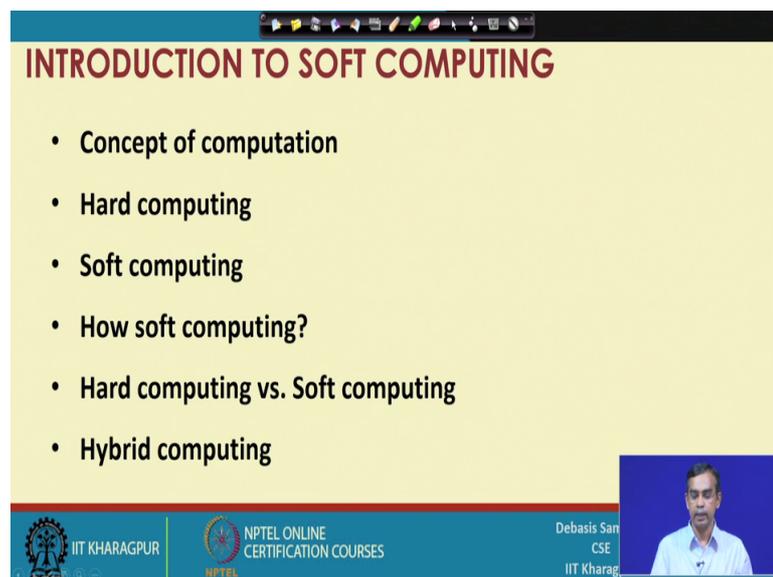


**Introduction to Soft Computing**  
**Prof. Debasis Samanta**  
**Department of Computer Science & Engineering**  
**Indian Institute of Technology, Kharagpur**

**Lecture – 01**  
**Introduction to soft computing**

I take this opportunity to welcome you to the course Soft Computing. In today's lecture we will discuss about basic concept of soft computing. So, basically we know exactly soft computing is related to in some sets computing.

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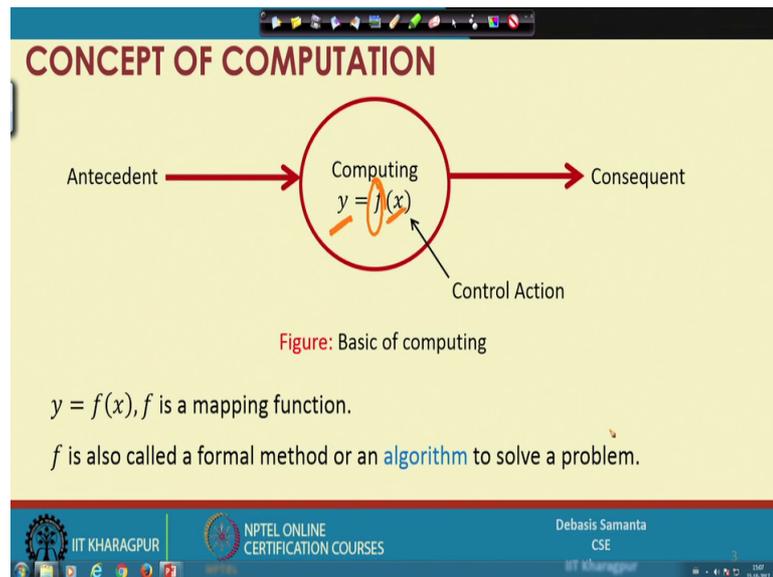
**INTRODUCTION TO SOFT COMPUTING**

- Concept of computation
- Hard computing
- Soft computing
- How soft computing?
- Hard computing vs. Soft computing
- Hybrid computing

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So, basically what is the concept of computation we will learn about it, after these things as the term soft computing they are may be something which is called the hard computing so we learn about the hard computing next and then in what way a soft computing is different from the hard computing, and then obviously, that natural question that arises that how the soft computing can be achieved and to understand better the soft computing we should know exactly what are the differences between the hard computing and soft computing. And there is also another concept it is basically the combination of the two computing paradigms hard computing and soft computing it is called the hybrid computing. So, in today's lecture we will try to cover the other different concept here.

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Now, let us first concept of computation. So, we know exactly a computing means there are certain input and then there is a procedure by which the input can be converted into some output. So, in the context of computing, the input is called the antecedent and then output is called the consequence and then computing is basically mapping. Here we see, so if  $f$  is the function  $f$  is the function basically which is responsible to convert  $x$  the input and to some output. So, this is the concept of computing is basically.

So, in other words, computing is nothing, but is a mapping function mapping from set of input to output. Now, this mapping is also alternatively called as formal method also it is called an algorithm, so basically algorithm to solve a problem.

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**Important characteristics of computing**

- Should provide **precise** solution.
- Control action should be **unambiguous** and **accurate**.
- Suitable for problem, which is easy to **model mathematically**.

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Now, say let us see, exactly what are the different characteristics of computing? So, computing is that for a given input it always give particular output this means that it should provide a precise solution. And in order to achieve from a given set of input to an output it should follow some setup unambiguous and accurate step.

And the next characteristic is that it should it is suitable for some problems which is easy to model mathematically this means that for which there is an algorithm is available.

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**Hard computing**

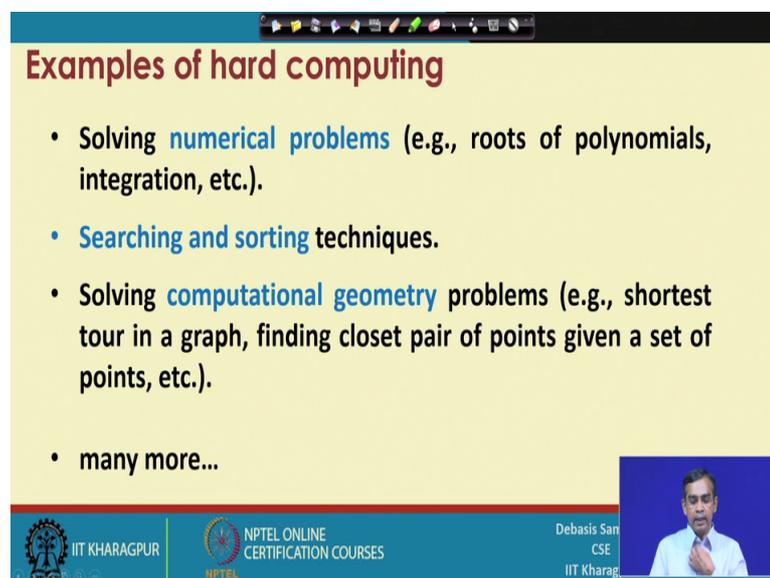
- In 1996, **L. A. Zade (LAZ)** introduced the term **hard computing**.
- According to LAZ: We term a computing as **Hard computing**, if
  - ✓ **Precise result** is guaranteed.
  - ✓ Control action is **unambiguous**.
  - ✓ Control action is **formally defined** (i.e., with mathematical model or algorithm).

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Now this is the concept of computing and this concept is first time coined by a mathematician is Lotfi Aliasker Zade. So, he is only termed as LAZ and he basically is the first person to introduce the concept of hard computing as a part of the concept of computing in general. So, according to LAZ the computing we can say it is hard competing if it provides precise result and the step that is required to solve the problem is unambiguous and then the control action; that means, those are the steps that is require is formally defined by means of some mathematical formula or some algorithm.

So, if a computing concept follows these are the three different characteristics then we say that computing is hard computing.

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**Examples of hard computing**

- Solving **numerical problems** (e.g., roots of polynomials, integration, etc.).
- **Searching and sorting techniques**.
- Solving **computational geometry problems** (e.g., shortest tour in a graph, finding closet pair of points given a set of points, etc.).
- many more...

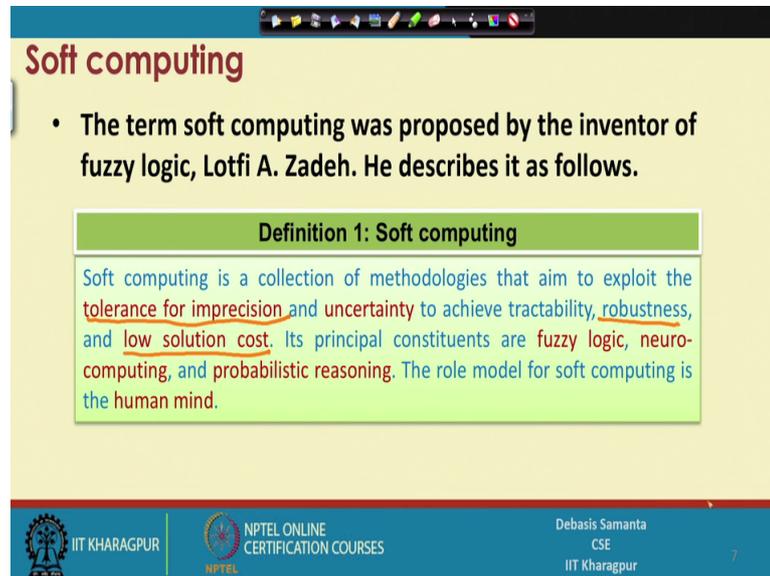
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Now, I will come to some example of hard computing. We know in order to solve numerical problems for example, finding root of polynomials or finding and integration or derivation we usually follow some mathematical models and therefore, it is an example of hard computing. Now, searching and sorting techniques are frequently used in many softwares. So, these are the basically followed by some unambiguous steps and it always gives the precise result and it is basically defined correctly by means of an algorithm. So, it is an example of hard computing.

There are many problems related to the computational geometry for example, finding the shortest tour in a graph, finding closest pair of points given a set of points etcetera is basically is a task of hard computing and there are many many such examples can be

given. So, these are the concept of hard computing. And now, let us come to the soft computing.

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**Soft computing**

- The term soft computing was proposed by the inventor of fuzzy logic, Lotfi A. Zadeh. He describes it as follows.

**Definition 1: Soft computing**

Soft computing is a collection of methodologies that aim to exploit the tolerance for imprecision and uncertainty to achieve tractability, robustness, and low solution cost. Its principal constituents are fuzzy logic, neuro-computing, and probabilistic reasoning. The role model for soft computing is the human mind.

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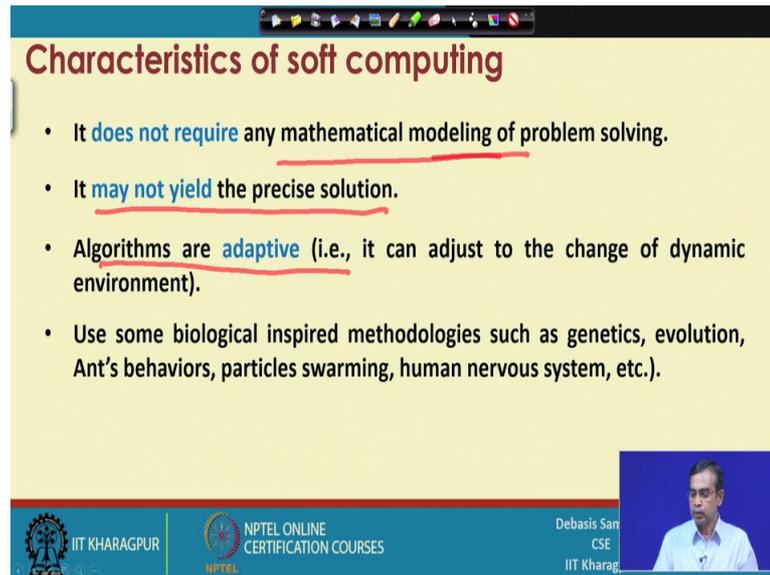
So, as I told you the hard computing first time proposed by LAZ he himself also defined the concept of soft computing first times. According to him the soft computing is defined as a collection of methodologies that aim to exploit the tolerance for imprecision and uncertainty to achieve tractability robustness and low solution cost.

Now, here I have underlined few things that you can mark it. So, the first thing it is basically tolerance for imprecision this is important. This means that the result that is obtained using the soft computing not necessarily to be precised and obviously, the result is uncertain this because if you solve this problem several times it may give different result different time and is a robustness means it can tackle any sort of input noise including. So, that is why it gives the robustness. And very important concept is called the low solution cost. Aome problems if we follow hard computing then it is computationally expensive; however, if we follow soft computing then it is compressionally very chip; that means, find a solution in real time.

Now, if this is the concept of some soft computing where the result is not necessarily to be precised the step that needs to be followed is not necessarily the certain or unambiguous and then the result that can be obtained is also not necessarily to be same always then how this can be achieved. So, in principle the soft computing concept follow

three computing paradigms these are called fuzzy logic, neural computing and probabilistic reasoning. So, these are basically the soft computing paradigms and is basically these concepts the fuzzy logic neural computing or probabilistic reasoning if you see this is the exactly the way the human can solve their own program. So, that is why the role model for soft computing is in fact human mind.

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**Characteristics of soft computing**

- It **does not require** any mathematical modeling of problem solving.
- It **may not yield** the precise solution.
- Algorithms are **adaptive** (i.e., it can adjust to the change of dynamic environment).
- Use some biological inspired methodologies such as genetics, evolution, Ant's behaviors, particles swarming, human nervous system, etc.).

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Now, let us see what are the different characteristics of soft computing? We have discussed little bit about it. So, soft computing is one concept of computing who is does not require any mathematical model. So, it does not require any mathematical model or problem; that means, it does not necessary that an algorithm should be followed or the problem that we have to solve should be expressed in terms of mathematical formulation. And it may not yield the precise solution the solution the is not that it will give you always the same or a unique it can give time to time the different solution for the same problem even with the same input also.

But the solution is near about the accurate value and algorithms are adoptive; that means, it can adjust to the change of any dynamical situation. I, by the means of dynamical situation I want to mean that if the input is changes suppose you want to solve one problem which require only two inputs, but later on the same problem require where twenty input is required. So, the same problem same competing concept can be easily adopted into whatever be the number of inputs are there, whatever the inputs value

maybe there, whatever the other parameters that is involved in order to solve the problem.

Now, so I told you that a human mind is the role model behind the soft computing and actually it is some biological inspired methodology. So, that also constitute the concept of human behavior, such a genetics the evolution the behaviors of ant colony swarming of particles, our nervous system etcetera. So, basically the way the different natural phenomena works for us if we follow the same method and then try to solve our own problem this is basically the way exactly the use of soft computing to solve our own problem.

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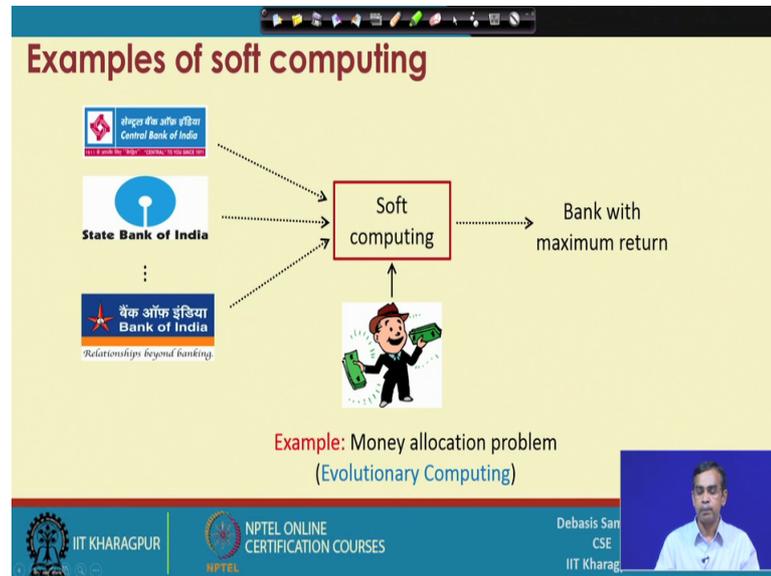
The slide is titled "Examples of soft computing" in a red font. It features a diagram where four handwritten instances of the character "3T" (written in various styles) have arrows pointing to a central box labeled "Soft computing". An arrow then points from this box to a single, large, standard "3T" character. Below the diagram, the text reads "Example: Hand written character recognition (Artificial Neural Networks)". The slide footer includes the IIT Kharagpur logo, NPTEL Online Certification Courses logo, and a small video inset of a speaker, Debasis San, CSE, IIT Kharagpur.

Now, I will give some example of soft computing so that we can understand how the soft computing can works for us. And in this example this is example is basically extracted from the hand written character recognition. Now, the different people if we collect the hand written character they can give the same characters in a different form.

Now, even we know exactly whatever the different form or the way the people can write we can understand easily. For example there is a different way the input is given here and we can exactly step it here we exactly tell that this is [FL]. Now, how it basically happens is basically we learn by the process that this is the letter resemble to a particular alphabets [FL]. So, it is in the same way we learn it and this learned somehow stored in our memory and this is the learning phase and these learning basically works for us to

recognize any unseen characters or unseen letters. And these basically the way actually our neural network our nervous system works and based on this concept the artificial neural network has been evolved and it is followed there.

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Now, another example say suppose a person wants to invest some money and for which the different the banks are available with the different policies the different schemes and there is a flexibility for the person to invest all or some money into the different banks so that he can return the maximum profit. Now, here is the one problem that how we can store the, how we can invest the money in different bank so that we can get the maximum return. So, this concept is basically can be followed using some probabilistic reasoning or it is called the evolution in competing for example, genetic algorithm can be followed to solve these kind of problem.

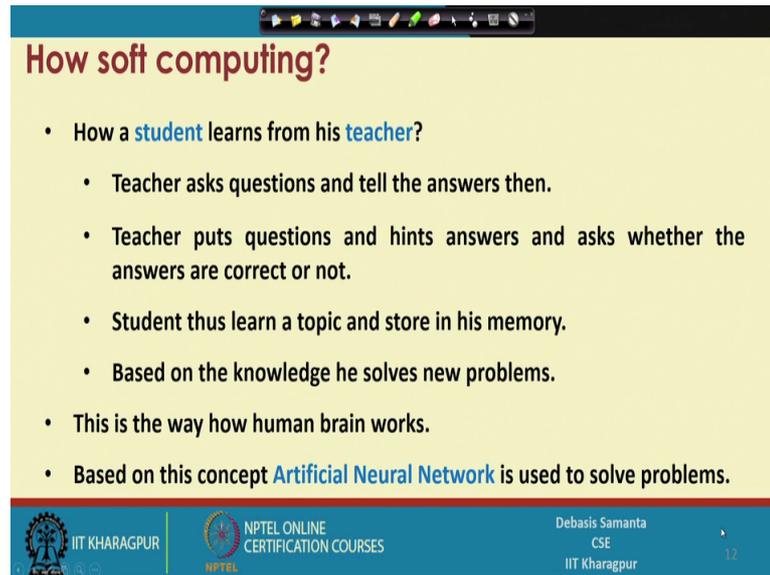
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The slide is titled "Examples of soft computing" in a red font at the top. It features a central diagram on a yellow background. On the left is a white humanoid robot, and on the right is a white cow-like robot. A blue line represents a path from the humanoid robot to the cow robot, curving around several red circular obstacles. Below the path, the text "Example: Robot movement (Fuzzy Logic)" is written in red and blue. At the bottom of the slide, there is a blue footer bar containing the IIT Kharagpur logo, the NPTEL Online Certification Courses logo, and the name "Debasis San CSE IIT Kharag" next to a small video inset of a man.

Another example it is from the robotics say suppose on robot wants to move from here to these place and there are many obstacles are there now; so how the robots can calculate his movement so that without any collision, with any objects, he can move from his current location to target location within shortest time. Now, these kind of problem in has lot of uncertainty impreciseness defining. So, for the input is concern because the robot is works like that and then that kind of uncertainty can be solved using the concept called the fuzzy logic. So, fuzzy logic is an important parts of soft computing.

Now, here is again another question. So, we have discussed three different problems hand written character recognition, allocation of money into the different banks and then movement of the robots in three different corners. Now, the first example that we have discussed that it is the problem which can be solved very effectively efficiently using artificial neural network. The second problem that we have discussed it basically solved using some probabilistic reasoning and it is basically one problem called evolution computing or genetic algorithm. The third problem that we have discussed it is basically the fuzzy logic, how the fuzzy logic can be exercise to solve some problem where lot of uncertainty involved.

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**How soft computing?**

- How a **student** learns from his **teacher**?
  - Teacher asks questions and tell the answers then.
  - Teacher puts questions and hints answers and asks whether the answers are correct or not.
  - Student thus learn a topic and store in his memory.
  - Based on the knowledge he solves new problems.
- This is the way how human brain works.
- Based on this concept **Artificial Neural Network** is used to solve problems.

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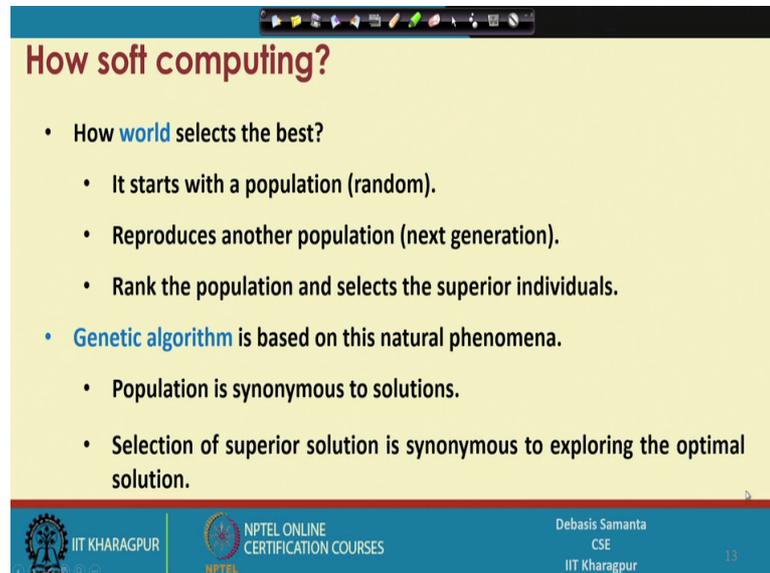
Now, I want to, now discuss about the different techniques that can be followed or the different techniques which is basically behind the above concepts. For example, how a student learn from his teacher here the two part is involved one is the student and is the teacher. Now, consider student is basically computing machine and teacher is basically once two I mean gets some output for a given input like. So, how a student is learn from his teacher or basically how such a system can be developed, here the teacher is responsible to develop a system and here system is student.

So, usually teacher ask questions and tell the answer. Then there is another way teacher puts some questions and hints an answers and ask whether the answers are correct or not, students here basically to check whether the answer correct or not. Students then, students thus learn a topic and store in his memory. So, basically by the process if we discuss several time the same different questions, different answers, different questions hints to the different answer for the same question or different answers for the different questions.

So, students listen to those and the by the process learn a topic and whatever the students learns it basically store in his memory. Now, based on the knowledge he then can solve many new problems assigned to him. So, basically it is a concept of learning how to learn something and then based on this learning how he can solve the problem. So, this is

the way exactly our human brain works in fact. And based on this concept the artificial neural network is used for example, hand written character can be recognized.

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**How soft computing?**

- How **world** selects the best?
  - It starts with a population (random).
  - Reproduces another population (next generation).
  - Rank the population and selects the superior individuals.
- **Genetic algorithm** is based on this natural phenomena.
  - Population is synonymous to solutions.
  - Selection of superior solution is synonymous to exploring the optimal solution.

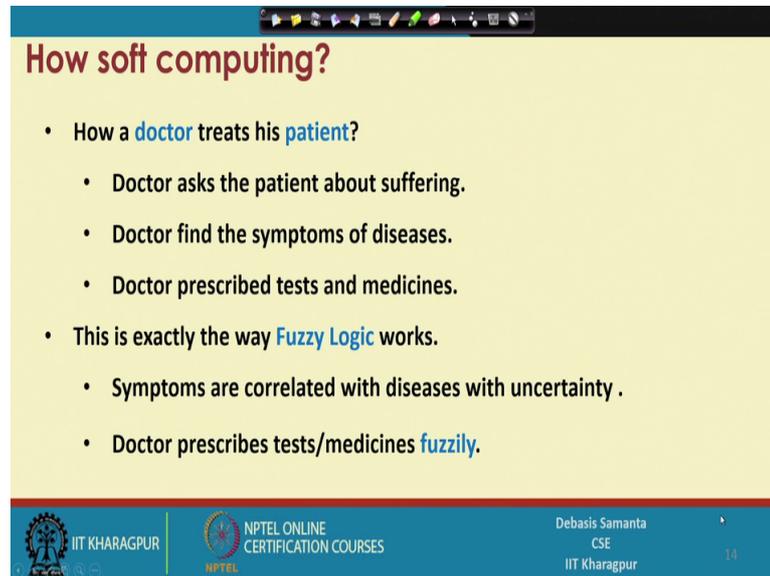
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Now, another example, so how world selects the best it basically a natural process. So, in this process is basically starts with a population and initially it consider a random population. So, when our worlds evolve first time it is started with some population and is a random population random means whatever the objects these are possible there and it then reproduces, reproduces to develop another population we called it is a next generation and then all the population that we obtained so we rank them and select the superior individuals. So, here basically population generation, then reproduction and reproduction followed by the ranking and then it basically selects based on this ranking the best individuals. So, basically best population or best solution.

Now, the concept of genetic algorithm is based exactly on the same phenomena it is called is basically genetics and here in this context the population is synonymous to solution. So, we can start with some random solution those are not necessary to be an optimal and then we have to reproduce from this set of solution another solution and then select the base solution. The same thing can be repeated several times ultimately until we can achieve the best result. Now, here selection of superior solution is synonymous to exploring the optimal solution

Now, here we can see all the method that can be followed in a probabilistic manner or in a randomized sense. So, that is why the genetic algorithm follows a probabilistic reasoning to solve problem particularly solving optimization problem.

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The slide is titled "How soft computing?" and contains a bulleted list. The list starts with "How a doctor treats his patient?" and lists three steps: "Doctor asks the patient about suffering.", "Doctor find the symptoms of diseases.", and "Doctor prescribed tests and medicines.". The fourth bullet point states "This is exactly the way Fuzzy Logic works." and lists two corresponding points: "Symptoms are correlated with diseases with uncertainty ." and "Doctor prescribes tests/medicines fuzzily." The slide footer includes the IIT Kharagpur logo, NPTEL ONLINE CERTIFICATION COURSES, and the name Debasis Samanta, CSE, IIT Kharagpur.

- How a **doctor** treats his **patient**?
  - Doctor asks the patient about suffering.
  - Doctor find the symptoms of diseases.
  - Doctor prescribed tests and medicines.
- This is exactly the way **Fuzzy Logic** works.
  - Symptoms are correlated with diseases with uncertainty .
  - Doctor prescribes tests/medicines **fuzzily**.

Now, as another example how a doctor treats his patient here doctor is a one party and patient is another party. Now, patient wants to solve his problem with the help of doctor. So, doctor is the computing system in this case. So, usually it works like this doctor asks the patient about the problem that he is suffering and doctor find the symptoms of disease from the patients input, and then doctor prescribe some tests and medicine this is the exactly the way the fuzzy logic works.

So, fuzzy logic take some input which is basically related to solving some problem and then based on this inputs he predict certain output. So, here symptoms are correlated with disease and you know whatever the disease doctor will guess or patient will tell they are basically not certain; there are some uncertainty with the input. So, this is why it is called the symptoms are correlated with disease uncertainty and then the doctor prescribe medicines or whatever the test it is also fuzzily; that means, with certain uncertainty. So, fuzzy means it is uncertain in this sense.

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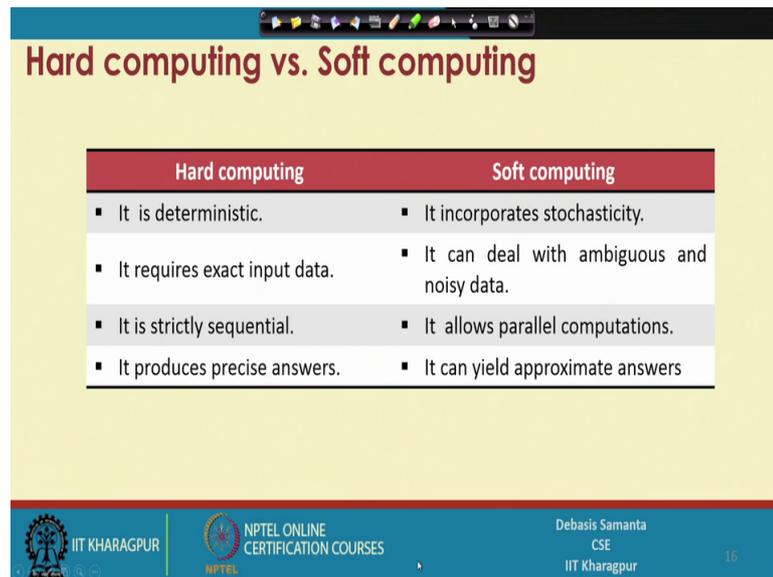
Hard computing	Soft computing
<ul style="list-style-type: none"><li>It requires a precisely stated analytical model and often a lot of computation time.</li></ul>	<ul style="list-style-type: none"><li>It is tolerant of imprecision, uncertainty, partial truth, and approximation.</li></ul>
<ul style="list-style-type: none"><li>It is based on binary logic, crisp systems, numerical analysis and crisp software.</li></ul>	<ul style="list-style-type: none"><li>It is based on fuzzy logic, neural nets and probabilistic reasoning.</li></ul>
<ul style="list-style-type: none"><li>It has the characteristics of precision and categoricity.</li></ul>	<ul style="list-style-type: none"><li>It has the characteristics of approximation and dispositinality.</li></ul>

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Now, let us discuss about hard computing versus soft computing. So, for the hard computing is concerned it requires a precisely stated analytical model and obviously, it is a computational expensive on methodology. On the other hand soft computing it is imprecision tolerance to imprecision means we can be happy with some solution which is not exactly the precise one and with uncertainty the partial truth and approximation may works for us. Only the requirement that is that the problem which cannot be solved using hard computing in real time can be solved using sub computing in a real time.

The concept of hard computing basically based on few concept called the binary logic, crisp system, numerical analysis and some crisp software; the software basically if run for the same input it always give the same output. Whereas, the concept that is followed in soft computing is based on the fuzzy logic the neural networks and probabilistic reasoning which is totally different then the concept that is followed in hard computing and. So, hard computing basically has the characteristics of precision and categoricity, it works for a certain kind of input and it works well for that input whereas, the soft computing is a characteristic of approximation exact result is not required, but it can be near accurate result and dispositinality; that means, it can be applied to verities of input, the different type of input, different number of inputs as well as.

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Hard computing	Soft computing
▪ It is deterministic.	▪ It incorporates stochasticity.
▪ It requires exact input data.	▪ It can deal with ambiguous and noisy data.
▪ It is strictly sequential.	▪ It allows parallel computations.
▪ It produces precise answers.	▪ It can yield approximate answers

The slide features a title 'Hard computing vs. Soft computing' in a dark red font. Below the title is a table with two columns: 'Hard computing' and 'Soft computing'. Each column contains four bullet points. The slide footer includes the IIT Kharagpur logo, NPTEL Online Certification Courses logo, the name 'Debasis Samanta CSE', and the IIT Kharagpur name, along with the slide number '16'.

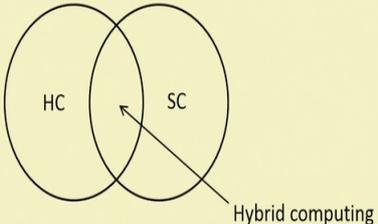
Now, another differences another differences between hard computing and soft computing it is deterministic whereas, the soft computing is stochastic means probabilistic. It requires exact input data in case of soft computing it basically requires an ambiguous and noisy data.

Hard computing usually is followed strictly sequential methods; however, the soft computing can be carried out using parallel computation hard computing produces precise answers whereas, soft computing can yields approximate answers. So, these are the differences between hard computing and soft computing and I hope you have understood the difference between the two.

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## Hybrid computing

- It is a combination of the conventional hard computing and emerging soft computing.



The diagram consists of two overlapping circles. The left circle is labeled 'HC' and the right circle is labeled 'SC'. The overlapping region in the center is pointed to by an arrow from the text 'Hybrid computing'.

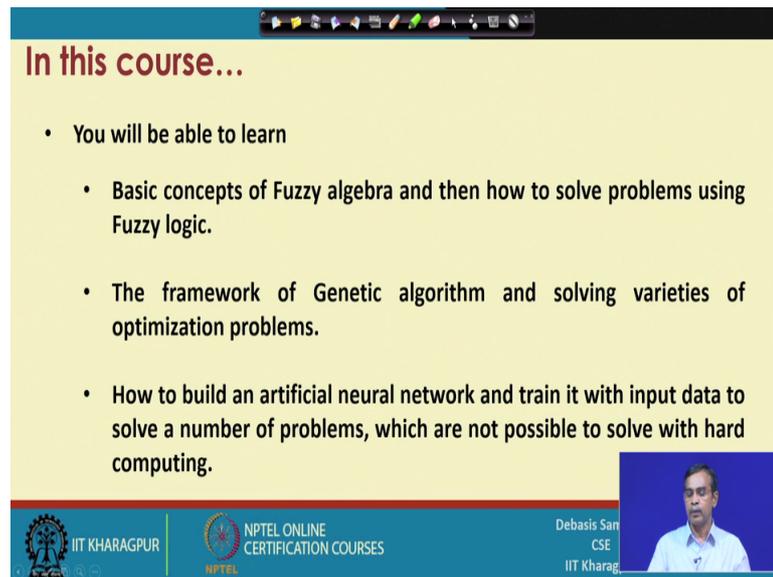
Figure: Concept of Hybrid Computing

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Now, so there is hybrid computing it is basically combination of the two into solving a particular problem. So, few portion of the problem can be solved using hard computing for which we have a mathematical formulation for that particular part and then where we required a precise input. And there are some part of the same problem maybe which cannot be solved in real time for which no good algorithm is available and we also do not required accurate result some near accurate result is sufficient for us then we can solve soft computing for that part and then mixing together is basically the hybrid computing.

So, if we know hybrid hard computing, if we know soft computing and if we know some problems where whatever the characteristic involved to solve either hard computing way of soft computing way we can inter mix the two approaches and then hybrid computing can be obtained.

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**In this course...**

- You will be able to learn
  - Basic concepts of Fuzzy algebra and then how to solve problems using Fuzzy logic.
  - The framework of Genetic algorithm and solving varieties of optimization problems.
  - How to build an artificial neural network and train it with input data to solve a number of problems, which are not possible to solve with hard computing.

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Now, in this course you will be able to learn basic concepts of fuzzy algebra and then how to solve problems using fuzzy logic. Then we will be able to learn the framework of genetic algorithm and solving varieties of optimization problems. And then how to build an artificial neural network and train it with input data to solve a number of problems which are not possible solve with hard computing.

Thank you.