Remote Sensing and GIS
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Lecture – 11
Image Classification-1

Today, we will start image classification. So in this one, we will learn how to classify a remotely sensed to image into different classes and classes will be based on the analyst wishes. So if you want to divide the whole area into five plus namely like water, forest, urban areas. So like that you can divide the whole image into different classes that we will see in detail today.

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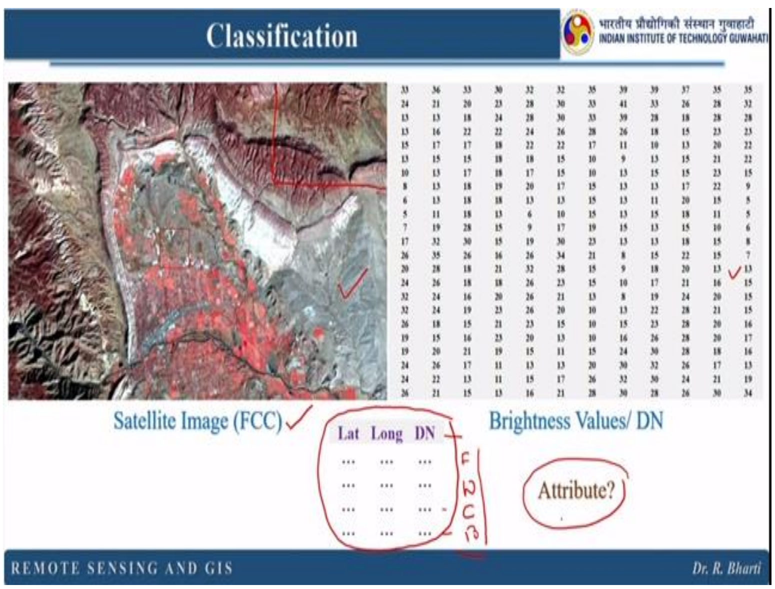

So before we start the classification, here you know this is one satellite image and here brightness values are right. So this is for only one part of it because for the whole image we cannot display the DN number here because the space is limited. So for one part this is the DN values. Now here you can see that these numbers are basically associated with your pixels which is captured by your satellite image.

But what other information you have here? nothing. Just dip position that means the spatial information. So latitude, longitude and then digital number. So here if you want to identify a house here or maybe let us say you want to identify forest here then what you have to do you have to open this image into standard false colour composite and then you have to look for the red colours because red colours are representing forest or vegetation.

So then you can say these are the colours which belong to forest right or maybe trees or maybe the shrubs or any other vegetation which contains chlorophyll right. So here in this condition everything is manual. But we do not want to do every time manually because this image pixel size maybe 10,000 by 10,000. So for 10,000 by 10,000 pixel we cannot do it manually. So what we have to do we have to start or we have to find a logic or a algorithm through which we can divide or identify the classes for individual pixels.

So once we have this logic or algorithm then the whole image will be classified into different classes right. So here you can see these are the information given by your satellite data. But we want to have another information that this DN value correspond to forest, this DN value correspond to water, this DN value correspond to concrete, this DN value correspond to maybe barren land right.

So here how we can achieve this information that is the question and that is the classification, right. So here I want to highlight one thing, this is known as attribute. So what do you mean by attribute? So attributes are the information associated with your unique ID. So here let us assume that this latitude longitude is unique ID because that is not going to change.

So here if you can append this particular information like this being value correspond to forests, this value correspond to water, this value correspond to other classes, then this is known as attribute table right. So this is what we will get after the classification, the location, the previous DN values or the location and the classes right. So let us see how we can do this.

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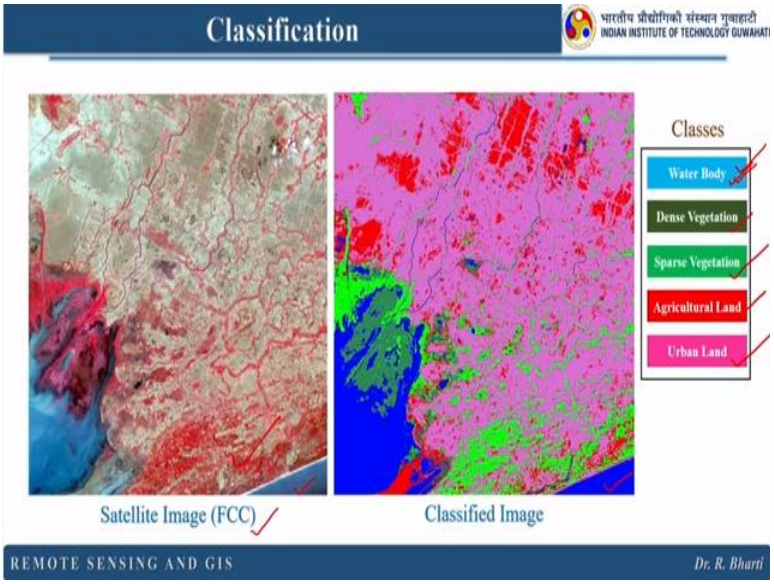

So before that I want to show you how these images looks like after classification. So this is one of the example here this is the raw data. Now you are comfortable with normal satellite image, how they look like and this is the standard false colour composite. So it is open with those three bands. Now after classification, what is happening here? There are different colours assigned to different pixels right.

So if you see this blue colour, so blue colour here also it is visible like it is water. So now this blue colour is water body. Then this colour represent dense vegetation, this is sparse vegetation, this is agriculture land, this is urban land. So this is how we are going to achieve classification or classified images. So here after this now your life will be very easy because if you want to calculate what is the area in this particular image covered by water body.

Then you have to identify number of pixels belonging to this particular colour right it is very easy. So this is how remote sensing will help you to identify the area covered by different classes in nature right. So this is for only this particular image or the study area right.

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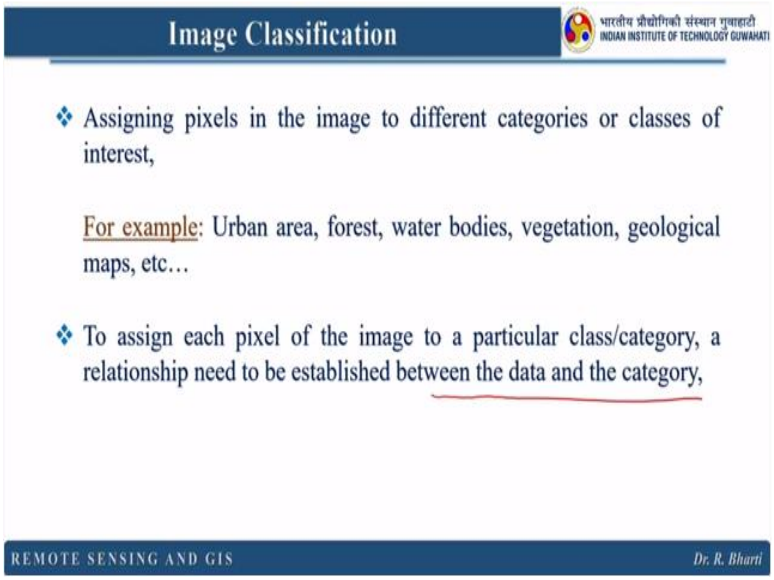

So let us see what exactly image classification mean. So assigning pixel in the image to different categories or classes of interest. So here what we are doing? we are assigning each and every pixel of my image to different categories or different classes right of interest. So if this is the image, right. So this pixel whether it belongs to forest or urban area or water or some other classes that we need to find out.

And if you do that that is known as image classification, right. For example, urban area, forest water, body vegetation, geological maps. So this is how we are going to use this image classification in our application, right. And to assign each pixel of the emails to a particular class or category, a relationship need to be established between the data and the category. So how we will do that?

Based on the relationship we develop between the classes like if you say forest and this is your image. So here you have DN values right and suppose this is the area of forest in this particular image. So you will have DN value corresponding to this particular class right and then you will develop a or establish a relationship. And that relationship will be used to assign each pixel of this image into different categories right.

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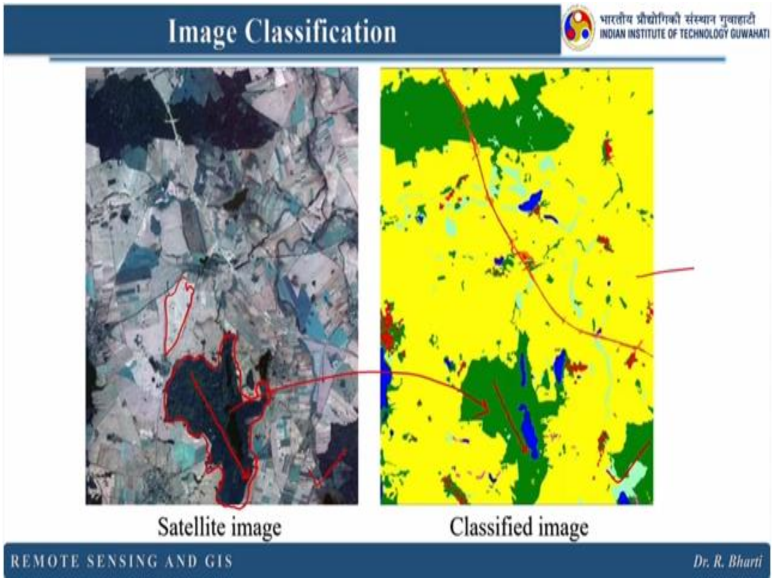

Here this is one example, you can see this is the satellite image and this is classified image. Again here there are different colours available, but here there only limited colours. That means here you can find out a small change in the intensity within the class. But after classification what happens? the whole area let us take the example of water right or let us take the example of vegetation.

So let us say this is the area for forest. Now here you can see there are some variation right from here to here if you see there are some variations. But here you see there is only one colour assigned to all the pixels right. So what is happening here? we have resolved all the variation within the class and we have given the attribute of forest right. So this is what we are doing here. Now after this classification obviously you will have only few colours which will represent different classes.

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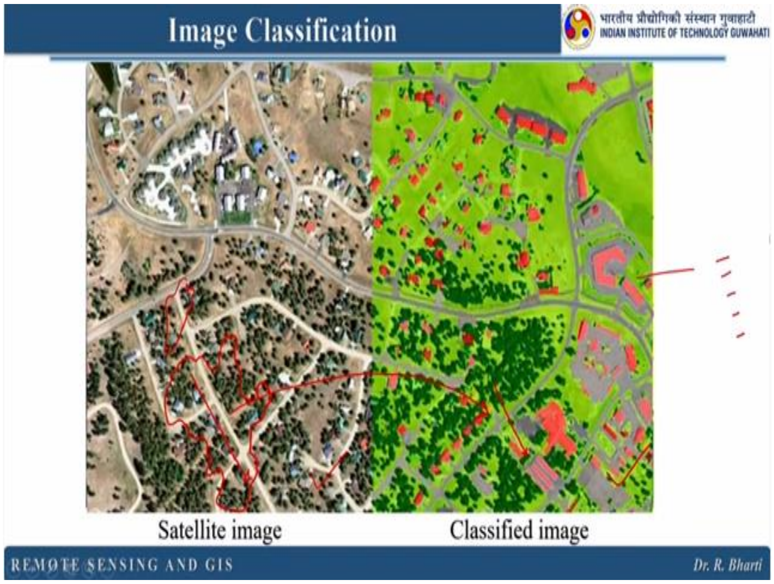

This is another example you can see here right. So this is what exactly classification is meant for.

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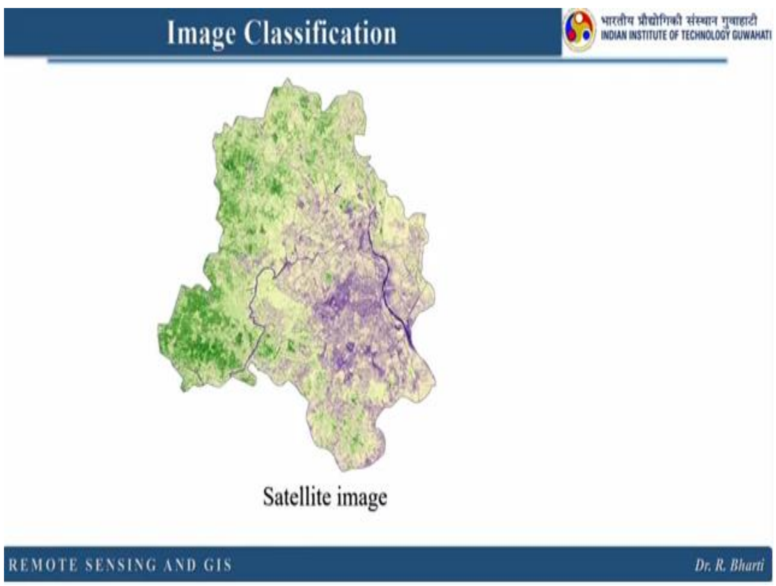

This is another example you can see this is satellite image of an area.

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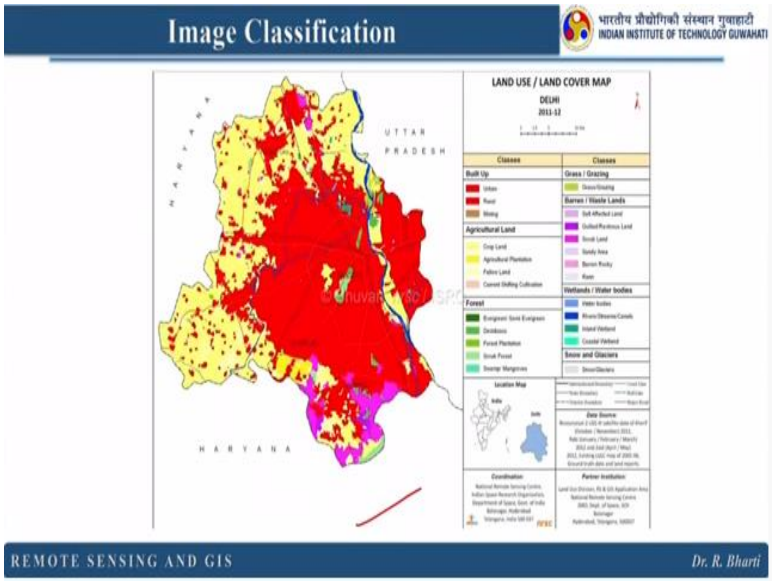

And this is the classified image of the same area. Now here you can see this is basically Delhi and here we have resolved the all the pixels into different classes like urban, rural, mining right and then there are within forest, there are variation. So if this is the standard classification scheme and the colour scheme which people have adopted. Now based on this table, if you find this colour that means it represent water body.

If you find this colour that represents river right, river, stream or cannels. So here if you find this colour then it is urban. If you find this colour in your classified images, then it is grass or grazing. So this is how we have to make sure that we use some standard colour combination. So that anybody can use or anybody can understand our classified image. That is the main objective of this classification scheme.

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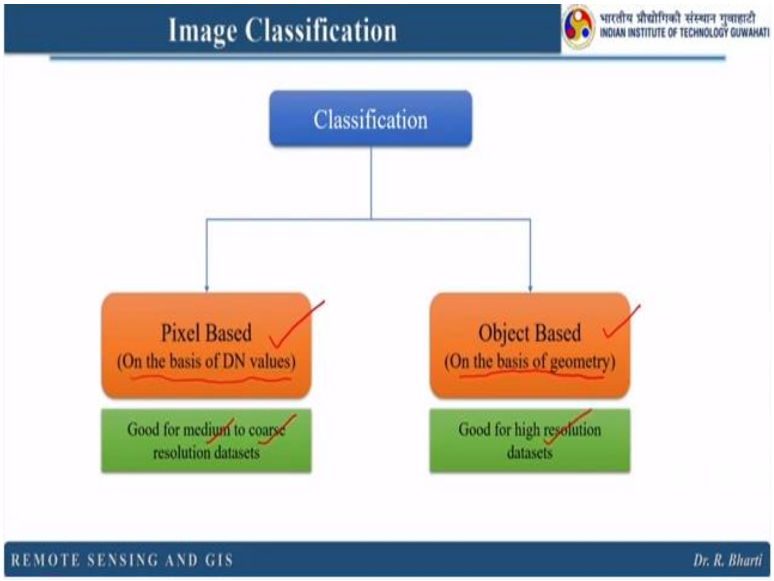

Now there are different types of classification technique right. So here we will see there are two different categories. First one is pixel based. Next one is object based. So here pixel based means on the basis of DN values. But in case of object based on the basis of geometry. So can you think of some logic like why we have made two different categories? because you have coarse resolution data, medium resolution data and very high resolution data and in terms of spatial resolution.

So if you want to go for pixel based classification it is good for medium and coarse whereas this object based classification is good for high resolution data set. That means high spatial resolution data sets. So this is the two different categories. So let us see what exactly what we do in image classification in detail.

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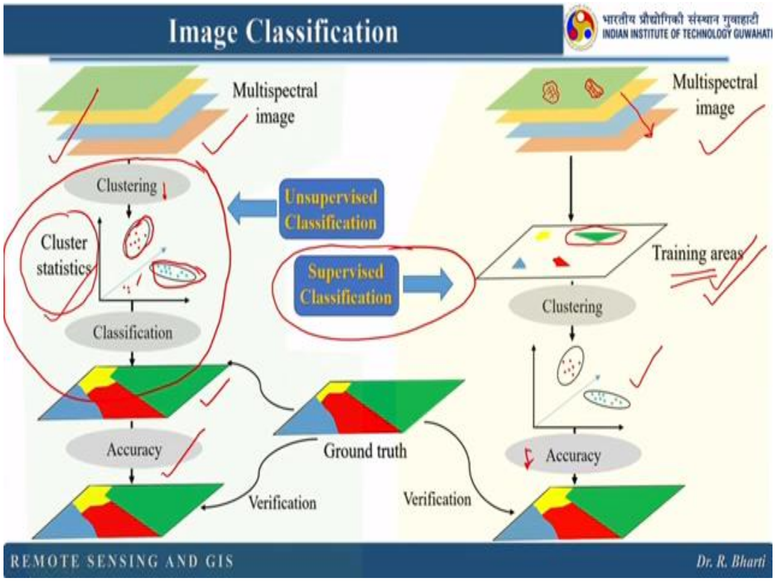

In this slide unsupervised and supervised classification everything, all the information related to image classification is available right. Now let us understand this slide, there are two different categories which we have discussed in the previous slide DN value based and the object based right. So if we go for DN value based. So here this is related to DN value only. Now this slide explains the pixel based classification technique.

Here we can see that we have a multispectral image right and then we are using clustering, classification, accuracy and then other side we have multispectral image again, then training areas, clustering and then accuracy and then finally we will achieve our classified image. But exactly what we are doing here. Let us understand that. So here in this case, basically we do not have any information about the area.

So what we want to do, we want to use some logic so that this algorithm can itself develop at cluster where all the pixels belonging in a class or from a class will be clustered together or will belong to same group. Now here you can see in this clustering mechanism suppose you have plotted band one versus band two right and here you have first class, second class and this is left out right.

So what is happening here? we have two different groups and which contains set of DN numbers. So from a cluster you have a variation in DN number. So let us say 10 to 15 belongs to class one. So based on that logic you will find in your image 10 to 50 and you will assign those pixels to class one and 52 or maybe 51 to 100, that is class two. Then in the image you will have class two all the pixels which had this 51 to 100 DN values.

Now in the third class 101 to 255 let us say only three classes we have. So all the values which are between this 101 to 255 they will be in class three. So accordingly this image this all the bands of this image will be used here and then based on this clustering logic, you will classify or you will assign each pixel of this class into three categories right, class one, class two, class three and that is known as classification.

But you have classified so you will say my classification is 100% accurate. But nobody will believe unless until you prove it. So for that we need to use some accuracy assessment techniques and then we will identify what is the accuracy of my classified emails right. And that we will report and then people can accept that that okay. This is the standard method used for classification and this is the standard method used for accuracy assessment.

So this classified image is good. In the other case here you have multispectral image again you have different bands here. Now based on your field experience or information collected from the field. You will say from this image DN value these area or the pixels belonging to this particular area are basically forest and pixels belonging to this particular area are basically water. So that will be used to develop a set or the range of values right.

Here it was based on the clustering mechanism. Here it is based on the training data set. So training data sets are actually collected from the field and that was plotted on the image and then those areas will be used to train our algorithm and to make the clusters right. And then you will find out the classified image and then again here also you have to use accuracy assessment. So this is how this is the whole story of this image classification.

So you have to use satellite images, you have to use either clustering mechanism or training data from the field. Then you will use some algorithm to classify your image. Then you have to find out what is the classification accuracy and then you will produce your classified image and the accuracy of your classification that is all.

So here when you are using the training data set from the field, it is known as supervised classification. Because you are supervising the algorithm or the method to classify this image into three or four categories based on your training data. But in clustering mechanism actually you do not control the whole process. So basically the based on the DN values and their variants and co-variants basically different clusters will be identified.

So based on that you will classify. So this is known as unsupervised classification right. Let us see in the tit what exactly these two are separately right.

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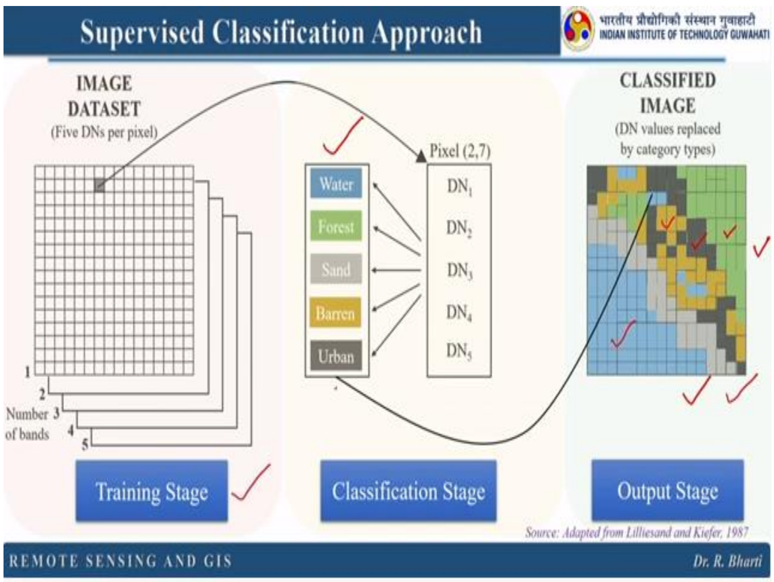

Here this is to explain supervised classification. So here you can see this is the multispectral data right and this pixel suppose if you have five band then this pixel will have five different values from five different bands right. So this is the image data set and this pixel basically the location of this pixel either you have to report or you have to identify in terms of Cartesian coordinate or latitude longitude.

So let us assume we are using Cartesian coordinate and here the location of this pixel is 2, 7 right. So this pixel value DN value will be used here the DN1, 2, 3, 4, 5 and we have information from the field that we want to classify into five classes. Let us say water, forest, sand, barren, urban right. Now what we will do? we will find out did water, forest or the pixels belonging to water area and the DN value of this particular pixel whether they have any similarity or not right.

So how we will do? we will see that methods in detail. But this is to understand basics of supervised classification. So here what exactly we are doing, we are identifying a unknown pixel from the image and we have collected this information from the field. Then we have plotted this let us say this is water, this one is here. So we know that the range of values DN values are coming from this particular class right.

So again for this training data, you have five different layers because the area which you have collected the GCPS ground control points that will be plotted here. Now when you know that okay this is the area for water then you will have five sets of DN values because you have five different bands. And once you have that then you can use some logic or method or algorithm to assign this particular pixel in any of these class right.

So this is the supervised classification. Once you do that, then what will happen? you will have a classified image where each pixel is assigned to at least one class. So now here you can see all these colours are available in this image. So based on this table you can understand this is basically forest right, this is basically sand, this is basically your barren land then this is urban right and this is water.

So all the colours or all the classes which we have used to train my algorithm that is available and all the classes are available in my classified image. So here we have three different stages. First one is training stage, then classification stage, then output stage right. So now let us see how we train our algorithm.

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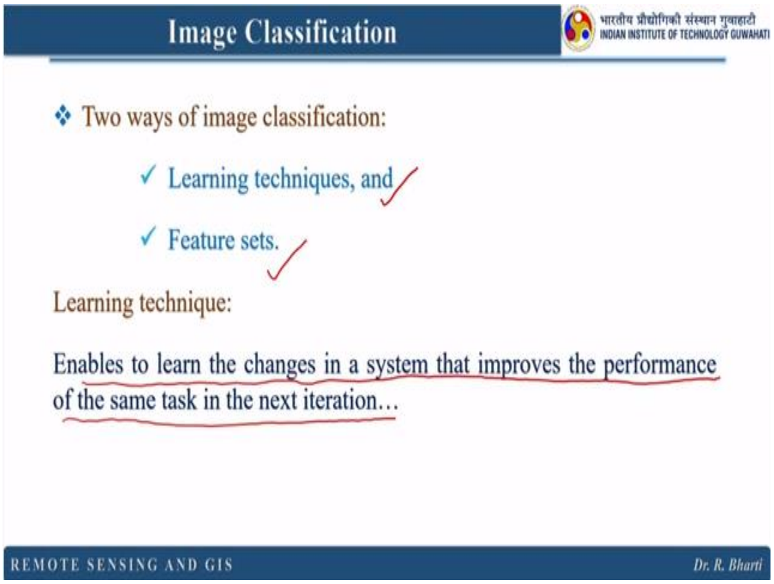

So there are two ways of image classification. First one is learning technique another one is feature sets right. In learning technique basically, it enables to learn the changes in a system that improves the performance of this same task in the next iteration. So can you imagine some example real world example, forget about this remote sensing. So when you carry a bottle right, so if it is five litre of water, so how to hold this one and how to carry this one that actually we learn with time.

So slowly you will improve your skills right to give maximum performance or to improve your performance that is actually learning technique. So let us see some examples of learning techniques.

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Like first one is driving right, the moment you start driving or learning driving then what happens. First time you fail, second time you will fail, third time you will learn something, then fourth time it will be better than and then maybe after thousands time then it will be like you will be the best driver right. So this is how we learn ourself with our mistakes or with our logics. So that is actually one example of learning technique.

The next one is cooking, the more you cook the more you will learn right. So exactly the same thing, the same logic we will apply in image classification also. So there is one more example like solving mathematical problems. So it is not like that if I tell you to solve this one problem then you will learn immediately. If you practice you can solve it much faster right. So this is how we are learning ourself in our day to day life.

So the same logic has been used or adopted for image classification where we will learn or we will give some fundamental information to our method and then slowly in each iteration it will learn itself and it will improve the accuracy of your classification.

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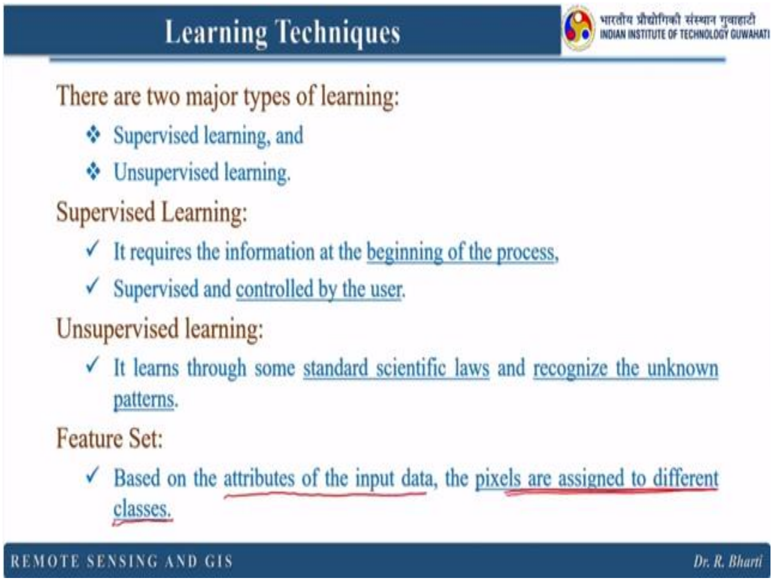

So there are two major types of learning right supervised learning and unsupervised learning. So in supervised learning that we have to or the analysts have to supervise the whole procedure. In unsupervised learning what happens there is no one to guide. So you have given the basic information and the system will start learning itself. So in supervised learning it requires the information at the beginning of the process right.

So you remember in the previous to previous slide, I told you that we will collect some training data and this is forest, this is water and this information will be provided in the beginning of the process and the system will learn right. So supervised and controlled by user. So this is the benefit of supervised learning. So in the previous one I gave you that some examples like driving, cooking, solving.

So if you want to solve a numerical, so beginning you need a teacher right. So who will teach you? how or what is the basics of maths or the physics or chemistry and then slowly you will learn that and then you can solve your own right. So that is basically supervised. But next day you have a car at in front of your home and you want to drive right and nobody is there to teach you but slowly you have learned. So that is unsupervised learning right.

In unsupervised learning it learns through some standards scientific laws and recognize the unknown patterns. So I told you that image if you plot this DN values it will be something like that right. So you will find that maybe in this particular section all the DM values are clustered together. So this in the beginning this will be your cluster one or the class one right. Next maybe you can group these four into one class.

Then these three into one class, these three into one class, these two into one class and these two into one class, these two into and one maybe left alone right. So this is what we are doing in unsupervised learning. So based on some standard scientific laws and recognize the unknown patterns.

So these patterns were unknown before but once you started the procedure then the system has identified some unknown pattern and system has grouped them into few categories or classes or the clusters right. Next one is feature set. So based on the attributes of the input data, the pixels are assigned to different classes. So this is the third category where we provide information about the features.

So what is the shape, size and dimension of this particular object and if the method identifies in the image we have similar information, then that will be grouped into that class right. So based on the attributes of the input data. The pixels are assigned to different classes. This is what feature set meant.

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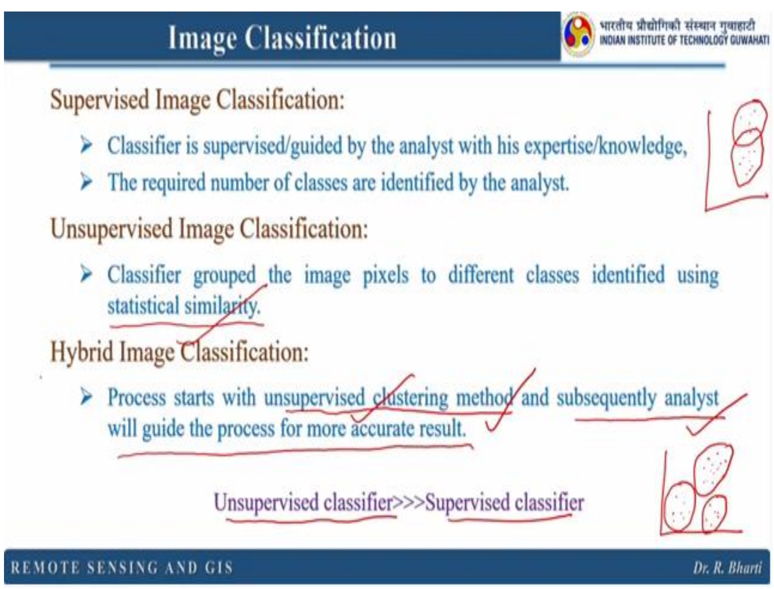

So supervised image classification. The classifier is supervised or guided by the analyst with his expertise or knowledge. Because it is very important to note here that supervised classification requests field information right. So the analyst who is going to perform this image classification, he or she should know the area and she should have or he should have the information from the field.

So suppose if this is your image, then the analysts should know that okay this is the bounding coordinates of forest class right. This is the bounding coordinates of water class. This is the bounding coordinates of urban area. So based on this information you can identify the pixels belonging to these class. What is the range of the values and whether they have any tendency to cluster together right?

So that will be supervised by your analyst. So here expertise and knowledge, it is involved right. The next point is that required number of classes are identified by the analyst. So here since this is supervised classification. So you have to tell that okay only these three classes I want in my classified image right. So in that case what will happen? the pixel belonging to these classes will be classified right.

And pixels belonging to maybe some other class like some rock type right and which I have not given any input. So that will be left out from this classification. So what will happen in the output these pixels will not be classified only these three classes will be available right. In unsupervised image classification, classifier grouped the image pixel to different classes identified using statistical similarity.

I told you that based on the clustering method, whether it is in this class or whether it is in this class that has to be identified using statistical similarity. Then next one is hybrid image classification. So this is actually the process starts with unsupervised clustering method and subsequently analyst will guide the process for more accurate results. So basically here we are doing unsupervised classification and then here we are changing it to supervised.

So you can see here we started with unsupervised. So it will tell you okay these pixels or this is the number of class in this image. But I want one more plus here. So that I can add later when I am running this supervised classification. So the output of this unsupervised clustering will be modified by the analyst based on his or her field experience and you will get this hybrid classification right.

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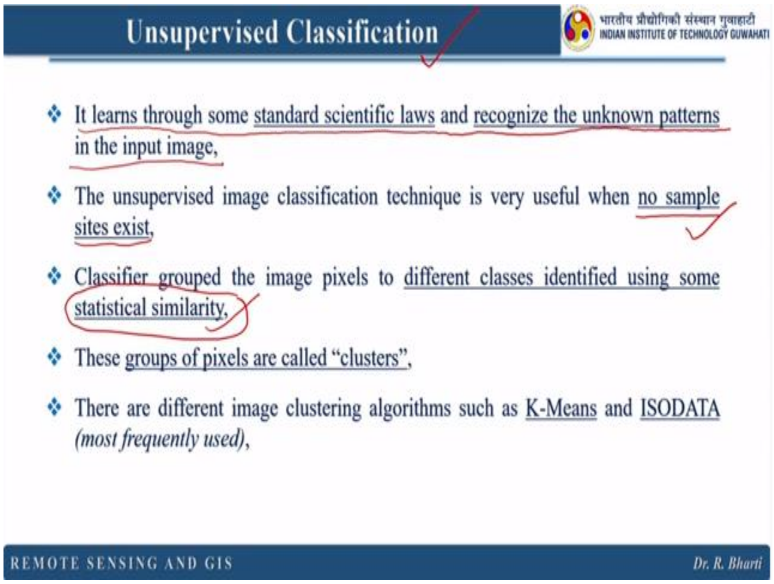

So let us see unsupervised classification in detail so it learns through some standard scientific laws and recognize the unknown patterns in the input image. I think you have understood this point. Now the next point is the unsupervised image classification technique is very useful when no sample site exist. That means from field you do not have any information, you do not have any information about different classes and their location.

So if that is the case it is better to go for the unsupervised classification. And in the third point classifier grouped the image pixel to different classes identified using some statistical similarity. So once you have this image where you want to identify unknown patterns. But you do not have any information from the field. So what we want? we want to identify groups or the clusters based on statistical similarity.

And these groups of pixels are called clusters right. There are different image clustering algorithm such as K-Means and ISODATA which I would frequently used. So let us understand what exactly clustering mean right.

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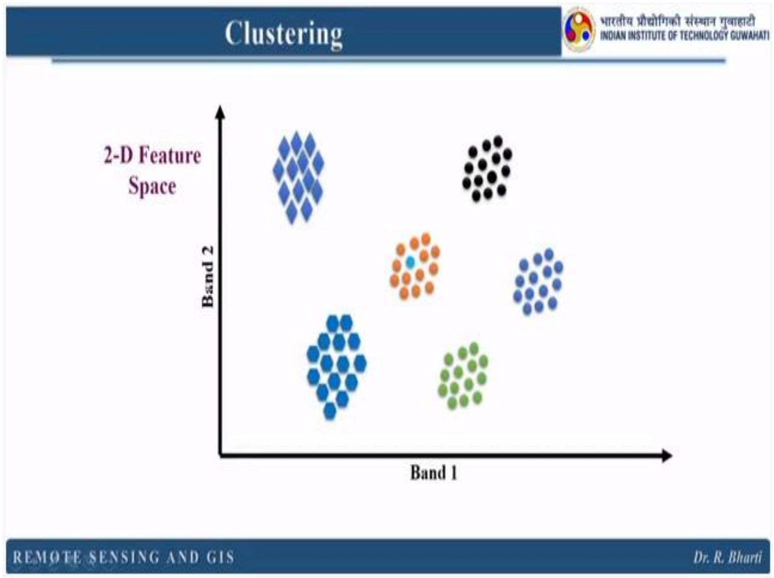

So this is the ideal case, but let us assume you have a DN value plotted in two dimension and as I told you before also that you will have or system or the method will have to identify the unknown patterns here right. So based on this you will say this is class one or cluster one or which is forest, water, or urban area. So here the same thing but in ideal condition I have demonstrated here.

So you can see 1, 2, 3, 4, 5, 6 classes are here right. And for each classes you will have a mean, mean of that cluster right. So you can easily find out the mean based on the DN values available here right. So all the values DN values will be averaged and you will find the mean. So mean pixel can be here, here, here, here, depending upon the value or the range of values for the pixels belonging to that particular cluster right.

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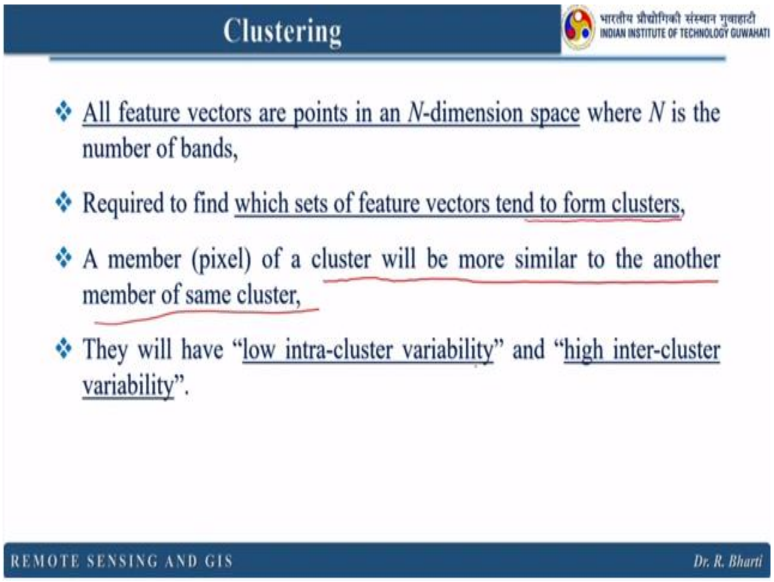

All the feature vectors are points in N-dimensional space where N is the number of band. So in the previous case you have seen this is 2-D feature space. But it is not necessary that always you will have two dimension plot. Because your input data sets are like 5 dimension, 10 dimension, 50, 100, 1000 dimension. So depending upon the number of band in your input that N-dimension space will be used right.

Requires to find which set of feature vector tends to form cluster. So here you will have to find out which set of feature vector tends to form cluster. A member of a clusters will be more similar to the other member of the same cluster. That means if you see this the pixel belonging to this particular cluster will vary together right. That is the probability right. So a member of the cluster will be more similar to the another member of the same cluster.

So similarity in terms of DN values. They will have low intra-cluster variability right within cluster they will not vary much but high interclass variability. But with respect to other cluster they will vary abruptly. So that means you have decided or the system has identified good cluster pixel right. So till now we have discussed the ideal condition when you have very well separated six classes that we have seen in the previous slide.

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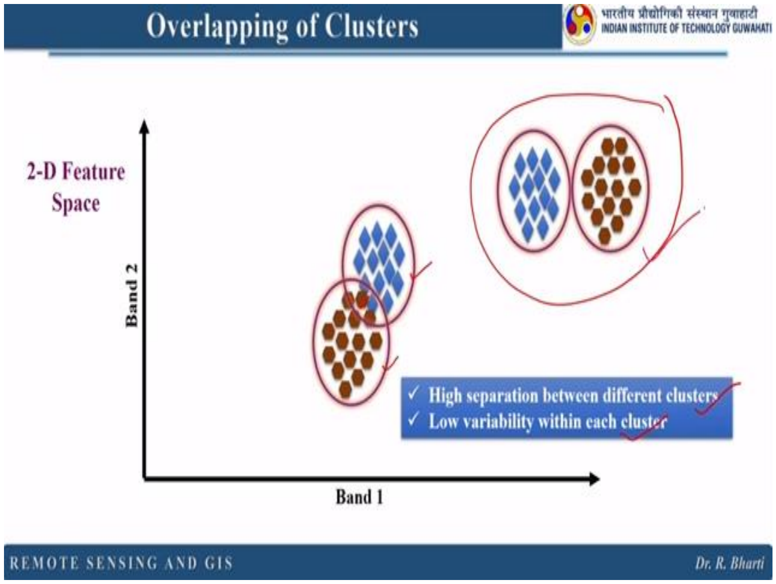

But what if when there is a overlapping of the pixels and it is very common in the image that it will be very difficult to find out whether this pixel will belong to this class or this class right. So here high separation between different clusters is required. Low variability within each cluster is required right. So in standard case or in the ideal case, this is this scenario. But in natural case this will be the scenario.

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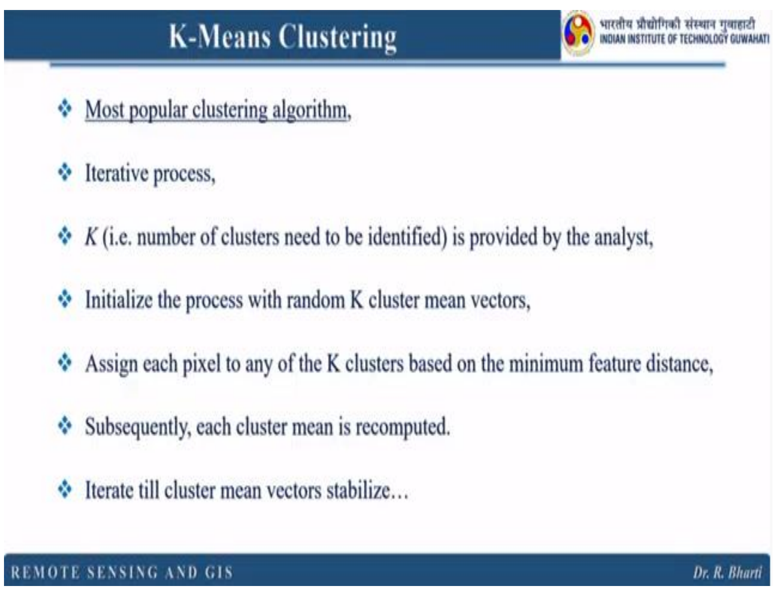

So let us see K-Means clustering algorithm. So here this is the most popular clustering algorithm in remote sensing and which is basically a iterative process. So iterative process means since this is a unsupervised classification the system has to learn its own. So in the first iteration it will learn maybe 10%, in second iteration it will improve to 20 then third 50 then sixth 100%. It is possible. So it is an iterative process.

So every time the system or the algorithm will train itself and it will find more better clusters for the given input data. So K that is the number of cluster needs to be identified is provided by the analyst. Even in the unsupervised classification came in clustering. We need to provide what is the maximum number of K we want in our image. So that many clusters will be generated. So the process will initialize randomly.

So random K cluster means will be identified. So suppose you have given 5 classes. But the system will start maybe from 100 in the first iteration based on their position and whether they are close to each other. So randomly system will identify 100 clusters then slowly it will converse to your given K value right. And when this random K clusters are identified what happens then? assign each pixel to any of the K cluster based on the minimum feature distance.

So let us assume this is your DN values right. And the system has started with 5 classes randomly. So here we have 5 random classes. Now again we need to resolve all these pixels whether they belong to this one or this one or this one. So that was decided based on the minimum feature distance. So the closest value or the closest located DN values will be assigned to this. So the boundary will extend right.

So this is how in the beginning system will start with random K value and then slowly it will converse to your given K value. Subsequently each cluster mean is recomputed right. So again, once you have extended this boundary of this particular clusters then mean will vary. So once this has resolved all the pixels and you have 5 classes, you will find out the mean of this cluster. Then again you will find out the minimum feature distance and then again redistribute the DN values in different clusters.

Does not matter in the previous iteration it was in cluster one but in next iteration it can go to cluster two based on the minimum feature distance from the cluster mean right. Iterate till cluster mean vector stabilizes. So it will keep on running unless until this cluster mean does not change right. So once it is stabilized or if you have given a threshold like okay this is the variation in the cluster mean then the system will stop or the method or the iteration will stop. Then back will be your final clusters right.

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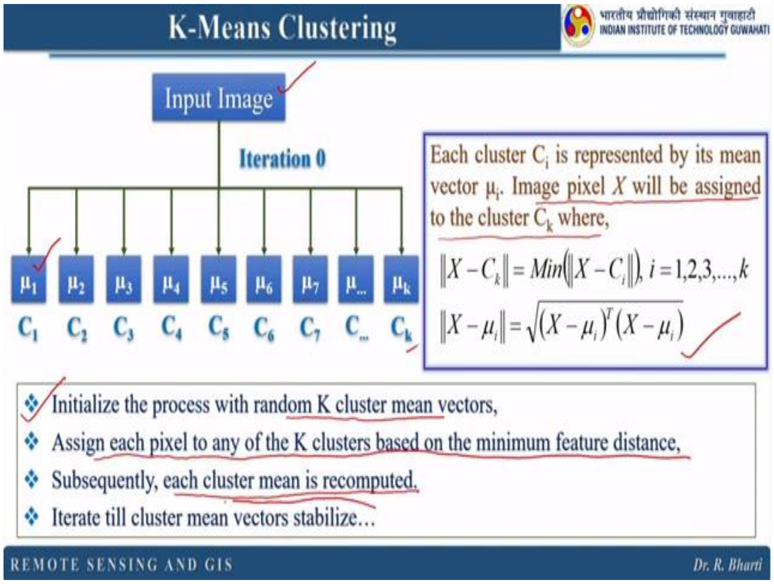

So to understand in better way, you have a input image and in the iteration 0 as I told you that system will identify or it will start with random K value right. So it has started with random K value here you can see. Now for each cluster it will calculate the mean right. And then it will calculate the minimum feature distance and then it will assign the pixel into that class. So each clusters Ci is represented by its mean vector and image pixel X will be assigned to the cluster Ck where this is satisfied right.

So here again this is the reputation. It initialized the process with random K cluster mean and then assign each pixel to any of the K cluster based on the minimum feature distance. Then each cluster mean is recomputed. So slowly this random K will be converse to your given K value. And then when it will start this iteration. When then there is no variation in the main cluster right. So then your K mean clustering will stop.

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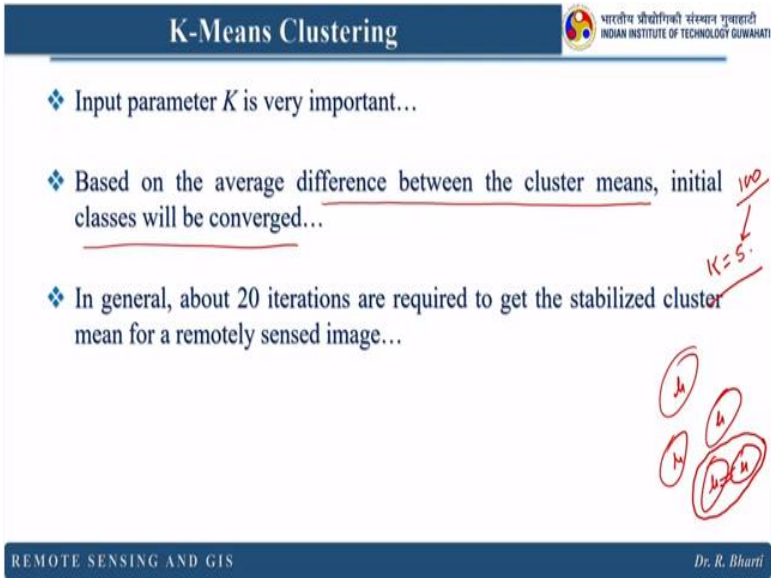

Input parameter K is very important in this method right. Based on the average difference between the cluster mean initial classes will be converged. So here difference between the cluster mean initial classes will be converged. Because as I told you that if you have given K is equal to 5, the system may start with 100 but 100 to 5 how it will come. So you have different clusters and suppose if this mean and this mean and next class is here.

So this mean and this mean will not be very far from each other right. So what will happen these two will converge and they will be one class. In general, about 20 iteration are required to get the stabilized clustered mean for a remotely sensed images. So this is not the standard so you can try that it may converse maybe after 10 iteration it may take 40, 30, 50 so this is not fixed but in general 20 iteration is good to get this stabilized cluster mean for remotely sensed image right. Here you can see some of the example.

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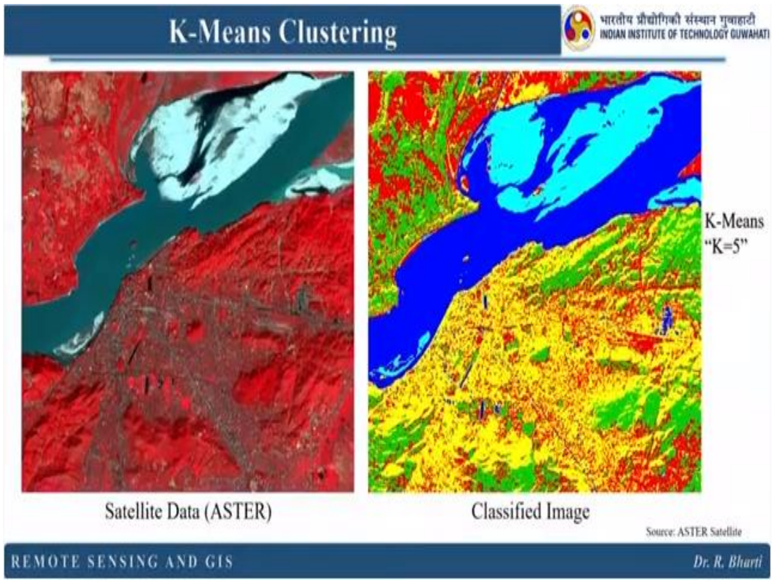

So here you have raw data right. This is from ASTER sensor and this is the classified image when I have given K is equal to 5.

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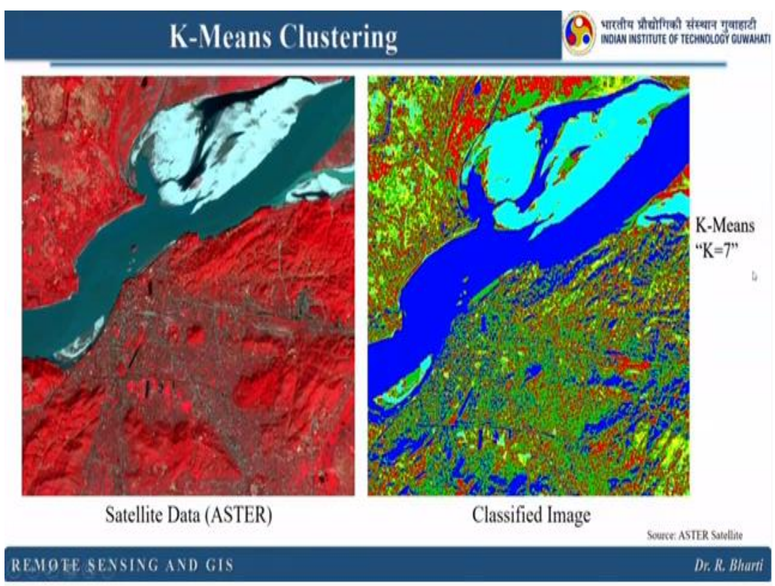

This is another for the same image when I increase the K from 5 to 7 these are the changes you can see here. So here analyst supervision or the analyst decision about this K value is very, very important. So you have to carefully analyze this image though you do not have any information from the field. But you need to know in how many categories you want to divide this whole image. So here you can see so you have only maybe 7 classes here.

So only 7 colours are used here to represent seven different classes. So once you know blue colour is water then all the blue colours belonging to this particular image right classified image they represent water or the presence of water right.

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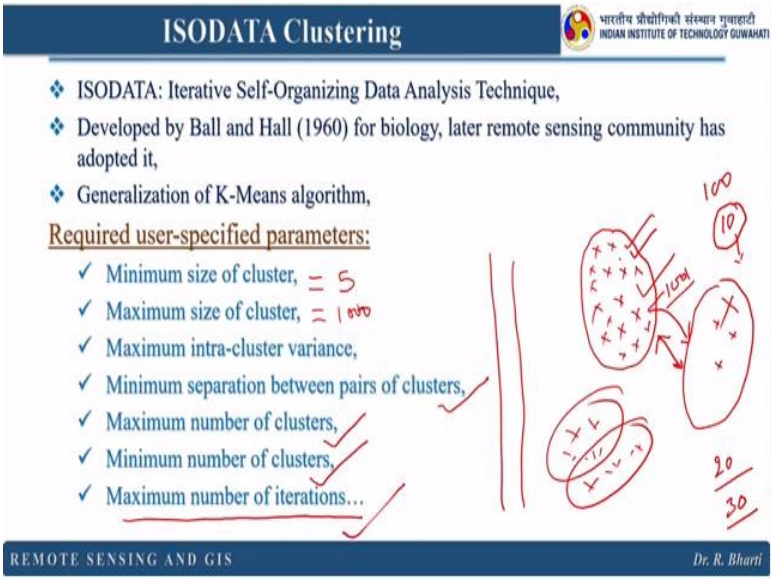

So the next method is ISODATA clustering. So ISODATA this is the full form Iterative Self-Organizing Data Analysis Technique and it is developed by Ball and Hall in 1960 for biology, later remote sensing community has adopted it. So you can see it is not necessary that you should be like expert in remote sensing. But you can use your basic understanding to propose something new once you are comfortable or once you know this basics of remote sensing.

Then you can apply your knowledge to progressively enhanced or progressively change the methods which people are using in some process. Generalization of K-Mean algorithm so basically this is the generalization of K-Mean algorithm right and it requires user specified parameters like minimum size of the cluster, maximum size of the cluster, maximum intra-cluster variance, minimum separation between pairs of cluster, maximum number of clusters, minimum number of cluster, maximum number of iteration.

So let us understand all of them separately. So let us talk about minimum size of the clusters. So here it requires how many pixels or the minimum number of pixels you want in each cluster right. So if you say that I need at least 5 pixel in my cluster right. So this is fine, on that basis it is fine. But in the other cluster where it is started with random K value, let us say it has only 3 right.

But I have given minimum 5 pixel is required, then this will not qualify so then this will not be club together right. Next is maximum size of clusters. So I can say maybe 1000 right. So maximum 1000 pixels will be allowed to be part of this cluster right. But if it exceeds like 1001 then that pixel will be out from this cluster and it will go to some other cluster. So this is how we are evolving ourself.

Now next is maximum intra-cluster variance. So intra-cluster means between the clusters or among this DN values of this particular cluster right. What is the variance you want? so minimum variants. Then maximum separation between pairs of clusters. So here maximum separation. What is the separation you want from or between these two clusters, that is very important?

So initially we had this kind of problem like it is coming here and here also. So how to separate them. So it is very difficult. So we should provide what is the distance or what is the minimum separation we want in our clustering mechanism. Then obviously maximum number of clusters, minimum number of cluster, so maximum number of cluster may be 100, minimum maybe 10. So at least the system will give you 10 classes at the end that is the criteria.

And maximum number of iteration so how many iterations it should run. So if you say 20, 30 so 30 times it will run and it will stop. So here there are other criteria like if you can say you may decide that based on any of this if it is not matching your iteration will stop. That is up to the analyst. So that you need to decide in the beginning then you have to run the system.

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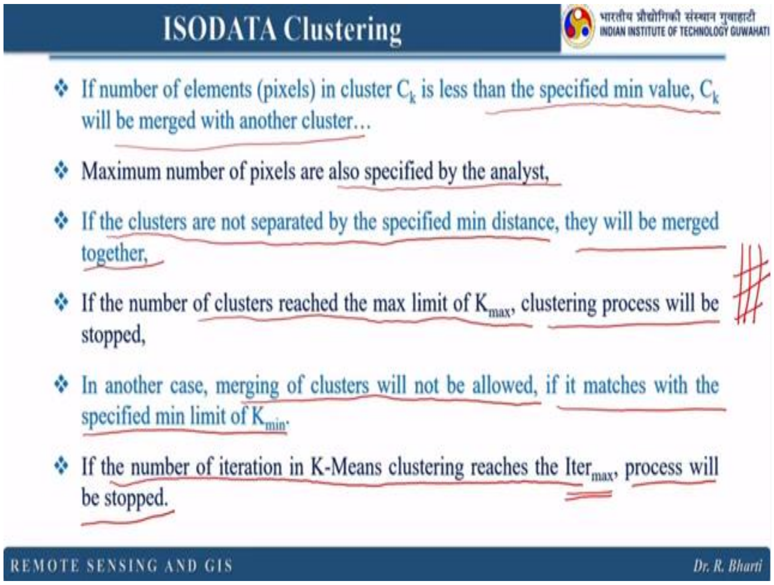

So here if number of elements in cluster Ck is less than the specified min value, Ck will be merged with another cluster. That is the first criteria right. Then maximum number of pixels are also specified by the analyst. If the cluster are not separated by specified minimum distance, they will be merged together right. Then if the number of cluster reaches to maximum limit of Kmax clustering process will be stopped.

In another case measuring of cluster will not be allowed if it matches with the specified min limit of Kmin right. So everything I have discussed in the previous slide. If the number of iteration in K-Means clustering riches to maximum number of iteration, process will be stopped. So because we need to be very careful while running this clustering methods because you need to stop somewhere. Otherwise it will keep on running. So any of them if they are not matching then the iteration will stop.

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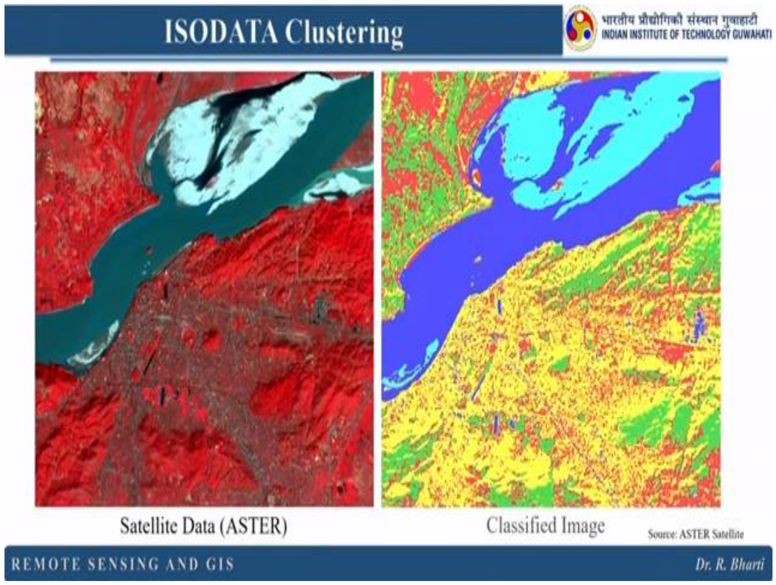

This is the example of ISODATA clustering right. So we have seen K-Means and ISODATA clustering till now. Now let us see supervised classification.

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So supervised classification. It is supervised and guided by the analyst and it requires training data at the beginning of the process. The required number of classes are identified by the analyst because that will be like how many training data or for how many classes you are providing the training data right. That will decide the total number of classes here. So let us understand what exactly we mean by training data.

And is there any scientific basis of deciding which a pixel or which class should be used in training data? yes, there are some standard logic that you have to know right.

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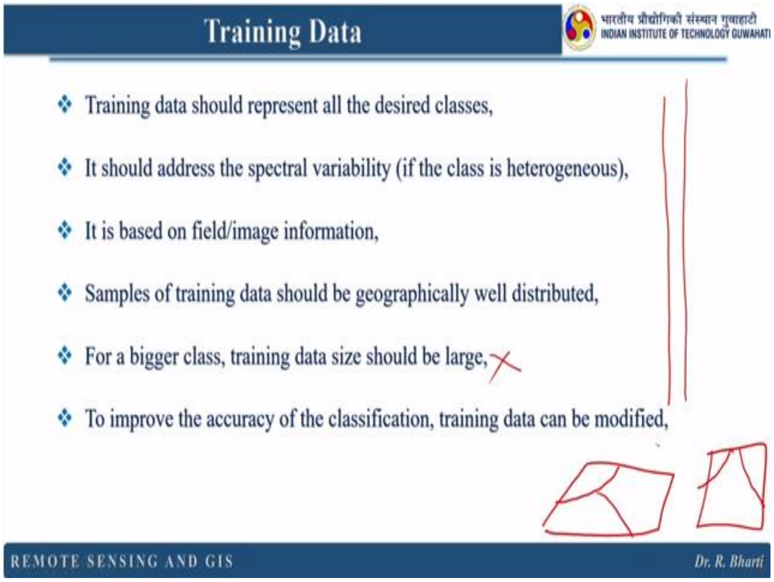

So training data should represent all the desired classes. So if you want to divide your study area or the image into 5 classes, then for 5 classes you have to provide training data right. It should address the spectral variability if the class is heterogeneous. So spectral variability means suppose if this is the image right and this is the forest class. So you may find some of the pixels if you have displayed it into FCC.

Then some of the pixel will be more red or dark red. Some will be very light right. So why there because based on their chlorophyll content and the other properties. So if you want to identify or you want to classify the image into forest and non-forest. Then you should collect all the pixels or the variability of the pixels belonging to this forest class. Then only your image classification will be good right.

And it is based on the field or image information. Because whenever we collect this ground control point using this GPS. Then that will be plotted on your image and then you will find these pixels are actually from this particular class and that class or that pixel value will be used to develop a relationship between this class and this DN value right. So it is based on field or image information.

Samples of training data should be geographically well distributed right. So this is another concern like suppose this is the forest class. Here you may also have forest, so you should collect forest training data from this class also or this area also from here also, from here also, from here also. So that training data should be geographically well distributed. For a bigger class training data should be large.

That says if this is the image and this is the forest right and this is water body and rest are urban area. So for the urban area if you have given 5 pixel right. So first of all you need to see whether they are geographically well distributed. If you say that okay they are distributed with this 10 points right. So will it satisfy all the criteria? No, because you have water class also. You may have collected 5 pixel for water.

For water maybe this is a very small area. So 5 pixel is good enough. But in case of urban and in case of forest right you may have to give sufficient number of training pixels right. So then only it will satisfy this criteria. For a bigger class, training data should be large. To improve the accuracy of the classification training data can be modified. Suppose you have followed everything.

But you have not followed this one. So your classified image which was supposed to be like this in three classes, but it is coming like this. So there is something wrong with my training data. So what I have to do, I have to revisit my training data and then I have to satisfy all these criteria and then I have to run the classification again right.

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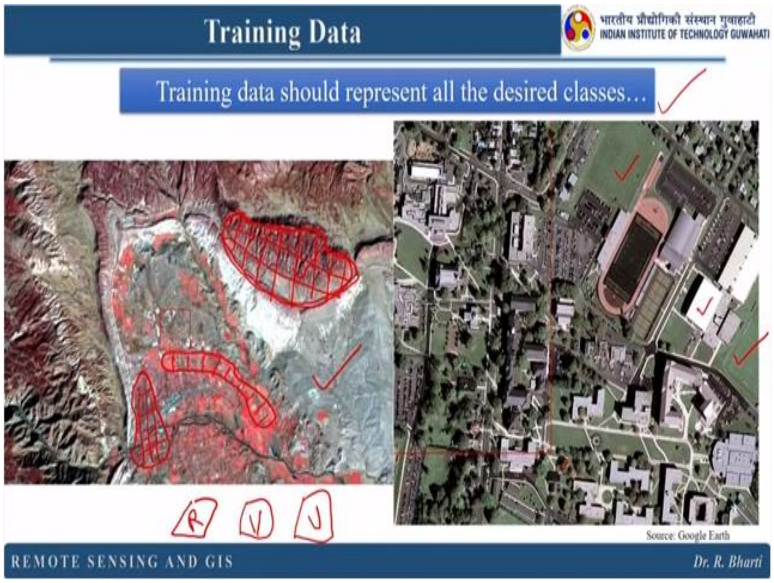

So let us understand each and every point of this training data with respect to images. So first point is training data should represent all the desired classes right. So here it says first analyst has to decide how many classes he or she wants. So let us assume that only 3 classes. So this is one class where we have exposed rock. This is another class where we have vegetation. This is another class where we have settlement right.

So training data should represent all the desired classes. So analysts should have at least 3 classes and how it will be done. You will go to the field, you will visit this particular area, you will collect the bounding coordinates of this particular class right and then you will plot that information on this particular image and then these pixels from the image will be treated as training data right.

For vegetation also the same thing will be happening. For urban also same thing we will do. So you will have 3 training data for let us say rock, forest, or vegetation, and then urban area right. So once you have that, then it is good. In case of high spatial resolution data, what happens? You can easily find out different classes. But in case of low resolution data it is hard to find even 4 or 5 classes.

But in high spatial resolution it is very easy. You can separate each and every different objects into different classes right. So here you can use maybe ground right playground or maybe grasses in one class, trees in another class, concrete in another class right and maybe roads in another class, then railway tracks in another class. So you can identify as many as you can and provided you should identify the same pixel on the image. So that that pixels will be treated as training data right.

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Next is training data addresses the spectral variability. So spectral variability means if you see the water is filled from here to here, here also you have water bodies right. So the pixels belonging to this particular location will have different DN value. So maybe let us say 5, here it may be 6. So that means you should take care of the spectral spectrum variability because if the location is different maybe the quality of the object is different. So you should include all the variability for that particular class right. So this is another example.

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When you have snow maybe if it is fresh snow you will have different value. If it is old snow, if it is dirty snow, if it is in melting phase, if it is in freezing phase, so those DN values will be different from each other. Not drastically but still you have to incorporate all the DN values from different locations. So then you will incorporate this spectral variability in your classification.

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Here this is another example when you have vegetation, so this is very good here. You can see here this is dark green, here it is light green. But actually there vegetation. So maybe you can divide them into two category maybe dense forest, sparse vegetation or you can name them as per their species. So that is also possible. So that is why it is highlighted here, spectral variability should be incorporated in your training data.

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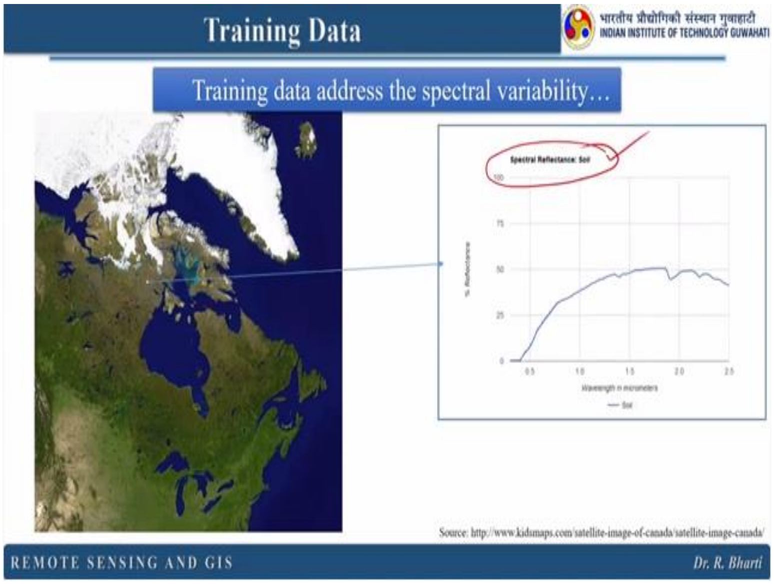

This is another example where soil is used. So soil also place to place their DN values will vary. So you have to take care of the spectral variability of the training data. So basically for that cluster or for that class you should incorporate all the spectral variability. So that training data will be good enough to classify all the pixels of your image.

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For a bigger class training data should be large. That says like here this exposed rock, the area of this exposed rock is too large right. So you cannot just take one or two pixels from here and you can say that okay this is enough for my classification. No that is wrong. So if the class size in your image is large, then you should incorporate more pixel in your training data. Then your accuracy will be more.

Here you can see if suppose if I want to classify only vegetation and non-vegetation area right. So then in vegetation I have to include more pixels right for my training data. Then only it will be good.

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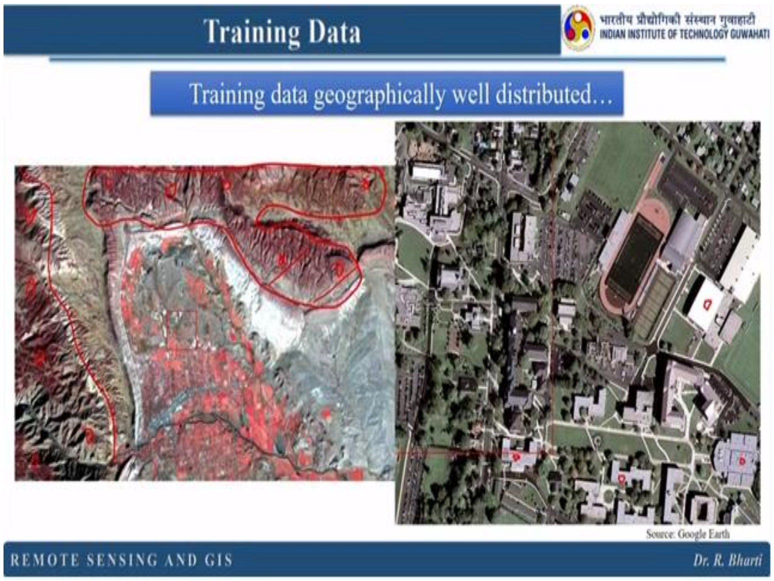

Training data should be geographically well distributed. So that says if this is the exposed rock right. So then one pixel you should take from here, from here, from here, from here, from here, from here and here also right. So that means you have to visit all those places and you have to incorporate a spectral variability and based on the size of that class in your image you should include more pixels.

And you have to make sure that these training pixels are well distributed in your image. Then your result will be better right. So here in case of this if you collect only concrete, you collect this 3 pixel right. Will it be sufficient? No, because place to place construction materials are different. So what do you have to do? You have to resolve that by collecting more sample and that should be distributed all over in your image right. So then only your classification result will be good.

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Now the next point is to improve the accuracy of the classification training data can be modified. So suppose you have followed some of the logics but some of the logics you have ignored. Because in the first at time it was not available, all the information was not available and you find that classified image is not good. So then what you can do, you can revisit your training data modify follow all the rules and then your classification result will be very good.

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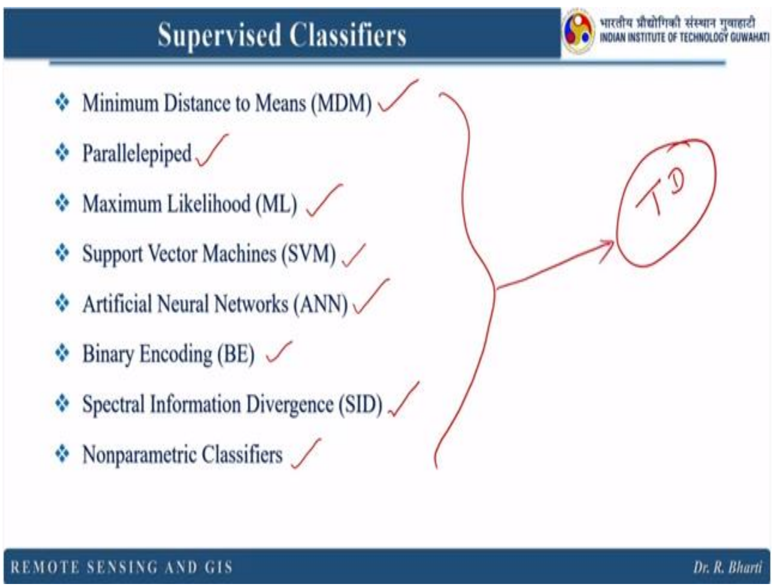

There are different types of supervised classifiers. So they are like, first one is minimum distance to Mean, second is parallelepiped, then third one is maximum likelihood, then support vector machine, artificial neural network, binary encoding, spectral information divergence, then nonparametric classifiers. So these are basically used in your supervised classification. But in that case training data is always required for any of them right.

You need to provide training data without that this method is not going to work right. Because this is supervised classification.

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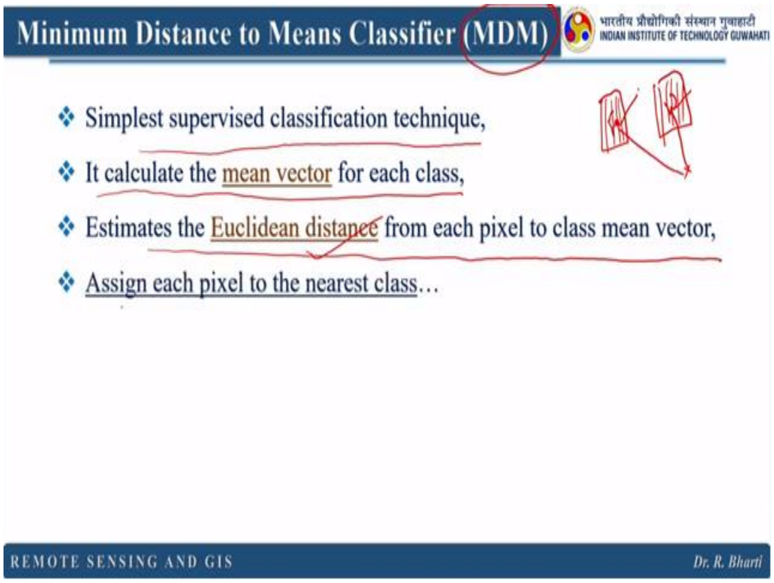

So let us see the first method which is minimum distance to mean classifier which is also known as MDM right. What it says is it is simplest supervised classification techniques which calculate the mean vector for each class right. Each class means we are talking about the training data right. Estimates the Euclidean distance from each pixel to the class mean vector. So in case if you have given two training data set like one is for forest and other is for water.

Then we will calculate the mean vector of this right because there will be too many pixels here, here also so you can find out mean vector here, mean vector here. Then for a unknown pixel we have to find Euclidean distance from each pixel to class mean vector right. And then whatever is nearest that will be assigned and it is assigned to each pixel to the nearest class.

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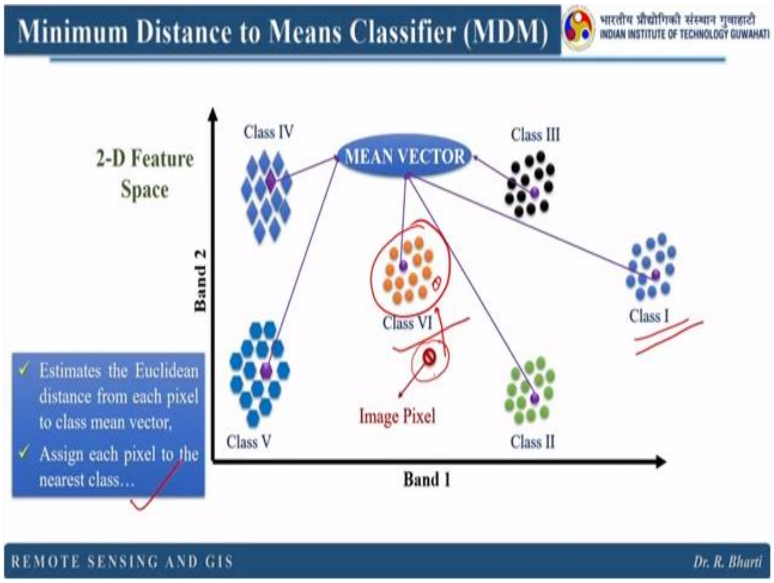

So to understand this, you can see this. So we have provided how many classes? 6 classes right. So now we have 6 classes as training data. Now what we have done, we have named them class one, class two, class three, class four, class five, class six. Now next step is calculate the mean vector right. So that will be identified and then this is my image pixel which has to be classified in any of these six classes.

So what we will do? we will calculate the Euclidean distance and then we will assign this unknown pixel into the nearest class. So in this case maybe this class is actually the nearer one right. So what we do, we assign this to this. So it will so this will go here. So here the same thing which have repeated.

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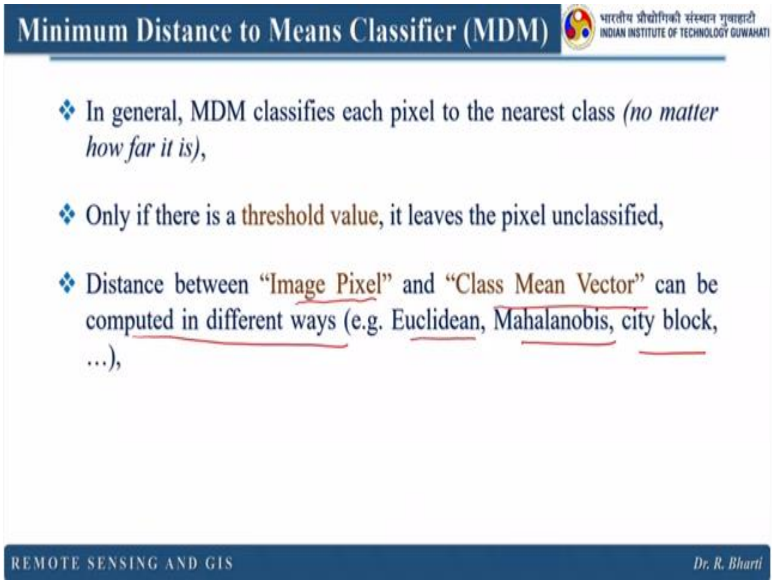

In general MDM classifies each pixel to the nearest class no matter how far it is right. Because you have to find distance from all the six clusters. If distance between class one and the pixel is the less value. Then definitely that unknown pixel or the image pixel will be classified into class one. But I exactly it may not be the same class but it is classifying that one. So that is the problem.

Only if there is a threshold value, it leaves the pixel unclassified. So suppose if this is these are the clusters right and this is the pixel. So obviously if you do not have any threshold value, this pixel will be classified into this class because this is the nearer. But probably we have left one class because we wanted only four class here. So this may be some other class, but because we do not have any threshold value here it will be classified into this.

So that is why to resolve that one you have to use threshold value so that there will be several pixels left unclassified. Next is distance between image pixel and class mean vector can be computed in different ways. Because it can be calculated using Euclidean, Mahalanobis, city block and you can use there are many distance calculator right. So those methods can be incorporated here when you are calculating the distance between class mean vector and the image pixel.

So that will be if you use a Euclidean, Mahalanobis maybe you will find that pixels are classified into different classes in all the methods. So you have to find which method works well for you.

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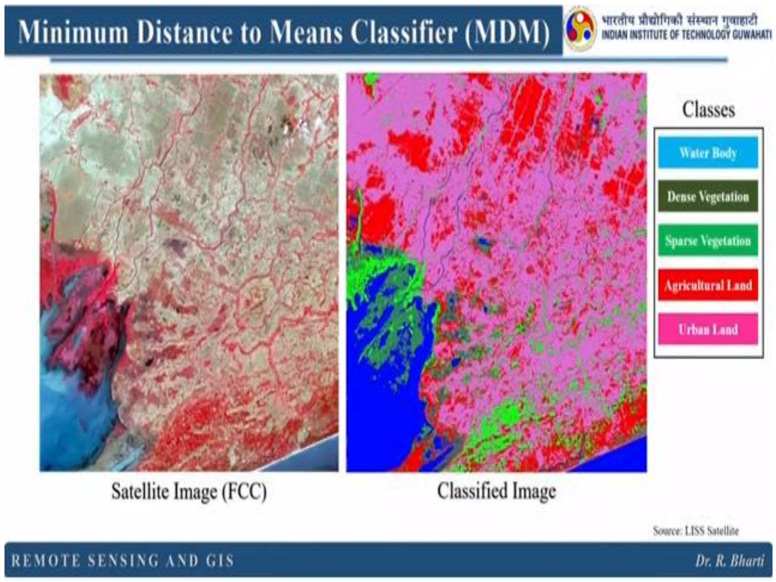

This is the example or this is the result of MDM. Here you can see water body, dense, sparse vegetation, agricultural land, urban area which are visible here right.

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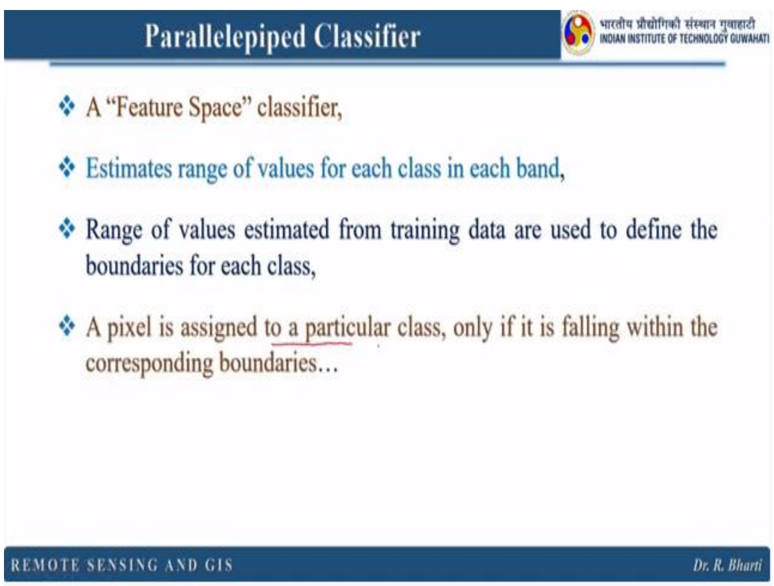

So the next method is parallelepiped right. So here what we do is we actually use the feature space right. So this is what it is written here. It is a feature space classifier and it estimates range of value for each class in each band right. So range of value for each class in each band that means class suppose this is the image and you have collected the ground control points and you know the latitude longitude and you know that these two pixels are basically forest.

So once you would say to identify or to mark your training data, you say these two pixels are forest, then what will happen? you will have maybe let us say let us assume that we have three band input data. So the same location will be used and the value will be extracted from these three images right. So the range of values estimated from training data are used to define the boundaries for each class.

So what happens here, this is suppose three bands. So you have three dimension and you know that from these four pixel what is the minimum and maximum value? So here you will have minimum and maximum, here you will have minimum maximum, here you will have minimum maximum. Then you can actually draw the boundary for each class right. So a pixel is assigned to a particular class only if it is falling within the corresponding boundaries. This is very important that you will understand here.

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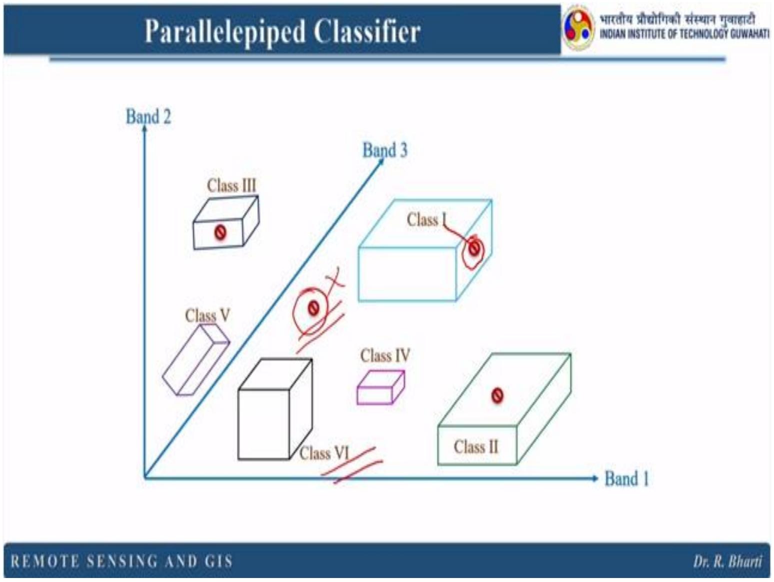

So based on that logic which I have explained just now for each class you will find the range or the minimum and maximum value. So let us assume you have three band image in your input. So for the training data for the cluster you will identify bounding or bounding values like minimum and maximum for all these three bands and accordingly this boxes will be made. So after that what will happen?

You will have to find out the pixels whether they are falling or matching with this particular boundaries or not. If so then this will be assigned to this. But what if they are lying outside? Then in this method these pixels will not be classified. So in at the end you will have only six classes from the classification. But you will have one more class that will be unclassified class right.

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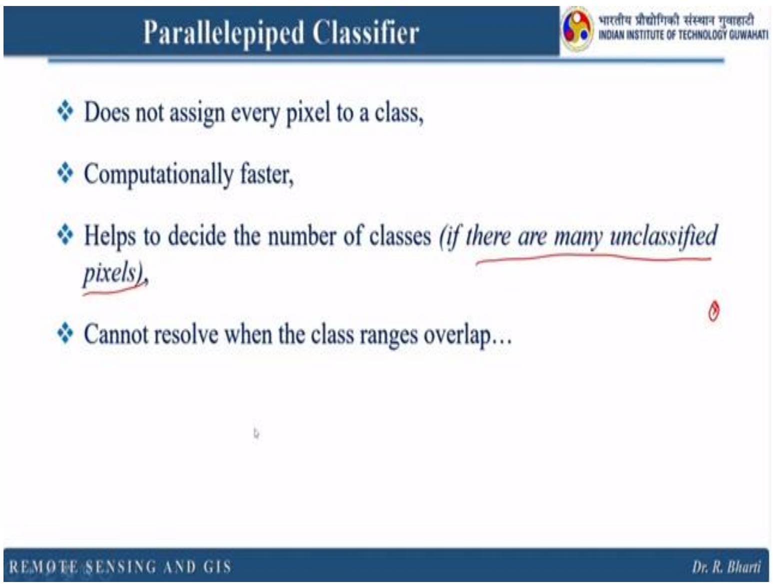

You can see in parallelepiped, basically it does not assign each pixel to a class that you have understood and computationally faster because once you know the bounding values it is very easy whether this particular unknown pixel is matching with that boundary or that value minimum maximum, yes or no then immediately you can produce the result. And it can be used to decide the number of classes in your input.

Because if there are many unclassified pixel left after this parallelepiped classification that means initially I have given three classes, but one more class is coming with too many pixels that is unclassified pixels. That means I need to increase the number of my training data right. So then you will have to produce or you have to provide maybe four, five or six training data sets right.

And it cannot resolve in the class range overlap. So if there is a overlap in the class range it will not classify or it will not resolve that problem because this method has its own limitation right.

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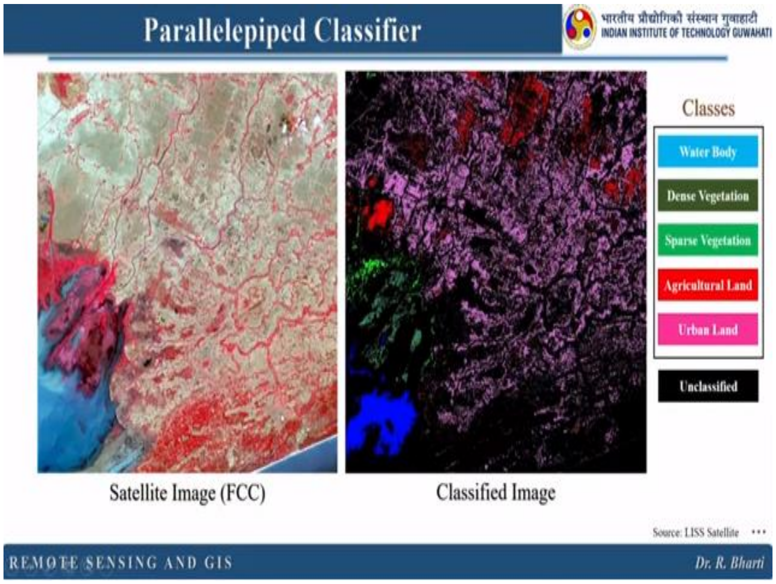

Here you can see the example of this classification. So there are some black pixel right. So they are basically unclassified. So initially we have given water body, dense vegetation, sparse, agriculture land, urban area. But there is one more class and you can realize from this image that there are too many pixels are falling in this category. That means still I need to increase my classes or I have to revisit my training data and I have to follow all the rules.

Then probably this classification accuracy will be more. And then finally you will have very less or maybe there will be no unclassified pixel in your image right. So that is all for today. Rest we will see in the next lecture. Thank you.