Mechatronics
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Lecture - 20
Artificial Intelligence

I welcome you all to today's NPTEL online certification course on Mechatronics. Today I am going to talk about Artificial Intelligence. There is much talked about things about artificial intelligence; in fact, there is a full-fledged course on artificial intelligence. My aim in introducing this topic here is to get or make you aware of the use of this concept in the mechatronics system. So, if you are interested, you can refer more to what I am going to discuss in the next thirty minutes.

The artificial intelligence these days is used in many mechatronic devices, people are using it in the washing machine and people are using it in robotics. The artificial intelligence or which is called AI in short is very useful in making appropriate decisions.

For example, if I talk about a robot, what the motor speed has to be at which type of situation came; if it is climbing, then whether the speed has to be increased or speed has to be decreased all those decisions can be taken by AI. So, the dictionary definition of intelligence might be endowed with the ability to reason.

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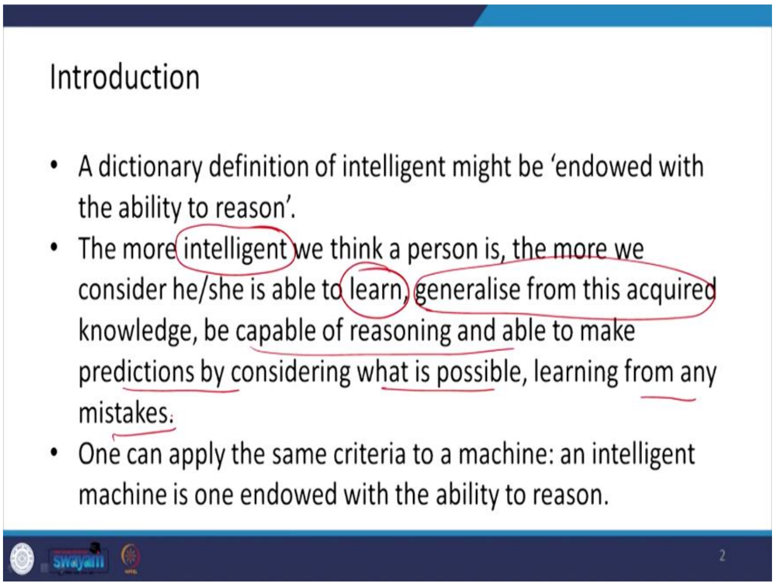

The more intelligent we think a person is more we consider he or she is able to learn, generalize from this acquired knowledge and be capable of reasoning, and be able to make predictions by considering what is possible and learning from the mistakes. So, essentially as I said let us look at some of the things here.

The more intelligent we think of a person is, let us look at what are the qualities to be intelligent; one is that, one should be able to learn and then after learning, generalize from this acquired knowledge. So, generalization of this knowledge and then capable of reasoning and able to make prediction by considering what is possible and learning from any mistakes. And one can apply this concept to machines as well, and intelligent machines are powered with the ability to reason. For example, if I talk about a boiler in a thermal power plant.

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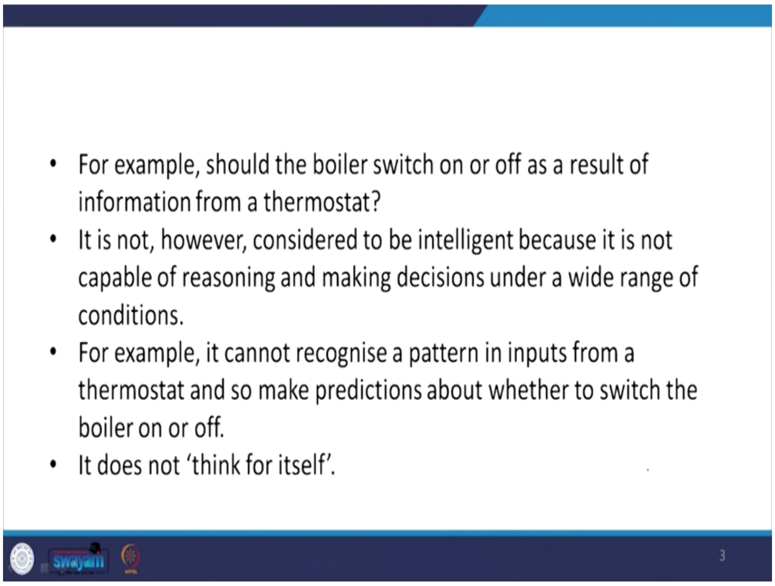

So, the question is that, should the boiler switch be on or off as a result of information from the thermostat? It is not. However, consider it to be intelligent because it is not capable of reasoning and making decisions. So, this is not intelligence, it is not considered to be intelligent; because it cannot take decisions over a wide range of conditions. It cannot recognize a pattern in inputs from a thermostat and so, it cannot make predictions about whether to switch the boiler on or off; it does not think for itself. If we talk about a closed-loop feedback system, these systems are what we call the self-regulated system; in the sense that they regulate the output of a system to a required value.

For example, a thermostatically controlled central heating system of a building is used to maintain the building temperature at the value, set for the thermostat; such systems are not considered intelligent at they only do what they were told to do. So, what constitutes intelligence? What properties intelligence should have?

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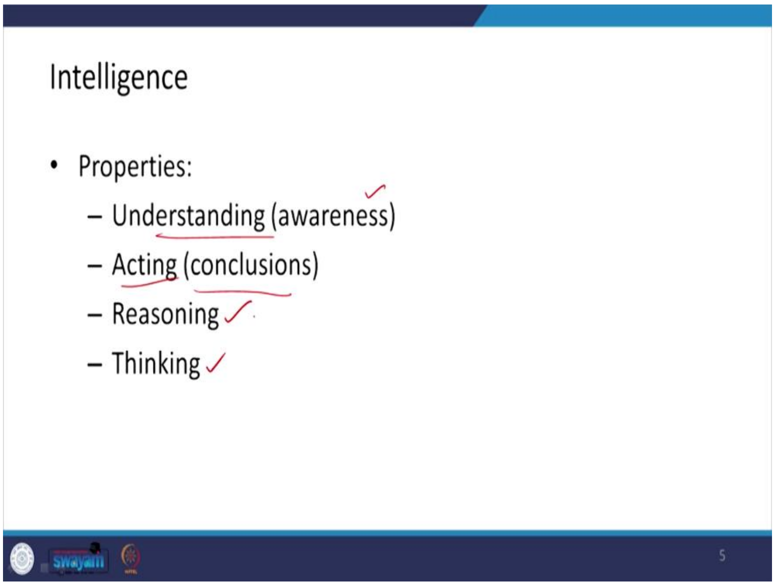

So, they should have the awareness or what we call it as the understanding; they should be able to conclude and act, they should behave the reasoning and they should be able to think.

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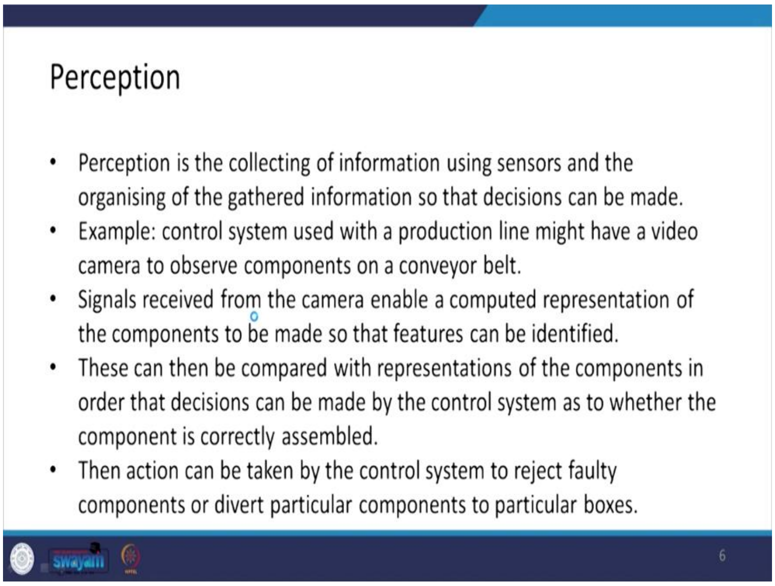

Next, let us talk about perception. Perception is collecting the information using sensors; if I am talking about a mechatronic system, I am not talking about the perception considered in another way, for example, perception of a person. So, perception is the collecting of information using sensors and organizing the gathered information, so the decisions can be made. For example, we may have a control system with a production line, where certain parts are moving with a help of a conveyor belt or through a conveyor belt and we might have a sensor like a video camera, kept to observe the component. Now, the signals received from the camera enable a computer representation of the component to be made and so, that the features can be identified.

And now these features are can be compared with the representation of components in order that, the decision can be made about the control system and whether your components are rightly assembled or not. So, the action can be taken by the control system to reject a faulty component or divert a particular component to particular boxes. So, this is what is meant by the perception in a mechatronic system.

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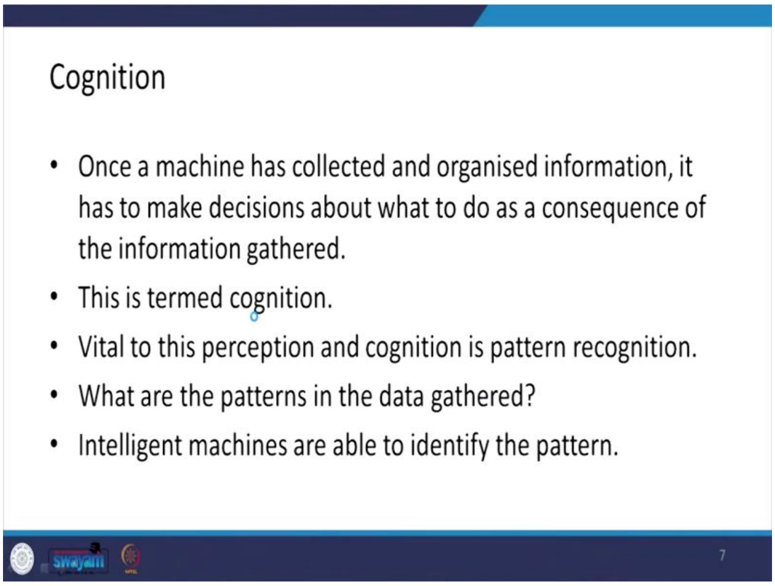

Next is cognition. Once a machine has collected and organized information, that is the perception has been made; it has to make the decision about what to do as a consequence of whatever information has been gathered or collected. This is termed cognition. Perception and cognition are vital in pattern recognition. What are the patterns in the data gathered. Intelligent machines are able to identify such a pattern.

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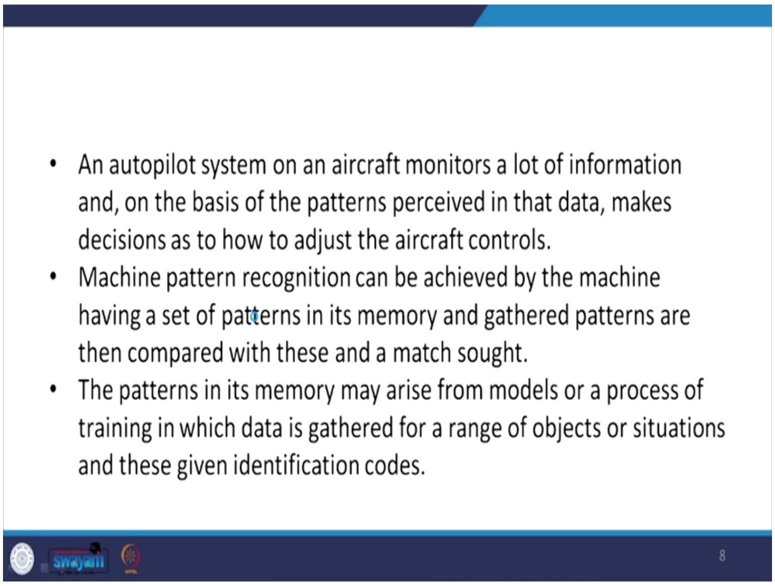

For example, suppose we have an autopilot system on an aircraft, it monitors a lot of information, and on the basis of that information as a pattern, it perceives the data and makes decisions on how to adjust the aircraft control. Machine pattern recognition can be achieved by the machine having a set of patterns in its memory and gathered patterns are then compared with these and a match is sought. The pattern in its memory may arise from the model or a process of training in which data is gathered for a range of objects or situations, and then the given identification code.

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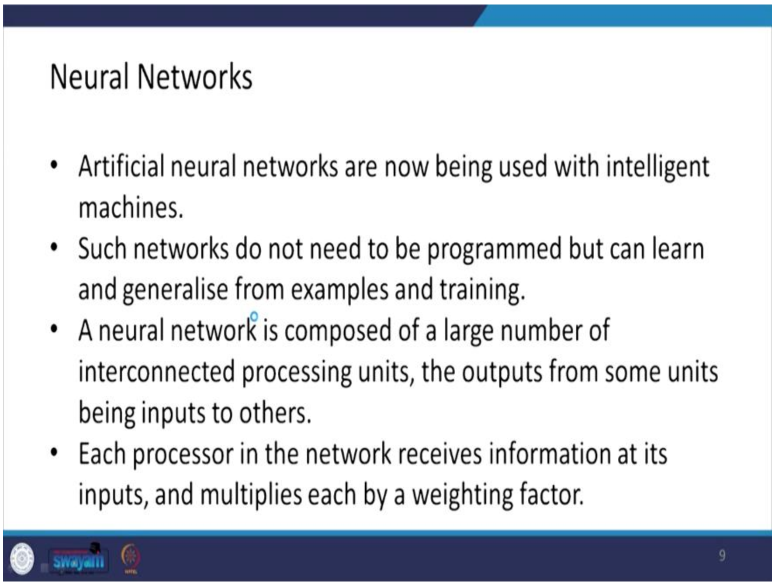

Next, let us talk about neural network, which is being used in intelligent machines. Such networks do not need to be programmed but can learn and generalize from examples and training. A neural network is composed of a large number of interconnected processing units and the output from some units being input to the other unit. Each processor in the network receives information at its input and multiply it by a weighting factor.

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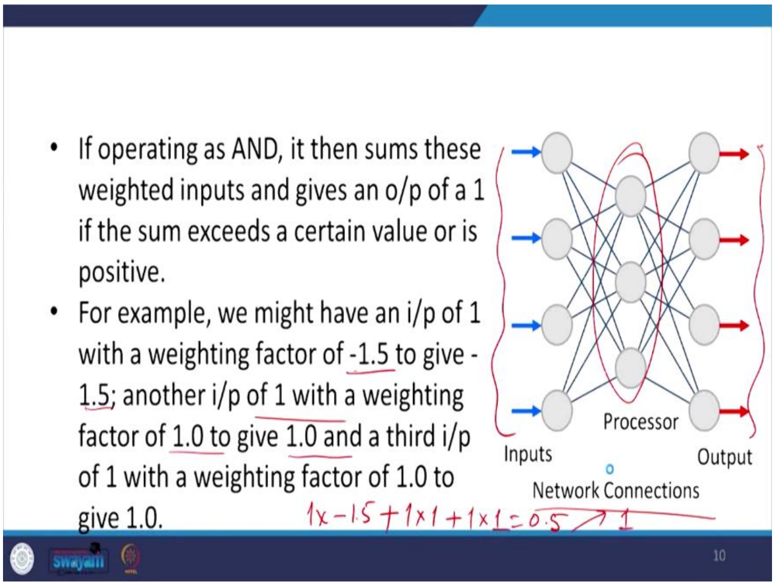

We could have a network something like this, where you have the inputs from here. And certain processes are taking place here and then you get the output from this side. And here in the process, you can have various weighing weights.

So, if operating as and it, then sums these weight input and give an output of 1; if the sum exceeds a certain value or it is positive. So, for example, we might have an input of one with a weighing factor of -1.5. So, this will be giving me 1 (- 1.5). So, that is -1.5; another input with one with a weighing factor 1 and another give input 1 and that gives 1, and third input 1 with a weighing factor 1, giving 1.

So, this way I have is; input 1 which is weighing factor -1.5, another input 1 with weighting factor 1, and another input 1 with weighting factor 1. So, this will be giving me a value of 0.5. So, this is a positive value. So, I can take it as representing that positive value by 1.

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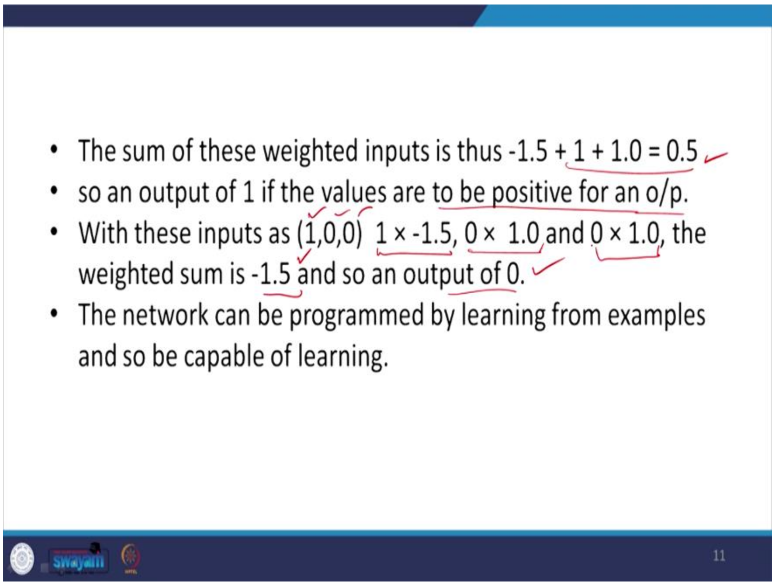

So, as I said the sum of these weights could be 0.5. So, an output of 1 if these values are positive for an output. Similarly, if I have input as 1, 0, 0; so in that case, my output will be 1 ×1 (-1.5), 0 × 1, and 0×1. So, this is -1.5. So, I could have an output of 0. So, this is how a neural network works.

So, the network can be programmed by learning from example and so, be capable of learning. Our next thing in AI is reasoning. The reasoning is the process of going from what is known to what is not known; there are a number of mechanisms to carry out the reasoning and this mechanism could be deterministic reasoning.

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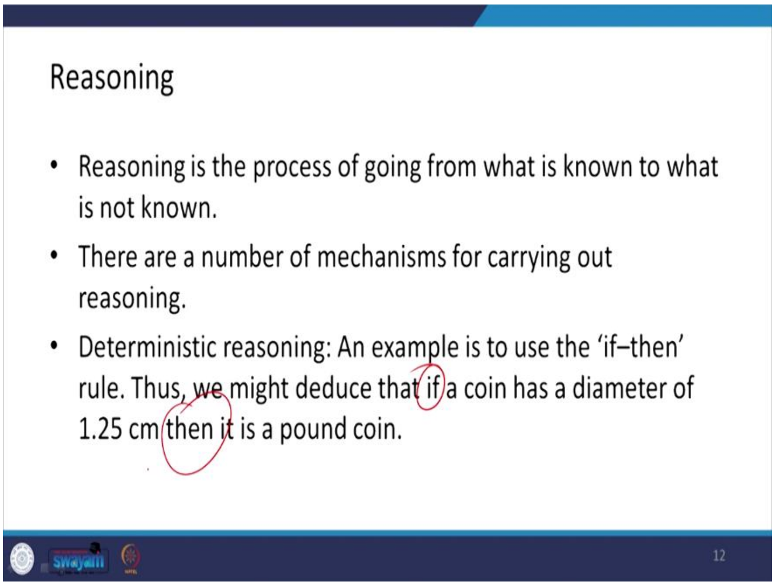

And this could be using, if-then type of statement or if-then type of rule, which we conventionally use in any of the programmings. So, suppose we might deduce that, if a coin has a diameter of 1.25 centimeters; then it is a pound coin. So, this type of deterministic reasoning using if and then could be formulated, and this is what we call deterministic reasoning.

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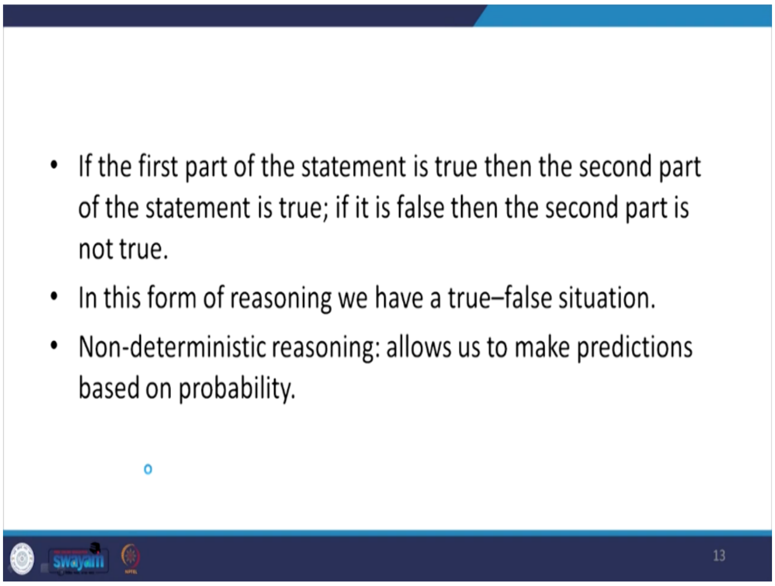

And if the first part of the statement is true, then the second part of the statement is true; if the first part of the statement is false, then the second part is not true. So, in this form of reasoning, we have the true-false type of situation. So, that type of thing also can be formulated. Then the other type of reasoning is non-deterministic reasoning and this allows to make predictions based on the concept of probability.

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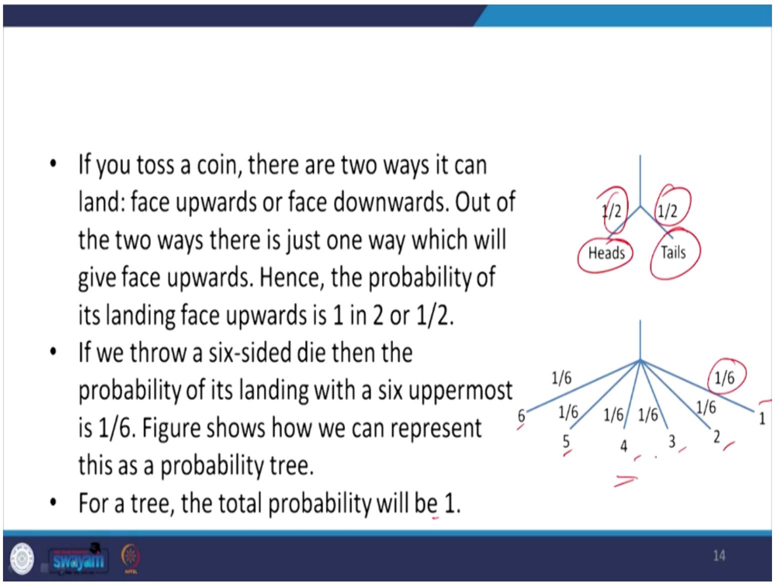

For example, suppose if I toss a coin; there are only two ways it can land, face upward or face downward. So, out of the two ways, there is just one way that will give the face upward. So, the probability of its landing face upward is 1 in 2 or 1/ 2. So, I can have the head's probability as 1/ 2 and I can have the tail's probability as also 1/ 2.

And suppose I can take another examples throwing of a six-sided die; then the probability of its landing with a six uppermost is 1/ 6. And this is how we can see. So, the probability for each type of face, landing of each type of face is 1/ 6 and the total probability, in this case, will be 1.

So, these types for the non-deterministic type of reasoning; we can use the concept of probability to make the prediction. And for a deterministic type of reasoning, we can use the if-then or the true-false type of situation in order to do the reasoning.

Then we could also have rule-based reasoning. So, at the heart of rule-based reasoning or a set of rules. And these rules when combined with input from sensors and users, enable inferences to be made which are then used to actuate your actuator and get the control output.

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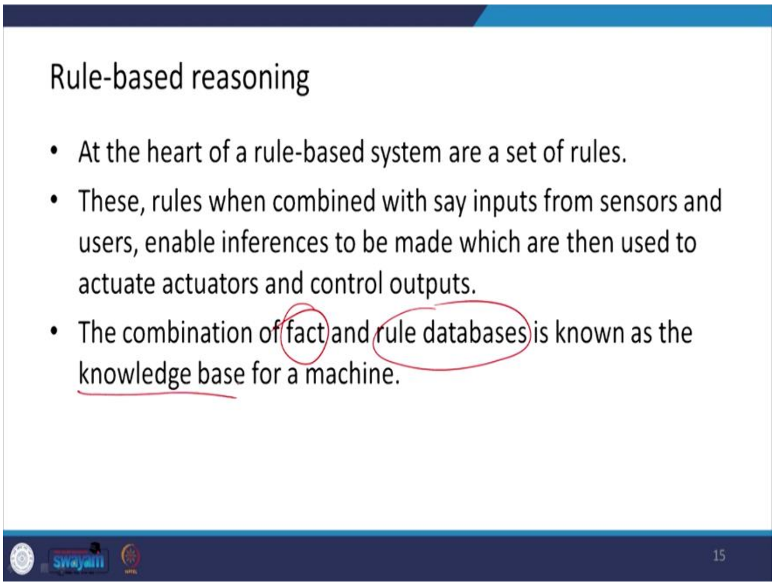

And the combination of the fact and rule database is known as the knowledge base for a machine. So, you have essentially the fact database as well as the rule database and this is what is known as the knowledge base for a machine.

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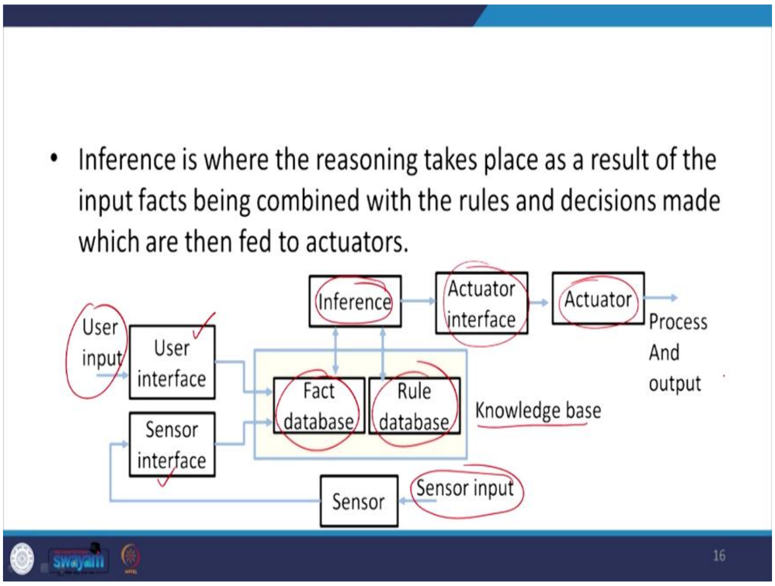

So, in the rule base reasoning, it is something like this. So, you have the user input and you have the sensor input. So, user input is fed through a user interface, sensor input is fed through the sensor interface. So, that is there and then these inputs are sent to the knowledge base and this knowledge base consists of the fact database as well as the rule database.

And from this, we carry out the inferences. The actuator interface is being connective and of course, this interface will be working on the actuator and you have the processes and output. So, inference is where reasoning takes place as a result of the input fact being combined with the rules and decisions made which are then fed to the actuator.

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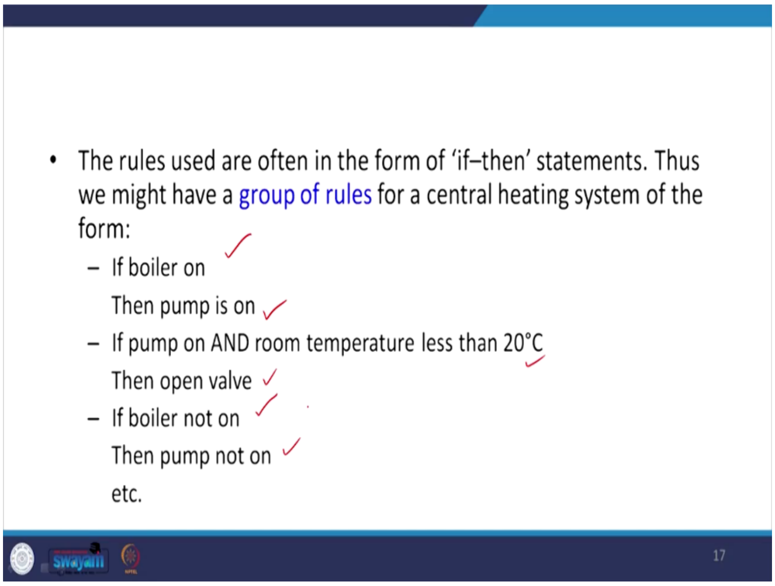

The rules used are often in the form of an if-then statement; thus we might have a group of rules for a central heating system of the room. So, it could be something like this; if a boiler is on, then your pump is on; if the pump is on and the room temperature is less than 20 degrees, then open the valve and if its boiler is not on, then your pump is not on. So, this type of rule base we can have here.

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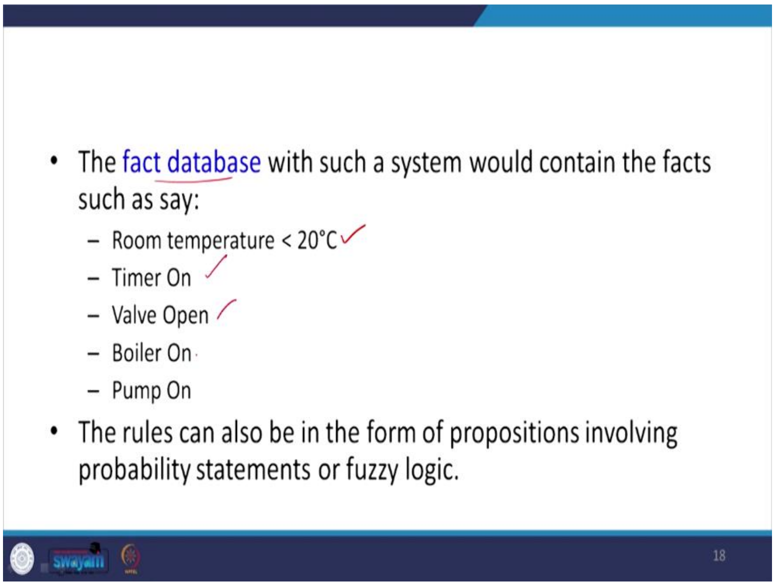

And the fact database, I have talked about two things over here in the knowledge base; the fact database, and the rule database. So, here I just talked about the rule thing, where we are using the if-then statement; and the fact database we could have the facts. For example, room temperature is less than 20 degrees, a timer is on, a valve is open, a boiler is on, and the pump is on.

So, we could have this type of fact database. And the rules can also be in the form of propositions involving probability statements or it could be in the form of fuzzy logic. So, this is what I talked about the rule-based reasoning. So, next, let us see the fuzzy logic. So, fuzzy logic also helps us in designing intelligent systems.

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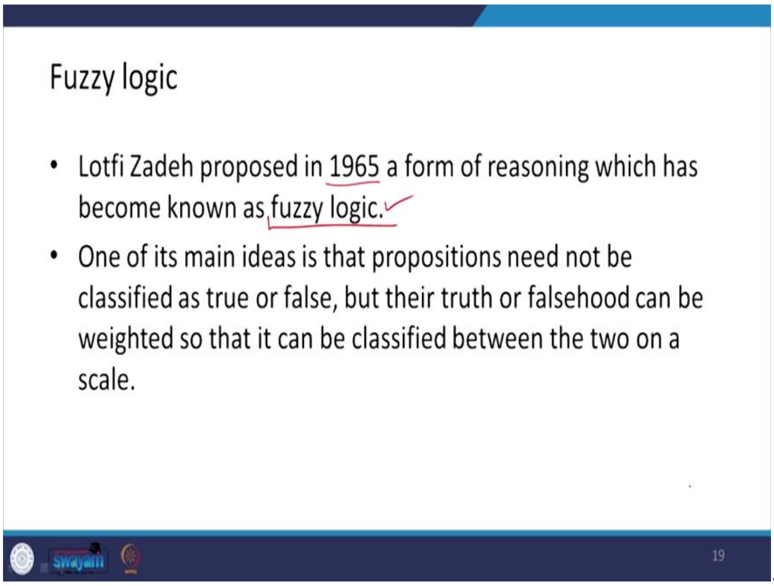

It was Lotfi Zadeh who proposed in 1965 a form of reasoning which has become what is popularly known today as fuzzy logic. And one of the main ideas here is that things could not be classified as true or false, but their true or false should be weighted so that they can be classified between the two on a scale. So, for example, before we proceed further; let us look at some fewer concepts of the fuzzy logic, consider this statement.

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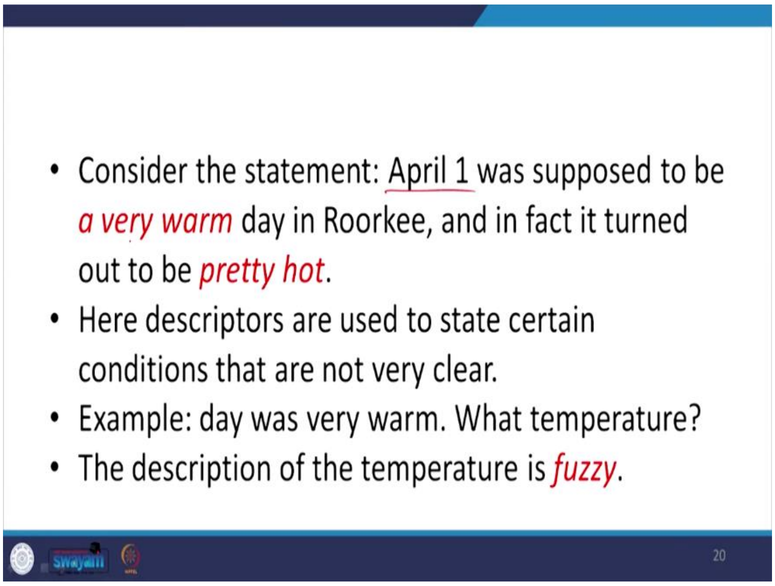

April 1st was supposed to be a very warm day in IIT Roorkee and in fact, it turned out to be pretty hot. So, here you see that I have used the warm, very warm, and pretty hot. So, these are not the crisp values, these are not the exact values to indicate the state of the weather.

So, here things are not certain, things are not clear. So, for example, if I that it is warm; you somebody may ask what temperature it is. So, the description, this type of description is what is of temperature is what is called as fuzzy. So, a fuzzy description of events and other phenomena is context-dependent.

For example, if somebody has got an accident. So, if it is a young child, its description of halt, because of the accident could be different than the description given by an adult. So, this fuzzy description and events are also context-dependent.

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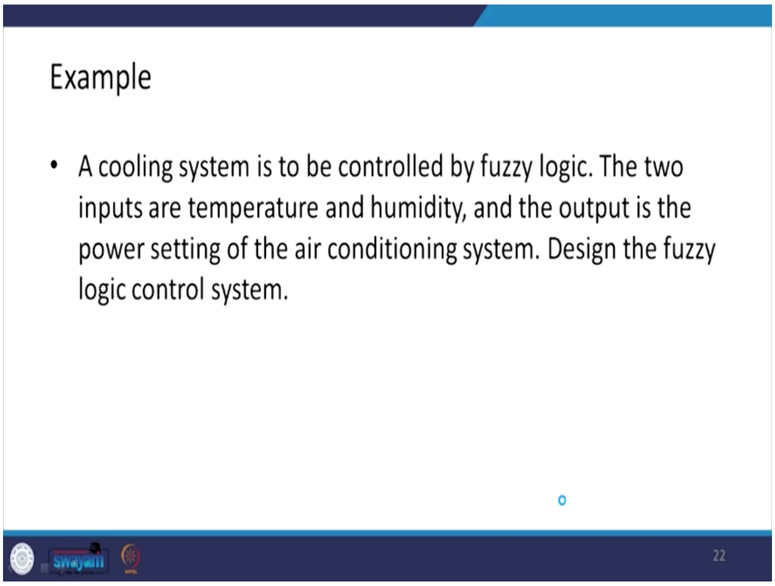

Now, to explain the concept of fuzzy logic, I take up a simple example, here a cooling system to be controlled by fuzzy logic. The two inputs are temperature and humidity, and the output is the power setting of the air conditioning system. And suppose we need to design a fuzzy logic control for such a system.

Now, here what we have to do is that what are our inputs are we have the temperature and humidity, and output is the power setting of the air conditioning system. So, here is the first process in any fuzzy logic control, the first is the fuzzification.

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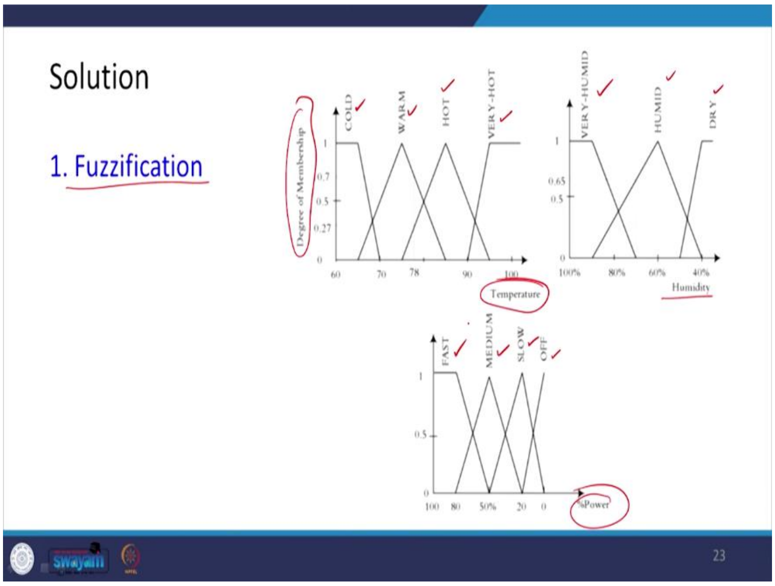

So, here is what we do with temperature, we mention the degree of membership; here temperatures are mentioned in Fahrenheit. So, here I could have the four conditions for the temperature, very hot, hot, warm, and cold. So, this way I can define over here.

And for the humidity also similarly I could have the three classifications that are dry, humid, and very humid. And my output is the percentage of power that could be off condition, slow, medium, and fast. So, this process is what we call fuzzification.

So, here I have considered their variations as the triangular variation. And then the next step after fuzzification is the development of the rule base. So, here you can see that we have four states here for the temperature and three for the humidity. So, I am going to have the 12 rules that are 4 into 3, so all the possible combinations.

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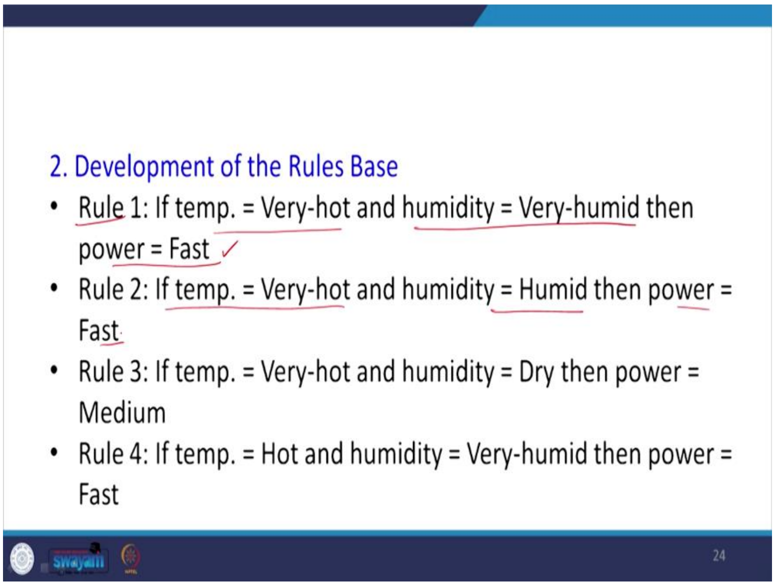

So, rule 1, could be if the temperature is very hot and humidity is very humid; then the power has to be fast. So, rule 2 could be, if the temperature is very hot and humidity is humid; then power is fast. So, this way we could generate the rule basis.

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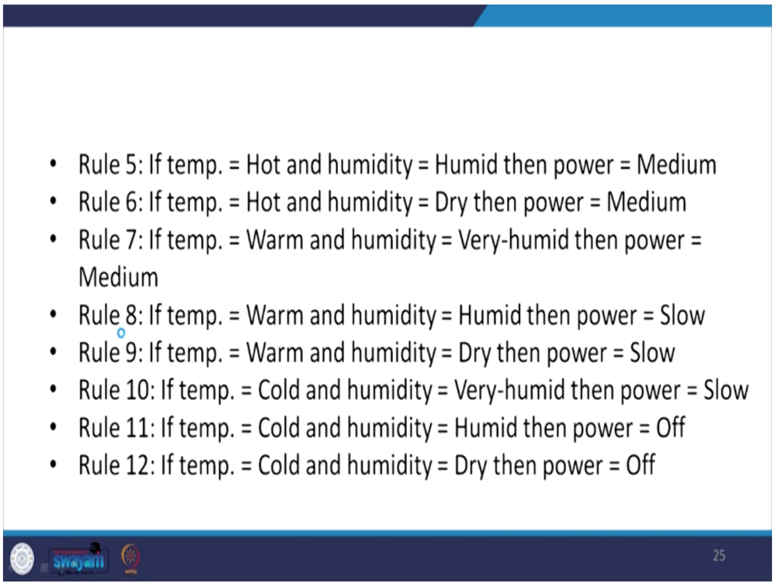

So, the last one could be, if the temperature is cold and humidity is dry and then the power has to be off; that is your air conditioner should not work. So, after this rule base, what we could do is that we could do to make the decisions, we can draw a diagram like this, where we have the temperature conditions mentioned over here and humidity condition mentioned over here and these are our output.

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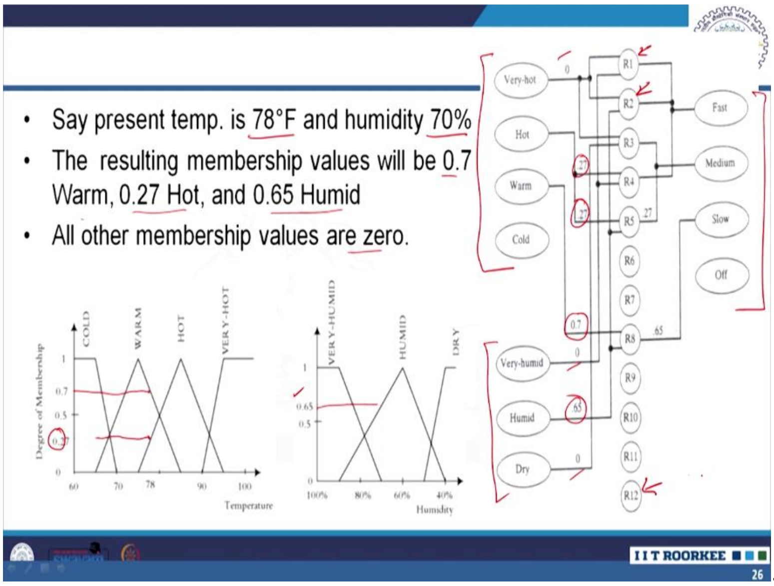

And here are the rules; so I have 1 to 12 rule which has been generated. So, suppose the present temperature is 78 degrees Fahrenheit and humidity is 70 percent. So, for 78 degrees Fahrenheit temperature, the resulting membership values will be 0.7 warm, 0.27 hot, and 0.65 humid. So, this is going to be there and all other membership values are going to be zero.

So, as I was telling for 78-degree temperature, corresponding to hot you have this value has 0.27, and corresponding to warm, you have value has 0.7, so that is there. And for 70 percent humidity, here you are going to have this value as 0.65 and all other members are going to be zero.

So, then we can substitute or we can out these values over here; for example, for humid, this is 0.65, for warm this is 0.7, and for hot it is 0.27 over here. So, these values could be put and for all other, these values are that is very hot is 0, very humid is 0, and dry is 0. Then based on this rule base, we could generate the output. So, based on this rule base from R1 to R12, the output could be generated.

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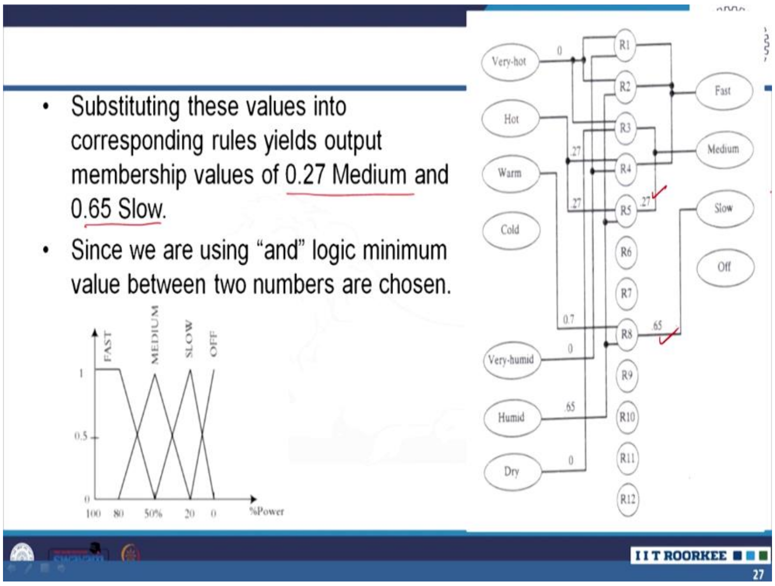

So, substituting these values into the corresponding rules, output membership values are 0.27 medium and 0.65 slow. So, we get here 0.27 medium and 0.65 slow. Since we are using "and" logic minimum value between the numbers is chosen, so that is there.

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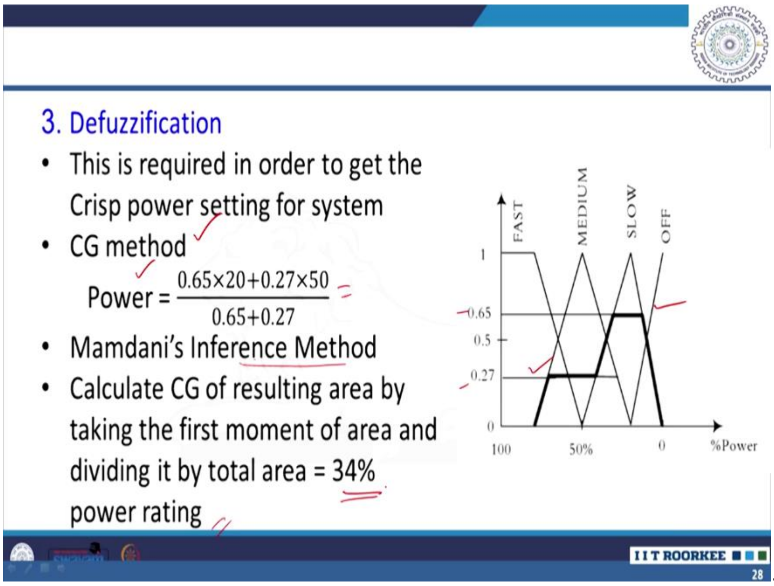

And the last step on this is the defuzzification; because or ultimately we want a certain value for the air conditioner, that is at what power setting it has to run. So, this value the 0.27 and 0.65 this which we have evaluated over here from this rule base, these values which we have evaluated; these values could be put into here and using the CG method, we can derive what power setting is going to be.

There could be another way of doing is what we call Mamdani's inference method, where we calculate the CG of the resulting area by taking the first moment of area and dividing it by total area. So, that will be coming around 34 percent of the power rating.

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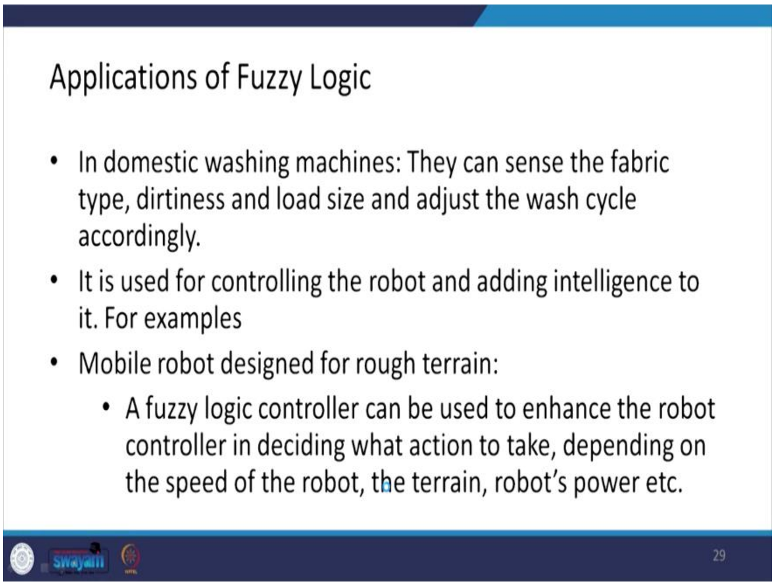

So, this way you can see that, we apply the fuzzy logic in taking or making an intelligent decision about the setting of the power for the air conditioner. Now, these fuzzy logic concepts are very much used in the domestic washing machines, where they can sense the fabric type; how much dirt is there in your fabric, and what is the load size, and adjust the wash cycle accordingly.

It could also be used in controlling the robot and adding intelligence to it; for example, we have the mobile robot designed for rough terrain. So, in that case, a fuzzy logic controller can be used to enhance the robot controller; in deciding what action to be taken, depending on the speed of the robot, the terrain, and the robot power. In industrial robots which are handling an object and end, the effector must exert a force proportional to two other inputs, the size of the part and its weight.

So, there we can use this fuzzy logic. Then we can also use it in case of sorting of bags. So, a robot is used to sort a bag of objects based on their color, according to the color of the rainbow.

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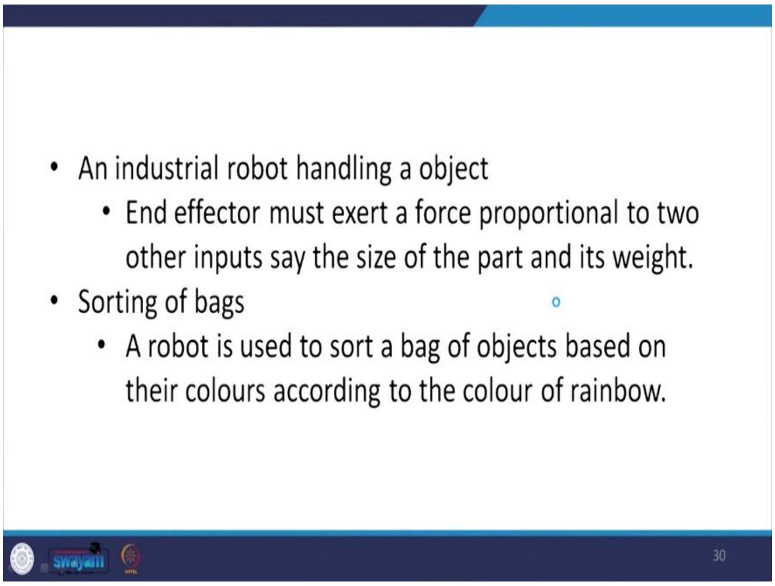

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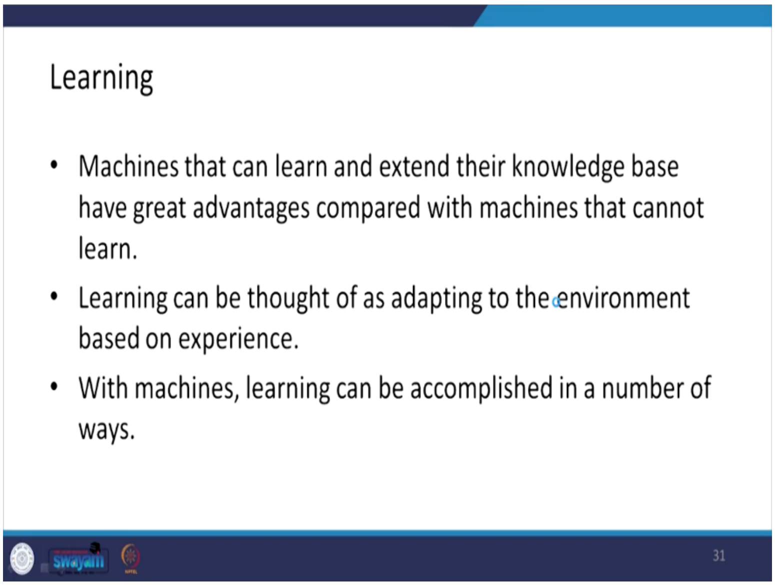

Then now, let us see about learning. So, the machine that can learn and extend its knowledge base has a greater advantage compared to a machine that cannot learn. And learning can be thought of as adapting to the environment based on experience. And with machines, learning can be accomplished in a number of ways. A simple method of learning is by the new data being inputted and accumulated in the memory.

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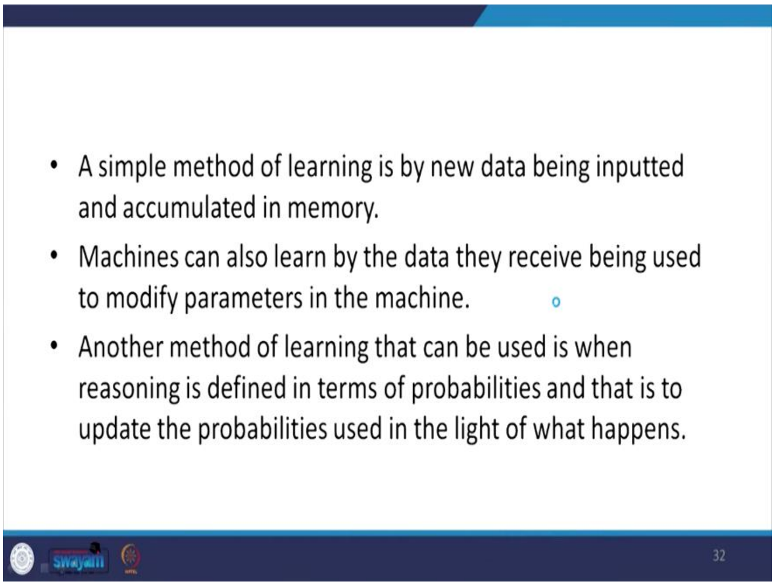

A machine can also learn by the data; they receive which is used to modify parameters in the machines. Another method of learning that can be used is when reasoning is defined in terms of probabilities and that is to update the probabilities used in the light of what happens.

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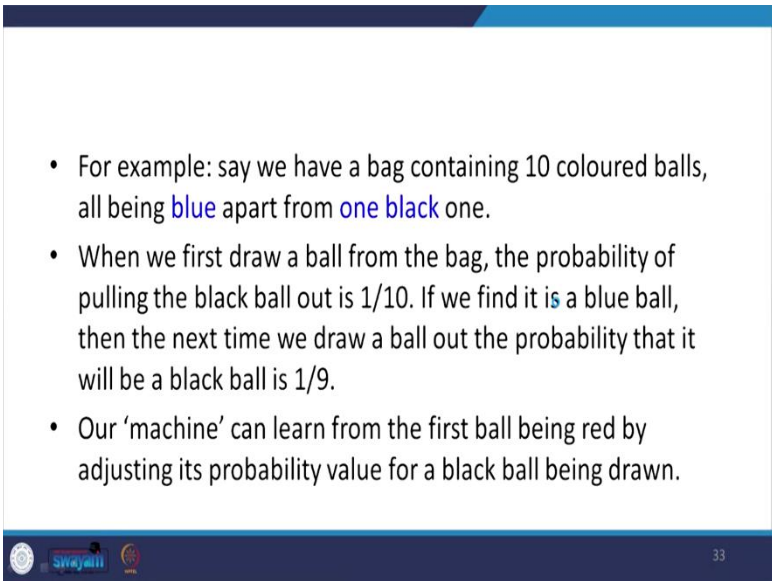

So, for example, we have a bag containing 10 colored balls and all being blue apart from one black. Now, when we draw the first ball from the bag the probability of pulling the black ball out of the bag is 1 by 10. If you find it is a blue ball; then the next time we draw a ball, the probability is going to be 1 by 9. So, our machine can learn from the first ball being red by adjusting its probability values for the black ball being drawn.

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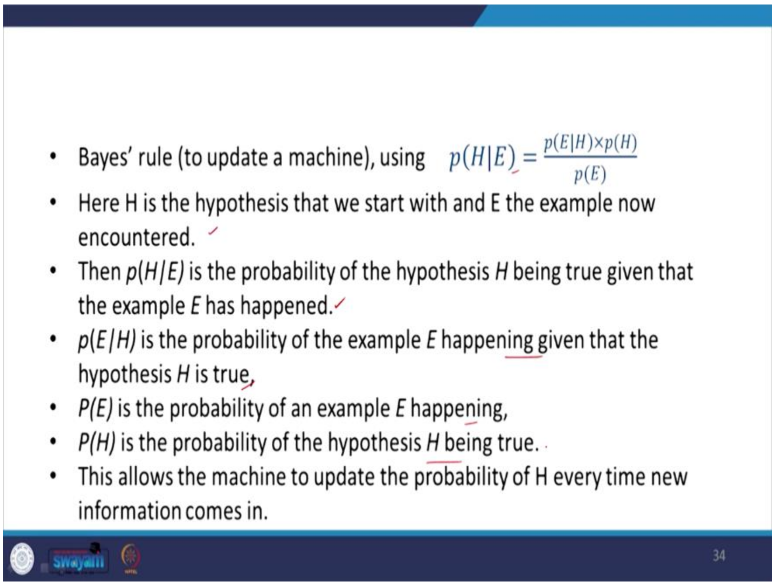

So, Baye's rule to update a machine is,

$$p(H|E) = \frac{p(E|H) \times p(H)}{p(E)}$$

Here H is the hypothesis that we start with E and the example now encountered. So, $p(H|E)$ is the probability of the hypothesis H being true given that the example E has happened; $p(E|H)$ is the probability of the example E happening giving that the hypothesis H is true. And $p(E)$ is the probability of example E happening ; $p(H)$ is the probability of the hypothesis H being true, . So, this allows the machine to update the probability of H every time new information occurs.

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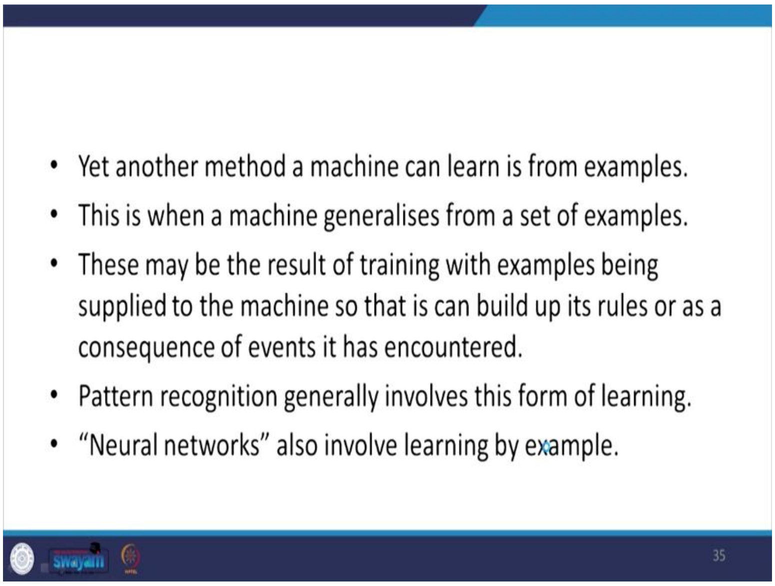

Yet another method a machine can learn is from the examples. And this is when a machine generalizes from the set of examples. These may be the result of training with the example being studied to the machine so that it can build up its rules or as a consequence of the event it has encountered. So, pattern recognition generally involves a form of learning, and neural network also involves learning by example.

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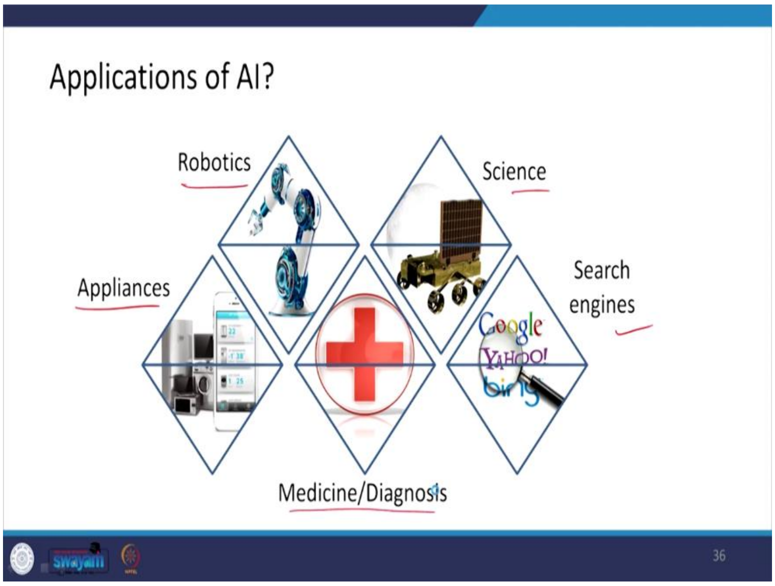

So, looking at the applications of AI, so this is used in the various appliances; robotics, science, search engines, and medicine and diagnosis.

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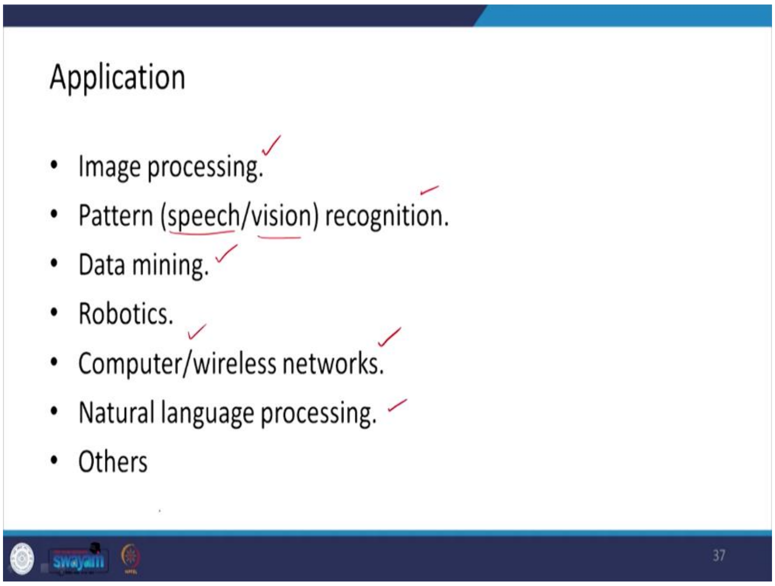

So, in applications it is used in image processing, pattern recognition; for example, from speech or vision, data mining, robotics, computer or wireless network, natural language processing, or others.

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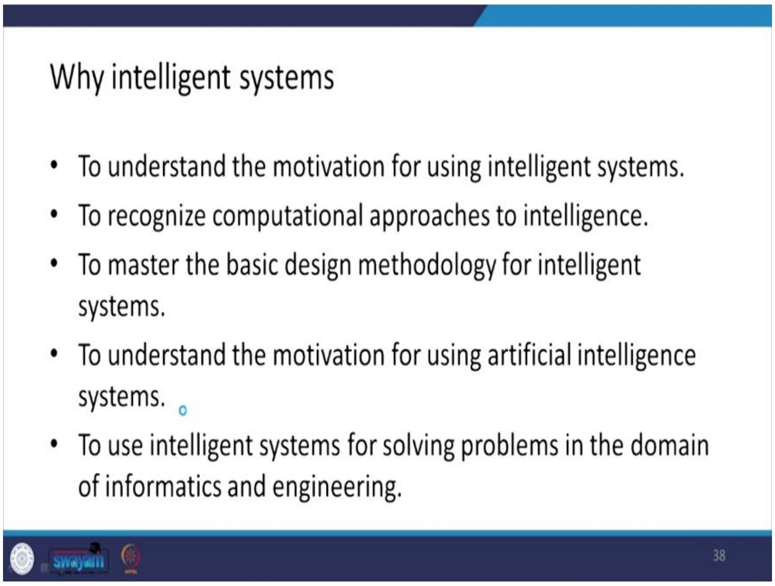

And why do we are looking for an intelligent system? so, to understand the motivation for using the intelligent system; to recognize computational approaches to intelligence; to master the basic design methodology for intelligent systems to understand the motivation for using the artificial intelligent system; to use an intelligent system for solving problems in the domain of informatics and engineering.

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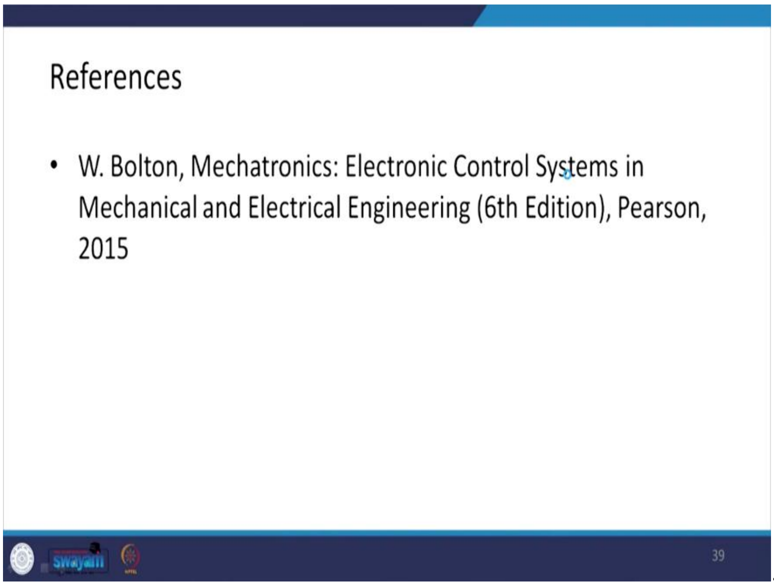

So, this is the reference you can refer to Bolton for Mechatronics, and for the fuzzy example which I have shown, you can refer to robotics by NICo.

So, thank you very much.