology	Strengths
1.	Neural Networks	Has capability of learning and adaptation.
2.	Fuzzy set theory	Handles uncertainty and incorporates human-like reasoning into the system.
3.	Evolutionary algorithms	Has capability of finding optimum solution to a problem.

- The seamless integration of these methodologies forms the base of soft computing.
- **Neural networks** have the capability of recognizing patterns and adapting themselves to cope with changing environments.
- The **evolutionary algorithms** such as Genetic Algorithms are search and optimization techniques based on biological evolution that help us to optimize certain parameters in a given problem.
- **Fuzzy logic** incorporates human knowledge and performs inference and decision making.

Syllabus Topic : Applications of Soft Computing

1.3.1 Applications of Soft Computing

Soft computing techniques are used almost in every area. Some of the applications of soft computing are listed below.

1. Handwriting recognition system using neural network
2. Image processing and data compression
3. Automotive system and manufacturing
4. Robotics
5. Medical image processing
6. Processing natural languages

Syllabus Topic : Basic Tools of Soft Computing

1.4 Basic Tools of Soft Computing

Syllabus Topic : Neural Network

1.4.1 Introduction to Neural Networks

- An artificial neural network (ANN), inspired by the biological nervous system basically tries to mimic the working of a human brain.
- An ANN is composed of a large number of highly interconnected processing elements called neurons. All these neurons work in parallel to solve a specific problem.
- An ANN learns by examples the way humans learn by their experiences.
- ANN can be designed and configured for a specific application such as data classification, pattern reorganization, data clustering etc.

1.4.1.1 Advantages of Neural Networks

1. Neural networks provide human like artificial intelligence.
2. A neural network learns and does not need to be reprogrammed.
3. A neural network can do a task that a linear program cannot do.
4. Parallel organization of neural networks permits solutions to problems where multiple constraints must be satisfied simultaneously.
5. Because of its parallel nature, when an element of the neural network fails, it can continue without any problem.

Syllabus Topic : Application Scope of Neural Networks

1.4.1.2 Application Scope of Neural Networks

Neural networks have been successfully applied to a broad spectrum of data-intensive applications. Few of them are listed below.

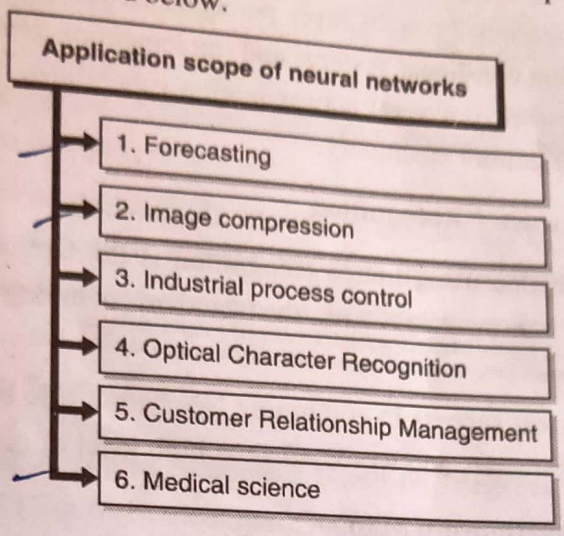

Fig. 1.4.1

→ **1. Forecasting**

Neural network can be used very effectively in forecasting exchange rates, predicting stock values, inflation and cash forecasting, forecasting weather conditions etc. Researchers have proved that the forecasting accuracy of NN systems tend to excel over that of the linear regression model.

→ **2. Image compression**

- Digital images require a large amount of memory for storage. As a result, the transmission of image from one computer to another can be very expensive in terms of time and bandwidth required.
- With the explosion of Internet, more sites are using images. Image compression is a technique that removes some of the redundant information present in the image without affecting its perceptibility, thus, reducing the storage size required to store the image.
- NN can be effectively used to compress the image. Several NN techniques such as Kohonen's self organizing maps, Back propagation algorithm, Cellular neural network etc. can be used for image compression.

3. Industrial process control

- Neural networks have been applied successfully in industrial process control of dynamic systems.
- Neural networks (especially multi layer perceptrons) have been proved to be the best choice for modelling non-linear systems and implementing general – purpose non-linear controllers, due to their universal approximation capabilities. For example control and management of agriculture machinery.

4. Optical Character Recognition

- Well known application using image recognition is the Optical Character Recognition (OCR) tools that are available with the standard scanning software for the home computer.
- **Scansoft** has had great success in combining NN with a rule based system for correctly recognizing both characters and words, to get a high level of accuracy.

5. Customer Relationship Management

- Another popular application for NN is Customer Relationship Management (CRM).
- Customer Relationship Management requires key information to be derived from raw data collected for each individual customer. This can be achieved by building models using historical data information.
- Many companies are now using neural technology to help in their day to day business
- processes. They are doing this to achieve better performance, greater insight, faster development and increased productivity.
- By using Neural Networks for data mining in the databases, patterns, however complex, can be identified for the different types of customers, thus giving valuable customer information to the company.
- Also, NN could be useful for important tasks related to CRM, such as forecasting call centre loading, demand & sales levels, monitoring & analysing the market, validating, completing and enhancing databases, clustering & profiling client base etc.
- One example is the airline reservation system AMT, which could predict sales of tickets in relation to destination, time of year and ticket price.

6. Medical science

- Medicine is the field that has always taken benefits from the latest and advanced technologies.
- Artificial Neural Networks (ANN) is currently the next promising area of interest in medical science.
- It is believed that neural networks will have extensive application to biomedical problems in the next few years.
- ANN has already been successfully applied in medical applications such as diagnostic systems, bio chemical analysis, disease detection, image analysis and drug development.

Syllabus Topic : Fuzzy Logic

1.4.2 Introduction to Fuzzy Logic

- **Fuzzy logic** is an approach to computing based on "**degrees of truth**" rather than the usual "true or false" (1 or 0) Boolean logic on which the modern computer is based.
- The idea of **fuzzy logic** was first proposed by Dr. Lotfi Zadeh of the University of California at Berkeley in the 1960s.
- The human brain can interpret imprecise, vague and incomplete information provided by sensory organs.
- Fuzzy logic is a powerful mathematical tool that can deal with such imprecise, incomplete and uncertain information present in complex real world problems.
- Using fuzzy logic, it is now possible to include vague human assessment in computing problems.
- Also, it provides an effective means for conflict resolution of multiple criteria and better assessment of options.
- Fuzzy logic can be used in the development of various applications such as pattern recognition, optimization, control applications, identification and any intelligent system for decision making.

1.4.2.1 Advantages of Fuzzy Logic Controllers

- Simplicity and flexibility
- Can handle problems with imprecise and incomplete data
- Can model nonlinear functions of arbitrary complexity

- Cheaper to develop,
- Cover a wider range of operating conditions, more readily customizable in natural language terms.

1.4.2.2 Applications of Fuzzy logic

- Fuzzy logic can be used in applications where human like decision making with an ability to generate precise solutions from certain or approximate information is required.
- Fuzzy logic has been extensively used in design of controllers for home appliances such as washing machine, vacuum cleaner, air conditioner etc.
- Fuzzy logic can also be used for other applications such as facial pattern recognition, anti-skid braking systems, transmission systems, control of subway systems and unmanned helicopters.
- Another application area of fuzzy logic is development of knowledge-based systems for multi objective optimization of power systems, weather forecasting systems, models for new product pricing or project risk assessment, medical diagnosis and treatment plans, and stock trading.
- Fuzzy logic has been successfully used in numerous fields such as control systems engineering, image processing, power engineering, industrial automation, robotics, consumer electronics and optimization.

Syllabus Topic : Evolutionary Computing

1.4.3 Evolutionary Computing

- Evolutionary computing refers to the class of algorithms that are inspired by the biological evolution process.
- They are heuristic-based approach to solve problems that cannot be easily solved in polynomial time, such as classically NP-Hard problems.
- 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.
- Evolutionary computation techniques can produce highly optimized solutions in a wide range of problem settings

- Many variations of evolutionary computation exist They are :
  There are three basic types of evolutionary algorithms, namely :
  - Genetic algorithms
  - Evolutionary programming
  - Evolutionary strategies
- Unlike traditional optimization techniques, evolutionary algorithms depend on random sampling.
- An evolutionary algorithm has a population of candidate solutions, unlike classical methods, which try to maintain a single best solution.
- Usually evolutionary algorithms contain four overall steps : **initialization, selection, genetic operators, and termination**.
- Evolutionary algorithms make use of concepts in biology such as selection, reproduction and mutation.

Syllabus Topic : Genetic Algorithm

1.4.4 Introduction to Genetic Algorithms

- Genetic Algorithms are ***adaptive heuristic search*** algorithms based on the evolutionary ideas of natural selection and genetics.
- GAs are often used to find optimal or near-optimal solutions to difficult problems which otherwise would take a lifetime to solve.
- A GA can efficiently explore a large space of candidate designs and find optimum solutions.
- GAs is a subset of an **Evolutionary Computation**.
- GAs were developed by John Holland and his students and colleagues at the University of Michigan,
- In GAs, we select the initial **pool or a population of possible solutions** to the given problem.
- These solutions then undergo various GA operations like recombination and mutation which in turn produce new children.
- The process is repeated over various generations.

- Each individual or candidate solution is assigned a fitness value and the fitter individuals are given a higher chance to mate and yield more "fitter" individuals. This is in line with the Darwinian Theory of "Survival of the Fittest".
- Thus GA keeps "evolving" better individuals or solutions over generations, till it reaches a stopping criterion.
- Genetic Algorithms are sufficiently randomized in nature, but they perform much better than random local search.

1.4.4.1 Advantages of Genetic Algorithms

1. GAs are easy to understand since they do not demand the knowledge of complex mathematics.
2. Does not require any derivative information
3. Good for noisy environment.
4. Easy to discover global optimum.
5. They can solve multimodal, non differentiable, non continuous or even NP-complete problems.
6. GAs are inherently parallel and distributed.
7. Provides a list of "good" solutions and not just a single solution.
8. Flexible in forming building blocks for hybrid applications.
9. Have substantial history and range of use.
10. Useful when the search space is very large and there are a large number of parameters involved.

1.4.4.2 Applications of Genetic Algorithms

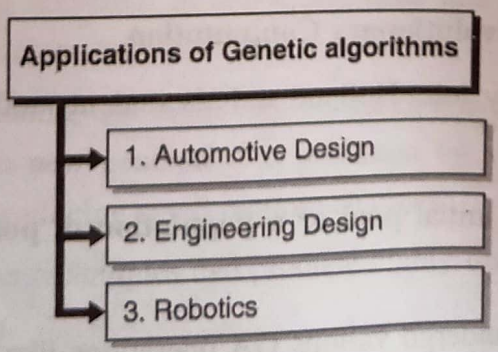

Fig. 1.4.2

1. Automotive Design

Genetic algorithms can be used to design composite materials and aerodynamic shapes for race cars to provide faster, lighter, more fuel efficient and safer vehicles for all the things we use vehicles for.

2. Engineering Design

GA are most commonly used to optimize the structural and operational design of buildings, factories, machines, etc. GA s are used for optimizing the design of robot gripping arms, satellite booms, building trusses turbines, , flywheels or any other computer-aided engineering design application.

3. Robotics

GAs has found applications that span the range of architectures for intelligent robotics. GAs can be used to design the entirely new types of robots that can perform multiple tasks and have more general application.

Syllabus Topic : Hybrid Systems

1.5 Hybrid Systems

- Hybrid systems are those for which more than one soft computing technique is integrated to solve a real-world problem.
- Neural networks, fuzzy logic and genetic algorithms are soft computing techniques which have been inspired by biological computational processes.
- Each of these technologies has its own merits. For example, **neural networks** can model complex non-linear relationship and are suited for solving pattern classification, data clustering and non-linear regression problems.
- Integration of neural networks into the system helps us to build intelligent systems that are adaptive to changing environment.
- **Fuzzy logic systems** can handle imprecision and uncertainty present in inputs and outputs and also incorporate human-like reasoning into the system.
- **Genetic algorithms** are adaptive search and optimization algorithms that can be used to optimize various control parameters used to solve a particular problem.

1.5.1 Types of Hybrid Systems

Hybrid systems can be classified as :

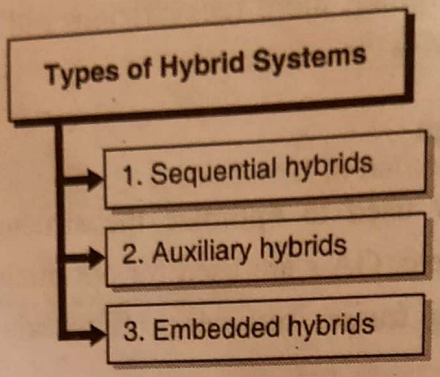

Fig. 1.5.1

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➜ 1. Sequential Hybrid Systems

- In sequential hybrid systems, all the technologies are used in a pipe-line fashion. The output of one technology becomes the input to another technology (Fig. 1.5.2).
- This kind of hybridization form is one of its weakest, because it does not integrate different technologies into a single unit.
- An example is a GA pre-processor which obtains the optimal parameters such as initial weights, threshold, learning rate etc. and hands over these parameters to a neural network.

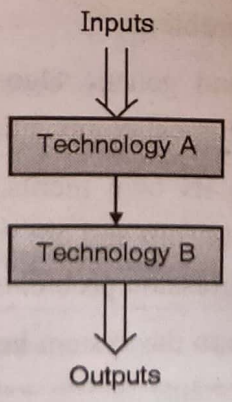

Fig. 1.5.2 : A sequential hybrid system

➜ 2. Auxiliary Hybrid Systems

- In this type, a technology treats another technology as a "subroutine" and calls it to process or generate whatever information is needed by it. Fig. 1.5.3 illustrates the auxiliary hybrid system.

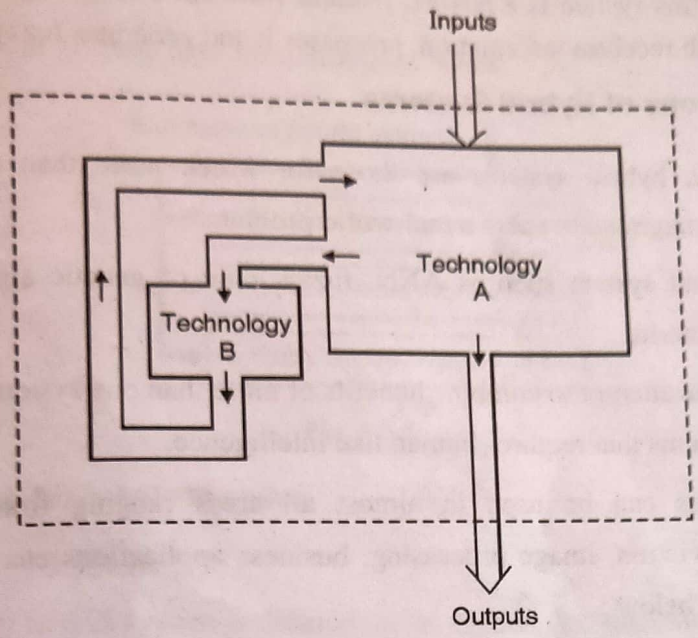

Fig. 1.5.3 : An auxiliary system

- An example is a neuro-genetic system in which an NN employs a GA to optimize its structural parameters, i.e. parameters which define Neural Network's architecture.

3. Embedded Hybrid Systems

- In embedded hybrid systems, the technologies are integrated in such a manner that they appear to be intertwined.
- The fusion is so complete that it would appear that no technology can be used without the other for solving the problem. Fig. 1.5.4 depicts the schema for an embedded hybrid system.

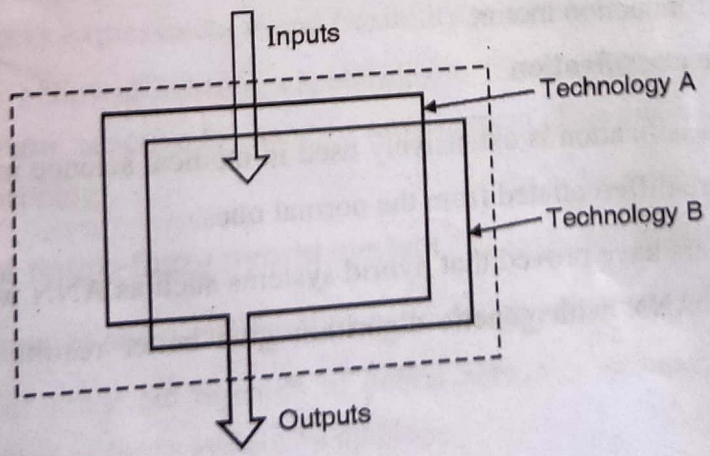

Fig. 1.5.4 : An embedded system

- Example of this system is a NN-FL (Neural Network Fuzzy Logic) hybrid system that has NN which receives information, processes it and generates fuzzy outputs as well.

1.5.2 Applications of Hybrid Systems

- As we know, hybrid systems are those for which more than one soft computing technique is integrated to solve a real-world problem.
- Each individual system such as ANN, fuzzy logic or genetic algorithm has its own merits and demerits.
- Hybrid systems attempt to combine benefits of more than one system to solve real-world complex problems that requires human like intelligence.
- Hybrid systems can be used in almost all areas ranging from medical science, engineering, aviation, image processing, business applications etc. Few of them have been discussed below :

1. **Process control**
   - Process control is an important application of any industry for controlling the complex system parameters, which can readily benefit from hybrid soft computing systems.
   - Hybrid artificial intelligent techniques provide more robust and reliable problem solving models than standalone models.
   - Integrating these techniques enhance the overall strengths and lessen weakness thereby helping to solve overall control problem in effective way.
   - For example, we can use fuzzy logic with genetic algorithm to control the direct torque of induction motor.
2. **Medical Image classification**
   - Image classification is extensively used in medical science in which the abnormal images are differentiated from the normal ones.
   - Researchers have proved that hybrid systems such as ANN with the integration of fuzzy or ANN with genetic algorithm give better results than the standalone system.

1.5.3 Examples of Hybrid Systems

Few of the hybrid systems have been discusses below.

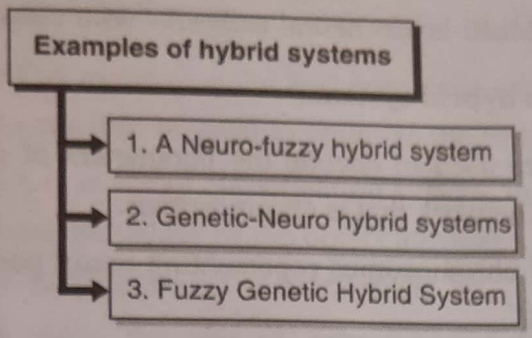

Fig. 1.5.5

→ **1. A Neuro-fuzzy hybrid system**

- It is proposed by J.S.R Jang.
- A Neuro fuzzy hybrid system is defined as the system that determines its parameters by processing data samples with the help of a learning algorithm taken from neural network theory.
- It is a hybrid intelligent system that integrates artificial neural network and fuzzy logic by combining the learning and connectionist structure of neural networks with human like reasoning style of fuzzy systems.
- These systems are useful in. Performing mapping with some degree of imprecision. Accomplishing mathematical relationship among many variables in a complex dynamic process.
- There are two ways to do hybridization:
  (1) Combining the neural networks (NNs) with fuzzy capabilities there by increasing the networks expressiveness and flexibility to adapt to uncertain environments.
  (2) To apply neuronal learning capabilities to fuzzy systems so that fuzzy systems become more adaptive to changing environment. This method is called NN driven fuzzy reasoning.

☞ **Advantages of neuro-fuzzy hybrid system**

- Easy to conceptualize and user friendly way to design non-linear controllers.
- Large amount of academic research of neural networks and explicit representation of process knowledge of fuzzy system available.

Disadvantages of neuro-fuzzy hybrid system

- Limited analysis is available.
- Difficult to combine Multi-layers neural networks with classical control.

2. Genetic-Neuro hybrid systems

- Genetic algorithms are used to encode the parameters of neural networks (NNs) as a string of properties of network that is chromosomes.
- A large population of chromosomes representing many possible parameter sets for the given NN is generated.
- GA-NN have the ability to locate the neighborhood of the optimal solution quicker than other conventional search strategies.
- GA based algorithms have provided encouraging result especially with regard to face recognition, animal control and many other applications.

Advantages of genetic-neuro hybrid system

- GA helps to generate better population from good parents, these results close to global optimum.
- It is robust.
- They works well in various fields as:
  - (a) In pattern matching
  - (b) Speech recognition, text-to-speech conversion
  - (c) Optical character recognition (OCR)
  - (d) Fraudulent credit card detection (VISA)
  - (e) Image compression etc.

Disadvantages of genetic-neuro hybrid system

- Inputs have to be altered before being fed to the network.
- It is fail to depict followings :
  - (a) Which network (architecture) to use?
  - (b) How many hidden layers?
  - (c) How many neurons?
  - (d) What activation functions should I use?

(e) What cost function is the most appropriate?

(f) Which training algorithm to apply?

3. Fuzzy Genetic Hybrid System

- In this model, we use GA to develop the best optimized set of rules to be used for fuzzy inference system. GAs can also be used to optimize the membership function.
- A particular use of GA is in fuzzy classification system, in which an object is classified on the basis of the linguistic values of the object attributes. The challenging task in such a system is to find the appropriate set of fuzzy rules.
- One approach is to make the use of expert knowledge and form translates this knowledge into a set of fuzzy rules. But this approach is time consuming.
- Another approach is to obtain fuzzy rules through machine learning where the knowledge is automatically extracted from the sample cases.
- Coding the rules genetically enables the system to deal with multi value FL and is more efficient.

Review Questions

Q. 1 Differentiate between soft computing and hard computing. *(Ans. : Refer Section 1.2)*

Q. 2 What are the constituents (or types) of Soft Computing techniques ? Explain each in brief. *(Ans. : Refer Section 1.3)*

Q. 3 What are hybrid systems? Explain different types of hybrid systems. *(Ans. : Refer Section 1.5)*

Q. 4 Explain the basics of genetic algorithm along with its applications. *(Ans. : Refer Section 1.4.4)*

Q. 5 Give the application scope of Neural Networks. *(Ans. : Refer Section 1.4.1.2)*

Q. 6 Define soft computing. Distinguish between soft computing and hard computing. *(Ans. : Refer Sections 1.1 and 1.2)*

Q. 7 Explain applications of Hybrid systems. *(Ans. : Refer Section1.5.2)*

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Chapter Ends...