MODULE-I (10 HOURS)

Introduction to Neuro, Fuzzy and Soft Computing, Fuzzy Sets : Basic Definition and Terminology, Set-theoretic Operations, Member Function Formulation and Parameterization, Fuzzy Rules and Fuzzy Reasoning, Extension Principle and Fuzzy Relations, Fuzzy If-Then Rules, Fuzzy Reasoning , Fuzzy Inference Systems, Mamdani Fuzzy Models, Sugeno Fuzzy Models, Tsukamoto Fuzzy Models, Input Space Partitioning and Fuzzy Modeling.

LECTURE-1

INTRODUCTION:

What is intelligence?

Real intelligence is what determines the <u>normal thought process of a human</u>.

Artificial intelligence is a property of machines which gives it ability to mimic the human thought process. The intelligent machines are developed based on the intelligence of a subject, of a designer, of a person, of a human being. Now two questions: can we construct a control system that hypothesizes its own control law? We encounter a plant and looking at the plant behavior, sometimes, we have to switch from one control system to another control system where the plant is operating. The plant is may be operating in a linear zone or non-linear zone; probably an operator can take a very nice intelligent decision about it, but can a machine do it? Can a machine actually hypothesize a control law, looking at the model? Can we design a method that can estimate any signal embedded in a noise without assuming any signal or noise behavior?

That is the first part; before we model a system, we need to observe. That is we collect certain data from the system and How do we actually do this? At the lowest level, we have to sense the environment, like if I want to do temperature control I must have temperature sensor. This data is polluted or corrupted by noise. How do we separate the actual data from the corrupted data? This is the second question. The first question is that can a control system be able to hypothesize its own control law? These are very important questions that we should think of actually. Similarly, also to represent knowledge in a world model, the way we manipulate the objects in this world and the advanced is a very high level of intelligence that we still do not understand; the capacity to perceive and understand.

What is AI ?
Artificial Intelligence is concerned with the design of intelligence in an artificial device.
The term was coined by McCarthy in 1956.
There are two ideas in the definition.

1. Intelligence
2. artificial device

What is intelligence?
- Is it that which characterize humans? Or is there an absolute standard of judgement?
- Accordingly there are two possibilities:
  – A system with intelligence is expected to behave as intelligently as a human
  – A system with intelligence is expected to behave in the best possible manner

– Secondly what type of behavior are we talking about?

– Are we looking at the thought process or reasoning ability of the system?
– Or are we only interested in the final manifestations of the system in terms of its actions?

Given this scenario different interpretations have been used by different researchers as defining the scope and view of Artificial Intelligence.

1. One view is that artificial intelligence is about designing systems that are as intelligent as humans. This view involves trying to understand human thought and an effort to build machines that emulate the human thought process. This view is the cognitive science approach to AI.

2. The second approach is best embodied by the concept of the Turing Test. Turing held that in future computers can be programmed to acquire abilities rivaling human intelligence. As part of his argument Turing put forward the idea of an 'imitation game', in which a human being and a computer would be interrogated under conditions where the interrogator would not know which was which, the communication being entirely by textual messages. Turing argued that if the interrogator could not distinguish them by questioning, then it would be unreasonable not to call the computer intelligent. Turing's 'imitation game' is now usually called 'the Turing test' for intelligence.

3. Logic and laws of thought deals with studies of ideal or rational thought process and inference. The emphasis in this case is on the inferencing mechanism, and its properties. That is how the system arrives at a conclusion, or the reasoning behind its selection of actions is very important in this point of view. The soundness and completeness of the inference mechanisms are important here.

4. The fourth view of AI is that it is the study of rational agents. This view deals with building machines that act rationally. The focus is on how the system acts and performs, and not so much on the reasoning process. A rational agent is one that acts rationally, that is, is in the best possible manner.

Typical AI problems

While studying the typical range of tasks that we might expect an “intelligent entity” to perform, we need to consider both “common-place” tasks as well as expert tasks.
Examples of common-place tasks include

– *Recognizing* people, objects.
– Communicating (through *natural language*).
– *Navigating* around obstacles on the streets

These tasks are done matter of factly and routinely by people and some other animals.
Expert tasks include:

• Medical diagnosis.
• Mathematical problem solving
• Playing games like chess

These tasks cannot be done by all people, and can only be performed by skilled specialists.
Now, which of these tasks are easy and which ones are hard? Clearly tasks of the first type are easy for humans to perform, and almost all are able to master them. However, when we look at what computer systems have been able to achieve to date, we see that their achievements include performing sophisticated tasks like medical diagnosis, performing symbolic integration, proving theorems and playing chess.

On the other hand it has proved to be very hard to make computer systems perform many routine tasks that all humans and a lot of animals can do. Examples of such tasks include navigating our way without running into things, catching prey and avoiding predators. Humans and animals are also capable of interpreting complex sensory information. We are able to recognize objects and people from the visual image that we receive. We are also able to perform complex social functions.

Intelligent behaviour

This discussion brings us back to the question of what constitutes intelligent behaviour. Some of these tasks and applications are:

1. Perception involving image recognition and computer vision
2. Reasoning
3. Learning
4. Understanding language involving natural language processing, speech processing
5. Solving problems
6. Robotics

Practical applications of AI

AI components are embedded in numerous devices e.g. in copy machines for automatic correction of operation for copy quality improvement. AI systems are in everyday use for identifying credit card fraud, for advising doctors, for recognizing speech and in helping complex planning tasks. Then there are intelligent tutoring systems that provide students with personalized attention.

Thus AI has increased understanding of the nature of intelligence and found many applications. It has helped in the understanding of human reasoning, and of the nature of intelligence. It has also helped us understand the complexity of modeling human reasoning.

Approaches to AI

<u>Strong AI</u> aims to build machines that can truly reason and solve problems. These machines should be self aware and their overall intellectual ability needs to be indistinguishable from that of a human being. Excessive optimism in the 1950s and 1960s concerning strong AI has given way to an appreciation of the extreme difficulty of the problem. Strong AI maintains that suitably programmed machines are capable of cognitive mental states.

<u>Weak AI</u>: deals with the creation of some form of computer-based artificial intelligence that cannot truly reason and solve problems, but can act as if it were intelligent. Weak AI holds that suitably programmed machines can simulate human cognition.

<u>Applied AI</u>: aims to produce commercially viable "smart" systems such as, for example, a security system that is able to recognise the faces of people who are permitted to enter a particular building. Applied AI has already enjoyed considerable success.

<u>Cognitive AI</u>: computers are used to test theories about how the human mind works--for example, theories about how we recognise faces and other objects, or about how we solve abstract problems.

Limits of AI Today

Today's successful AI systems operate in well-defined domains and employ narrow, specialized knowledge. Common sense knowledge is needed to function in complex, open-ended worlds. Such a system also needs to understand unconstrained natural language. However these capabilities are not yet fully present in today's intelligent systems.

What can AI systems do

Today's AI systems have been able to achieve limited success in some of these tasks.

- In <u>Computer vision</u>, the systems are capable of face recognition
- In <u>Robotics</u>, we have been able to make vehicles that are mostly autonomous.

- In Natural language processing, we have systems that are capable of simple machine translation.
- Today’s Expert systems can carry out medical diagnosis in a narrow domain
- Speech understanding systems are capable of recognizing several thousand words continuous speech
- Planning and scheduling systems had been employed in scheduling experiments with the Hubble Telescope.
- The Learning systems are capable of doing text categorization into about a 1000 topics
- In Games, AI systems can play at the Grand Master level in chess (world champion), checkers, etc.

What can AI systems NOT do yet?

- Understand natural language robustly (e.g., read and understand articles in a newspaper)
- Surf the web
- Interpret an arbitrary visual scene
- Learn a natural language
- Construct plans in dynamic real-time domains
- Exhibit true autonomy and intelligence

Applications:

We will now look at a few famous AI system that has been developed over the years.

1. ALVINN:
Autonomous Land Vehicle In a Neural Network

In 1989, Dean Pomerleau at CMU created ALVINN. This is a system which learns to control vehicles by watching a person drive. It contains a neural network whose input is a 30x32 unit two dimensional camera image. The output layer is a representation of the direction the vehicle should travel.

The system drove a car from the East Coast of USA to the west coast, a total of about 2850 miles. Out of this about 50 miles were driven by a human, and the rest solely by the system.

2. Deep Blue
In 1997, the Deep Blue chess program created by IBM, beat the current world chess champion, Gary Kasparov.

3. Machine translation
A system capable of translations between people speaking different languages will be a remarkable achievement of enormous economic and cultural benefit. Machine translation is one of the important fields of endeavour in AI. While some translating systems have been developed, there is a lot of scope for improvement in translation quality.

4. Autonomous agents
In space exploration, robotic space probes autonomously monitor their surroundings, make decisions and act to achieve their goals.
NASA's Mars rovers successfully completed their primary three-month missions in April, 2004. The Spirit rover had been exploring a range of Martian hills that took two months to reach. It is finding curiously eroded rocks that may be new pieces to the puzzle of the region's past. Spirit's twin, Opportunity, had been examining exposed rock layers inside a crater.

5. Internet agents
The explosive growth of the internet has also led to growing interest in internet agents to monitor users' tasks, seek needed information, and to learn which information is most useful

What is soft computing?

An approach to computing which parallels the remarkable ability of the human mind to reason and learn in an environment of uncertainty and imprecision.

It is characterized by the use of inexact solutions to computationally hard tasks such as the solution of nonparametric complex problems for which an exact solution can't be derived in polynomial of time.

Why soft computing approach?

Mathematical model & analysis can be done for relatively simple systems. More complex systems arising in biology, medicine and management systems remain intractable to conventional mathematical and analytical methods. Soft computing deals with imprecision, uncertainty, partial truth and approximation to achieve tractability, robustness and low solution cost. It extends its application to various disciplines of Engg. and science. Typically human can:

1. Take decisions
2. Inference from previous situations experienced
3. Expertise in an area
4. Adapt to changing environment
5. Learn to do better
6. Social behaviour of collective intelligence

Intelligent control strategies have emerged from the above mentioned characteristics of human/ animals. The first two characteristics have given rise to Fuzzy logic;2^{nd} , 3^{rd} and 4^{th} have led to Neural Networks; 4^{th} , 5^{th} and 6^{th} have been used in evolutionary algorithms.

Characteristics of Neuro-Fuzzy & Soft Computing:

1. Human Expertise
2. Biologically inspired computing models
3. New Optimization Techniques
4. Numerical Computation
5. New Application domains
6. Model-free learning
7. Intensive computation
8. Fault tolerance
9. Goal driven characteristics
10. Real world applications

Intelligent Control Strategies (Components of Soft Computing): The popular soft computing components in designing intelligent control theory are:

1. Fuzzy Logic
2. Neural Networks
3. Evolutionary Algorithms

Fuzzy logic:

Most of the time, people are fascinated about fuzzy logic controller. At some point of time in Japan, the scientists designed fuzzy logic controller even for household appliances like a room heater or a washing machine. Its popularity is such that it has been applied to various engineering products.

Fuzzy number or fuzzy variable:

We are discussing the concept of a fuzzy number. Let us take three statements: zero, almost zero, near zero. Zero is exactly zero with truth value assigned 1. If it is almost 0, then I can think that between minus 1 to 1, the values around 0 is 0, because this is almost 0. I am not very precise, but that is the way I use my day to day language in interpreting the real world. When I say near 0, maybe the bandwidth of the membership which represents actually the truth value. You can see that it is more, bandwidth increases near 0. This is the concept of fuzzy number. Without talking about membership now, but a notion is that I allow some small bandwidth when I say almost 0. When I say near 0 my bandwidth still further increases. In the case minus 2 to 2, when I encounter any data between minus 2 to 2, still I will consider them to be near 0. As I go away from 0 towards minus 2, the confidence level how near they are to 0 reduces; like if it is very near to 0, I am very certain. As I progressively go away from 0, the level of confidence also goes down, but still there is a tolerance limit. So when zero I am precise, I become imprecise when almost and I further become more imprecise in the third case.

When we say fuzzy logic, that is the variables that we encounter in physical devices, fuzzy numbers are used to describe these variables and using this methodology when a controller is designed, it is a fuzzy logic controller.

Neural networks :

Neural networks are basically inspired by various way of observing the biological organism. Most of the time, it is motivated from human way of learning. It is a learning theory. This is an artificial network that learns from example and because it is distributed in nature, fault tolerant, parallel processing of data and distributed structure.

The basic elements of artificial Neural Network are: input nodes, weights, activation function and output node. Inputs are associated with synaptic weights. They are all summed and passed through an activation function giving output y. In a way, output is summation of the signal multiplied with synaptic weight over many input channels.

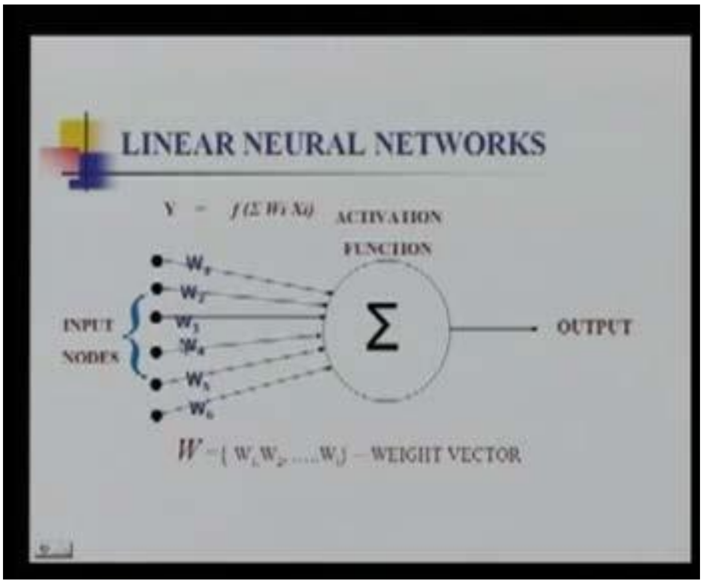

Fig. Basic elements of an artificial neuron

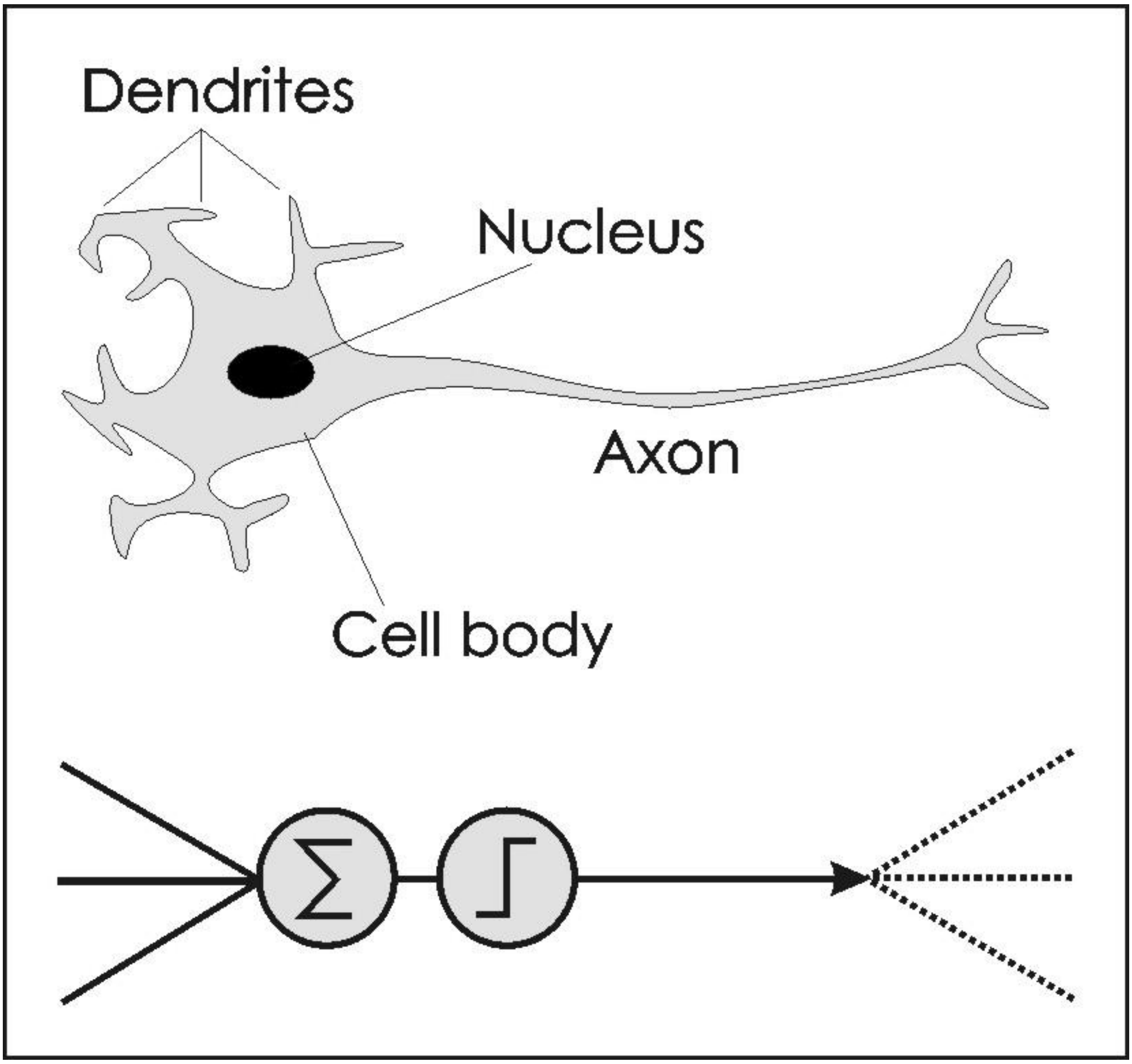

Fig. Analogy of biological neuron and artificial neuron

Above fig. Shows a biological neuron on top. Through axon this neuron actuates the signal and this signal is sent out through synapses to various neurons. Similarly shown a classical artificial neuron(bottom).This is a computational unit. There are many inputs reaching this. The input excites this neuron. Similarly, there are many inputs that excite this computational unit and the output again excites many other units like here. Like that taking certain concepts in actual neural network, we develop these artificial computing models having similar structure.

There are various locations where various functions take place in the brain.

If we look at a computer and a brain, this is the central processing unit and a brain. Let us compare the connection between our high speed computers that are available in the market today and a brain. Approximately there are 10 to the power of 14 synapses in the human brain, whereas typically you will have 10 to the power of 8 transistors inside a CPU. The element size is almost comparable, both are 10 to the power minus 6 and energy use is almost like 30 Watts and comparable actually; that is energy dissipated in a brain is almost same as in a computer. But you see the processing speed. Processing speed is only 100 hertz; our brain is very slow, whereas computers nowadays, are some Giga hertz.

When you compare this, you get an idea that although computer is very fast, it is very slow to do intelligent tasks like pattern recognition, language understanding, etc. These are certain activities which humans do much better, but with such a slow speed, 100 Hz. ….. contrast between these two, one of the very big difference between these two is the structure; one is brain, another is central processing unit is that the brain learns, we learn. Certain mapping that is found in biological brain that we have studied in neuroscience is not there in a central processing unit and we do not know whether self awareness takes place in the brain or somewhere else, but we know that in a computer there is no self-awareness.

Neural networks are analogous to adaptive control concepts that we have in control theory and one of the most important aspects of intelligent control is to learn the control parameters, to learn the system model. Some of the learning methodologies we will be learning here is the error-back propagation algorithm, real-time learning algorithm for recurrent network, Kohonen's self organizing feature map & Hopfield network.

Features of Artificial Neural Network (ANN) models:

1. Parallel Distributed information processing
2. High degree of connectivity between basic units
3. Connections are modifiable based on experience
4. Learning is a continuous unsupervised process
5. Learns based on local information
6. Performance degrades with less units

All the methods discussed so far makes a strong assumption about the space around; that is, when we use whether a neural network or fuzzy logic or …. and …. any method that may have been adopted in intelligent control framework, they all make always very strong assumptions and normally they cannot work in a generalized condition. The question is that can they hypothesize a theory? When I design all these controllers, I always take the data; the engineer takes the data. He always builds these models that are updated. They update their own weights based on the feedback from the plant. But the structure of the controller, the model by which we assume the physical plant, all these are done by the engineer and also the structure of the intelligent controller is also decided by the engineer. We do not have a machine that can hypothesize everything; the model it should select, the controller it should select, looking at simply data. As it encounters a specific kind of data from a plant can it come up with specific controller architecture and can it come up with specific type of system model? That is the question we are asking now.

You will see that in the entire course we will be discussing various tools. They will only be dealing with these two things; behaviour. These tools are actually developed by mimicking the human behavior, but not the human way of working. An intelligent machine is one which learns, thinks and behaves in line with the thought process. That we would like but we are very far from it. At least, at the moment, we are very far from this target of achieving real intelligence.

We perceive the environment in a very unique way, in a coherent manner. This is called unity of perception and intelligence has also something to do with this unity of perception, awareness and certain things are not very clear to us until now. So an intelligent machine is one which learns, thinks & behaves in line with thought process.

Evolutionary algorithms:

These are mostly derivative free optimization algorithms that perform random search in a systematic manner to optimize the solution to a hard problem. In this course Genetic Algorithm being the first such algorithm developed in 1970's will be discussed in detail. The other algorithms are swarm based that mimic behaviour of organisms, or any systematic process.