Fuzzy Logic and Neural Networks
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Lecture - 34
Neuro - Fuzzy System (Contd.)

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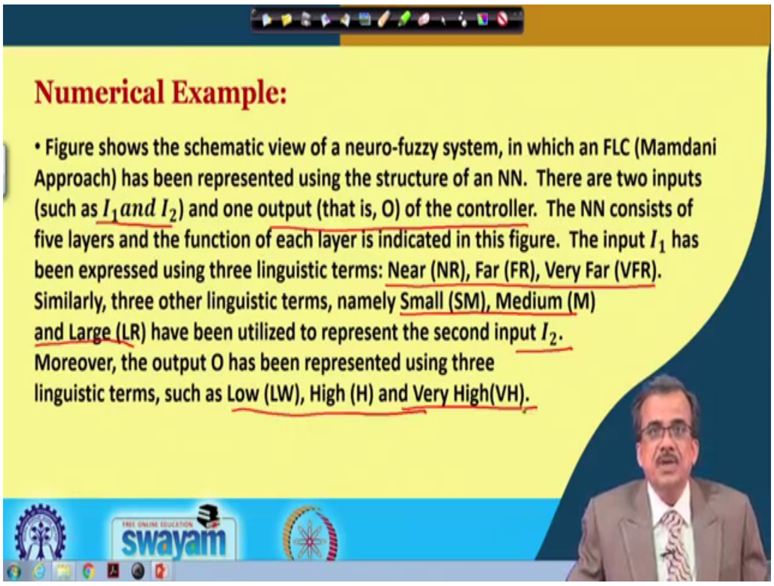

Now, we are going to discuss how to solve a numerical example, related to the Neuro Fuzzy System Mamdani approach. The statement of the problem is as follows. So, here we are going to develop one neuro fuzzy system based on the Mamdani approach, and this particular fuzzy reasoning tool is represented using the structure of a multilayered the network. There are two inputs I 1 I 2 and there is only one output that is O of the fuzzy logic controller. The neural network consists of 5 layers as we discussed, and the function of each layer is indicated in the figure; the figure I am going to show you.

The input I 1 has been expressed using the linguistic term like near far very far. So, there are three linguistic terms near far and very far. Now, similarly you are the three other linguistic terms like here small medium and large have been utilized to represent the second input that is your I 2. And, the output has been represented using three other linguistic term like your low medium low high and very high that is LWH and your the VH.

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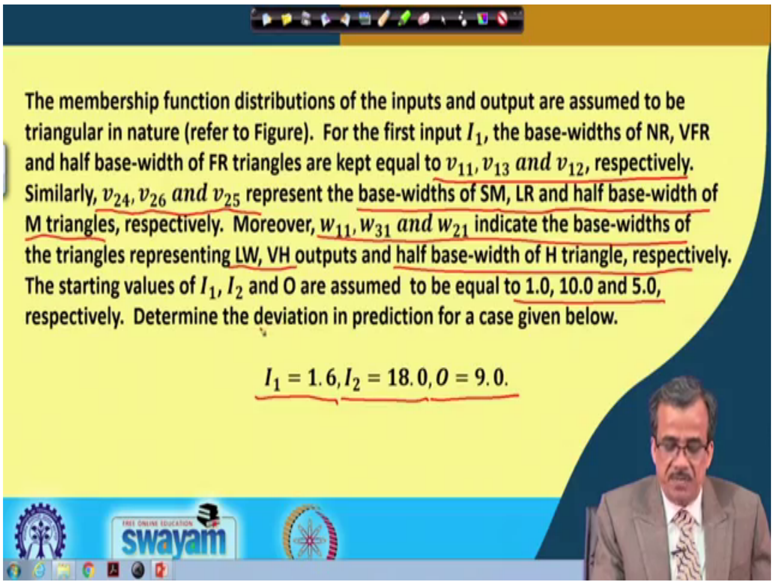

Now, I am just going to show you. So, this particular the network the membership function distribution of the inputs and the outputs are assumed to be triangular in nature and here the base width of near, very far and half base width of far triangle are kept equal to v 11 then comes your v 13 and 1 2 respectively for the first input that is I 1. Similarly, for I 2 so, your this v 24 v 26 v 25 are used to represent the base width of small large and half base width of your the medium triangles. Now, your this w 11 w 31 and w 21 indicate the base width of triangles representing low and very high outputs and half base width of your the high triangle.

Now, here actually the starting values for this I 1 I 2 and this output are assumed to be equal to 1.0, 10.0 and 5.0 I am just going to show you that the figure. Now we will have to find out the deviation in prediction for the training scenario which is nothing, but I 1 equals to 1.6 I 2 equals to 18.0 and the output is nothing, but is your 9.0. So, for this particular training scenario so, I will have to find out what should be your the deviation in prediction. Now let us see how to determine so, that particular the deviation in prediction.

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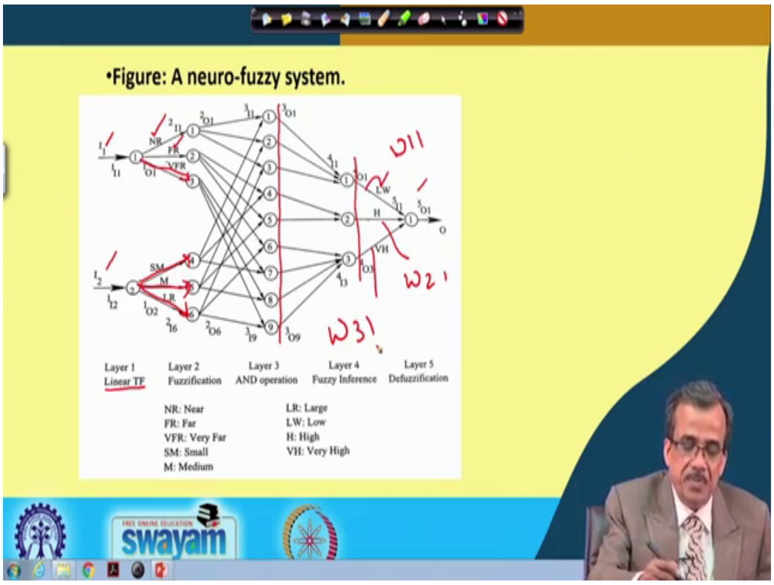

Now, this shows actually the neuro fuzzy system now here let me explain. So, I have got two inputs here one is I 1 I 2 and as usual on this layer 1 we use the linear transfer function. Now on layer 2 actually we try to represent the connecting weights between your the first neuron lying on the input layer and the first neuron lying on the your the second layer. So, that is nothing, but is your say v 11 then comes v 12 v 13.

Now, v 11 is going to represent near, v 12 is going to represent your half base width for the far and VFR the your v 13 is going to represent your the base width for very far right angle triangle. Similarly your the membership function distribution for the linguistic terms used to represent I 2 are actually denoted by v 24, then comes v 25, then comes your v 26. Now there are three linguistic terms for I 1, three other linguistic terms for I 2. So, here I have got actually the 9 rules and this is nothing, but the layer 3 that is the end operation layer and the layer 4 is nothing, but the fuzzy inference and layer 5 is a defuzzification.

Now, the connecting weights that is your w 11 w 11, then comes your w 21 and this is nothing, but w 31 are going to represent either the half base width or the base width of your the triangular membership function distribution used to represent the output variable. Now, let us see how to how to find out the deviation in prediction so, for this particular your the trading scenario.

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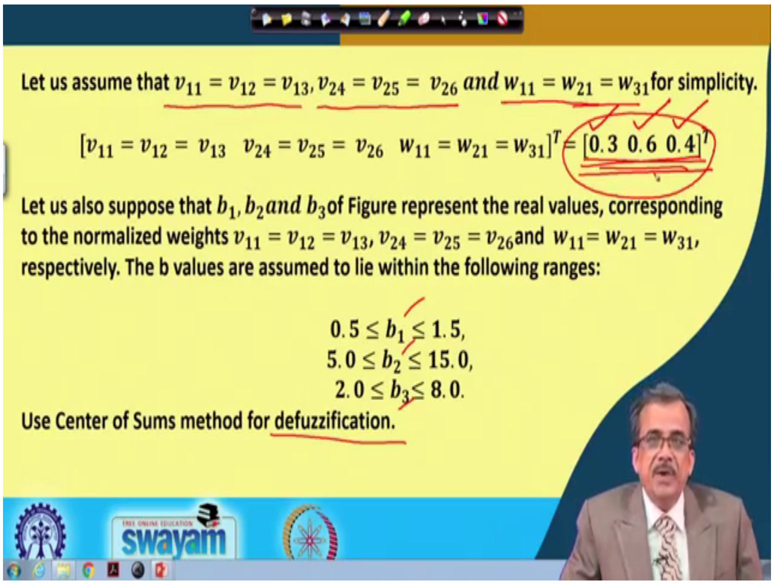

Now, as we discussed previously. So, here you can find out that v 11 is kept equal to v 1 2 and that is kept equal to v 13 just to ensure the symmetrical triangular membership function distribution for I 1. Then v 24 v 25 and v 26 are nothing, but your are going to represent the symmetrical membership function distribution to represent I 2.

Then comes your w 11 equals to w 21 equals to w 31 are used to represent the triangular membership function distribution for this your the output and we consider the symmetrical membership function distribution. Now, here we assume the numerical values for so, this particular v that is v 11 equals to v 12 equals to v 13 and that is kept equal to 0.3, then v 24 equals to v 25 equals to v 26 that is kept equal to 0.6, then w 11 is equals to w 21 is equals to w 31 so, that is kept equals to your 0.4. And you can see that so, all such values are in the normalize scale lying between 0 and 1.

Now, here the range for this b 1, b 2 and b 3; now this b 1 is going to represent what should be the half base width or base width of the triangular membership function distribution used to represent I 1, b 2 is the half base width or the base width of the triangular membership function distribution used to represent I 2. And b 3 is nothing, but it is going to represent either half base width or base width of the triangular membership function distribution used to represent the output and we are going to use actually the center of sums method for defuzzification.

Now, here one thing I should mention that although these values the v v and w values are in normalize scale. So, will have to find out the real scale values corresponding to this particular the normalize value, and considering the ranges for your the different variables like your b 1 b 2 and b 3. Now, b 1 b 2 b 3 are having different ranges and will have use this normalize value to find out what should be the actual real values for this b 1 b 2 and b 3, this I am going to discuss in details now.

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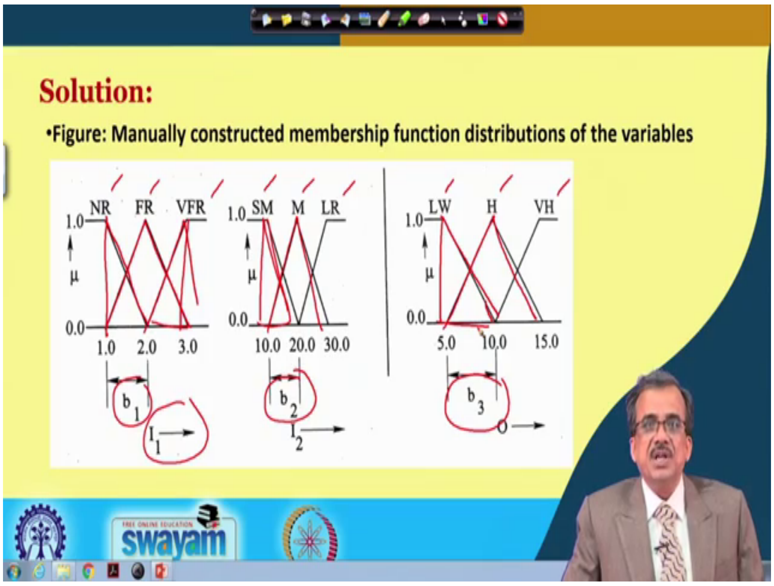

Now, this was actually the manually constructed membership function distribution for this I 1 I 2 and your the output and as I told that for this particular I 1, there are 3 linguistic term near far and very far and we are considering the triangular membership function distribution. Now, this is actually 1 right angle triangle here also we consider one right angle triangle and this is nothing, but the isosceles triangle and this b 1 is going to represent the base width of this triangular right angle triangle or the half base width of this isosceles triangle.

Similarly, to represent I 2 we use 3 other linguistic term that is your small, medium and large and the b 2 is used to represent the half base width of this isosceles triangle or the base width of this particular the right angle triangle. Now similarly to represent the output O, we use three linguistic terms that is your low medium and very high sorry low high and very high and b 3 represents either the half base width of this isosceles triangle or the base width of this particular the right angle triangle and for simplicity we are considering the symmetrical membership function distribution.

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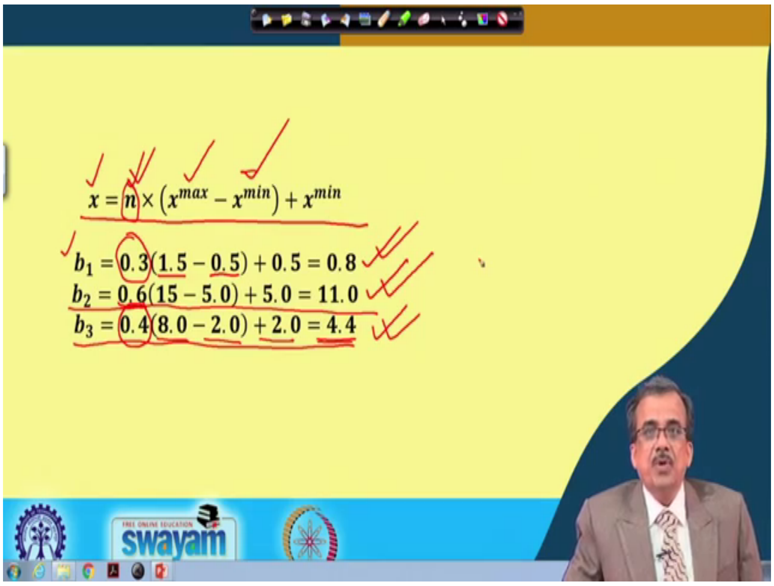

Now, as I told that corresponding to this normalized value of your the connecting weight. So, will have to find out the real values, how to find out the real values? Now, to find out the real values; so, we use this particular the equation that is x real value is nothing, but n, n is nothing, but the normalized value multiplied by x max minus x mean plus x mean. Now for a particular variable say b 1, if I know the normalized value that is nothing, but 0.3, if I know the maximum value for b 1 that is 1.5 and the minimum value for this particular your b 1 that is 0.5. So, very easily I can find out what is the real value for this particular the b 1.

So, the real value for this b 1 is found to be equal to 0.8 similarly we can find out the real value for this particular b 2 and b 2 is nothing, but the normalized value as 0.6 multiplied by. So, b 2 maximum is 15.0 b 2 minimum is 5.0 plus b 2 minimum is 5.0. So, this is nothing, but 11.0, similarly for this b 3 we can find out the real value. So, n is the normalized value 0.4, b 3 maximum is 8.0, b 3 minimum is 2.0 and b 3 minimum is 2.0 and if you substitute will be getting that is 4.4. So, the real value for v 1 0.8, b 2 is 11.0 and b 3 is nothing, but 4.4.

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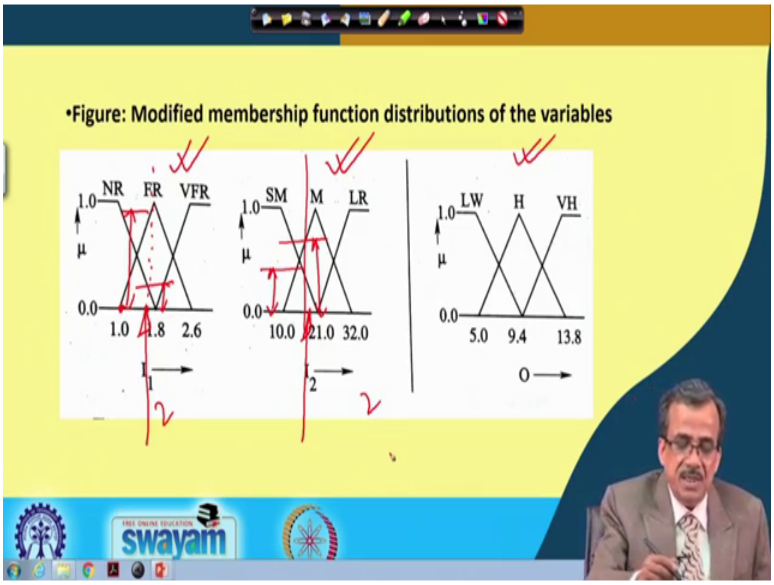

Now using these real values actually we can modify the membership function distribution now. So, the modified membership function distribution we look like this. So, the starting value for I 1 that has been kept constant to 1.0, but this particular b 1 I has been changed. Now similarly I will be getting this modified membership function distribution for I 1 similarly we get the modified membership function distribution for I 2, and we also get the modified membership function distribution for your the output.

And once you have got the modified membership function distribution, now if I just pass a particular value of I 1 input another value of this particular say I 2. Now corresponding to this particular I 1. So, I will be getting actually the two mu values one is corresponding to the near another is corresponding to your r. Similarly corresponding to this particular value of I 2. So, I will be getting so, a particular mu value corresponding to small another mu value corresponding to this particular the medium.

So, here there are 2 mu values here there are 2 mu values. So, 2 multiplied by 2. So, there is a maximum 4 fried rules and using that particular fried rules. So, will have to find out what should be the fuzzy find output and then will have to go for your the crisp output using defuzzification.

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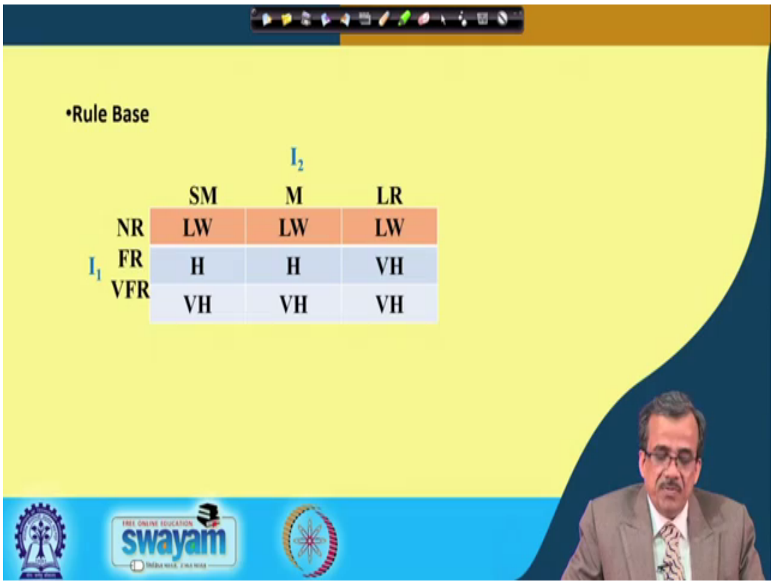

Now this table shows actually those 9 rules, the rules are as follows. So, if I 1 is near and I 2 is small then the output is low and so on. So, here we have got 9 rules and as you discuss that out of this 9 rules only 4 are going to be fired.

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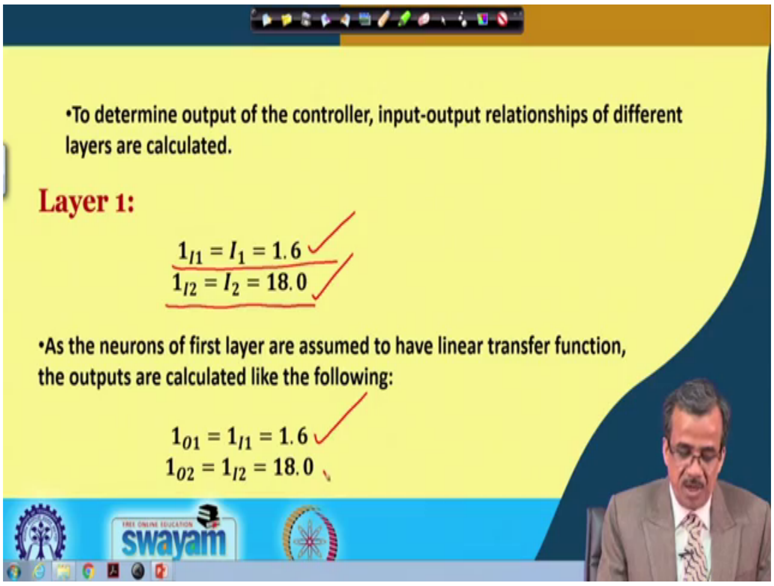

Now, whatever I discuss little bit. So, we have written it here. So, let us try to see. So, we can see that on layer 1 we consider the linear transfer function. So, the inputs are actually I 1 was 1.6, I 2 was 18.0. So, 1 I 1 is nothing, but I 1 is 1.6, then 1 I 2 is nothing, but I 2 is 18.0 and as we consider linear transfer function of the first layer. So, output is equals to input. So, 1 O 1 is nothing, but 1 I 1 is 1.6 then comes here 1 O 2 is equals to 1 I 2 is nothing, but 18.0.

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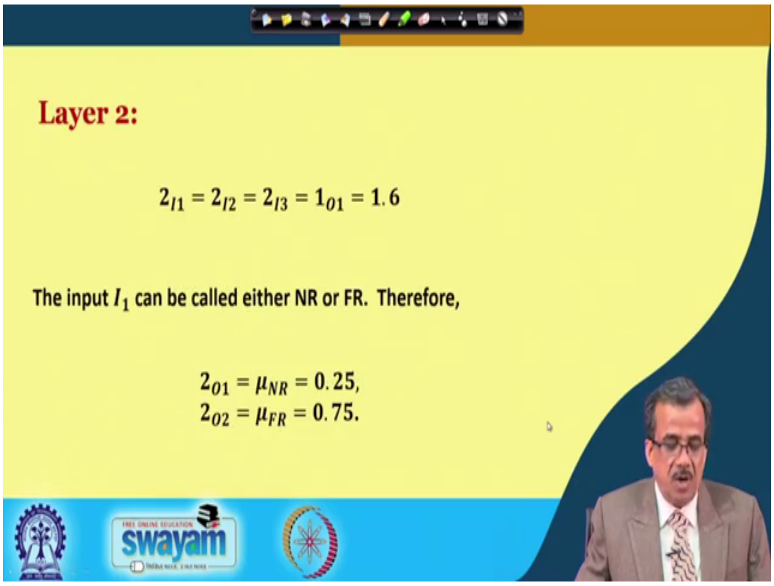

Now, here once you got this particular the output now actually what we do is, we try to find out what should be the mu value. Now I 1 is nothing, but I 1 is nothing, but 1.6 and I 2 was 18.0. So, corresponding to this 1.6 now if I just draw it here 1.6. Now if I draw 1 point 6 here then we can see that it could be near or it could be far. So, there are two possibilities. So, corresponding to this particular I 1. So, I 1 can be called either near or far.

Now, it can be called a near with some membership function value that is 0.25 and it can also be called far with another membership function value 0.75. Now for this triangular membership function distribution how to find out this mu value using the principle of similar triangle. So, that thing we have discussed in much more details. So, I am not going for that once again.

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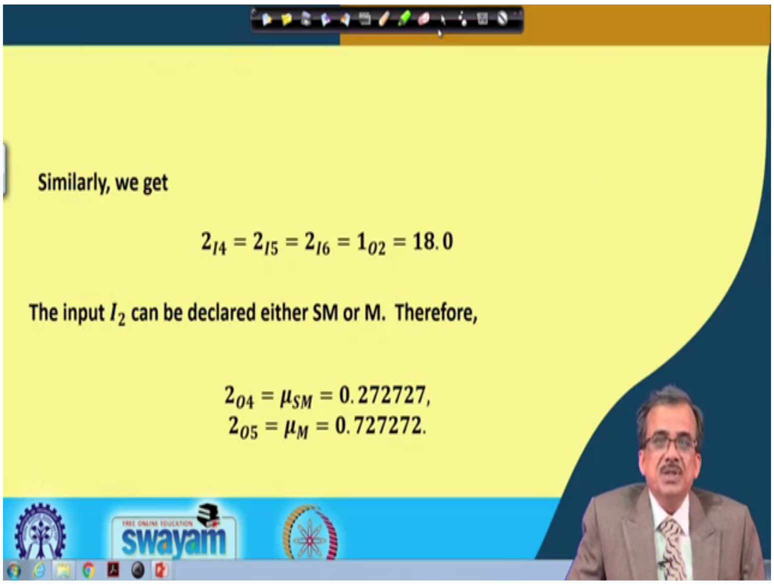

So, corresponding to I 1 the 2 mu values we can find out similarly corresponding to your I 2. So, this I 2 can be called either small or medium and we can find out mu small is 0.272727 and mu medium is nothing, but is your 0.727272. So, we can find out your the mu values that is a membership function values; that means, your the fuzzification is over.

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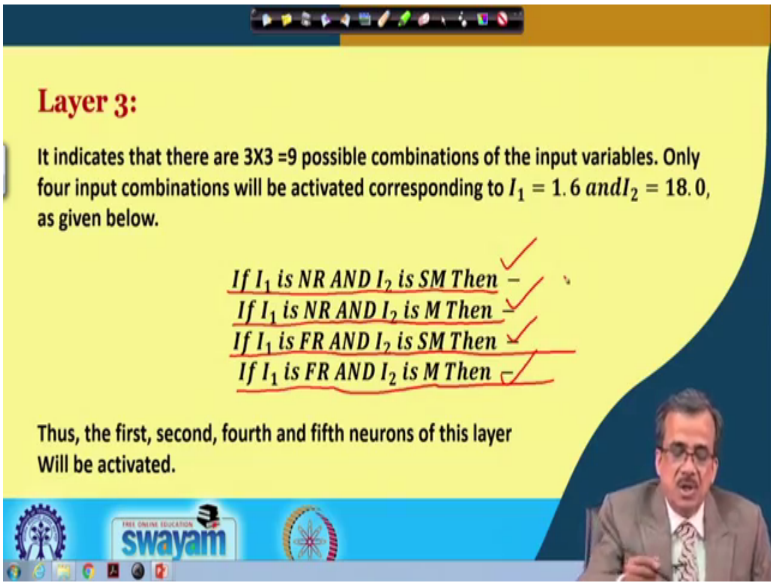

Now, once I have done this particular fuzzification now we go to layer 3. Now, as I told that on layer 3 we have got 3 multiplied by 3, 9 combination or the 9 possible rules and out of 9 in fact, only 4 rules are going to be fired. The 4 fired rules as follows if I 1 is near and I 2 is small then the output is something that are not written it here. The second fired rule if I 1 is near and I 2 is medium then the output is something the third fired rule if I 1 is far and I 2 is small then the output is something, then if I 1 is far and I 2 is medium then the output is something. So, there are 4 fired rules. So, out of9 4 rules are going to be fired now corresponding to this fired rules actually will have to find out what should be the output.

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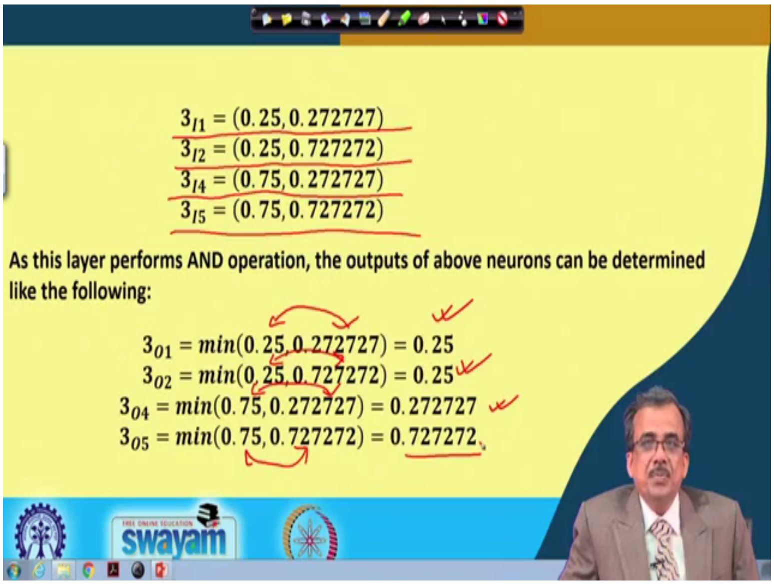

Now, if you see the inputs of the third layer. So, that is nothing, but your the 2 mu values corresponding with the first fired rule. So, 3 I 1 is nothing, but so, the 2 mu values that is 0.25 and 0.272727 then 3 I 2 0.25 and 0.727272 then 3 I 4 0.75 and 0.272727 and 3 I 5 0.75 and 0.727272 now we compare. So, we try to find out what should be the output of the AND operation layer.

So, 3 O 1 that is the output that is nothing, but the minimum between these two and this will be the minimum, then 3 O 2 is the minimum between these two and this will be the output and 3 O 4 is the minimum between these two. So, this is output and 3 O 5 is the minimum between these two and this is actually you are the output. So, we try to find out the minimum of the two mu values. And, once you have got this now we are in a position to know the output of your the third layer

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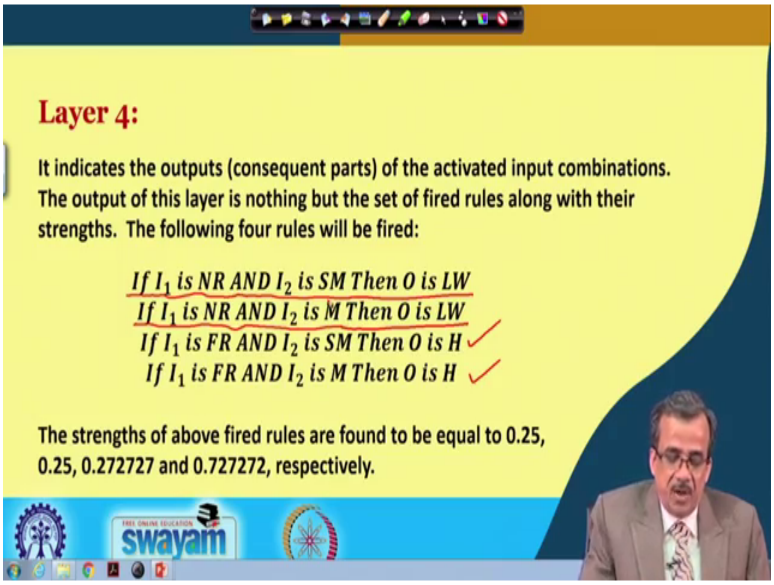

Now, we go for your the fuzzy inference and that is nothing, but layer 4. Now in the layer 4 corresponding to each of this particular input combination the fired input combination. So, we know this particular output for example, say the first fired rule is if I 1 is near and I 2 is small then the output is low. Similarly the second fired rule if I 1 is near and I 2 is medium then the output is low, similarly you can also read the third rule and the fourth fired rule.

Now, actually what will have to do is. So, will have to find out the firing strength of each of this particular rule of that firing strength we have already determined in as output of the layer 3. And once you know this particular fire strength firing strength now, we are in a position to find out like what should be the fuzzified output of each of the fired rules.

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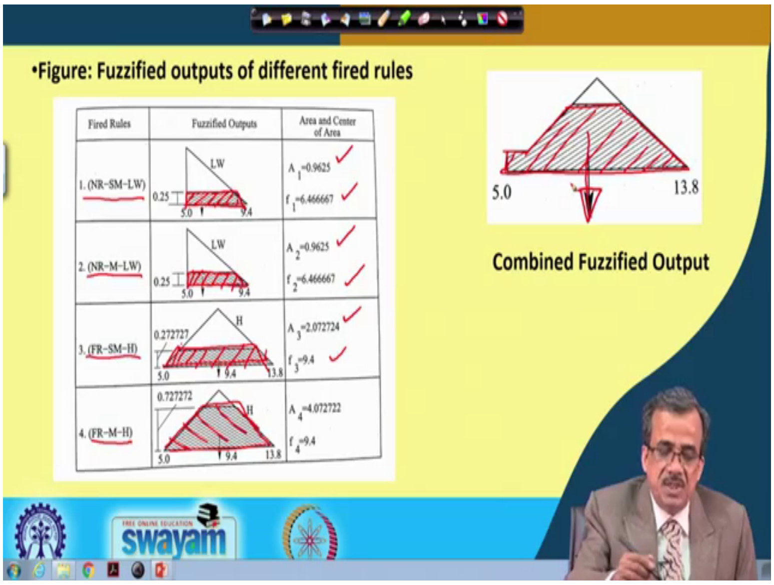

For example, say if you concentrate on the first fired rule that is your NR SM LW that is if I 1 is NR and I 2 is SM then the output is LW. So, I will be getting the fuzzified output is nothing, but so, this particular the shaded portion and its corresponding area and center of area we can find out and how to determine those things we have discussed in much more details.

The second fired rule if I 1 is near and I 2 is M then the output is low and this particular area is nothing, but is your the your the fuzzified output I can find out the area you can find out the center of area than the third fired rule if I 1 is far and I 2 is small then the output is high. So, I will be getting like this as the fuzzified output the shaded portion, I can find out its area and center of area. Similarly corresponding to the post fired rule the fourth fired rule if I 1 is far and I 2 is medium the output is your high. So, we can find out like what should be your so, this particular the fuzzified output.

And once you have got this particular fuzzified output now, actually we carry out the OR operation. So, just to superimpose also fuzzified output and if you superimposed also fuzzified output. So, you will be getting actually so, this type of combined fuzzified output. So, this is nothing, but the combined fuzzified output and once you have got this particular combined fuzzified output, we can use the centre of sums method for defuzzification and we can find out. So, this particular your the crisp output.

Now, this is the way actually we determine actually the crisp output for a set of input parameters.

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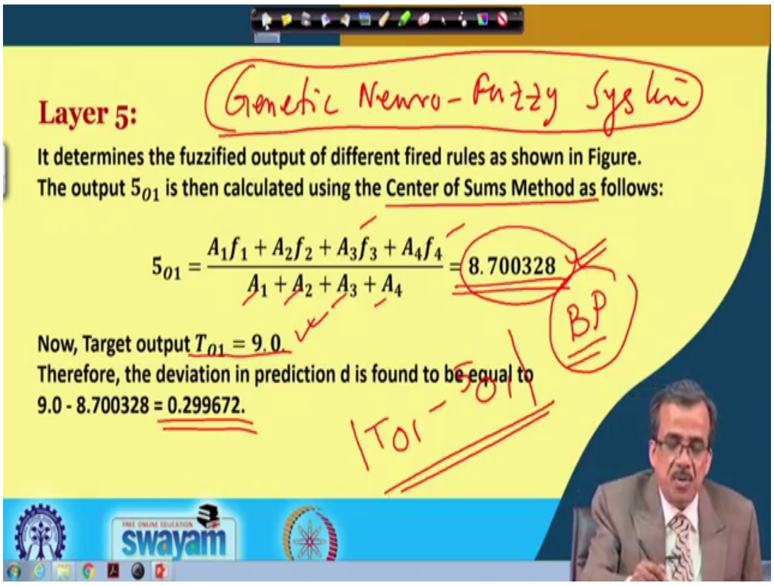

That means on layer 5 we carry out. So, this type of your defuzzification using the centre of sums method, and this 5 O1 is nothing, but the output of the first neuron laying on the 5th layer and that is nothing, but A 1 f 1 plus A 2 f 2 plus A 3 f 3 plus A 4 f 4 divided by A 1 plus A 2 plus A 3 plus A 4; so, we will be getting this as the crisp output. Now, if this is the crisp output. So, this particular crisp output can be used just to find out the deviation by comparing with your the target value that is a 9.0.

So, we compare so, this calculated value with the target value and we try to find out so, this particular the deviation. Now, this deviation could be either the positive value or negative value, but here fortunately we are getting the positive value. But, it could be negative also and that is why is better to find out actually the mode value of the difference between your TO 1 and that is nothing, but 5 O 1. So, we can find out so, the mode value of this particular the deviation.

Now, based on this particular mode value; so, what you do is so, this error will have to propagate it back for you have the further modification of the network. So, we can use the back propagation algorithm for its training or the tuning, but your the transfer function are to be defined in a very nice way. So, that we can carry out the differentiation at least the logical sense and we can implement this particular BP algorithm so, just to modify the connecting weights or other design variables of this particular the network.

Now, we can also use actually a genetic algorithm or any other nature inspired optimization algorithm. Now if I use the genetic algorithm. So, all the design variables we can keep it inside that particular the GA string, the GA will try to find out or try to evolve one optimal the neuro fuzzy system. And if you use genetic algorithm just to evolve that optimal neuro fuzzy system so, that will be known as actually your genetic neuro fuzzy system. So, genetic neuro fuzzy system is this so; that means, you are using the genetic algorithm just to evolve the neuro fuzzy system that is nothing, but the genetic neuro fuzzy system.

So, this is the way actually we can combine this your fuzzy logic and neural network particularly this Mamdani approach, and we can design and develop the optimal fuzzy reasoning tool based on the Mamdani approach. And, this particular the fuzzy reasoning tool has been implemented using the structure of a network and these structure we can utilize for further tuning training and ultimately we are going to train that Mamdani approach of fuzzy reasoning tool. Now, this is the way actually we can develop your the neuro fuzzy system.

Thank you.