Pattern Recognition and Application
Prof. P. K. Biswas
Department of Electronics and Electrical Communication Engineering
Indian Institute of Technology, Kharagpur

Lecture - 33
Reflex Fuzzy Min Max Neural Network

Today, we are going to discuss about the construction of reflex fuzzy min max neural network, which makes use of the compensative neurons. So, in the last class we have said or we have seen that how to construct a fuzzy min max network. But there is no concept of the reflex mechanism or there is no concept of compensation to the membership functions computed by the different nodes or the different neurons, which represent the different hyper boxes.

So, I will take the same example as in that example we had two cases; one of the overlap of hyper boxes and one of the contentment of hyper boxes belonging to different classes. And see that without modifying the min max points of the classifying neurons, how we can add the different types of compensation neurons to have reflex fuzzy min max neural networks. So, I will take the same example that we have taken in the last class.

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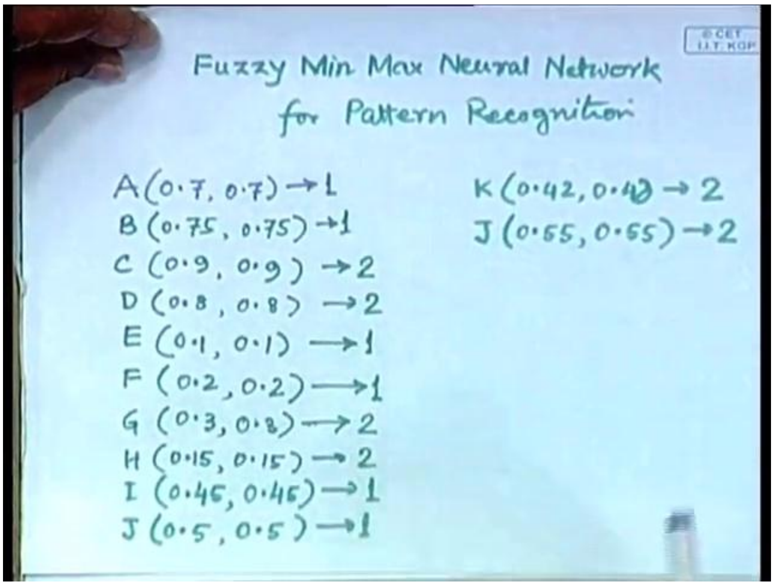

That is we have taken a set of points as given over here. So, if I take the first point, that is 0.7, 0.7.

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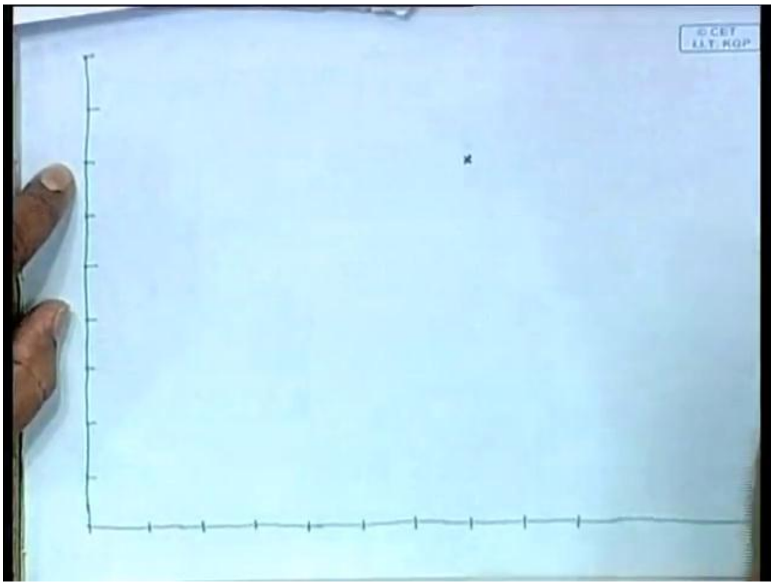

So, 0.7, 0.7 as we said comes somewhere over here, that is this point. So, whenever we have A this telling example of feature vector as we said that we construct a neural network or we construct one neuron.

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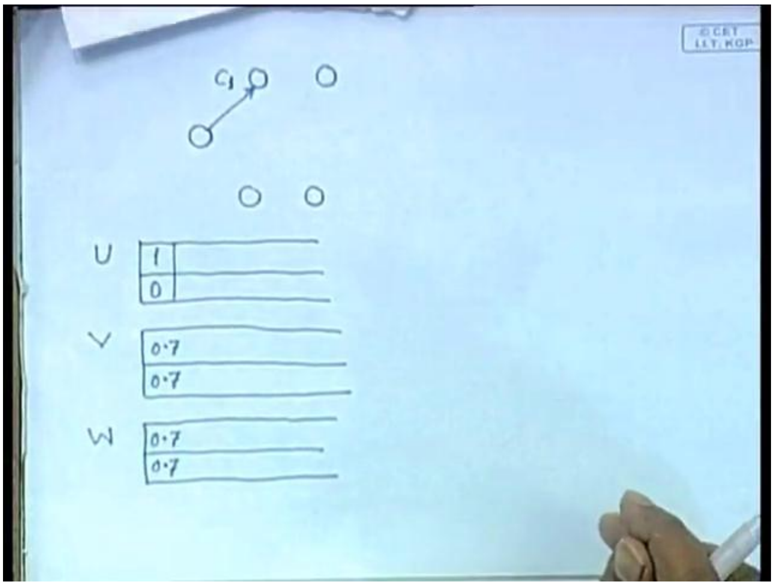

In the middle layer of all fuzzy neural min max network as we said that we have the number of input nodes and the number of output nodes which are fixed. So, as we are considering two dimensional feature vector, so number of nodes in the input layer will be

2 and as we are considering just two classes, C 1 C 3. So, number of nodes in the output layer will also be fixed.

So, earlier what we tried to see is we try to construct three metrices, one metrics is U and the other metrics V and the third metrics W, right? U metrics represent a connection from the middle layer neurons to the output layer neurons. And V metrics and W metrics they represent the min max points of the hyper boxes represented by different neurons. So, as we said that each of these matrices will have two rows and the entries in the matrices will be made, while the neural network is trained. So, once I get this first training sample this represents a point hyper box for which the min point and max point will be the same. And as we know that this point belongs to plus 1.

So, in the U metrics I will make an entry 1 0 indicating that this neuron is connected to the output layer neuron, representing class C 1 and the min points and max points. And max points will be same as this feature vector, that is 0.7, 0.7. So, we put 0.7 over here and 0.7 over here. Here also you put 0.7, here also you put 0.7 and then when I took we take the second point, that is 0.75, 0.75 which also belongs to the same class, class 1.

So, the hyper box configuration in it will come over here, and I can expand the previous hyper box to include these points. So, I take a hyper box something like this and as we said that, as you are not creating any new hyper box so there is no neuron added in the middle layer, and as such the U metrics remain the same. Now, what happens is the min point and the max point.

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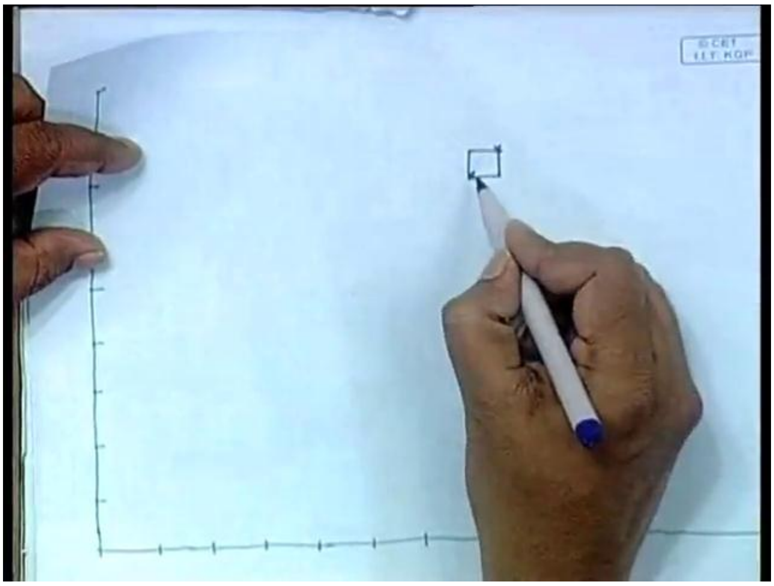

So, you find that the min point that remains the same as 0.7, 0.7 whereas, the new max point becomes 0.75, 0.75. So, I make the corresponding change in metrics W representing the max point, then I take the third point training sample which is 0.9, 0.9 at the and this can example belongs to plus 2. So, obviously have to make a new hyper box and over here it will be again a point hyper box representing 0.9, 0.9, and that will be somewhere over here, and because this belongs to class C 2.

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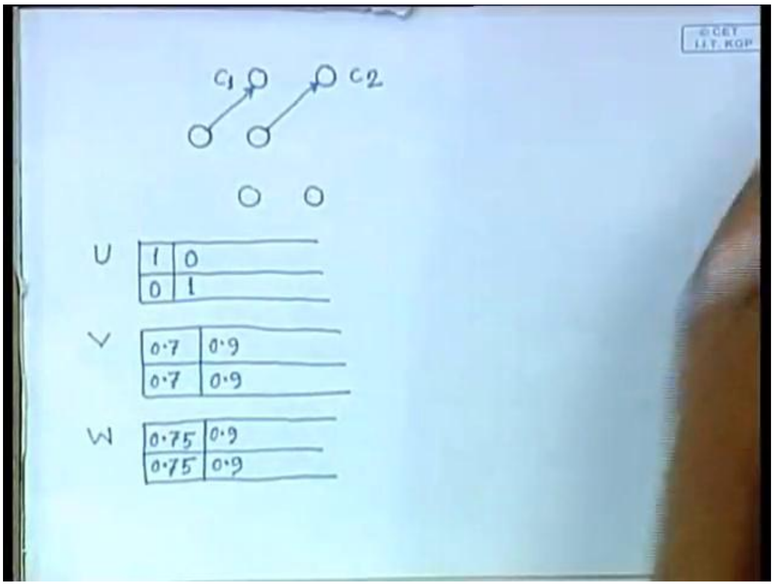

So, obviously I have to make a new neuron in the middle layer and as this neuron belongs to class C 2 so I will have the connection from here to here, at this output layer neuron represents class C 2. Accordingly, in the new metrics I have represent, I have the entry 0 1, the min point and max point of this new hyper box, because it is a point hyper box. Again it will be 0.9 and 0.9. Here also it is 0.9 and 0.9, okay? So, then I take the next point which is 0.8, 0.8 and this also belongs to class C 2.

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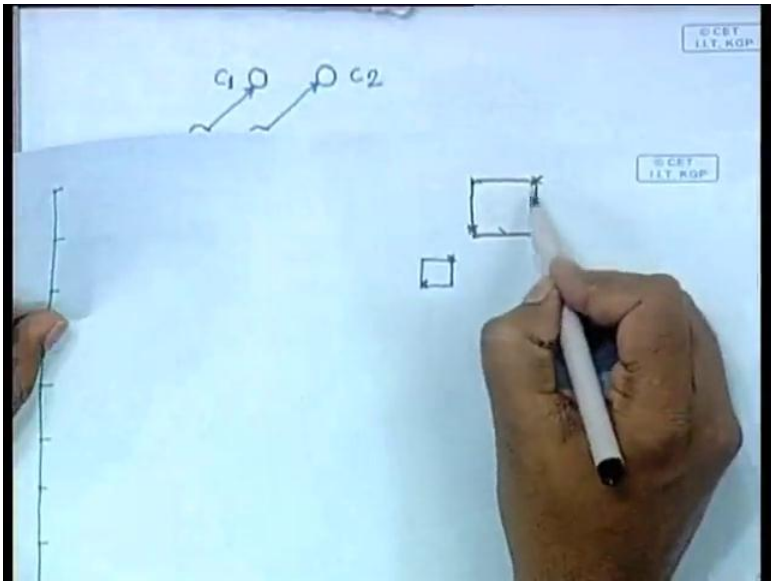

So, I take this next point which comes here 0.8, 0.8, this point. And assuming that this can be expanded to include this point I expand this hyper box to include this point.

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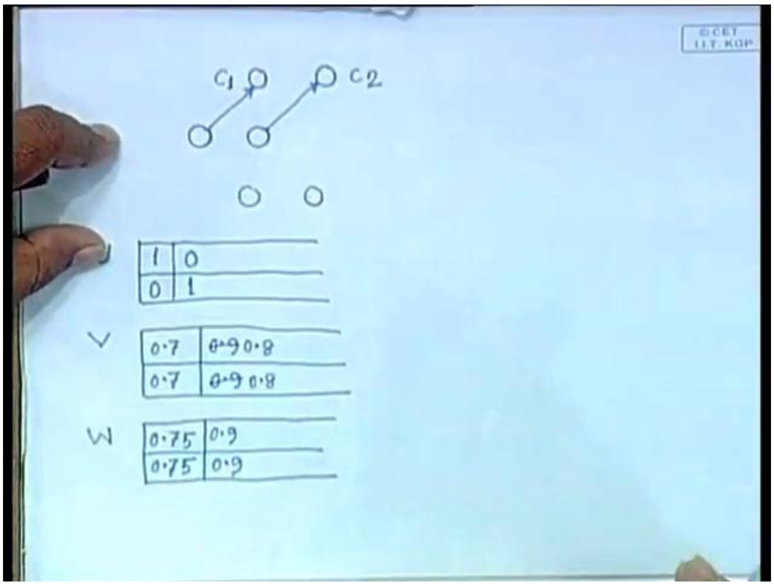

Accordingly, there will not be any change in the middle layer neuron and there will not be any change in the U metrics, but the min point and max point we have to change and over here the max point remains the same, that is 0.9, 0.9 and the min point that becomes 0.8, 0.8. So, I change the min point to 0.8 and 0.8 and then I take the other point, that is 0.1, 0.1.

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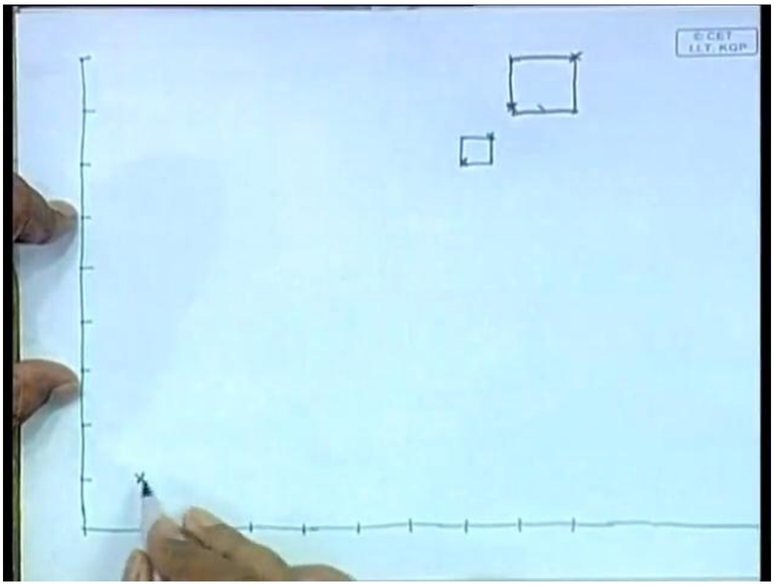

Centres in this is 0.1, 0.1 and here as this cannot be included within the first point because this also belongs to class C 1. And this also belongs to class C 1, I cannot expand this to include this. So, I have to enter a new node in the middle layer.

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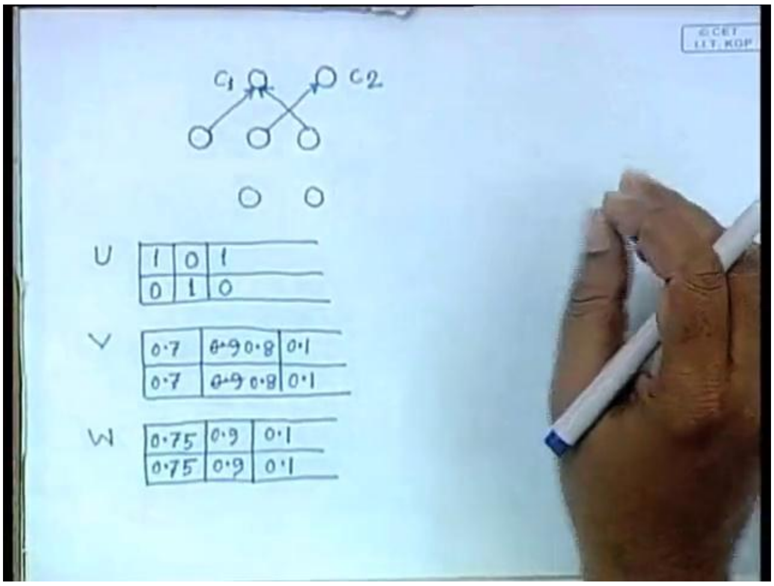

And this node belongs to class C 1. So, accordingly I have to enter in the U matrix, 1 0 and the new entry in the min point and max points will be 0 1 0 1. Similarly, here it is 0 1 0 1 then come to the next point, which is 0.2, 0.2 again belonging to the same class C 1.

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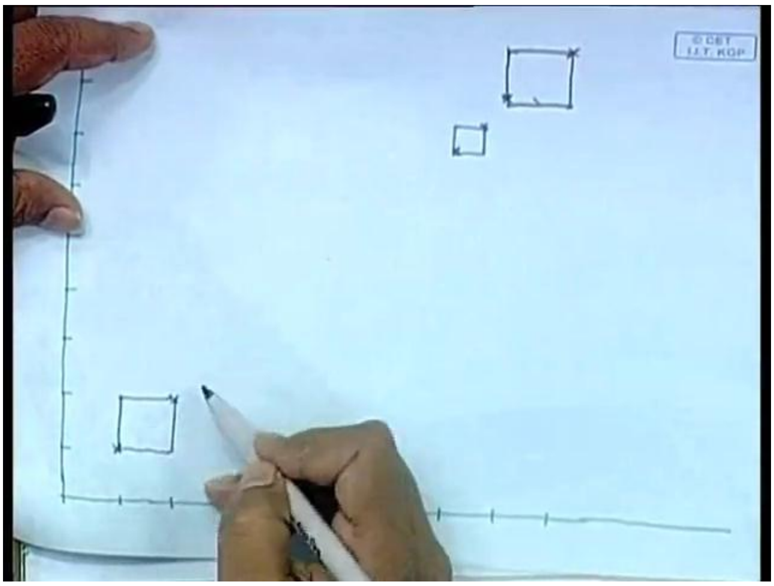

So, 0.2, 0.2 is over here, I can expand this point hyper box to include this 0.2 0.2. So, I am not adding any new hyper box.

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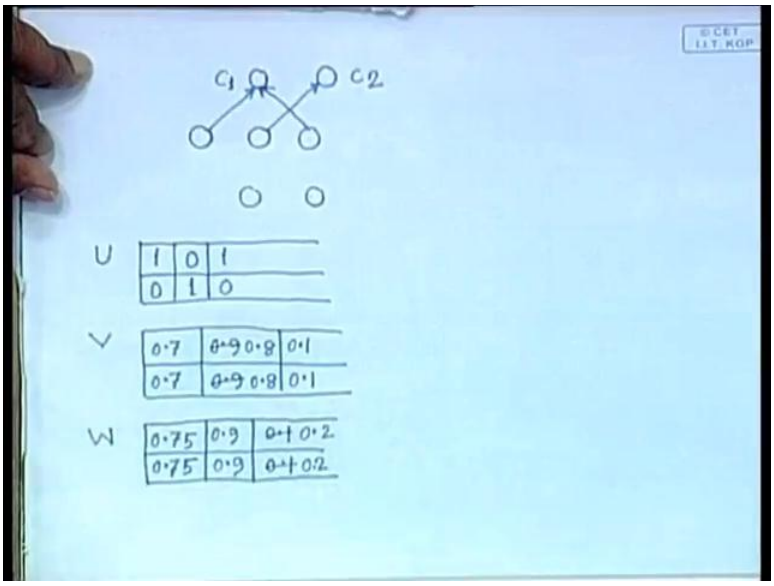

So, accordingly there will not be any change or any node added in the middle layer and there will not be any change in the U matrix.

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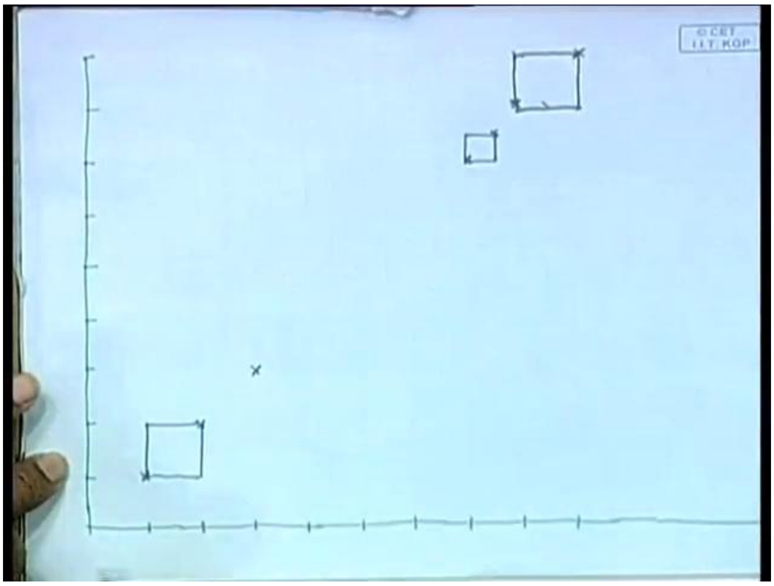

However, the min point and max point of the previous hyper box which has been expanded that will change.

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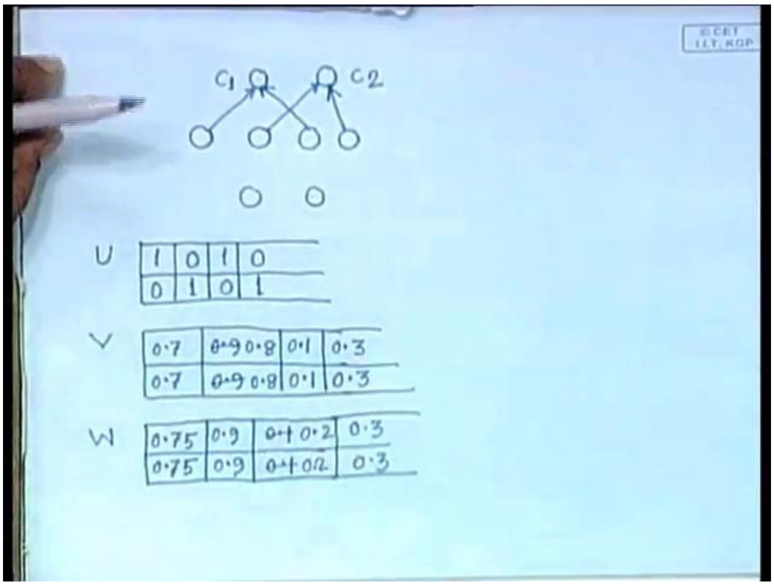

Here the max point will be 0.2, 0.2, okay? Then take the next point which belongs to class C 2 and the vector is 0.3, 0.3.

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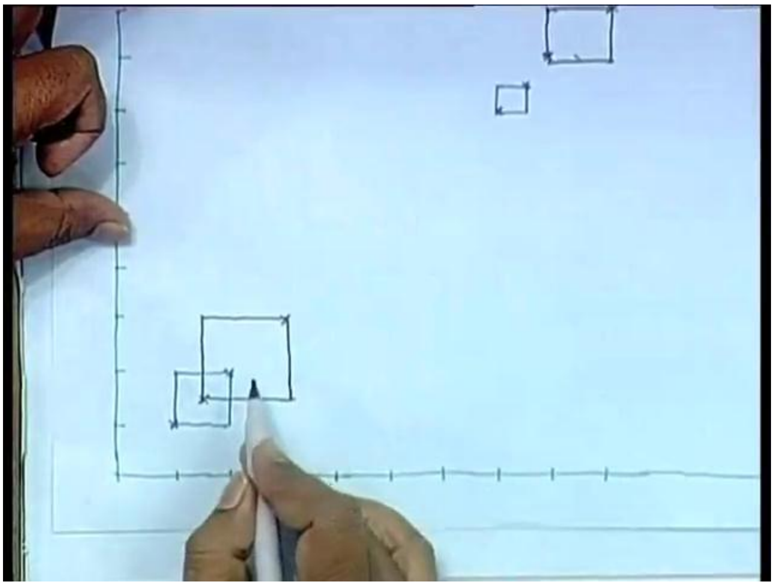

So, I take this 0.3, 0.3 which is over here and this belongs to class C 2. So, I have to add new neuron in the middle layer.

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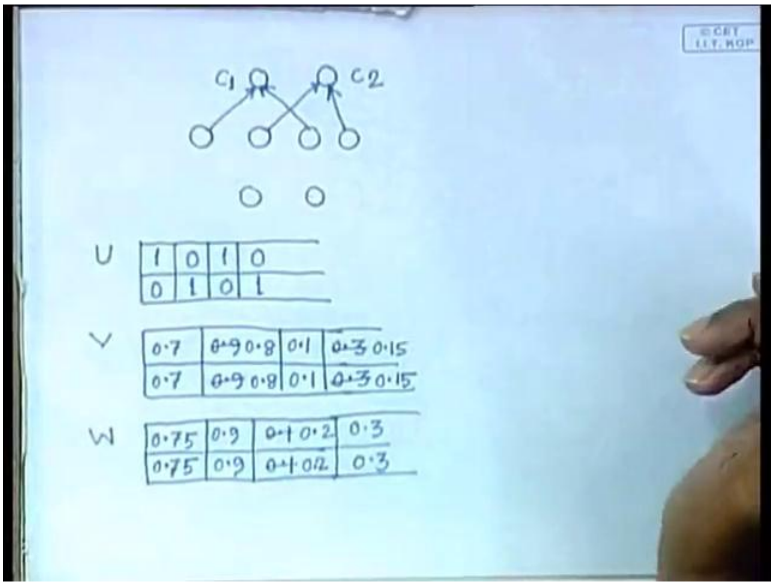

So, I have to add a neuron over here and these belongs to class C 2. So, I have to change. I have to make an entry in the U matrix which is 0 1 and for this one I have to enter the min point and max point. And this being a point hyper box, both of them will be 0.3 and 0.3, okay? Then I consider the next one which is 0.15, 0.15 belonging to the same class C 2. Say you enter 0.15, 0.15 expand this point hyper box to include this 0.15, 0.15. So, when I expand this what I have to do is, because I am not adding any new node so in the middle layer the structure will remain the same. In matrix U I do not have to make any more entry, only the min point and max point of this two will be different.

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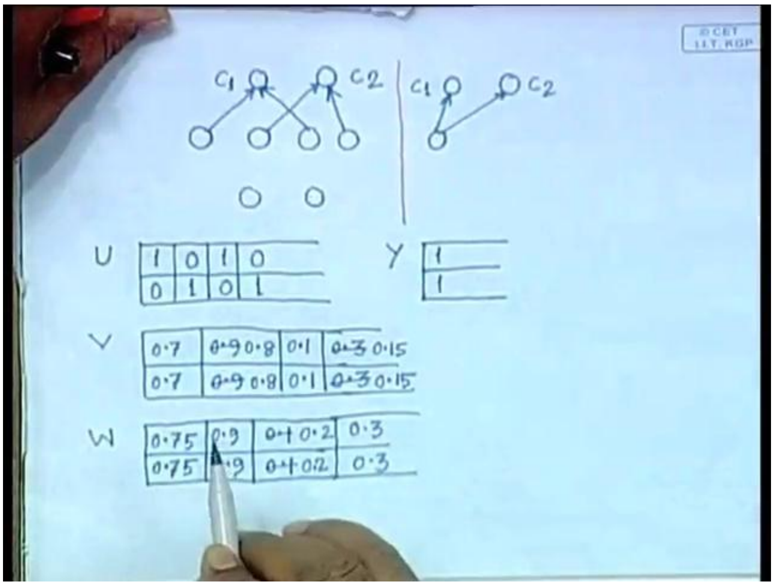

So, the min point, new min point of the previous hyper box will be 0.15 and here it is 0.15. Now, there will be a difference between the previous neural network that we were constructing and this new neural min max network we are making, because in this case you will find that there is an overlap, I have a overlap in this particular region.

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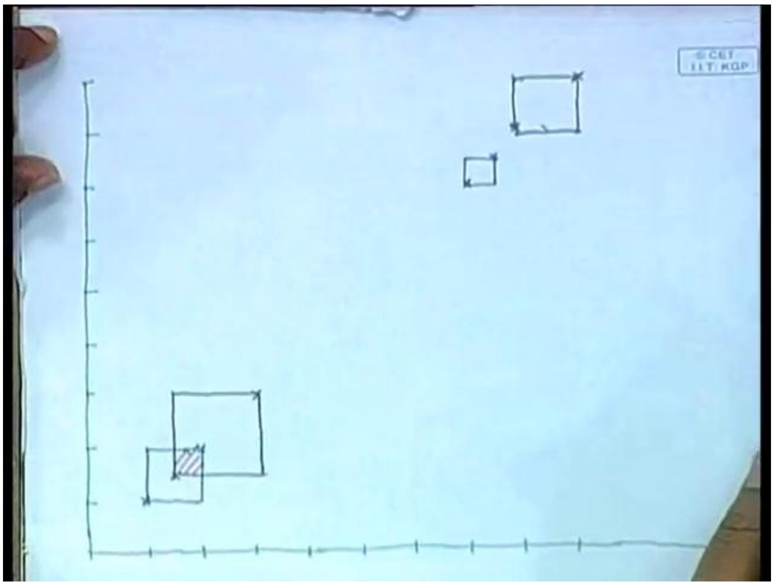

So, what I have to do is in a compensatory section I have to add a new neuron which represents a hyper box of this overlap region. So, I will add a new neuron in the compensation section or in the reflex section. So, I will put over here in the overlap compensation section, I will add a new neuron.

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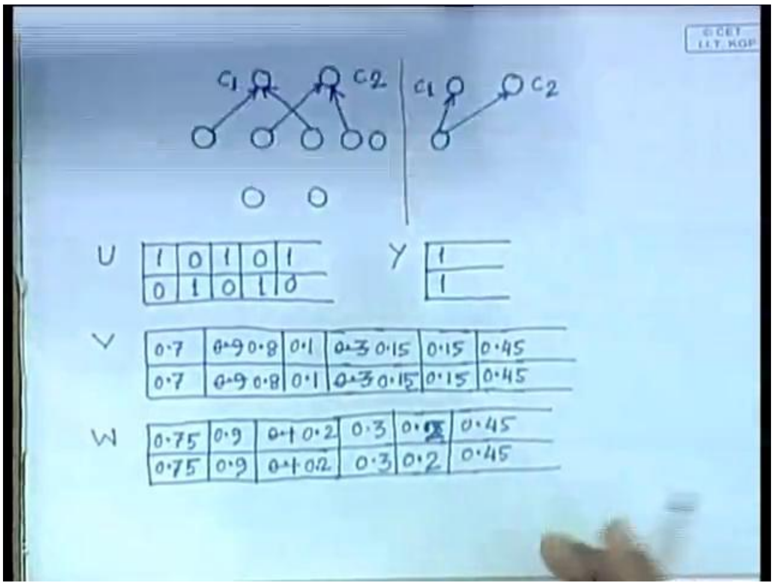

In the overlap compensation section also I will have two output layer nodes, one corresponding to class C 1, other one corresponding to class C 2. And the function of this overlap compensation neuron will be to calculate, what is the amount of compensation that has to be provided while calculating the membership function. And that compensation has to be added to the outputs of the neurons as given in the classification section.

So, it has to get compensation to both C 1 and C 1. So, it has to give compensation to this class, also it has to give compensation to this class. So, this is an output layer neuron in the reflex action responding to class C 1 and this is output layer neuron in the reflex section corresponding to class C 2. However, so accordingly as we had proposed the matrix U over here, let us assume that for this overlap compensation section I have another matrix, say Y. And in this matrix Y because this neuron is feeding the output to both class C 1 and C 2.

So, both of them will be made equal to 1. However, if I have three classes, three such classes, one of the class will be equal to 0. Because every node in the middle layer in the compensation section or overlap compensation section provides compensation only to two classes corresponding to the two hyper boxes, belonging to classes which overlap. So, every neuron in the middle layer over the overlap compensation section will be connected to two output layer neurons in the overlap compensation section. So, here it is this Y matrix will be 1, 1 and the min point and max point of this particular hyper box will be the min max point of this region.

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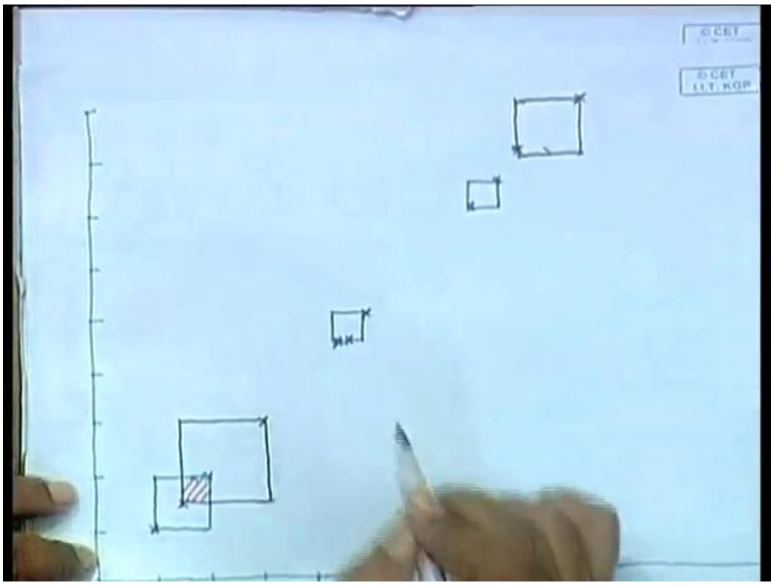

So, here you find that the max point is given by 0.2, 0.2 and min point is given by 0.15, 0.15, okay? So, accordingly more than two hyper boxes overlap in the same region is unlikely, because whenever by expansion hyper box gets over lapped with another hyper box the same hyper box will not be expanded any more. The reason then if there is such a possibility then I will have pair wise compensation class 1 class 2, class 1 class 2, class 1 class 3 like that, but it is quite unlikely because once the hyper box overlaps, the same hyper box will not be expanded. So, here the min point is 0.15, 0.15 and the max point is 0.2, 0.2.

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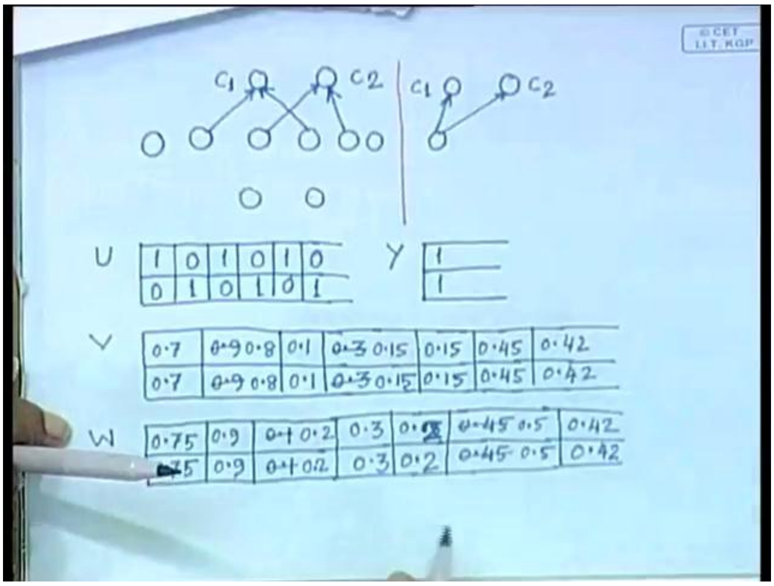

So, corresponding to this particular neuron I will enter in V matrix and the W matrix. The min point and max point as 0.15, 0.15, and here it will be the max point will be 0.12, sorry 0.2 and 0.2. So, these are the min point and max point of the hyper box. So, the node in the overlap compensation region, but you notice that unlike in the previous case where we had broken these two hyper boxes to avoid such overlap

Accordingly these min max point are changing, but here we are not disturbing the hyper boxes which are already created in the classification section. So, that ensures that the points which are already launched, that knowledge which is already acquired, this knowledge will not be disturbed. And after that when I take the next point, that is 0.45, 0.45 which belongs to class 1.

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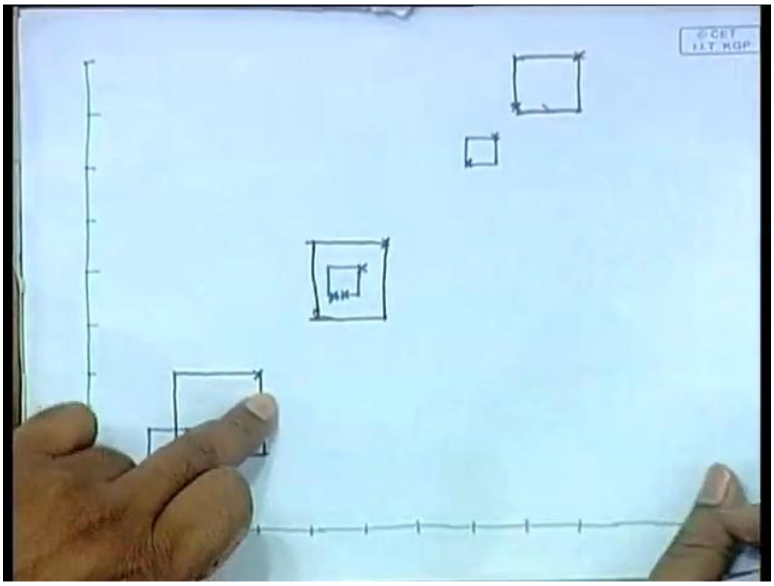

So, 0.45, 0.45 that will come somewhere over here and this belongs to class 1.

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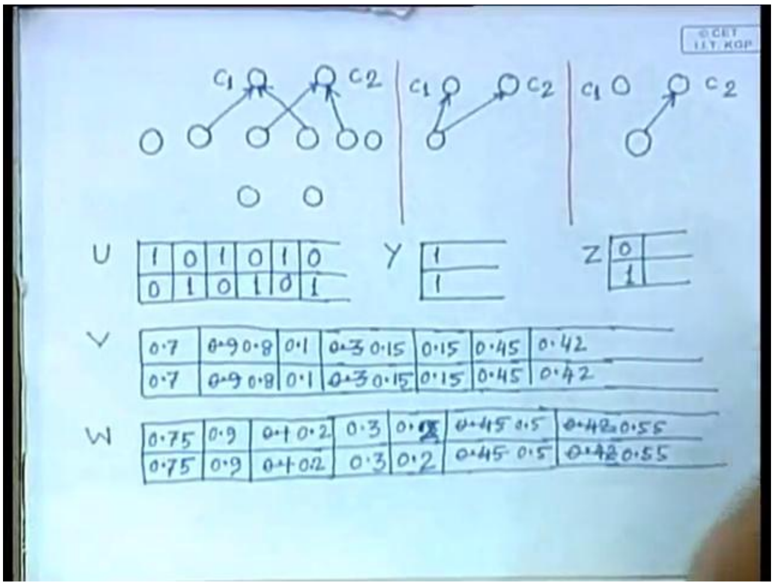

Again for this I have to enter one node in the classification section and this node belongs to class C 1. So, I have to make in the U metrics an entry which is 1 0 and min point and max point of that is 0.45, 0.45 max point will also be 0.45 and 0.45, okay? Then I take the next point which is 0.5, 0.5 that is this one. Put over here, the previous one is 0.45, 0.45 is somewhere over here, 0.5, 0.5 that points come over here.

So, I have this hyper box and I do not have to add any node, because the node is already added. So, accordingly I do not have any modification, the U matrix but V and W matrices will be changed, but the min point is the same, but the max point now becomes 0.5 and 0.5.

Then I take the next point which is 0.42, 0.42, that will come somewhere over here. This belongs to class C 2. So, for this I have to add one more node, does not matter if I put on this side. And for this the min point and max point will be 0.42, 0.42 and because new node is added so I have to make an entry in the matrix U and this belongs to class C 2. So, the entry matrix U would be class C 1 and for this my min point and max points will be 0.42 0.42 0.42 0.42. Then I take the next point which is 0.55, 0.55 put in this 0.55, 0.55 this is 0.55 this was 0.55, 0.55 comes over here.

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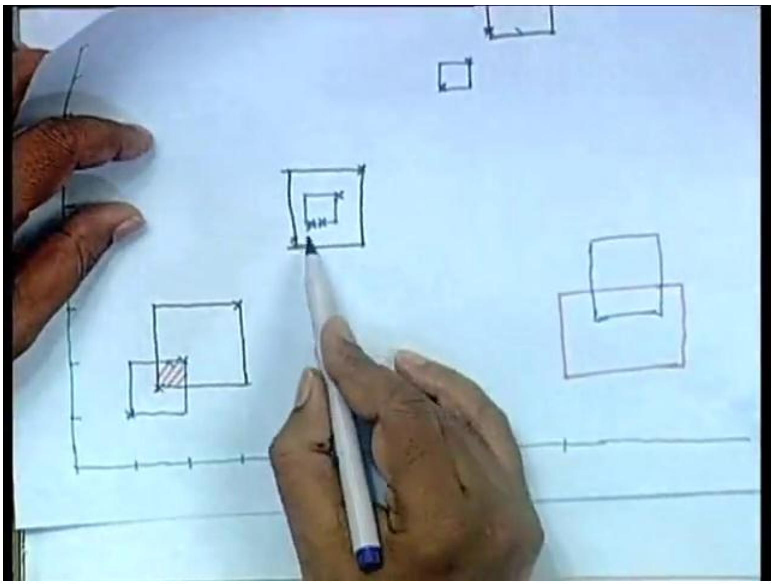

I expand the previous hyper box. So, accordingly because it is expansion of the previous hyper box was any entry in the middle of the classification section. So, the classification section remains the same. U metrics also remains the same, but the change I have to make is in the max point of this new neuron, that is now added.

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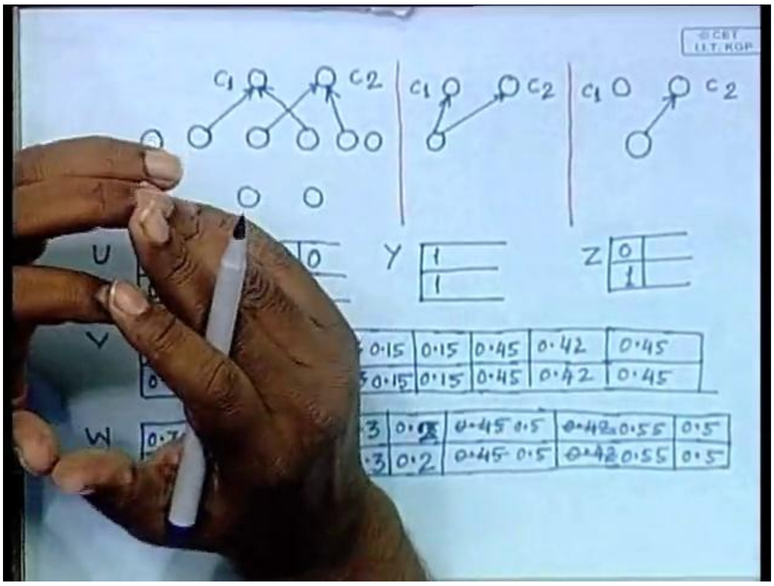

So, when I change this max point it becomes instead of 0.42, 0.42 it becomes 0.55, 0.55 but while doing so you find that I have a containment. So, because there is containment I have put one compensation neuron in the containment compensation section. So, in one more section that is containment compensation, so I have one more section here. Again I will have two neurons in the output layer corresponding to class C 1 and corresponding to class C 2. I have to add one compensation neuron containment compensation neuron.

So, to and this containment compensation neuron will give the compensation output to one of the classes, not to both. So, it will compensate the membership function of the class which contains the hyper box of the other case, right? So, accordingly the output of this neuron will be connected to class C 2 and not to C 1. Because the membership function of class C 1 is not to be compensated under the membership function of class C 2 is to be compensated. So, accordingly I have to have it, pardon container has to be compensated, not the one which is content.

So, because here it is hyper box no need to class C 2. So, the output of this neuron will be fed to the classifying neuron C 2 in the containment compensation section. And to have this connectivity there is a code that will maintain another matrix, which is Z matrix, and here the entry will be 0 1, right? And you find that unlike in case of overlap where both the min point and max points are changed. In this particular case, I have the same hyper box belonging to class 1 whose min point and max point will be the min point and max point of this particular neuron. However, that is not always the case because I can have a situation where I will have partial, as we have already said that I can have a containment of this form.

Suppose, I have one hyper box like this belonging one class and I can have another hyper box like this, which belongs to another class, where this hyper box is not fully contained in this hyper box. But still it is containment because one of the dimension is content in the respect dimension of the other hyper box. So, to take care of such situations I have to make entries in the U matrix and the W matrix, those indicate that what will be the min point and max point of this particular neuron. And here the min point and max point of this neuron, this neuron is nothing but the min point and max point of the neuron, which is previously added. So, for that the min point max point was 0.45 0.45 0.5 0.5, right? So, I will have 0.45, 0.45 and here it is 0.5 and 0.5.

So, you find that these two matrices B and W, they give you the min point and max point of all the hyper box nodes in the middle layer, whether that node is in the classified section falling overlap compensation section or in the compliments section, matrix U to give you the information of the connectivity from the middle layer nodes to the output layer nodes.

In the classifying section matrix Y gives you the information about connectivity between the middle of nodes to the output layer nodes in the overlap compensation section. And this matrix Z that gives you the information of connectivity between the middle layer nodes and output layer nodes in the containment compensation section. And after this is done what is required is that I have to combine the correspond outputs of the corresponding classes.

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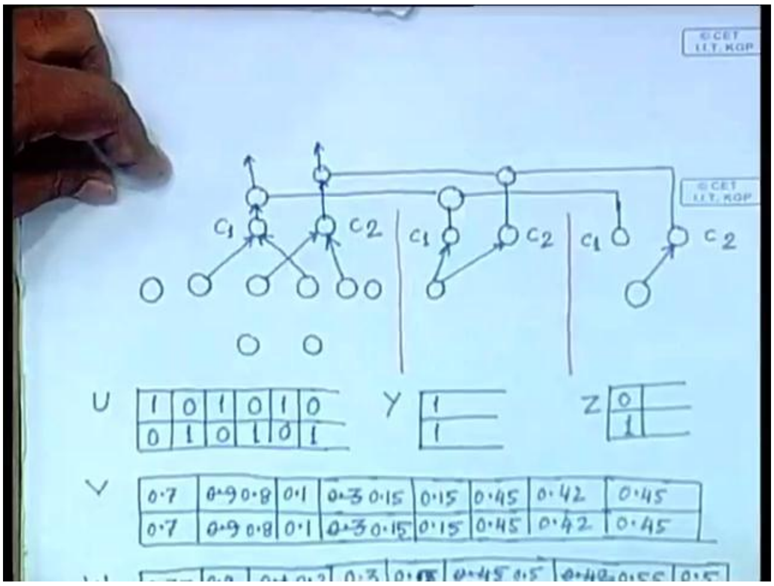

So, I have to combine the compensation output of class C 1 over here with the compensation output of compensation class C 1 over here. Similarly, I have to combine the output of compensation neuron C 2 over here and output of this. So, that gives you the overall compensation that has to be made and finally, this is to be added to the membership function which has been computed by the classified neuron section. So, it comes over here. Similarly, over here and so final membership output I get from this point. So, these are the memberships which of the compensated membership functions of the sample to two different classes.

So, then what we said is same case of overlap, I want that if a sample is somewhere over here that means it is near the min point and max point of one of the hyper box. If this distance is greater than the distance of the same point from the min point and max point of the other class, then its membership the previous person. Similarly, if the point is somewhere over here, which is nearer to min point and max point of this class then the min point and max point of this class, then the membership function of this point to this class is more, okay?

Similarly, in case of containment if the point belongs inside then its membership to this content class has to be 1. Its membership to the container class has to be 0. So, the membership functions of the compensation that has to be computed in case of overlap and the compensation that has to be computed. In case of comp containment they are different.

So, accordingly the functions, the compensation values which are to be computed by the middle layer neurons in the overlap compensation section. And the compensation has to be computed by the middle layer neurons in the containment compensation section, they will be different. So, how do they differ if I take a neuron input connections to the middle layers are given by the matrices V and W. It is the same matrix which is used for these connections, used for this connections because what I need over here is for this neuron.

What is important point for this neuron? What is the min point max point? And for each of these neurons what are the min points and max points? So, the inputs connections to all these neurons in the middle layer, whether it belongs to classifying section or it belongs to the compensation section, whether overlap compensation or containment compensation, all of them will come from the corresponding entries from the V matrix and U matrix. So, considering this that the compensation that has to be given to different classes at different compensation that has to be computed by the overlap compensation neurons, and containment compensation neurons are different. So, the kind of compensation that we can compute something like this.

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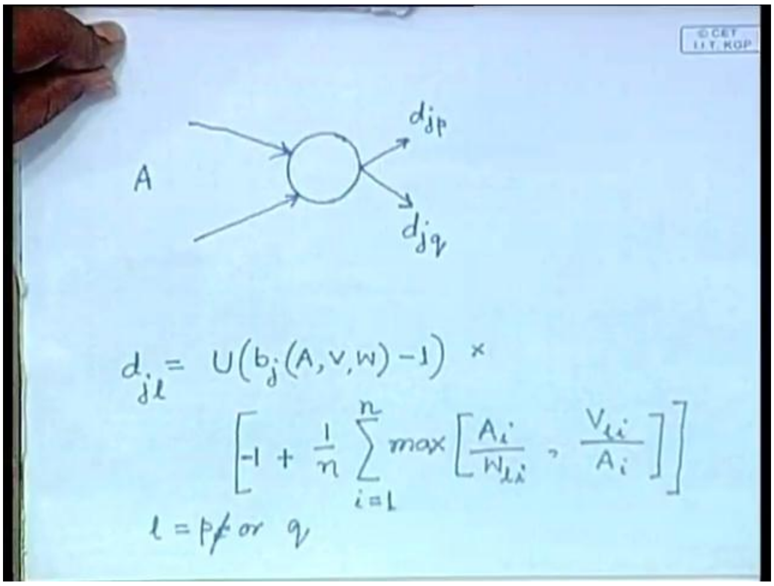

So, we said that if we consider a neuron in the middle layer of the of the overlap compensation section, okay? So, to conclude this what are the imports that it makes that it needs? Obviously, it needs the information of the input vector A because that will decide, I mean location of this A will tell whether this is in the overlap section or not. In the overlap section, it also needs the information of the min points and max points of the hyper boxes which are overlapped. That will be used to calculate the amount of compensation that you want to give.

And it also needs the information of min point and max point of this node itself, because that will be used to check whether this point A is within the overlap region or it is not within the overlap region. And this neuron will give me two outputs corresponding to the two hyper boxes that is developed. I can put it like this, if this neuron in the overlap region I represent this by say d j.

So, this will give me two outputs, one corresponding to say the d j p and one corresponding to d j q. Indicating that the hyper boxes labelled as p and hyper boxes labelled as q, they have overlapped. And accordingly this output will be connected to the qth output layer neuron, and this output will be connected to input of the q thou put layer neuron and the output function can be put like. This is d j, let me put it as l that will be is equal to U b j A V W minus 1 into 1 minus, sorry minus 1 plus 1 upon n summation of max A i by W l i and V l i by A i. But this summation will be i varying from 1 to n. If i have n dimensional feature vector and this l can be p or q.

So, what does this expression give you? This b j A V W, this V and W these are min points and max points of this neuron, that is the compensation neuron. Whereas, this V land W l they are the min points and max points of the hyper boxes which has overlapped. So, this v and w there are the min points and max points of the compensation neuron. Whereas, V l and W l min points and max points of the hyper boxes which are overlapped.

So, you find that this function b j A V W, this is the same membership competition function of the classified section neurons. So, there we said that if a point falls within the hyper box then is its membership function, membership value will be equal to 1. So, this V and W these being the min point and max point of the overlapped region. So, if a point falls within the overlap region then this b j A V W will be equal to 1.

If it does not fall within the overlap region then the value of b j A V W will be less than 1 and its value will depend upon how far it is from that hyper boxes. So, you find that if the point falls within the hyper box then b j A V W minus 1 is equal to 0. If it falls out outside the hyper box the overlap region in that case is this value is negative and if I use this U to be the unit step function.

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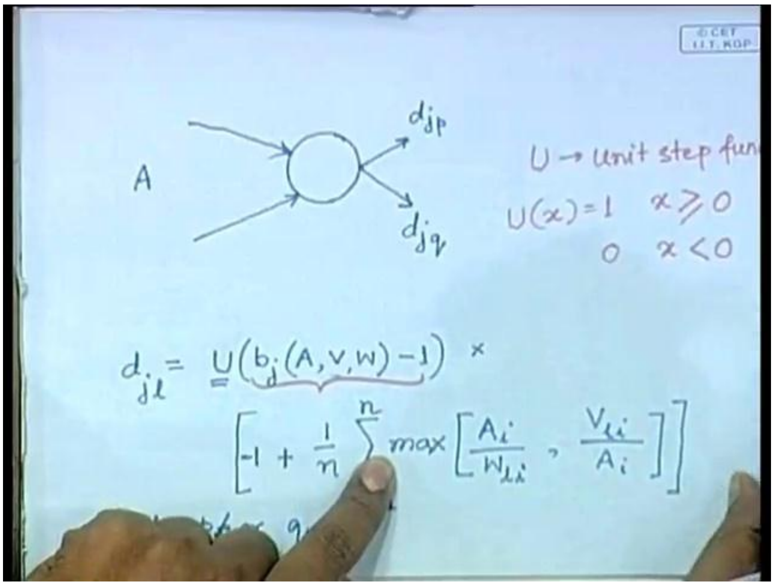

So, here what is U? U is the unit step function. So, if it is unit step function, in that case U x will be is equal to 1 for x greater than or equal to 0, and this is equal to 0 for x less than zero, okay? So, this clearly says that if the point falls within the hyper box then this b j A V W minus 1 is equal to 0 and the value of this function U will be equal to 1. If it falls outside the hyper box then this quantity is negative, it is less than 0. So, the value of U will be equal to 0 and if the value of U is equal to 0 then this entire product is equal to 0. And if this U is 1 then the amount of computation depends upon what is of value computed. Now, here you find that the computation is 1 upon n into summation of max function A i by W l i, w l i is the ith component of the max point of w l. Similarly, V l i is the ith component of the min point of V i. So, forgetting about n dimension, n dimensional feature vector. So, if I consider only one dimension, okay?

So, what effectively I will have is max A upon W and V upon A or A upon W l or V i upon A i. Considering only one dimension, here you find that if A and W l they are same, that means this unknown feature vector coincides with the max point then this is equal to 1. Or if V and A they are also same, that is unknown feature vector coinciding with the min point, they are same. This is 1 if unknown feature vector coincides with the max point. Then obviously V l upon A will be less than 1 if unknown feature vector coincides with the min point. Then obviously A upon W l will be less than 1, okay?

So, here you find that if the unknown point coincides with either the min point or max point then this max operator will return you value 1. And depending upon the distance of the point from the min point or max point, this max operator will return a value whichever is maximum. And if you compute this value only between the min point and max point of the same hyper box then the kind of function that was going to get is something like this.

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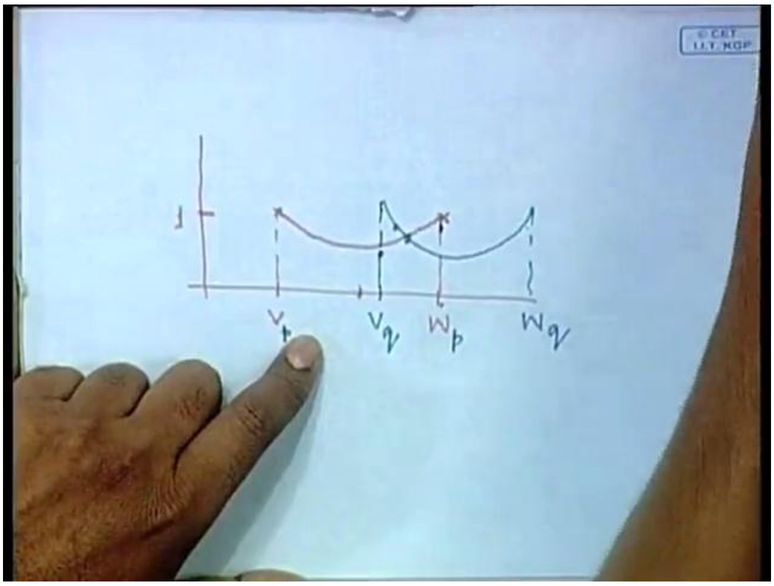

Suppose, I have V over here and W over here of the same hyper box and depending upon the position of the point with respect to V and W, if it coincides with V or if it coincides with W then the value returned by this max operator, that is equal to 1. As I move from V or as I move away from W, this value will go on to the x. So, I will have again after the midpoint as it approaches V the value will go on increasing. So, I will have a situation something like, this is not it and so as a move away from W the value goes on reducing. It will go on reducing up to midpoint, then again it will go on increasing because of influence of V.

Similarly, over here if I have another hyper box. So, this is a V p W p i have another hyper box somewhere over here, it is V q and W q which are overlapped. Here also the compensation values will vary in this point. So, you find that if the point is nearer to V q the compensation given by this is more. If it is nearer to W p the compensation given by this is more.

This is another hyper box, I am considering only in one dimension, I cannot go multiple dimensions in a client. So, this corresponds to one hyper box belonging to V th class, this corresponds to another hyper box belonging to here. So, you find the compensation amounts, amount of compensation as computed by two hyper boxes. As computed by the hyper box for different classes is it and that is being subtracted from 1, right?

So, wherever this component is more minus 1, this will be less. By this component is less minus 1, that will be more and the magnitude will be high, and then this and obviously this component will be either 0 or negative, isn’t it? Because this value will be greater than 1, it can be less than 1 and it is this component is always negative. And this is this component that I am adding to the membership functions as calculated by the classifying section neurons. So, the final output, the maximum will be 1 if there is no compensation or it will be less than 1 if there is compensation. And by how much less that depends upon the relative position of the point within the overlap region, whether it is nearer to the min point of max point of one class with respect to the other class.

So, as a result within the overlap region what we get is somewhere over here. The membership function computed to this class will be more and somewhere over here the membership function computed to this class will be more. So, that is what is about the overlap compensation regions. Now, what about this containment compensation? As we have said membership functions of the amount of compensation that provide will be bit different from the amount of compensation that you provided in this case. So, here this is what is given by the, let us put it as O C N or overlap compensation neuron.

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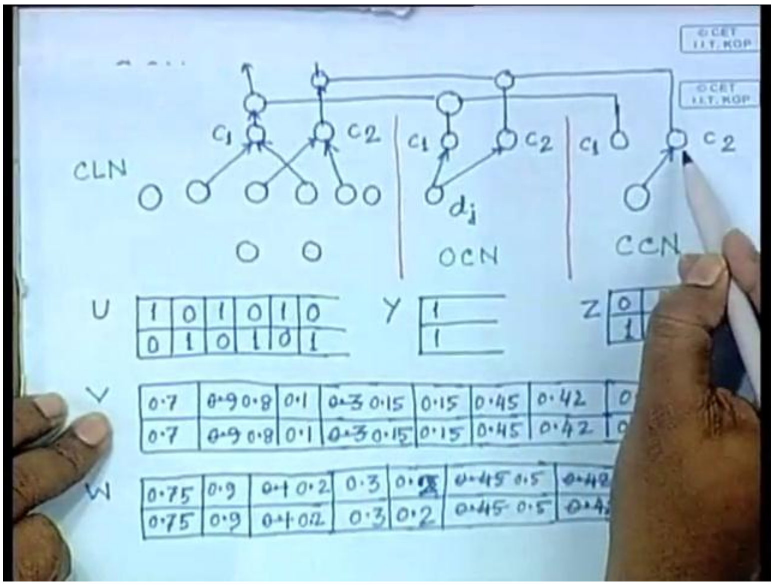

Accordingly, I marked this as, I will put it as C C N section C L N section classifying neuron section. This section is the overlap compensation section and this is C C N containment compensation section, okay? As we said that unlike in this overlap compensation section where the output will be provided to the neurons of two classes in case of containment compensation, the output will be given to one of the class.

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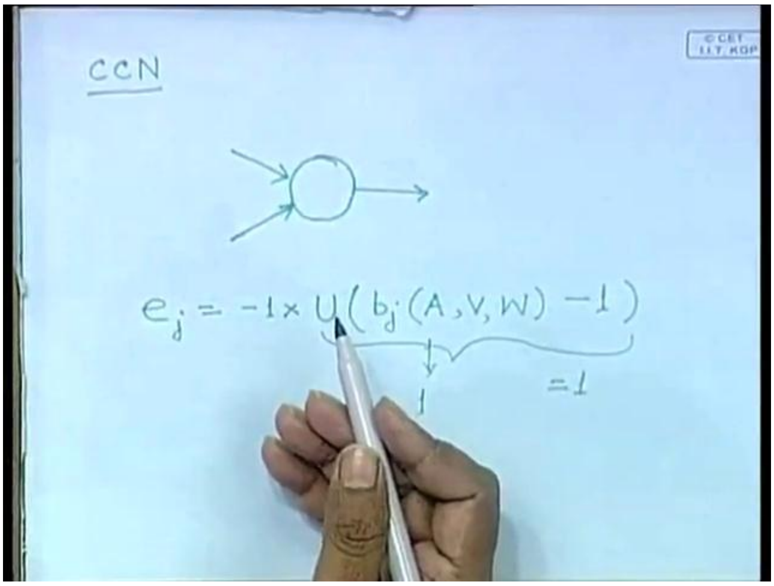

So, accordingly a schematic diagram of CCN, a containment compensation neuron will be something like this. Again it needs the input of the min points and max points and it has a symbol because output will be going to only one output layer neuron, and if I put it as say neuron e I, call this as neuron say e j. So, the output of e j i can put it like this, that this will be minus 1 into U b j A V W minus 1. So, this function simpler than the functions to be computed by overlap compensation neurons. So, we find that here what is it compute when an unknown point falls within the content region. So, by content region what I mean is either in this region, in case of partial containment, if it is full containment in this region and this V and W they are the min points and max points of the content hyper box. That is either is min point or max point of this or it is the min point and max point this in this partial containment.

So, again as before if the point A falls within the content region in that is b j A V W as before, this is equal to 1 and this quantity b j A V W minus 1 will be equal to 0, right? If it falls outside this then value of this will be equal to 0 indicating that there is no compensation. And if it is also within this then what is the amount of compensation value of this function U? This is equal to 1 if it falls within the containment region, because then only this argument is equal to 0. That means, the value of e j will be equal to minus 1.

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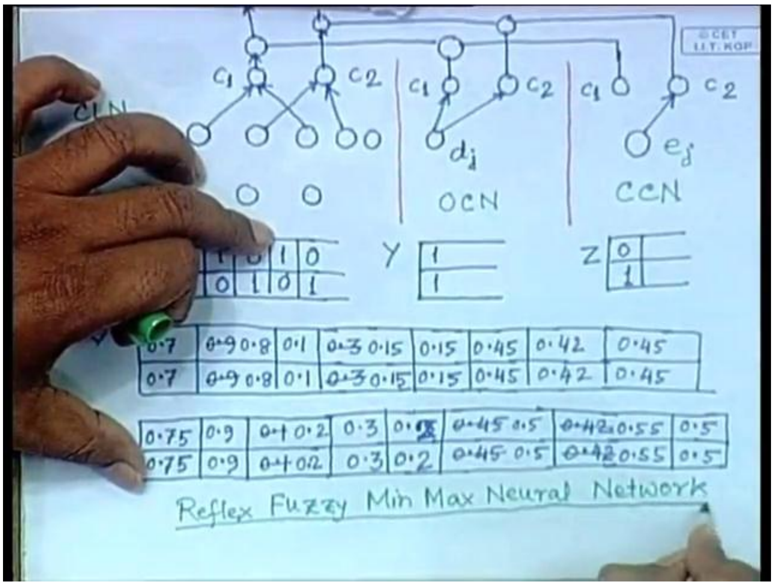

So, if the value of e j equal to minus 1 and this output is connected to the output layer neuron which contains the other hyper box. So, in the classifying section neuron the corresponding output node has computed a value of plus 1. This gives a compensation of minus 1, when you add this two, another final value become equal to 0, right? For this sort of containment compensation is not connected to is not compensating out of other classifying neurons. So, those values will be as they are computed. So, by using this over here the membership function to class C 2 will be equal to 0. Membership function to class C 1 is equal to 1, because this output is not connected to the output. It is not compensating the output of C 1 classifying neuron, other it is compensating out of output of C 2 classifying neuron. And the amount of compensation is minus 1. So, this neuron has computed a value of plus 1, this has given a compensation of minus 1. So, final value is equal to 0. Whereas, for this one this also has computed a value of plus 1 but there is no compensation.

So, the final output will be the final membership value will be equal to 1 to class 1, right? Now, what happens if it falls in this region? The amount of compensation will be equal to 0, if the amount of compensation is 0 then the neurons in the classifying section, this neuron C 2, yeah the neuron C 2 will give you membership value equal to 1. This neuron C 1 will give a membership function which is less than 1 and that depends upon the distance of this point from the min point and max point of this hyper box, which is obviously less than 1. Whereas, the membership function computed by C 2 will be equal to 1.

So, here I get a membership function where output of C 2 is one output of C 1 is less than 1. So, if I go for hard classification using this membership values then obviously the point will be classified to point class C 2, not C 1, whereas if it is within the content region, the classification will be to plus C 1 and not to plus C 2. So, you can make this modification for a improvement of this fuzzy neural min max network and this is what we are calling as reflex fuzzy neural min max network.

And it has been found experimental that the performance of this reflex fuzzy min max neural network is much, much better than the performance of the fuzzy neural min max network as proposed by Sims. On of all this reasons we are not going to any contraction and as a result error introduced while learning or training of the neural network is avoided. And then we will see later when you talk about the clustering that of further modification of this neural network can also be used for clustering operation. So, what you have discussed so far is classification operation.

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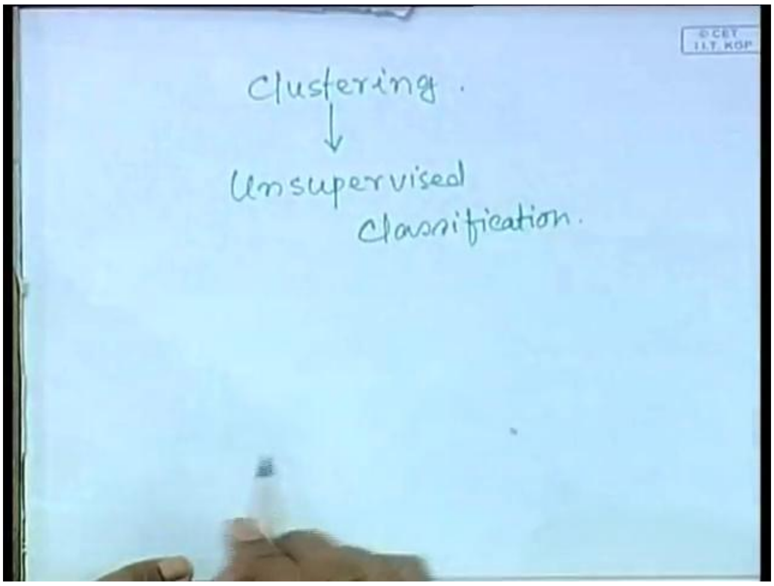

So, the next point that will discuss is the clustering, which makes use of the concept of unsupervised classification. So, what we have seen so far? We have said that the boozer supervised classification because for designing the classifier or even for training the neural network, we use a set of samples for which a class domination mode or the labelled samples. And using the labelled samples you train the classifier or you train the neural network, and then use that trained classifier to classify the unknown samples, as we are training the classifier or you are designing the classified using the labelled samples.

So, as if you training operation is supervised, you supervising the training operation. So, that is why this is called supervised learning. Whereas, there is another kind of situation that we frequently come across by giving the raw set of data, we have to analyse the data and based on some sort of similarity we have to form clusters. So, it is something like this that have been given a set of data and you patrician that set into number of sub sets. Fired the data of the vectors belong to each partition will be similar based on some similarity. Whereas, if I take a vector from one partition and another vector from another partition, those two victors will be different based on the same similarities. So, what you have to do is we have to analyse the data and based on the similarity measure we have partition the data into different subsets. And that is what is known as clustering and because in this case we are not using any labelled sample for doing this clustering operation.

So, this is what is also known as unsupervised learning or unsupervised classification. And if time permits, later on we will see how hybrid approach that we can have a mixture of supervised and unsupervised learning. Because if your problem domain is very complicated where you will have thousands and thousands of data for training of classifier, it is not physically possible to level each and every training data for its class belonging. So, we can have a small set or few samples of data from different classes, level them using that you go for classification. And the unlabelled samples because this will be similar to the labelled samples taken from the same class.

So, the unlabelled samples can further define your classifier, that is what is a hybrid approach where both classic clustering and classification or supervised and unsupervised learning approaches that used together. So, if time permits we will discuss about that also. But next class onwards I will talk about the unsupervised classification of clustering. Let us talk related to that.