Fuzzy Logic and Neural Networks

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Lecture – 37
Concepts of Soft Computing and Expert Systems

We are going to discuss another topic that is Concepts of Soft Computing and Expert Systems. Now here actually what I am going to do? I am just going to define what do you mean by soft computing and why should you go for the soft computing? And then I will try to concentrate on the expert system, like how to design and develop a suitable expert system, so that we can solve the real world complex problem in a very efficient way.

Now as I told that we are going to define the term soft computing and we are going to give a brief introduction to the soft computing tools. The tools we have already discussed and now I am just going to put them under a family that is called the soft computing family. Then I will try to explain what do you mean by an expert system and a few applications will be discussed in detail.

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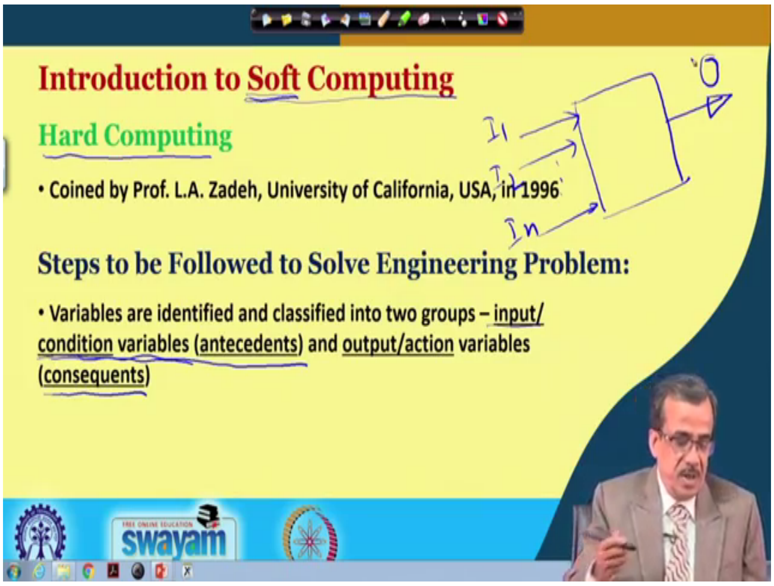

Now, to start with the concept of soft computing, now the name soft indicates that it is not hard; that means, it is not so much precise and it is not so much accurate. So, by the term these particular the soft we means it is not precise, not accurate and if we get some acceptable solution. So, we are happy with this particular the solution. Now before we define this particular term soft computing. Let us try to explain what do you mean by the hard computing? The moment we say that there is something called soft computing then we have something else that is called your the hard computing.

Now, these particular term the hard computing, that was proposed in the year 1996 by Professor Zadeh of University of California USA; the same Professor Zadeh who introduced the concept of the fuzzy sets. Now to explain or to understand the concept of hard computing, now let us try to see what are the steps we follow to solve some engineering problems. Now if we want to solve some engineering problems or if you want to determine the input output relationship, the first thing we will have to do is we will have to identify the inputs and the output variables.

Now, these input variables these are known as actually the condition variables or antecedents and the output variables are nothing, but the action variables and these are also known as actually the consequence. Now let me take a very simple example. Now supposing that we want to control the temperature and humidity of this particular the studio where I am just recording this lecture. Now if I want to control the temperature and humidity inside this particular room so, what I will have to do is so I will have to find out what are the inputs and what are the outputs, which are having some influence on the temperature and humidity.

Now, what we do is we try to find out the input variables first, for example, say input variables could be the present temperature inside this particular room, the present humidity inside this particular room, outside temperature, outside humidity, then comes your the number of people sitting in this particular room, then comes the thermal conductivity of the walls and so on. So, these are all input parameters or the input variables and these are nothing, but the condition variables. Now these input variables are in general independent. They are not dependent on others.

Now, once you have identified the input variables, now we will have to search for what should be the output variable. Now, supposing that I have gotten air conditioner just to control the temperature and humidity of these particular the room. Now what we will have to do is we will have to control the angle of valve opening for these particular the air conditioner. Now depending on the angle of valve opening some conditioned air will enter this particular room and that is going to influence the temperature and humidity of these particular the room.

Now, if I want to keep the temperature and humidity within the comfortable zone. So, I will have to do is I will have to control the valve opening, I will have to adjust the angle of valve opening accordingly. For example, say might be I will have to rotate that angle of valve opening by say 10 degrees or 20 degrees something like this. So, this could be the output variable. Now; that means, in the schematic we if we write down. So, if this is the process to be controlled or processed to be one model we have got a large number of inputs here like your I 1, I 2, and say I n and supposing that we have got only one output here that is nothing, but the angle of the valve opening.

So, this is the way actually we will have to identify your the inputs and the output variables and once we have identified so this particular input and output variable the next thing what we do is.

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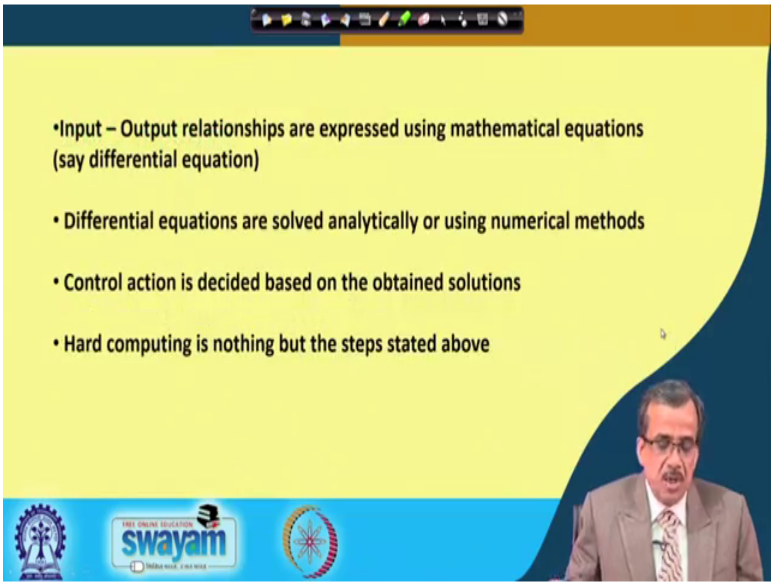

So, we try to find out the input output relationship and we try to see the physics of this particular process. Now if the physics is known then we can find out the mathematical equations. Say we can find out the differential equations. Now if we can get the differential equations, now we can solve it either analytically or you can use some numerical methods to solve this particular the differential equations and if you get the solution of these particular your differential equation that will be nothing, but the input output relationship and these output or the control action so, we can use for controlling your the condition of these particular the system.

So, this is the way actually we try to identify the inputs and outputs of a process, which we are going to model, which you are going to control and then we try to find out the mathematical equation, based on the physics we solve those equations try to find out the solution and that particular solution is nothing, but the input output relationship. Now these steps are nothing, but the concept of the hard computing. Now in hard computing actually we take the help of mathematics. So, there is a possibility that we will be getting very accurate very precise solutions. So, this is actually what we mean by your the hard computing.

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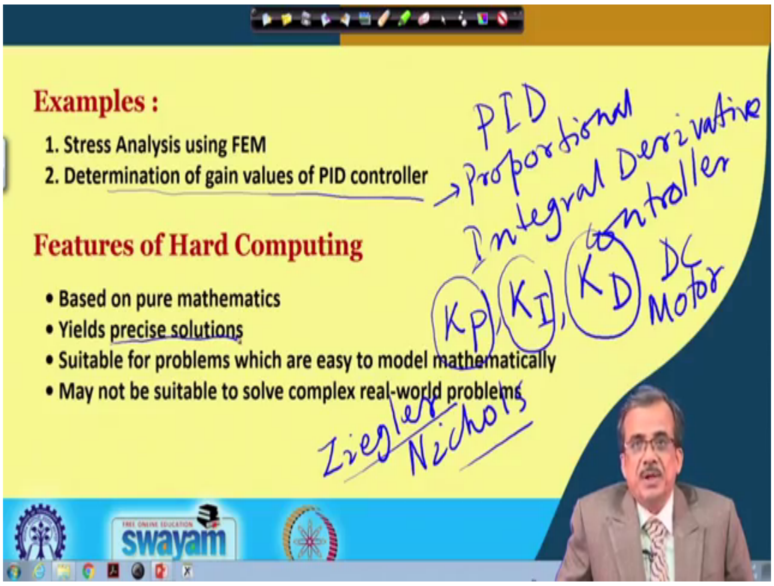

Now, let us see let us just take the example of these particular the hard computing. Now supposing that here I have taken one example stress analysis using the finite element analysis. Now you know that using this finite element analysis we try to solve the your the differential equation and this is nothing, but a numerical methods, one of the numerical methods to solve the differential equation. Now let me take a very simple example, very simple example of a cantilever beam. Now supposing that I have got a beam something like this it is a very simple beam. So, this type of beam I have got and here so, there is one concentrate load say P this is the supporting end and this is the free end and supposing that the length of these particular the beam is nothing, but your L and so this beam is having a one rectangular cross section supposing that say this is a and this is your b

Now, very easily for these particular the cantilever beam; so, we can find out what should be your the maximum deflection and what should be the stress developed? For example, say for this type of beam we can find out the maximum deflection which will come here and this particular maximum deflection that is your delta max is nothing, but your P L cube divided by 3 say P L cube divided by 3 I E P L cube by 3. So, P L cube by 3 I E.

Now, see so, this particular you can find out your the maximum the stress develop that is your sigma is nothing, but M by I into y ok. So, M is nothing, but the maximum bending moment I is the moment of inertia and y can find out. So, we can find out how much if the stress developed in that particular the beam. Now once i have got this particular the stress developed. So, this is how to determine the stress developed in the beam mathematically. Now what you can do we supposing that we have got a beam which is having some sort of complicated cross section or the varying cross section along the length.

Now, supposing that the beam looks like this now if the beam looks like this. So, this type of beam if I consider and supposing that the same concentrated load P is acting here and this is actually the fixed end and this is the free end and if I tell you that can you please find out what should be the stress developed? It is not so easy because along this particular length L. So, the cross section that is going to vary, so this will become a more difficult problem; now how to find out the stress developed? To find out the stress developed actually what we will have to do is we will have to take the help of finite element analysis.

Now, this FEM analysis we will have to carry out and for that so these particular beams, so this will be divided into a large number of small small elements and for each of the elements actually we will have to find out what should be the stress developed and what should be the deflection and then you will have to combine to find out what should be the combined stress develop for this the complicated beam having the varying cross section.

Now, this is the way actually we carry out some sort of stress analysis for a beam having varying cross section using the finite element analysis. So, this is nothing, but an example of your hard computing. So, this is nothing, but a hard computing. Now let me take another example like your determination of gain values of PID controller. Now we know that that in robotic joints we use some DC motors and for each of the motor we generally use one controller and we generally use a controller that is called the PID controller and that is nothing, but is your proportional integral derivative controller derivative controller.

Now, to implement this PID controller actually what we do is we try to find out what are the gain values? What is the proportional gain values that is denoted by K P then we have got the integral gain value that is called the K I and we have got the derivative gain value that is your K D. Now what we do is we try to find out the values for this K P, K I, and K D. Now if you get the values for this K P, K I and K D. Now I can control that particular the D C motor; now how to determine these particular K P, K I, and K D? Now there are some methods and there is a standard method that is called the Ziegler Nichols method. So, this Ziegler Nichols method we can use to find out what should be the gain values that is K P, K I and K D. To so we solve that particular equation to find out what should be the gain values and that is another very good example of your the hard computing.

Now, if you see the features of hard computing so as it works based on pure mathematics. So, there is a possibility that you will be getting very precise solutions. Now this particular the concept of hard computing we can use if the problem is simple and if this particular problem can be model mathematically, but for a complex problem for a complex real world problem so this particular principle of hard computing we cannot use and if we cannot use this particular the concept of hard computing then we will have to go for your the concept of the soft computing.

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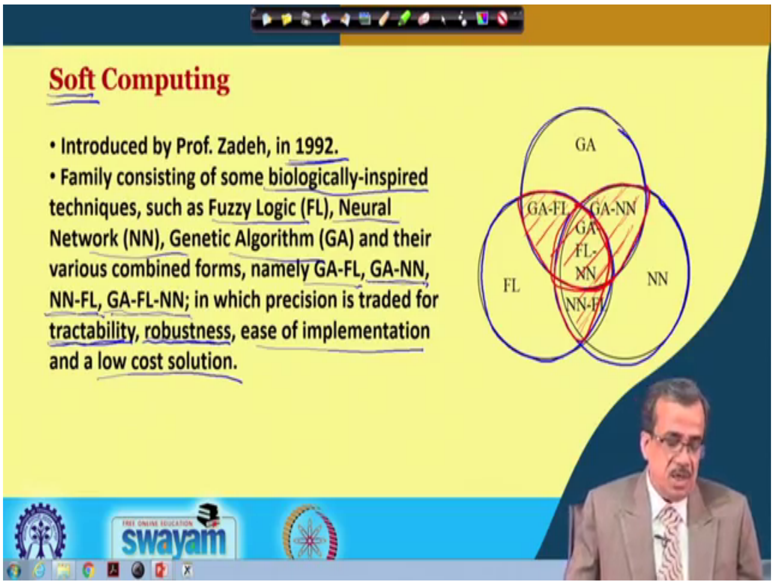

Now, let us see what we do in soft computing and how to define this particular term the soft computing. Now this I have already mentioned that in soft computing we are not very much interested to get very precise solution or accurate solution, on the other hand if we get some acceptable solution some approximate solution or the heuristic solutions like we should be happy and that is actually that is why we use these particular term that is called the soft. So, by soft computing we mean we do not want so much precision and if we get some acceptable solution so we are happy. Now this term soft computing was coined by Professor Zadeh in the year 1992.

Now, you see the hard computing that term hard computing was introduced in the year 1996, but soft computing that particular term was introduced before 96 that is in the year 1992, although people are using the concept of hard computing for such a long time. Now to define the soft computing soft computing is actually a family consisting of some biologically inspired techniques like your we have got Fuzzy Logic, then Neural Networks, Genetic Algorithms and others and their combined forms like your G Fuzzy Logic that is Genetic Fuzzy system GA, neural network that is genetic neural system NN-FL that is Neuro Fuzzy system GA-FL-NN that is Genetic Neuro Fuzzy System in which precision is traded for tractability, robustness ease of implementation and low cost solution.

Now, here as I told that this is a big family and this family consist of a large number of members for example, Fuzzy Logic, Neural Networks different types of your nature inspired optimization tools and their combined techniques and in fact, by definition of the soft computing so, we mean the combined techniques like your the way we have already discussed Genetic Fuzzy System that is the combination of genetic algorithm and Fuzzy Logic system. Genetic neural system that is the combination of genetic algorithm and Neural Networks then Neuro Fuzzy it is a combination of Neural Network and Fuzzy Logic and Genetic Neuro Fuzzy that is GA-FL and NN.

Now, we try to combine because there is a reason, the reason is as follows like each of these particular tools are having their own merits and demerits. So, in combined tools actually what we do is we try to remove their demerits and at the same time try to utilize their merits to design some combined techniques show that we can solve the real world problem in a very efficient way. Now here this particular algorithm has to be computationally tractable; that means, the computational complexity should not be very heavy. It should be robust; that means, the same algorithm can be used to solve a variety of problems. It should be easy to implement and low solution cost means your in terms of computational complexity; that means, it should be computationally faster.

Now, here in this schematic view. So, we are going to show you what do you mean by the soft computing now this particular circle. So this indicates actually if it is genetic algorithm, so the region of Fuzzy Logic that is denoted by so this particular the circle. Similarly this circle is going to represent your the Neural Network. Now what we do is here we try to consider the combined techniques. Now the combined techniques means your so, we are going to consider the combination between the GA and Fuzzy Logic. So, this is actually the combination of GA and Fuzzy Logic.

Now, similarly we are going to consider the combination of GA and Neural Network and we are also going to consider the combination of these particular Fuzzy Logic and Neural Network and this is actually the region of your the soft computing. So, these particular combined region that is actually your the region of soft computing. This is what you mean by the concept of your the soft computing.

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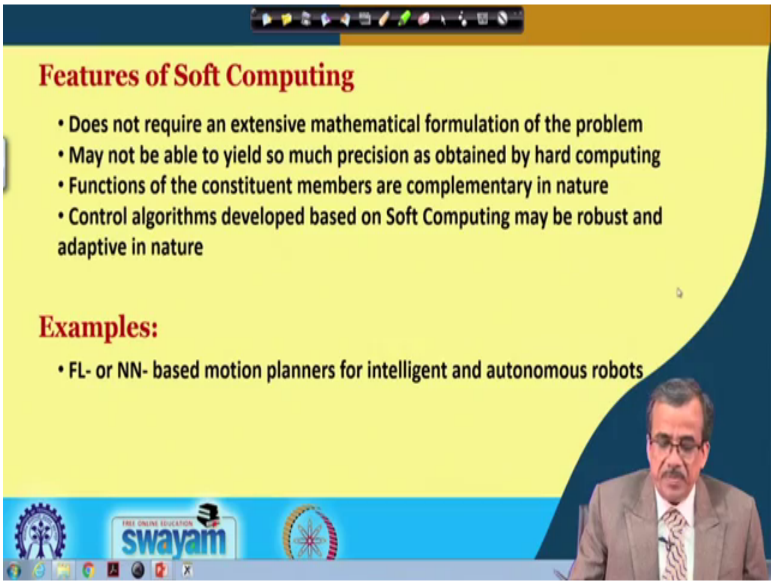

Now, if you see the features of soft computing. So, it does not require the extensive mathematical formulation of the problem. In fact, for the real world problems it is bit difficult to know the physics. So, it is big difficult to derive that mathematical equations, but if you want to get some solution for a complicated real world problem. So, we will have to take the help of your in the soft computing. Now as I told that we may not be able to reach very precise solution like your the heard computing.

So, here if we get some acceptable solutions so, we are happy and here in soft computing as I told that we are going to copy the merits of the different tools and we are going to actually remove the demerits. Now whenever we combine the tools for example, I am combining say the fuzzy logic with the neural networks. So, we try to take the advantage or the merits of both of the techniques and we try to remove their inherent demerits, but whenever we combine we do not consider that these two tools are fighting with each other. So, they are helping each other to develop one combined tools and that is nothing, but the soft computing tool, so that we can solve the real world problem in a very efficient way.

Now, there are some examples like your for example, say we can design and develop the adaptive motion planner for the intelligent robots. We can design and develop like fuzzy logic based or the neural network based adaptive controller for the motors used in the robots. So, actually so, this type of these are all applications of your the soft computing and we are going to discuss some more applications of soft computing in much more details. Now here if you see if you use the principle of soft computing. So, there is a possibility that you will be getting some robust and we will be getting some adaptive solutions to the problem and which is very interesting like if you get some adaptive solution which will be able to cope with the varying situations of the environment. Now, this is actually what you mean by your the soft computing.

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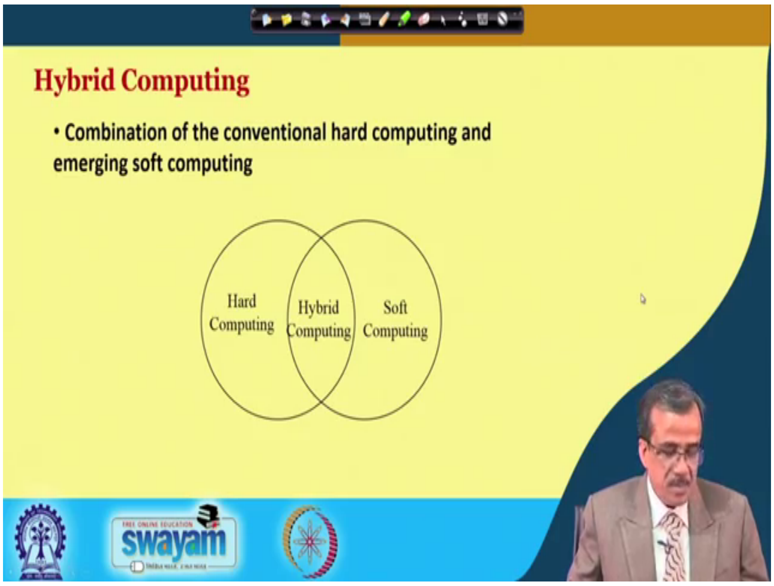

Now, then comes your the concept of your the hybrid computing. Now by definition so, hybrid computing is nothing, but a combination of the hard computing and your the soft computing. Now here if you see in this particular the schematic view. Now if this is actually the area of hard computing, and this is the area of your the soft computing. Then the common area between them is nothing, but these and this is nothing, but is your the hybrid computing.

Now, I am just going to take some very practical example just to understand the utility of the concept of these particular the hybrid computing. Now let us let us take some example.

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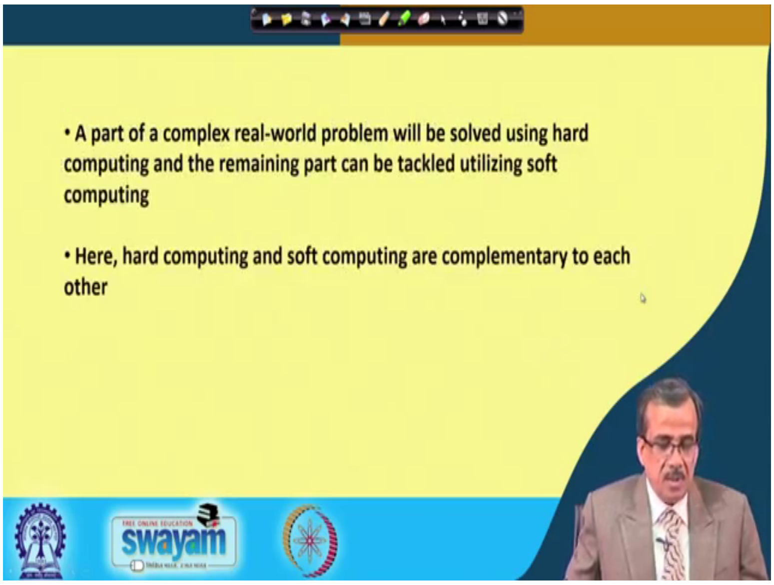

Now, here as we told that a complex real world problem will be solved using the concept of your both hard computing as well as soft computing; that means, a part of the complex problem will be solved using the principle of hard computing and the remaining part will be solved using the principle of your the soft computing. The moment we consider the concept of hybrid computing, the hard computing and the soft computing they are not fighting with each other, instead they are helping each other. In fact, in hybrid computing, the hard computing and soft computing are complementary in nature.

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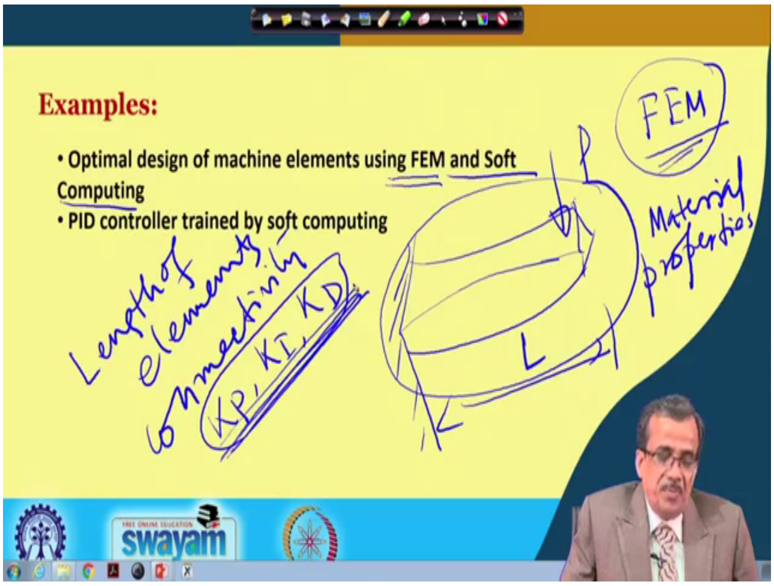

Now, I am just going to take some example of your, this the hybrid computing. Now supposing that now I am just going to design some machine elements using the principle of your the finite element analysis. Now if I take the same example which I took. So, let me let me once again consider the same example of this type of beam having say varying cross section. Now, along this particular length, the cross section is going to vary and if I take this particular the same problem. Now if I want to find out how much is the stress developed?

Now, to determine the stress developed as we told that we will have to take the help of your the finite element analysis. Now in finite element analysis the quality of the solution depends on a number of parameters for example, it depends on the length of the element, the length of elements. So, it depends on the connectivity the connectivity of your the elements. Now depending on the length of the elements and the connectivity of the elements we consider. So, we will be getting the different types of solutions.

Now, if I change the length of the element and the connectivity several times while running this FEM package there is a possibility that you will be getting different solutions. Now my question is which one to believe, which one to consider? So, there is fuzziness, there is fuzziness in the results of these particular your finite element analysis. Now there is another fuzziness that fuzziness belongs to the fuzziness of the material properties. Now if I consider the material properties of this the steel which I am going to use as the material for the beam it has got some ill strength, it has got some ultimate strength, and all such things the moment it is in working condition. So, there is a possibility that these particular ill strength, ultimate strength those strength values are going to vary little bit. So, there is fuzziness in the material properties.

Now, if I want to find out a very efficient design for this. Now what you will have to do is so we will have to consider the fuzziness of the FEM package and we will have to consider the fuzziness of these particular your the material properties. Now to model these fuzziness of the material properties and your finite element analysis. So, what you can do is we can take the help of your the soft computing and then we can use the principle of the hard computing; that means, we can use the finite element analysis to carry out these particular analysis in a very efficient way, so that we can get one efficient optimal design for this particular the cantilever beam.

So, this is an example of your the hybrid computing. Now another example we can take that is PID controller trained by soft computing. Now, as I told that the gain values that is your K P then comes your K I and this K D values now these are determined mathematically and once those values have been determined, so these are kept constant. Now supposing that the motor is working in a particular say cycle of time cycle time, now during that the cycle time so we are not going to vary this particular K P, K I and K D and once those values have been determined. So, those are kept constant. So, this is the conventional the way we use the PID controller to control the DC motor.

Now, there could be a possibility that we may need some adaptive controller where the values of this K P, KI, and KD are going to vary depending on the situation depending on the requirements. Now if we can vary the values for this K P, K I, and K D depending on the requirements or depending on the situation. So, we will be getting some adaptive PID controller where the values for this K P, K I and K D actually are going to vary, depending on the requirement. This is another very good example of your the hybrid computing. Now the combined tools used in soft computing their working principle we have already discussed for example, say we have discussed the genetic fuzzy system, genetic neural system and the neuro fuzzy system or the genetic neuro fuzzy system and so on and those combine tools the soft computing tools can be utilized to solve the real world problem in a very efficient way.

Now, let me once again discuss little bit why should we go for these combined tools as the soft computing tools? Now this we have already discussed that each of these particular tools are having their own merits and demerits. For example, say if you see the fuzzy reasoning tool, the fuzzy reasoning tool is a very efficient tool powerful tool for your imprecision and uncertainty, but it has got one drawback, drawback in the sense like if you want to implement the fuzzy reasoning tool or if you want to find out the knowledge base for the fuzzy reasoning tool you should have at least some information of this process which you are going to model; that means, the physics of this particular process has to be known little bit otherwise you cannot design the database and a rule base initially.

Now, if we can design the database and rule base initially after that you can optimize with the help of some optimizer with the help of some trading scenario, but initially you will have to design some database and rule base. And if you want to design these database and rule base you should have at least some preliminary information of these particular the physics of the process. Now there is another demerits for this fuzzy reasoning tool which we have already discussed. Now as the number of inputs increases and if we use more number of linguistic terms to represent each of the design variables or the input variables, the number of rules is going to increase and that is going to increase actually the computational complexity of these particular the algorithm.

So, these are the merits and demerits of fuzzy reasoning tool. Similarly if you see the neural network, the neural network if you see its computational complexity during the training is much more compared to that of your fuzzy reasoning tool, on the other hand. So this particular neural network can handle a large number of design variables or the input variables. So, it has got its own merits and demerits and as I told in soft computing, we generally go for the combined tools just to capture the merits of these tools and to remove their demerits and we have seen that if properly designed, so these soft computing tools can handle the real world problems are in a in a very efficient way.

Thank you.