Fuzzy Logic and Neural Networks
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Lecture – 41
A Few Applications (Contd.)

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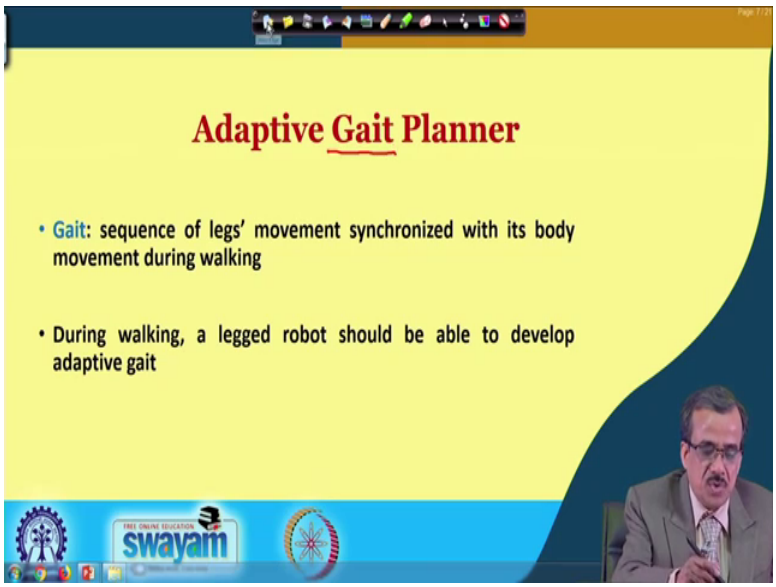

Now, we are going to discuss how to use the principle of Fuzzy Logic and Neural Networks just to design and develop adaptive gait planner. Now, once again let me tell you that the principle of robotics which I am going to discuss here you may not understand 100 percent. You need not worry, once again the main emphasis of taking this example is to tell you like how to use the principle of fuzzy logic and neural networks to solve or tackle this type of problem.

So, we are going to discuss how to design and develop adaptive gait planner. Now, this gait is actually the sequence of legs movement synchronized with its body movements during walking up a humanoid robot. Now we human being while walking we follow some gait cycle. Now, let us see how to design one adaptive gait depending on the requirement.

Now, during a walking actually a legged robot or a humanoid robot should be able to design and develop your the your adaptive gaits, otherwise it will not be able to negotiate, so, that particular terrain very efficiently.

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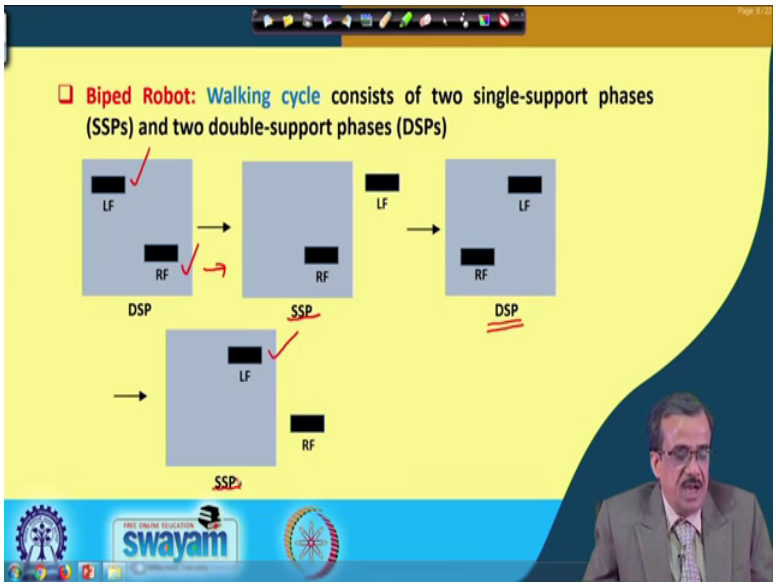

Now, here I am just going to take one example just to show you the walking cycle of a particular your the biped robot. Now, this walking cycle consist of 2 double support phases and 2 single support phases. Now, here you can see a biped robot the human robot is walking and in a particular cycle supposing that so, the left foot is on the ground and the right foot is also on the ground. So, this is nothing but the double support phase or both the feet are on the ground.

Now, while walking so, what we do is? So, this right foot that will be on the ground, but the left foot. So, that will be taken away from your ground and this will be in the swing phase. Now, if it is in the swing phase and this right foot is on the your ground, so, this is nothing but is your the single support phase. Then comes your so, this particular the left foot we are going to put on the ground and the right foot is already on the ground. So, what will happen is this will constitute one double support phase and next what we do is. So, this particular right left foot will be here and the right foot will be taken from the ground and it will be in air.

So, this is in swing phase. So, that is nothing but is your the single support phase that completes actually one walking cycle. So, one walking cycle consist of two single support phases and your two double support phases. Now while walking the biped robot or the humanoid robot should be able to maintain its balance during both the single support phase as well as your the double support phase.

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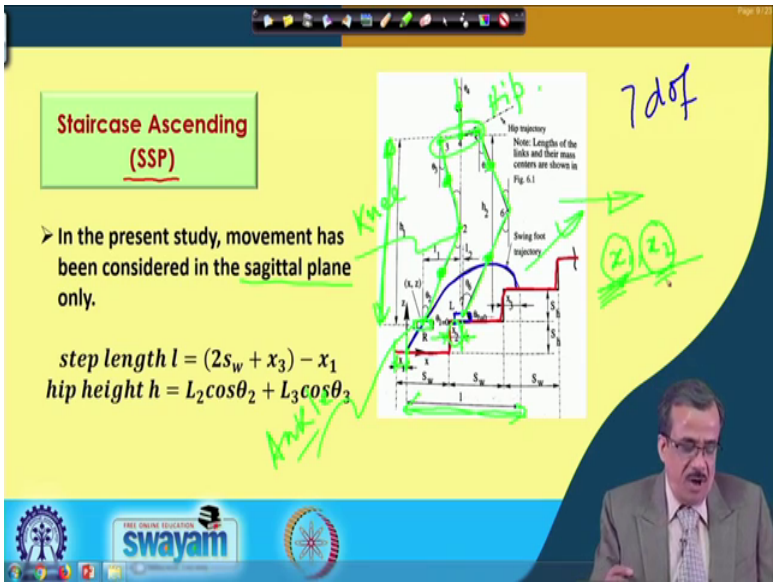

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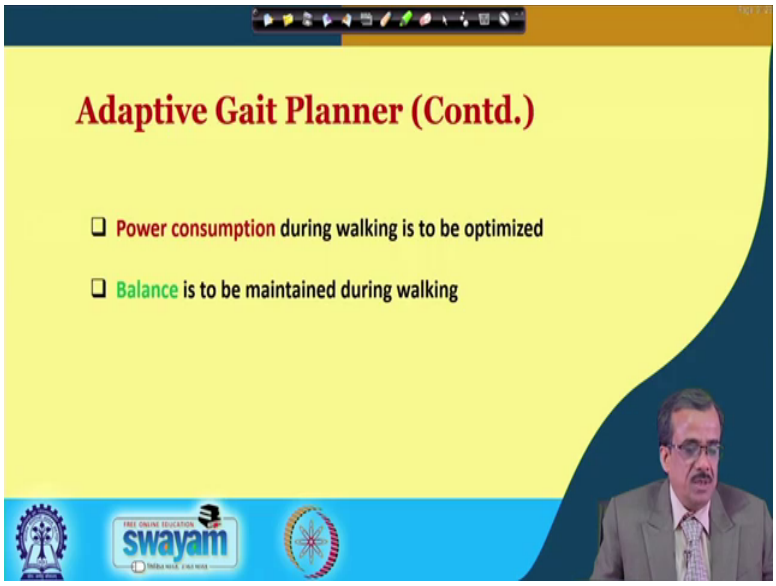

Now, here actually the main requirement while walking like we should be able to walk by consuming the minimum power and at the same time the dynamic balance should be the maximum we should not lose the balance.

So, how to maintain this? And let us see how to implement these with the help of fuzzy reasoning tool and the neural networks. Now, here let me spend on the physical problem this is a very simple problem this is simple model. Now, here I am just going to explain. So, this is nothing but actually the single support phase; that means, there is one foot on

this particular the ground and another foot is on the air. And supposing that so, this particular biped robot is negotiating, so, this type of staircase. So, this shows actually the staircase and if you see the biped robot; the biped robot it is a very simple biped robot having 7 degrees of freedom and if you just want to show it here. So, this particular foot is on the ground and your. So, this particular foot is in air and the swing foot. So, it is going to follow this particular your the trajectory while walking or while negotiating this particular the staircase.

Now, similarly if you see your the limbs of these particular biped robot. So, this is actually one foot. So, this is one link here, then we have got another link here, then this is your the hip joint then comes another link here, another link here and here we have got the ankle joint. So, we have got ankle joint here the knee joint here and we have got these particular hip joint. In fact, all three points are coinciding. So, this is nothing but is your the hip joint.

So, this is the hip joint and this is nothing but is your knee joint and this is your ankle joint So, this is the ankle joint and it joined for simplicity we have considered it is having only 1 degree of freedom. So, 1 degree of freedom plus 1 plus 1 3, 3 plus 3 6 and here you have got another degree of freedom for this trunk this is actually the trunk and so, it is having 7 degrees of freedom say.

Now, each of these particular links is having its mass and mass center for example, if I consider. So, this particular foot it is having some mass and mass center. So, these particular link is having some mass and mass center mass and mass center mass and mass center. So, each of these particular link is having it is mass and mass center and supposing that I am considering the movement only in the sagittal plane.

Now, if I consider movement in the sagittal plane; that means, in these particular the biped robot is moving in this particular the direction. So, this is the direction of movement I should say now if this is the direction of movement. So, what you can do is? So, I will have to generate these particular gait that is the sequence of the leg movement. So, that it consumes minimum amount of energy and it can maintain that particular dynamic balance while negotiating, so, these particular the staircase.

Now, if I want to model it using fuzzy logic and neural networks. So, I will show you that a few things are important. For example so, here you can see, so, at the starting so, I

put the foot here and that is taken as the swing foot later on. So, the initial position of the foot that is from the edge of this particular staircase that is nothing but x 1 and the placement of this particular ground foot with respect to the edge of this particular staircase that is nothing but is your x 2. So, I can consider so, these particular x 1 and x 2 are nothing but the inputs for my gait planner.

Now, if you see the way one old person walk or negotiate the staircase and the way one young person negotiate the staircase there will be lot of different. Difference in the sense the place where they are going to put the foot will be different like x 1 x 2 for the old person x 1 x 2 for a young person will be different. And for the same person if the slope is much for this particular staircase, so, the same person is going to change these particular x 1 and x 2. And once we decide while negotiating the staircase the x 1 and x 2 then a few things are determined mathematically.

For example what will be this particular hip height? For example, if you see the old person the hip height for the old person will be less, but for a young person the hip height could be more. Now, once you know this particular your x 1 x 2 and if I know these particular your the joint angles like theta 1 theta 2 theta 3 and all such joint angles So, I can find out what should be your the hip height and another thing is your the step length.

Now, while walking what should be my step length for example, for a old person the step length could be less for a young person the step length could be more. So, what do you do is we try to find out what is the height of this particular knee joint and what is this particular your step length and while negotiating the staircase. So, we take the decision regarding x 1 and x 2 where to put my feet. Now, all such things actually can be modeled using the principle of fuzzy logic that I am going to discuss.

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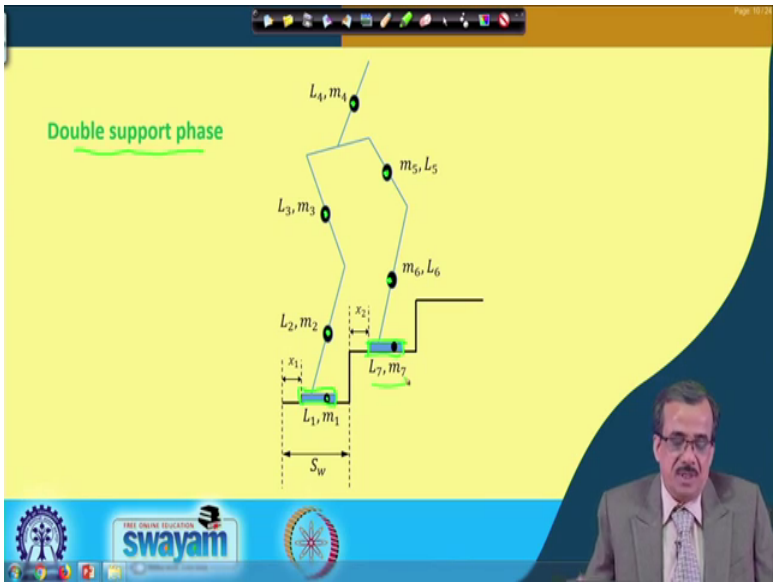

Now, the in the previous slide we consider the single support phase and this is actually the scenario for your the double support phase. For example, if you see in the double support phase, so, I have got one foot here on the ground another foot here on the ground. So, both the feet are on the ground. So, this is the double support phase and this particular the link is having the mass m 1 and it is having the length l 1. Similarly it is having m 2 l 2, m 3 l 3, m 4 l 4, m 5 l 5, m 6 l 6 and here we have got m 7 l 7 and for these particular the double support phase also. So, we will have to find out what should be the adaptive gait, so, that it can negotiate. So, these particular the staircase by consuming the minimum energy and after maintaining the maximum the dynamic balance.

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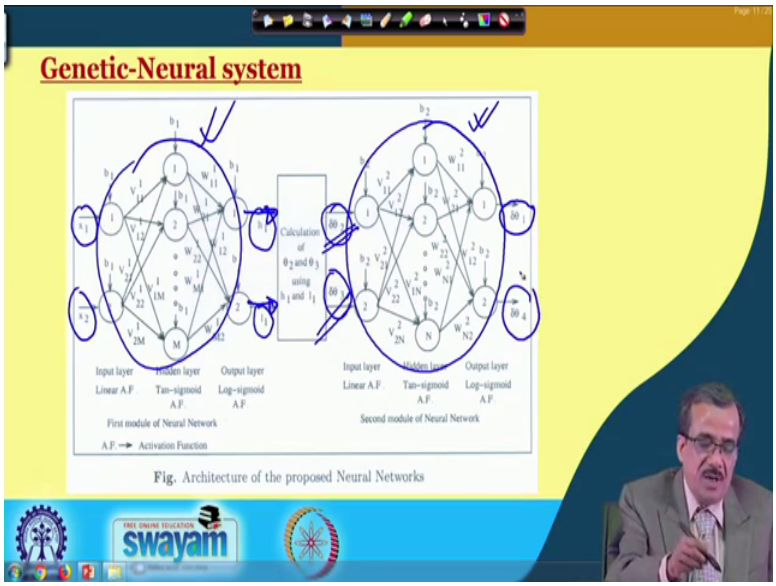

Now, let us see how to implement or how to model this with the help of your the fuzzy logic and neural networks. Now, here you can see that I am using two multi layer feed forward network. So, this is a 3 layer network and this is another 3 layer network. So, this is a 3 layer network and here I have got another 3 layer network. So, two multi layered feed forward network I am using and this x 1 and x 2 are fed as input to this particular than network and here I have already discussed how does it work. So, I am not going to repeat that. So, ultimately I will be getting this h 1 and l 1 as the output of this particular the first network.

Now, what is h 1 and l 1? H 1 and l 1 are going to tell you what should be the height of the hip and what should be your the step length sort of thing that particular information or what should be the projection of hip with respect to your the ground foot. So, that is nothing but is your l 1 and once you have got these particular h 1 and l 1, so, mathematically we can find out what should be the joint angle.

So, trigonometrically we can find out what should be the joint angle. So, all the joint angles we can calculate except that your the theta 4. Now, once you have got these particular the joint angle I can find out what is the change in theta 2, what is the change in theta 3 and that will be fed as input to the second network.

And in the second network as output will be getting what should be the change in theta 1 and what is the change in theta 4. Now let me once again go back your once again go back to the picture.

Now, here if you see, now what we are getting as output we are getting as output is nothing but the change in theta 4 and your change in theta 1; that is nothing but the change in joint angle for the swing leg. Now, whenever the biped robot is negotiating the staircase it balance largely depends on your the trunk mass the angle of the trunk mass that is your theta 4 and another is your the angle of these particular the swing foot.

And those 2 things are the output and once we have got those particular output. Now, we are in a position to find out what should be the stability, whether it is dynamically stable or not and we can also mathematically found out what should be your the torque values how much if the power consumption. So, I am not going for all such things because this course actually does not permit that, so, in robotics course actually we consider all such things and we calculate.

Now here so, the purpose of these is actually to find out what is the change in theta 1 and change in theta 4? So, that the balance is maintained for this particular your the biped robot. So, this is the way actually we can implement the gait planning using the 2 multi layer feed forward network.

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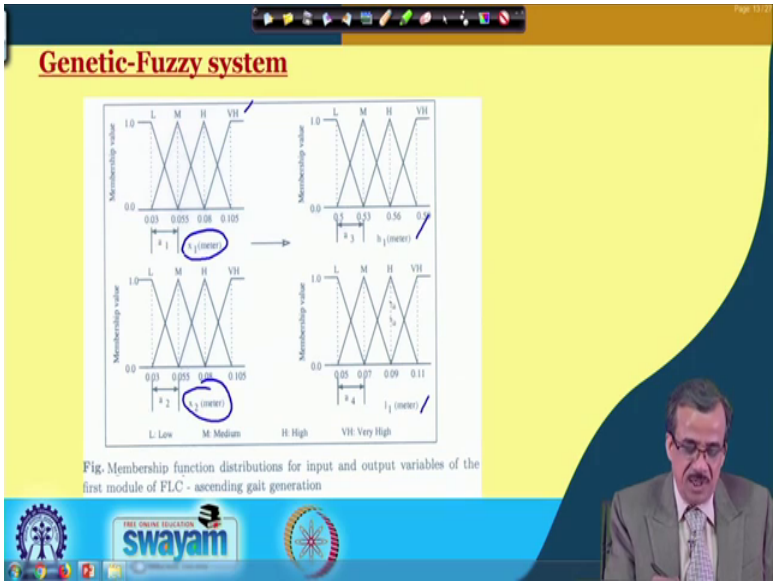

Fig. Membership function distributions for input and output variables of the first module of FLC - ascending gait generation

And the same problem can also be tackled using the fuzzy reasoning tool and you can see that exactly in the same way. So, we can represent this particular x 1 as the input and x 2 is another input, we can use some linguistic terms like if you remember like low medium high and very high. So, for simplicity we have considered triangular membership function distribution for the 2 inputs x 1 and x 2 and I will be getting the output as h 1 and l 1. And that is nothing but the output of the your the first fuzzy reasoning tool. Now, using this h 1 and l 1, so, mathematically we will be able to calculate what should be the joint angle values.

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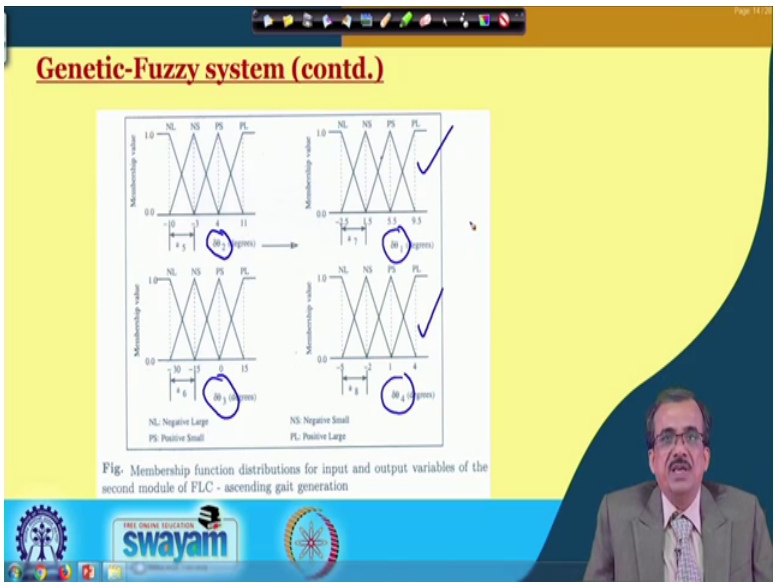

And once we have got these particular joint angle values exactly in the same way we are in a position to find out what should be your the change in theta 2 and your change in theta 3. And this particular change in theta 2 and theta 3 it is going to follow some triangular membership function distribution and as output will be getting that is nothing but change in theta 1 and change in theta 4. And these are the membership function distribution for this particular your theta 1 and theta 4.

So, we can find out the joint angles. So, that it can maintain the dynamic balance and we can also find out how much will be the power consumption. So, this is the way actually we can model so, this biped walking just to find out what should be your the adaptive your gaits if you want to negotiate. So, the different types of terrains or different types of

your staircase in an optimal sense. So, this is how to use the principle of fuzzy logic and neural networks just to find out the adaptive gaits.

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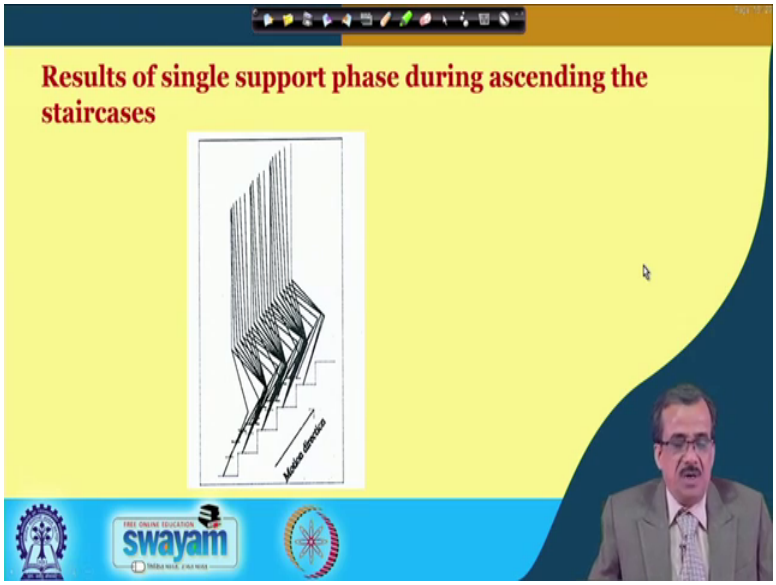

Now, if you solve it. In fact, we have solved it and this shows the stick diagram during your the single support phase while ascending that particular the staircase.

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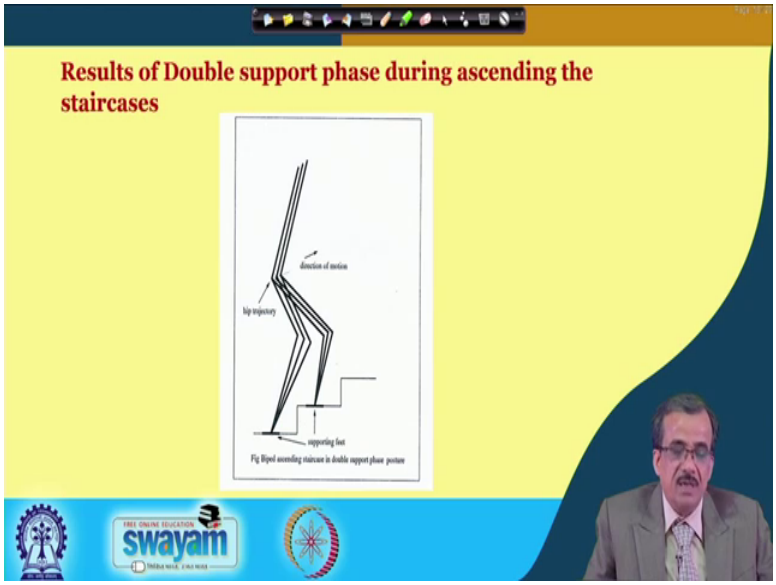

And these shows actually the stick diagram while ascending that staircase using during the double support phase. So, this is the way actually we can develop your the adaptive gait.

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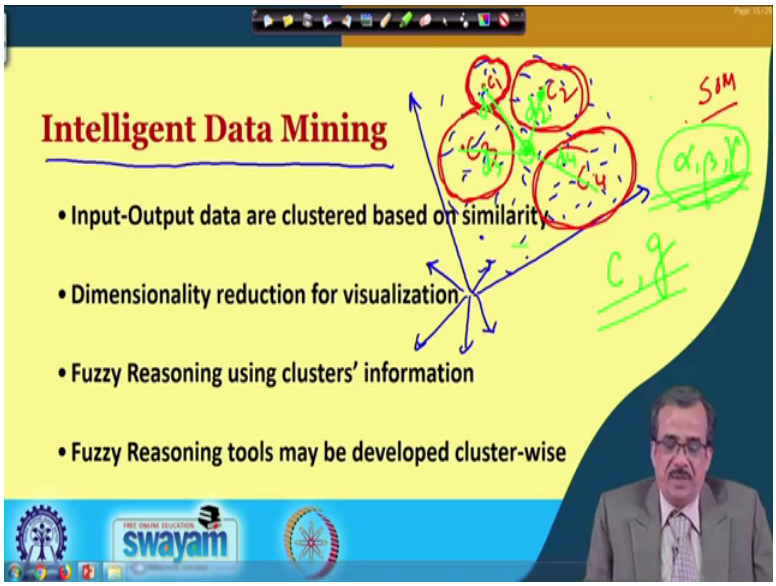

Now, I am just going to discuss another area which is very interesting and we can use the principle of the fuzzy logic and neural networks also just to develop the intelligent data miner. So, the problem which I am going to discuss is nothing but is your intelligent data mining. Now, this particular problem of intelligent data mining the purpose is how to model the input output relationship of a process in both forward and reverse direction. And if required whether we can map the data from higher dimension to lower dimension for the purpose of visualization, whether we can do some sort of clustering using the principle of similarity.

Now, here the input output data are cluster based on similarity we do some mapping from higher dimension to lower dimension for the purpose of visualization. Now, this I have already mentioned that we human being can visualize only up to 3 dimension. Supposing that the data are in say higher dimension. So, for the purpose of visualization, so we will have to do the mapping.

In fact, we can use self organizing map for carrying out. So, this particular the mapping and we can also carry out some set up clustering also using self organizing map or some fuzzy clustering tools like fuzzy c means clustering or entropy based fuzzy clustering and so on. And once you have got this particular cluster, now let us see like how to develop the reasoning tool it is very interesting.

Now, supposing that say I have got the higher dimensional data. So, this represents the higher dimensional data. So, this is nothing but the higher dimensional data and I have got a large number of data points here. So, we have got a large number of data points like input output relationship and our aim is to design and develop one expert system. So, that you can do this particular the your input output modeling as accurately as possible.

Now, what we do is? We first try to carry out some sort of your clustering based on your the similarity and based on the similarity. So, we have already discussed some tools like fuzzy c means clustering or entropy based clustering supposing that we have got some clusters here. So, I have got one clusters here and it has got a center, I have got another clusters here, say it has got a center. I have got another cluster here, so, it has got a center here, I have got another cluster here, say it has got a center here and so on. For simplicity let me consider for the timing there are only 4 clusters, the data are such that we have got only 4 clusters ok.

Now, if this is the situation and supposing that this particular data are in higher dimension. So, we cannot visualize that particular the cluster. So, what we will have to do is? We will have to use some your dimensionality reduction technique like self organizing map just to map these higher dimensional data to the lower dimension and if you can do the mapping. So, very easily we can see very distinctly we can see so, these particular the cluster.

Now, once you have got this particular cluster now what you can do is? We can go for some sort of cluster wise regression or we can go for some sort of fuzzy reasoning tool development of fuzzy reasoning tool. So, that you can do this mapping or we can do this particular modeling very accurately. Now, let us see how to do it? Now, supposing that we have got say for clusters for each of the 4 clusters. So, I have got a cluster center and the cluster center has got some property.

So, what I can do is? I can carry out some, I can use some fuzzy reasoning tool here just to find out the input output relationship or I can use some neural network here to find out the input output relationship. Similarly, I can find out one another fuzzy reasoning tool or neural network another fuzzy reasoning tool or neural network another fuzzy logic tool or neural network I can develop.

Now, supposing that one new test case has come. Now the moment you find a new test case supposing that the test case is here. So, this is I am supplying the set of inputs and our aim is to find out what should be the set of outputs? The moment I pass these particular test scenario. So, I have got the set of input parameters. So, these set of input parameters will be compared with a set of inputs of c 1 the first cluster center then it will be compared with the second cluster center, then the third cluster center and the fourth cluster center. And we try to find out the equilibrium distance values between the test scenario, so, this is the unknown whose outputs are not known. So, this is the test scenario.

So, we try to find out like what should be your the cluster center the distance between this point and c 1, the distance between this point and this center and this is your d 3 and this is your d 4 and you try to find out the similarity between, so, these particular test scenario and each of these particular the cluster center.

Now, the more the equilibrant distance value the less will be the similarity and vice versa now and the more will be the similarity the contribution of that particular cluster towards the output of this particular your the test scenario will be more. Now supposing that, so, this particular data point is found to be very close to say c 2. So, while determining its output for this particular the test scenario. So, this particular your c 2 will have more contribution while determining the output of this particular your the test scenario.

This is the way actually we can implement your the data miner. And here actually what we can do is we can make it intelligent also. Intelligent in the sense like your the quality of the cluster each of the cluster depends on a number of parameters for example, if it is fuzzy c means clustering it depends on the number of clusters which we are going to make, then comes the level of cluster fuzziness. If it is entropy based clustering if you remember, it depends on the parameters like alpha, beta and gamma and the quality of clusters will depend on. So, these particular parameters like your alpha beta and gamma.

Now, what you can do is you can link it to one nature inspired optimization tool say genetic algorithm. And so, this particular genetic algorithm we will try to evolve all such optimal parameters like alpha beta and gamma depending on the nature of this particular the data set or if it is fuzzy c means algorithm.

So, it will try to find out what should be the number of cluster center and what should be your the level of cluster fuzziness say denoted by g. So, those optimal values so, that. So, these particular your reasoning tool the fuzzy reasoning tool will be able to predict the output as accurately as possible and g a through a large number of iterations we will try to find out what should be the optimal parameters of these particular clustering algorithm.

So, that it can make the clusters in an optimal sense and using these optimal clusters. So, we will be able to predict the output or a set of inputs very accurately that is actually the concept of intelligent data mining. Now, for this intelligent data mining actually your makes a very good sense practical sense the reason is your supposing that let me take a very simple example, say I have got, say one 3 dimensional data. Now, for this 3 dimensional data if you want to represent we can do it very easily. I can just consider the corner of a room like x, y and z.

So, the whole volume of a particular room will be the search space or the designed space for this particular the problem now generally the real world problems are non-linear. Now, for this non-linear problem the level of non-linearity may not be exactly the same at the different regions of these particular the variables. Might be at some corner the degree of linearity could be more compared to some other corners. So, that is why this particular concept of clustering makes a very good sense if we want to determine the input output relationship, so, it is better to go for.

So, this type of clustering and clustering based regression like it could be your fuzzy reasoning based regression or you can use some neural networks also to determine and after that actually we can combine. So, this is the way in fact, we can develop the intelligent data mining tools just to determine the input output relationship in a very efficient way. So, this particular your the fuzzy logic and your the neural networks has got a large number of applications.

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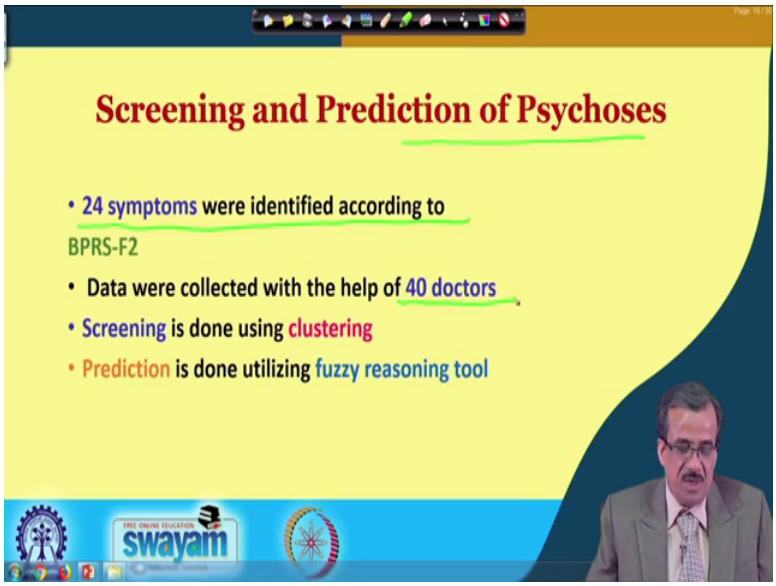

Now, here quickly I am just going to take one example which we have solved, it is actually the screening and prediction of psychosis. This work we carried out a few years ago. Now, we carried out some sort of intelligent data mining using some data related to psychosis. Now, for these psychosis in fact, we consulted some doctors and we collected the data and there are 24 symptoms related to these mental disease or psychosis.

And the data we are collected with the help of 40 doctors and we carried out some sort of screening using the clustering and we carried out some prediction using the fuzzy reasoning tool. Now, let us see how to carry out, so, this particular your the your screening and prediction for these psychosis using the fuzzy reasoning tool.

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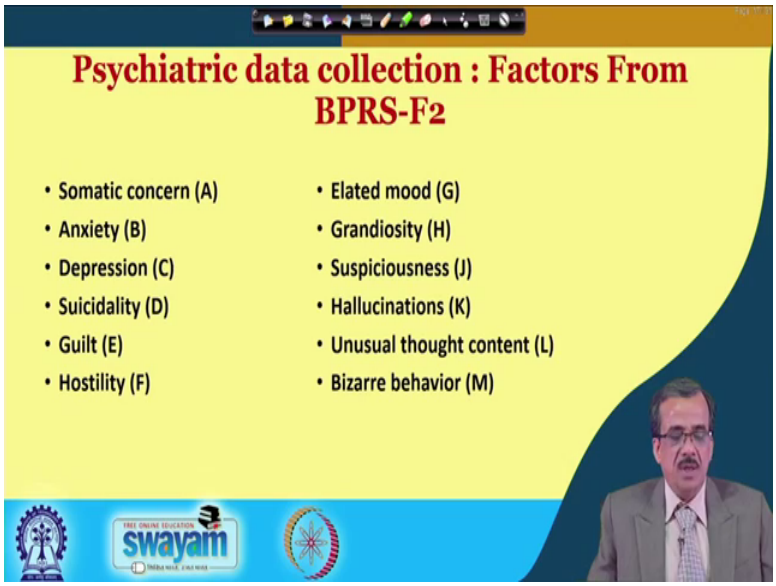

Now, as I told that we consider 24 parameters. So, here you can see that we are considering like your 1 2 3 4 5 6, 6 plus 6 12 and the next slide you will find 12 more.

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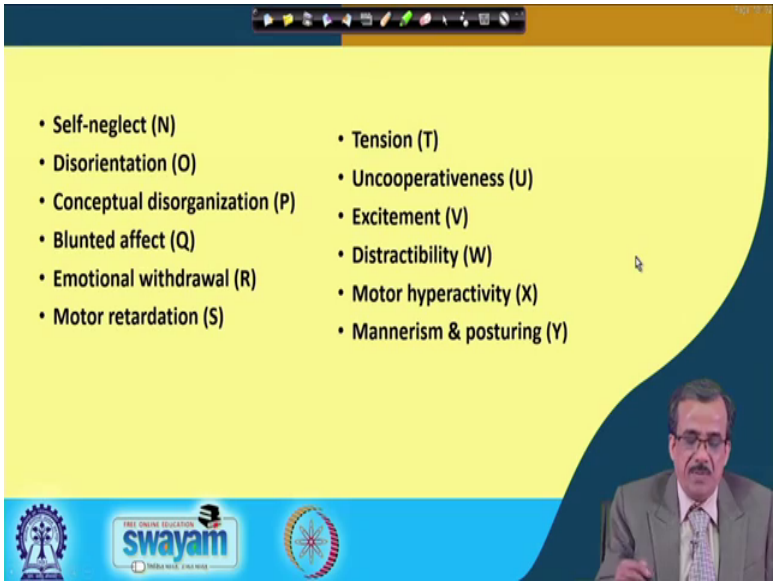

So, we have got 24 your the parameters or the so, we consider in that particular the model.

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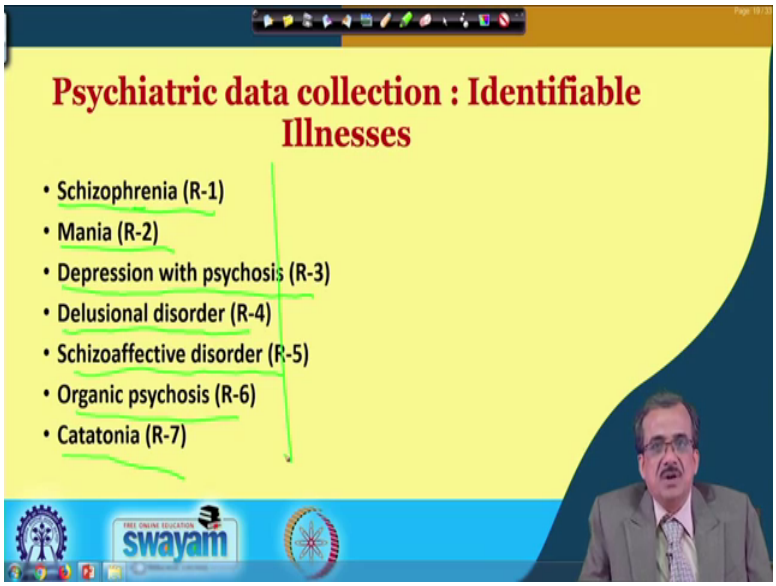

And using that 24 parameters actually we will have to classify or we will have to do the clustering into 7 grades of mental disease or your the psychosis. Now, the 7 grades of mental diseases are as follows. Now, these are schizophrenia, then comes your mania, then depression with psychosis, then delusional disorder, schizoaffective disorder, organic psychosis and catatonia. So, there are 7 grades of mental diseases or psychosis and we collected a huge amount of data with the help of 40 doctors.

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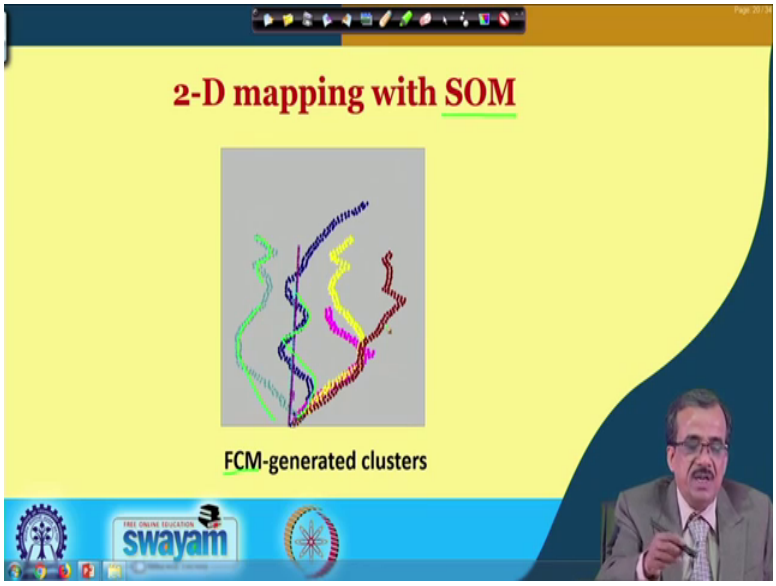

And those data where actually the clusters using the fuzzy c means clustering and entropy based clustering. Now, here you can see, very distinctly I can show you there are 7 clusters of these particular the diseases you can see that. So, these 24 data; that means, it was in 25 dimension.

So, those data were clustered and then the mapping was done to 2 dimension for the purpose of visualization, using the self organizing map whose principle I have already discussed. So, after doing this clustering using fuzzy c means algorithm and after carrying out the self organizing map based analysis. So, we could find out the 7 distinct clusters of these particular the psychosis and it is very interesting that we can find out for example, this is one cluster, this is the second cluster similarly we will be getting actually the 7 clusters of the psychosis.

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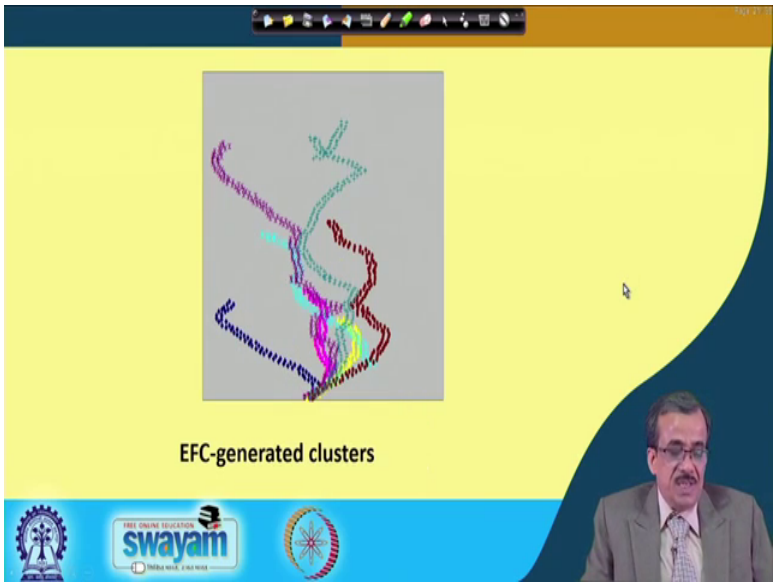

Now, this is for the same data using the entropy based clustering. So, we got the 7 cluster and here once again you can identify the 7 different clusters very clearly. And once you have got these particular clusters as I discussed like we could develop some fuzzy reasoning based your the predictive tools. And using that fuzzy reasoning means predictive tools we were able to predict the status of a disease like the degree from which a particular patient is suffering from the mental disease. That could be predicted using the fuzzy logic based screening and prediction system.

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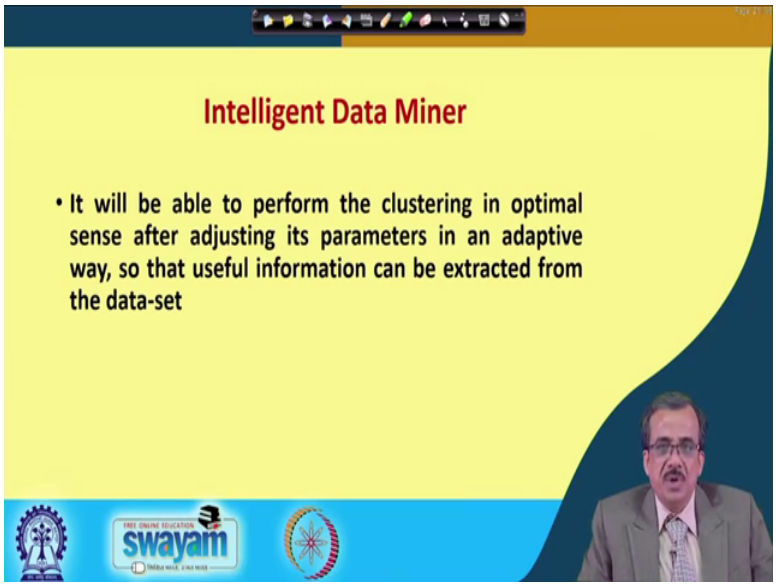

So, this is the way actually we developed that intelligent data miner for carrying out some sort of screening and prediction of the mental disease. Now, this particular thing has got a very practical meaning in the sense supposing that one x part of mental disease. So, one medical doctor, say he is examining a large number of patients one after another. The moment a particular patient comes in front of him he generally ask a number of questions and he tries to find out the similarity of the answers he is getting with those seven well defined the your the clusters.

And he tries to make a fit like whether this particular patient is going to fit to any of the clusters or he is totally unfit, he is not going to fit. If he is not going to fit, he is mentally healthy person and if he is going to fit to a particular clusters. So, accordingly your the medicines will be prescribed.

So, this is the way actually the medical diagnosis can be carried out for mental disease using your fuzzy reasoning tool using fuzzy clustering and the data can be mapped for the purpose of visualization.

Thank you.