Fuzzy Logic and Neural Networks
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Lecture – 38
Concepts of Soft Computing and Expert Systems (Contd.)

Now, we are going to explain the terms expert systems or the knowledge based system. Now, let us see what do you mean by; so, this particular expert system or the knowledge based system and let us try to understand why do you need this expert system, what are the utilities of these expert systems.

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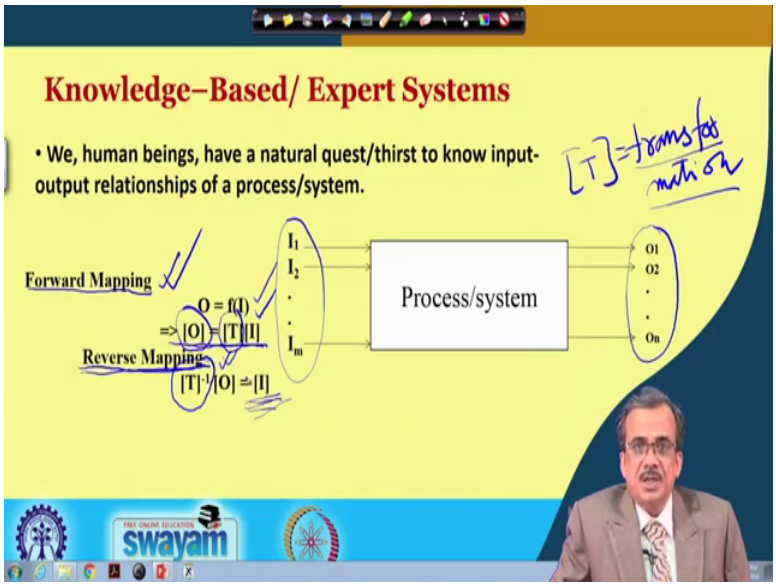

Now, to start with let me mention that we human being we have got a natural thirst or quest to know input output relationship of a process. Now, supposing that so, we have got one hinging system or a process here and supposing that we have got a number of inputs, say m number of inputs we have and supposing that we have got n number of outputs. So, our aim is always to find out what should be the input output relationship for example, if this is the set of inputs what should be the set of outputs and vice versa. Supposing, that I want to achieve so, this set of outputs. So, how to set my input parameters so, that I can reach that particular the level of outputs.

Now, mathematically if you see. So, this output is nothing, but the function of the input parameters. So, in the matrix form this can be written as the output matrix is nothing, but

the transformation matrix T multiplied by the input matrix and this is actually what we mean by the forward mapping. So, in forward mapping so, we try to find out the output matrix if I know the input matrix and supposing that we know these particular, the T matrix that is nothing, but your transformation matrix.

So, T matrix is nothing, but the transformation matrix. So, if I know these particular transformation matrix and if I supply the I matrix. So, very easily I can find out what should be the output matrix and that is nothing, but is your the forward mapping. Now, supposing that my requirement is reverse. So, I want to reach a level of output then how to set my input parameters. And that is what you mean by the reverse mapping. Now, this mathematical expression if I just multiply both the sides by T inverse that is the inverse of these particular the transformation matrix. So, this will become T inverse multiplied by O is nothing, but is your the input matrix.

Now, here supposing that I know this particular output matrix which I am going to reach and supposing that the inverse of the transformation matrix is known to us. So, very easily you can find out how to set these particular the input parameters. This is what is known as the reverse mapping. Now, for any such process or the system; so, we should know both the information both in the forward direction as well as in the reverse direction; that means, we should be able to carry out both the forward mapping as well as reverse mapping. And if we can carry out that both forward as well as the reverse mapping; so, we can automate that particular the process and our aim is ultimately to automate that particular the hinging system or the hinging process.

Now, let us see how to do it. Now, before I proceed further let me tell you that if I want to carry out that these particular your the reverse mapping. So, we should know the inverse of these particular, your the transformation matrix; that means, your the transformation matrix has to be invertible. That means, the inverse of these particular transformation matrix should exist; that means, this particular transformation matrix has to be your non singular. And if that particular condition is fulfilled then only we can carry out. So, these type of the reverse mapping.

Now, let us see like how to develop these particular expert system and what are the different components of these particular the expert system.

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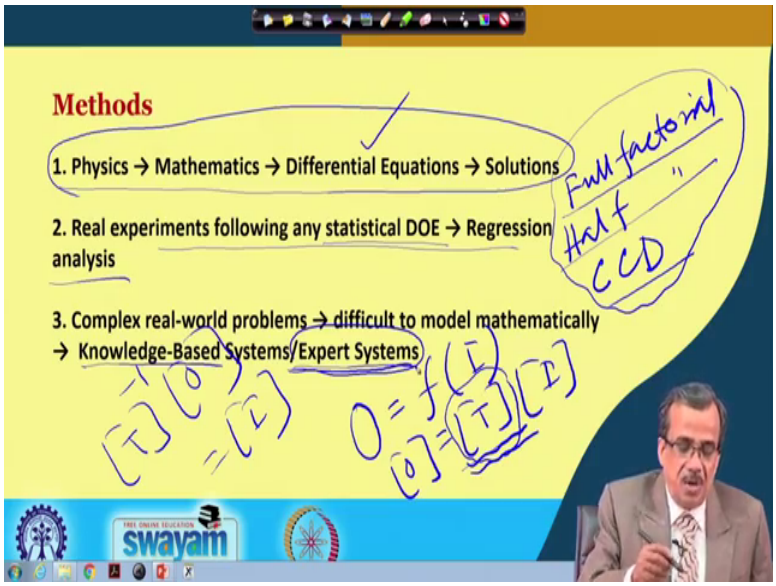

Now, let me once again go back how do you solve any such problem hinging problem. So, as I told that we first try to see the physics of this particular process and once you have understood the physics. So, we try to express mathematically supposing that we are getting the differential equation. So, we solve the differential equation and once you have got this particular the solution.

So, now actually we can use that particular your the control action. Now, this is actually one way of solving the problem. So, this is nothing, but is your hard computing which I have already discussed. Now, there is another way of solution getting the solution for example, say supposing that we do not know the physics of the process 100 percent. So, we are not in a position to derive the differential equation. So, what you can do is we can carry out some real experiments.

Now, to carry out the real experiment; so, we follow some statistical design of experiments for example, say DOE stands for design of experiments for example, say we can use some full factorial design or we can use say the half factorial design or we can use central composite design that is CCD or some there are some other designs like box bank and design and others. So, we just follow a particular design and we try to carry out some real experiment. And once I have got that particular data for the real experiment collected in this particular fashion, say either full factorial or half factorial or the

fractional factorial or central composed design. Now, you can carry out some sort of statistical regression analysis.

Now, by carrying out this statistical regression analysis what you can do is we can find out output as a function of your input parameters. Now, that means, we will be getting in the matrix form. So, output is nothing, but the transformation matrix multiplied by input. Now, this particular transformation matrix has to be invertible if I want to carry out the inverse mapping or the reverse mapping. Now, for this reverse mapping; so, based on the your the statistical regression equation which you have got. If you want to carry out the reverse mapping so, this particular transformation matrix has to be invertible.

Now, there is no guarantee that every time you will be getting the invertible transformation matrix for example, say this T matrix could be a your non square matrix. Now, it could be a singular matrix now, in that case actually we cannot carry out the reverse mapping that is your T inverse multiplied by O is nothing, but I. So, that we cannot carry out then what is the solution the solution is for a complicated problem, we can take the help of some sort of expert system or the knowledge base system and using this expert system or the knowledge base system. So, you can find out the input output relationship and here actually we do not need actually the hard computing. So, we will have to take the help of some sort of the soft computing to find out or to establish the input output relationship.

Now, this is actually one of the applicability or I should say the plus point of using these particular expert system; that for a complex problem actually we can model the input output relationship using this expert system or the knowledge base system. Now, the same example which I took a few minutes ago for example, say the example of the controlling the temperature and humidity of these particular room. So, what we can do is, we can establish the input output relationship and we can design and develop one expert system. Now, this expert system is actually its going to help us just to control what should be the angle of valve opening and depending on the requirement depending on the temperature and humidity and load of this particular the room.

So, this particular your expert system is going to change the angle of valve opening just to keep the temperature and humidity within a very comfortable zone. So, this could be one of the applications of these particular your the expert system.

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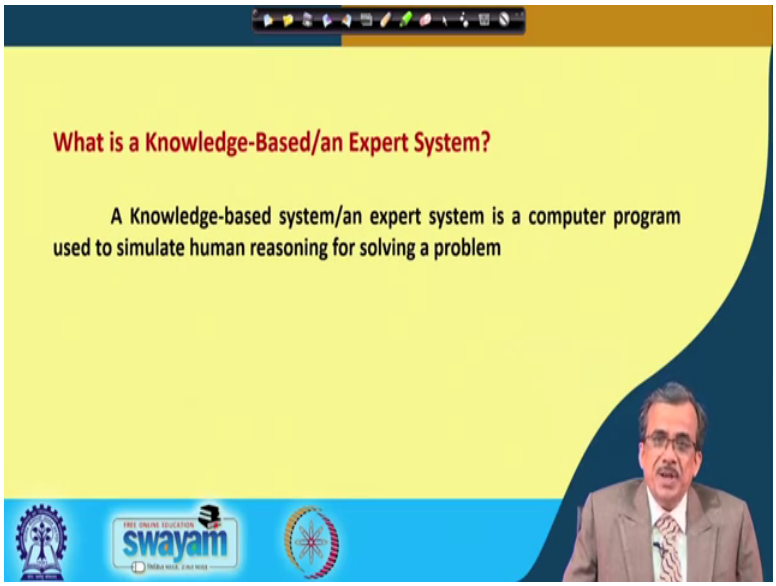

Now, if you see the definition of these particular the expert system you will see that this expert system is nothing, but a computer program, but it is used just to simulate the human reasoning to solve a particular problem. Now, let me try to find out the difference between. So, these particular expert system an ordinary computer program. Now, let me take the same example the same example of controlling the valve opening of the air conditioner just to keep the temperature and humidity of this particular room in a very comfortable zone.

Now, there are at least two ways of solving this particular problem. The first method is your you find out the physics, find out the differential equation solve it and accordingly you control the angle of the valve opening. And another way of solving this particular problem supposing that I have got an human operator. So, this human operator is going to sense the temperature and humidity inside this particular the room and accordingly he or she is going to control the angle of valve opening depending on his experience or his expert system.

Now, the second example is the example of expert system, but the first example is not actually an expert system and that is nothing, but your the solution using the principle of hard computing. And here in the first the solution what we can do is we can develop one computer program. We can solve the differential equation if any we can find out the solution, but in second method we are not going to solve any differential equation. We

are going to actually copy the way one human operator is going to control that particular the angle of valve opening depending on his observation of the temperature and humidity.

Now, in expert system or the knowledge base system we try to copy the behavior of that particular the human being. And that is why we say that all the computer program may not be the expert system, but all the expert systems are nothing, but the computer programs. Now, this is the way actually we define and this is the way we define the knowledge base system or the expert system.

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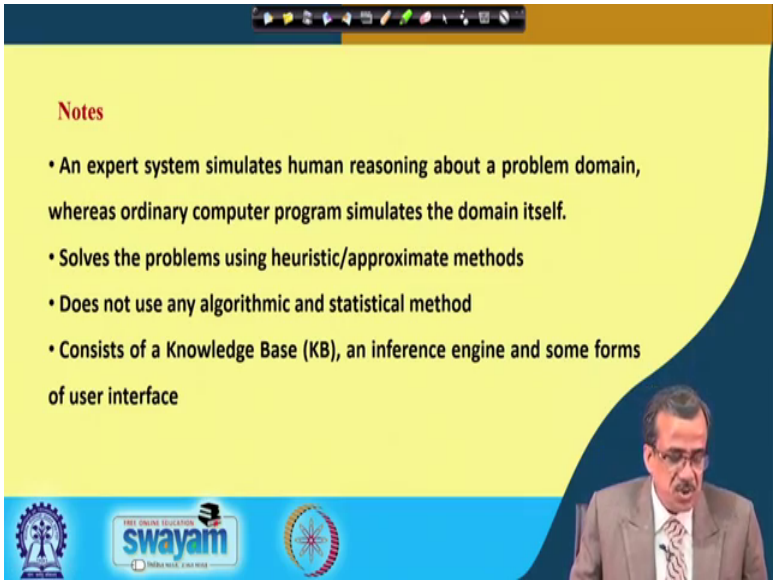

Now, here I am just going to put some notes these things I have already mentioned that in an expert system. We try to simulate the human reasoning just to solve that particular problem. But we do not simulate the domain of that problem; that means, we do not try to find out the physics or the differential equation of that particular the problem.

Now, in expert system actually we take the help of some heuristic or the approximate method we do not use the principle of the hard computing here and in expert system. In fact, we do not use any statistical method also or we do not use any algorithmic approaches. So, what we do is in expert system we try to design and develop the knowledge base. So, we try to find out that the knowledge base of that particular expert system. So, that it can perform in the optimal sense as the situation demands. Now, if you see the construction of the a particular the knowledge base it looks like this.

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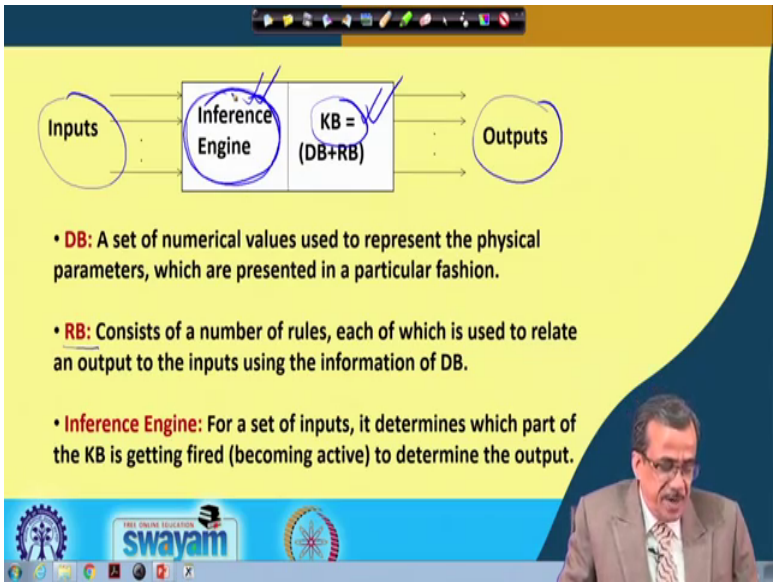

Now, the construction wise a knowledge base consist of a few components for example, say there will be some the inputs. We will have to provide the inputs and our aim is to determine these particular outputs. And inside we have got the inference engine and we have got the knowledge base and these knowledge base consist of your the data base and your the rule base. Now, the concept of data base concept of rule base concept of knowledge base those things we have already discussed in much more details. Now, just to just to summarize.

So, this particular concept of data base I should say the data base consist of a few numerical values used to represent the physical parameters. Now, while discussing the concept of fuzzy reasoning tool we have discussed the concept of these data base. That is the membership function distribution in much more details for example, the height could be the low height, it could be medium height, it could be your the very high height I should say. Now, what should be the range of the height. So, that we can say it is the low height or what should be the range of the height. So, that we can say it is the medium height. So, it has got some numerical values.

Now, those values are going to constitute what we mean by the database for the different variables. Now, then comes your the concept of the rule base and as I have already discussed. So, a particular rule is nothing, but the relationship between the inputs and the outputs. Now, if this is the set of inputs what should be the set of outputs something like

this. And to design a particular the rule we take the help of your the database. And as I told that a rule is nothing, but the known input output relationship and in a rule base we have got a large number of rules.

Now, then so, we have got the inference engine and the function of the inference engine is to determine which part of the knowledge base will be activated just to give reply to a set of queries. Or if we have or if you pass a set of inputs and if you want to determine what should be the output; then which part of the knowledge base is actually going to be activated just to give reply or answer that will be decided by is your inference engine. So, that is the function of the inference engine. Now, let me take a very simple example, whenever in a class the students ask questions or queries to the teacher. The teacher uses his or her knowledge base to give reply to that particular the queries and depending on the type of the question the type of the doubts and the queries.

So, if certain part of this knowledge base will be activated and the teacher is going to give reply or give answer to the queries of the student and. In fact, his inference engine is going to help like which part of the knowledge base should be activated to give reply to a set of questions. So, this is the way actually one inference engine who works and by an expert system. We mean it should have the inputs it should have inference engine and the knowledge base which consist of database and rule base and it should have the outputs.

Now, how to design these particular the knowledge base that is the data base or the rule base. To design this particular knowledge base we take the help of actually the principle of the soft computing. We can use some fuzzy logic based expert system. We can develop some neural network based expert system and to gather this particular the knowledge base actually and just to retain that particular information, we use the structure of neural networks. Or we use actually the structure of some set of the fuzzy reasoning tools. Now, here I just want to take another example just to understand what do you mean by the knowledge base for example, the participants who are going to take these particular course as a credit course or audit course or whatever may be.

Now, what is the purpose of taking this particular course the purpose of taking this particular course is to develop their knowledge base; so, in these particular the field now. So, after attending this particular course there is a possibility that some sort of knowledge base will be design and develop in the head of the participant and the

participants will be able to handle. So, this type of problem in a very efficient way, that is actually the purpose of taking this particular the course.

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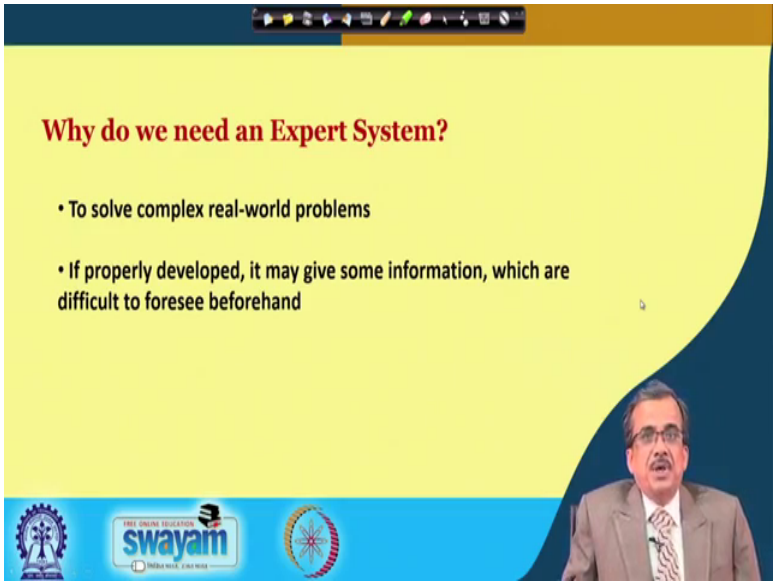

Now, if you see why do you need an expert system this I have already mentioned that if I have got a complex real world problem. So, we cannot find out the differential equation, we cannot use the principle of hard computing and to get some acceptable solution. So, we will have to take the help of your some sort of expert system and to develop the expert system or to develop the knowledge base of the expert system we take the help of some sort of your the principle of soft computing.

Now, our experience says that if this particular expert system is developed in a very efficient way there is a possibility that it is going to solve or it is going to give some solutions which is bit difficult to foresee beforehand. Let me take a very simple example, supposing that we have design and developed say one fuzzy logic based or neural network based expert system for an intelligent robot. Now, there could be a possibility that while training that particular the robot a few situations a few problem scenarios I had not considered.

But there is a possibility that this fuzzy logic based expert system or the neural network based expert system can give rise to some sort of adaptive solution. And that particular adaptive solution is bit difficult to foresee beforehand, but these expert system if it is properly designed there is a possibility it can provide some feasible solution even to

slightly unknown situations. So, that possibility is there. So, expert systems are very much useful very effective and it has got lot of applications.

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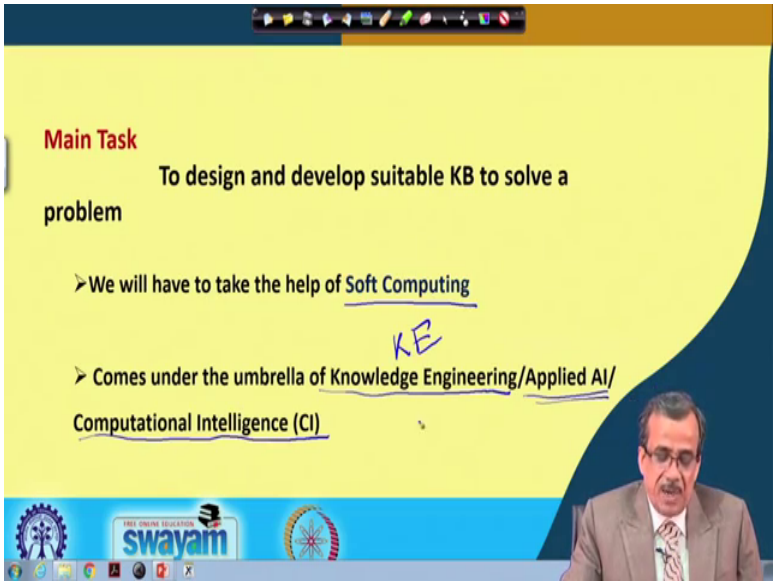

Now, if you see the applications of these particular the expert system we will see that we are using expert system to solve a variety of problems. I am just going to take a few examples, but before that let me tell you that as I have already mentioned that to design the expert system to design and develop the knowledge base of the expert system we are going to take the help of your some sort of the soft computing.

And which we have already discussed we have already discussed the principle of fuzzy logic. We have already discussed the working principle of different types of neural networks. We have also discussed their combined tools and in fact, we have already learned the principle of soft computing. And that principle of soft computing can be used very efficiently to design and develop the expert system.

Now, this particular area if you see. This is coming under the umbrella of your knowledge engineering. So, in short this is known as your KE and this is also known as applied artificial intelligence. So, applied AI and this is also coming under the purview of computational intelligence which is very popularly known as CI. So, the principles which we have already discussed those are nothing, but the principles of computational intelligence. Those are nothing, but the principles of applied artificial intelligence and that is also coming under the umbrella of knowledge engineering.

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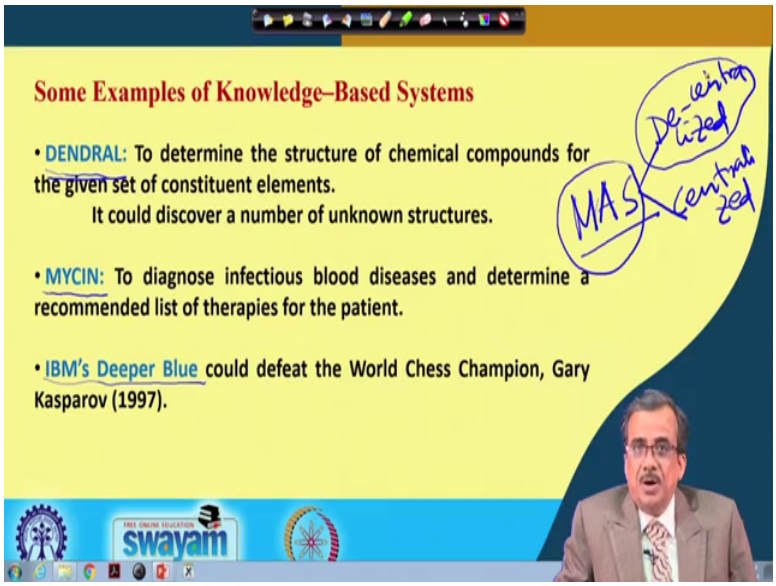

Now, let us see a few applications of already developed some expert system or the knowledge based systems. Now, if you see the literature we have got a large number of expert systems available for example, say you might have heard about; so, this expert system which is known as DENDRAL.

So, DENDRAL is actually a very popular expert system which has been used just to determine the structure of the chemical compounds by controlling actually the constituent elements. Now, supposing that we have got a set of constituent elements. Now, if I use the set of constituent elements under different operating conditions there is a possibility we may get different types of chemical compounds. And these particular DENDRAL is actually a very popular expert system or the knowledge base system. And its aim is to determine the structure of chemical compounds for a set of constituent elements.

Now, using this DENDRAL people could actually discover a number of unknown structures of chemical compounds. Now, then comes another very popular expert system or the knowledge base system which is known as MYCIN. Now, MYCIN is a very popular expert system used in the field of medical science. And the aim of this expert system is to diagnose infectious blood diseases. And it will also going to recommend a list of therapies to the patients. So, this is also a very popular expert system used in medical science.

Now, another expert system I hope you have already heard about IBM's Deeper Blue. Now, this IBM's Deeper Blue is actually one expert system which was developed in the year 1997. And these expert system could defeat world chess champion Gary Kasparov. Now, this is nothing, but an expert system. So, IBM's Deeper Blue is nothing, but an expert system which could even defeat Gary Kasparov.

Now, here this particular problem of chess playing is actually a problem of static environment. Now, if you see the chess board, we have got a fixed location for the different members. And we try to play that particular thing so, that you can win. So, the environment is known to the players and there is lot of calculations and lot of thinking. So, that one player can win that particular the game. So, this particular thinking process has been modeled and this expert system was developed by IBM and which could defeat Gary Kasparov.

Now, if you see today, we in fact, talk about the dynamic environment and how to design and develop the dynamic environment that is actually a very difficult task. For example, we might have heard about the soccer playing, the soccer playing games or soccer playing robots and that is nothing, but is your the multi agent system of robotics. That is MAS; multi agent system of robotics. Now, this multi agent system of robotics it could be either decentralized. So, it could be either decentralized or it could be your the decentralized.

Now, if it is centralized then there will be one controller and one main computer which is going to control the movement of the different agents. Now, agents are nothing, but all intelligent robots and if it is decentralized there is no centralized control and each of the robots are intelligent. They are able to take their decision and they are going to interact and ultimately they are going to reach their goal. Now, this multi agent system of robotics, particularly if you consider the decentralized system is bit difficult. And soccer playing robots we can consider that this is some sort of more towards decentralize multi agent system of robotics although it has got some centralized component also. But, it is more towards decentralized and that is actually a very complex problem.

Now, to solve this the soccer playing games problem or the decentralized multi agent system in robotics. So, we can take the help of some sort of knowledge base system or the expert system. Now, this knowledge based system or the expert system can be

develop using the principle of fuzzy logic, using the principle of neural network which we have already discussed in much more details and we have solved a number of numerical examples also.

Thank you.