Remote Sensing and GIS
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Lecture - 07
Digital Image Processing (DIP) - I

Today, we will start digital image processing. How do we process the images acquired from airborne or space borne sensors? So, in this digital image processing, there are many different elements which are included.

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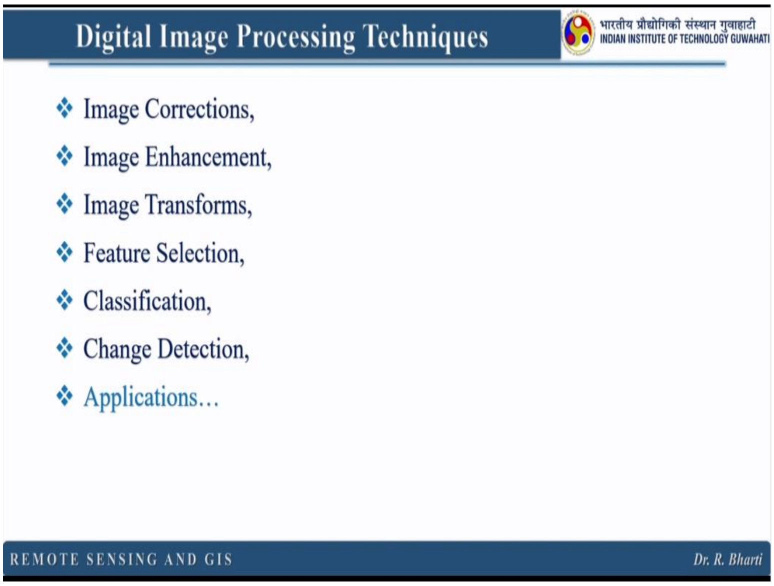

So, one of them is image correction, then image enhancement, then image transformation, feature selection, classification, change detection and why we do all those things because we want to apply or use these images in our application right. So, slowly we will get it into this image processing but before that do you remember that images which are captured by satellite, they are actually captured in different wavelengths.

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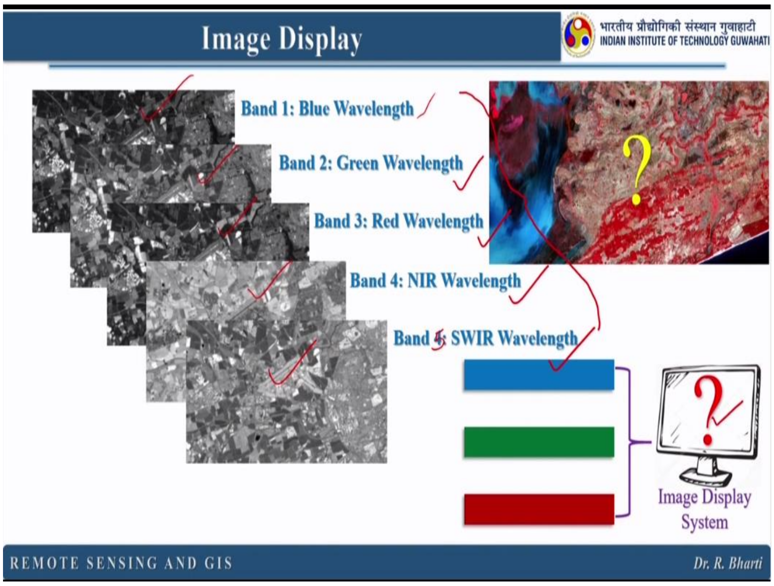

So, for one individual area you have many images in different wavelengths right. So, here you already have seen this one right. So, for the same area you have different bands. So, here for example band 1, band 2, band 3, band 4, band 5 right. So, this will be band 5 right and they are captured in blue wavelength, green wavelength, red, NIR and SWIR. So, their information is different.

But this we are looking individually but suppose if you like to see these images in color composite, so how do you generate this color composite. So, you have to understand the basic fundamental of this. So, first of all for any kind of display, you have 3 primary colors right; blue, green and red and all the colors which you are seeing that is the combination of these 3 right. So, how do we represent or how do we visualize these black and white images separately into a color image right.

So, ultimately we want to see something like this right where red represents some x material, blue represents some y material. So, how do we represent this one that we need to understand first?

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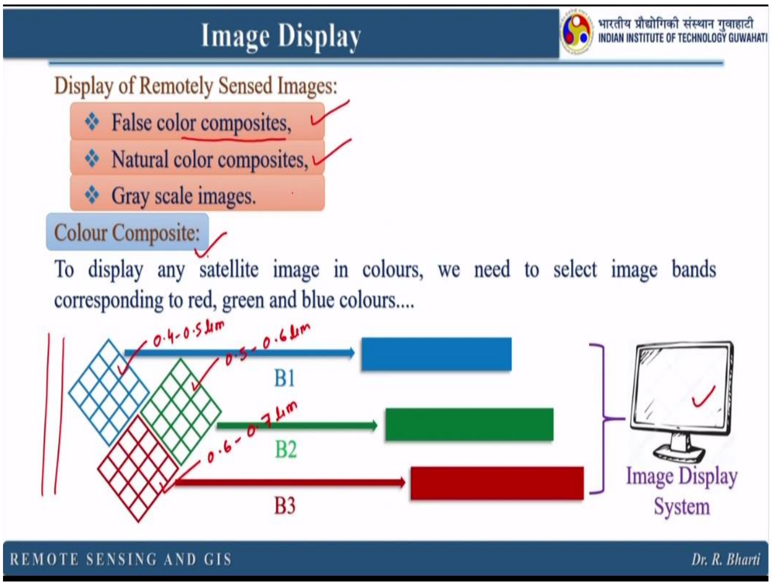

So, how do we display remotely sensed images? There are 3 different concept; first one is false color composite, then second is natural color composite, third one is gray scale images right. So, first of all let us understand what do we mean by this color composite. So, color composite is used to display any satellite image in color, we need to select image band corresponding to red, green and blue colors of our monitor or any display system right.

So, let us assume that you have a display system right and you have only 3 bands captured in different wavelengths. So, here let us assume that you have a blue wavelength band, then green wavelength band and red wavelength band right. So, to make it more clear this is the wavelength of 0.4 to 0.5 micrometer right and this is 0.5 to 0.6 micrometer and this is 0.6 to 0.7 micrometer right.

So, now you have 3 images captured from satellite data or satellite sensor and you want to display this in our normal or regular monitor but in color composition right. So, here what we do, we assign blue band to blue color of the monitor or blue band of the image to green or blue to red. So, this flexibility you will have. So, you will have to select which band you want to represent in blue color or green color or red color.

So, if you have such flexibility and if you are displaying the same image, those images like combined images color images, they are known as color composite right. So, now we will see what do we mean by false color composite, natural color composite, gray scale images right. So, already we have covered color composite, then false color composite, natural color composite and gray scale image.

So, false color composite means your color will not represent exactly how they look like in the nature right and in natural color composite it will have the similar color as they appear on the ground. In gray scale image, what will happen, you will have no color, only black to white, that range you will have right. There is some convention which we need to follow to call them or call this color in composite to false color composite, natural color composite or gray scale image right.

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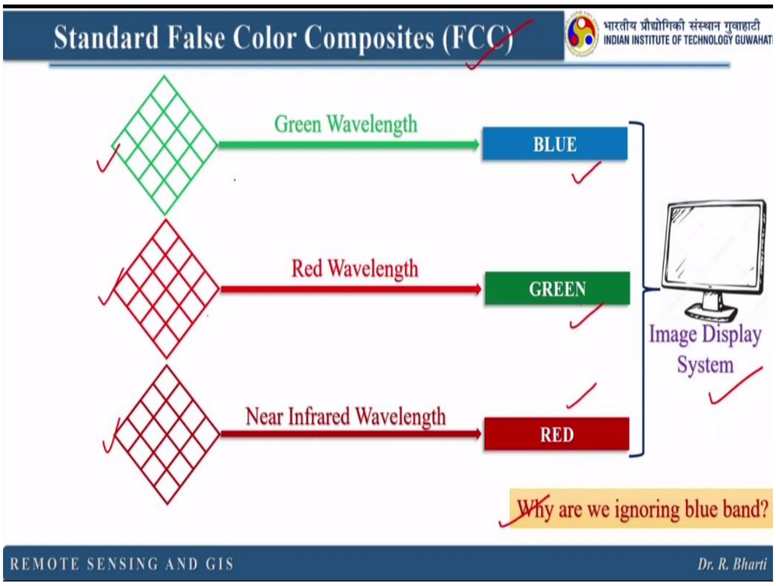

In standard false color composite, let us assume that again we have 3 bands. So, first band is green band right and you have different types of display system. Here, we have a monitor and we are having blue gun, red gun and green gun right. So, these 3 color gun we have in our monitor and these are the images captured from satellite. Now, if we are going to call this FCC or standard FCC, we need to assign green wavelength to blue color of our monitor right.

And red color to green and near infrared wavelength to red. Strictly, if you are following this convention, then only they are qualified to called as standard false color composite. Otherwise, they will have different name, we will see that. Now, here I have not included any blue band. Why? Because in blue band, you have more scattering, so always we try to ignore this blue band.

If we are not interested to study some material, which are sensitive or their peak absorption feature right they are away from the blue band. So, in this case, here we are using green, red and near infrared.

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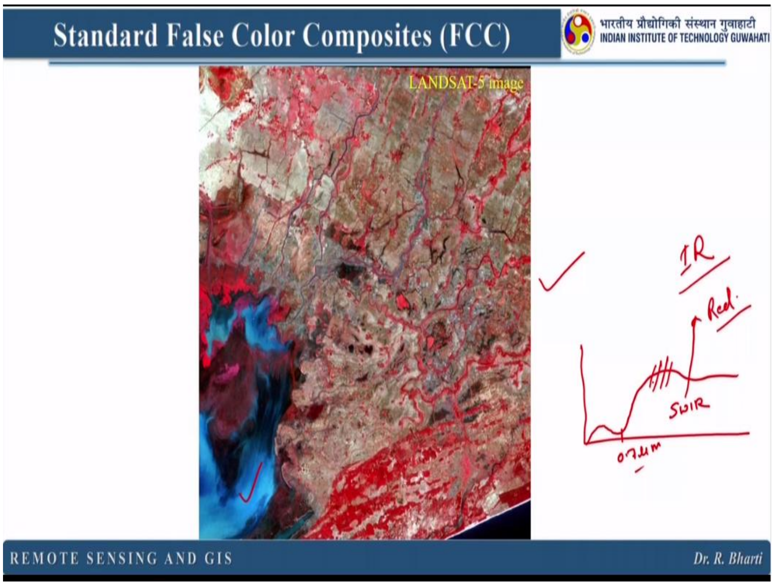

So, if you display your image using this standard convention where we are assigning green to blue, red to green, near infrared to red, then your image will appear something like this. Here, we have assigned near infrared to red right. Here you can remember, so here all the red colors are basically IR. Now, do you remember that vegetation curve? That it was something like this and this is basically SWIR.

Now, this is 0.7 micrometer, so you have assigned red color to this particular band. So, your vegetation will appear in red because they are having maximum reflectance in this particular area. So, that is why if you have used standard false color composite display, then red color of your image will be essentially representing vegetation and blue will be your water, blue or black will be water and if you have settlement, it will be in cyan color.

So, that is the definition of this standard false color composite and how do we represent this one. Sometime, I will show you how we select these bands in the display so that it will appear in different colors right. Now, let us see what do we mean by natural color composite. So, as I told you in natural color composite, it will be something similar how they appear on the ground.

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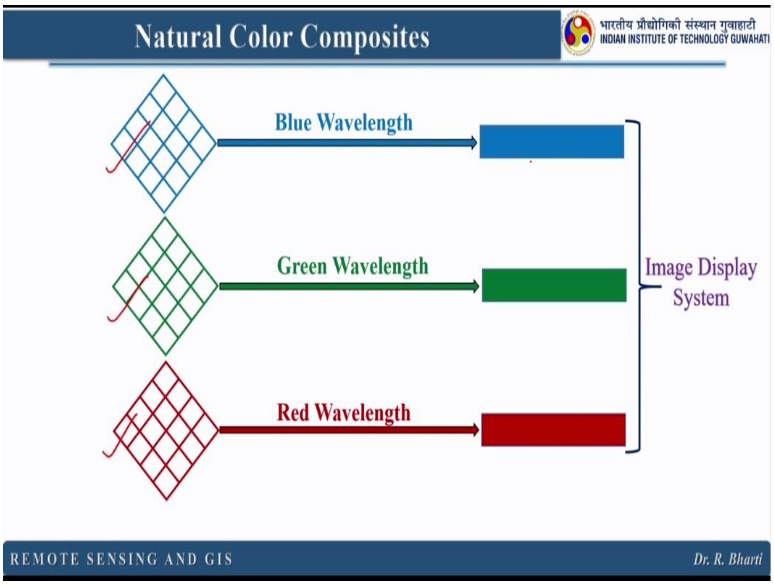

So, in this case, again we have blue, green and red and here we have included this blue band, green and red right and again this display system will have similar guns like blue, green and red guns. Now, if you are assigning blue to blue, green to green and red to red, then they are known as natural color composite. So, here basically we are assigning same color to the same wavelength that is why it is known as natural color composite.

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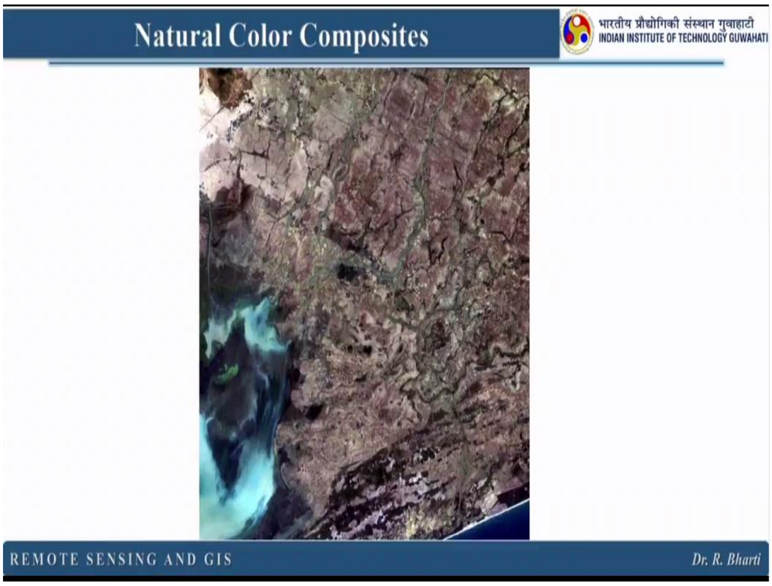

So, if you see this image, it is very similar to how they appear on the ground with our eyes right. So, we can also see blue, green and red and here also we are using blue, green and red. So, that is why it will appear more closer how they appear on the ground with our eyes right but in the false color composite what we did, we have included infrared bands so that is why the infrared information we cannot see but the instrument can measure.

So, that flexibility we have with remote sensing which we cannot have with our eyes. So, that is why in standard false color composite, red color was representing vegetation but here the green color will represent vegetation right.

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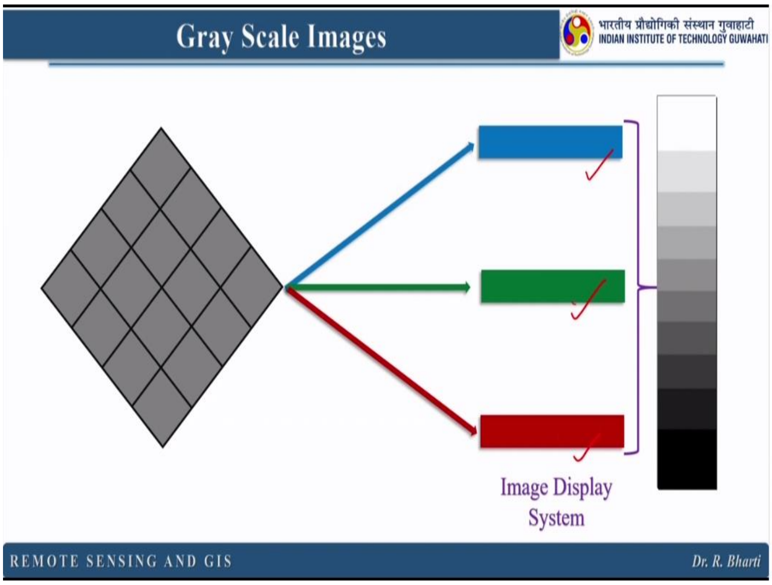

Now, the next is gray scale images. So, how do we represent because if you remember that we have these 3 color guns available in our system right but how do we represent our image into black and white. So, what we do, we will assign the same matrix or the same image in blue, green and red. So, if you do that then your image will be black and white. So, higher the value, they will appear brighter, lower the value they will appear darker.

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So, here you can see the same image I have displayed in black and white. So, this is known as gray scale image. So, if you use any freeware or commercially available remote sensing software, there you will have this flexibility to select which band you want to represent or display in blue color, green color and red color. So, if you are going for a standard FCC, you have to select green in blue, red in green and infrared in red.

So, then your vegetation will appear in red, in gray scale all the colors will be assigned to same image. So, then it will be black and white right.

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So, why do we do this in digital image enhancement or digital image processing? So, basically the idea is the raw remotely sensed images often have poor visible appearance due to poor brightness and contrast of the image. Why? Because of the different atmospheric component, maybe instrument related things but we can remove that using this image processing technique right.

So, you can see this is one image and sometimes you might have come across with the similar problem. If you take the photograph, the contrast brightness is not good for that photograph right. Sometimes it may appear like this, sometimes like this, sometimes like this. So, it depends how good your camera is, how good your ambience is, how good your atmosphere is. So, they play very significant role in acquiring these images.

Now, you can just imagine, this is the problem you are facing with the normal camera but when you are sitting in the space and from there if you are taking the photograph, then what will happen? There are lots of things which are playing significant role and they are producing error. So, these images should be processed with some logic right. So, those logics we will see.

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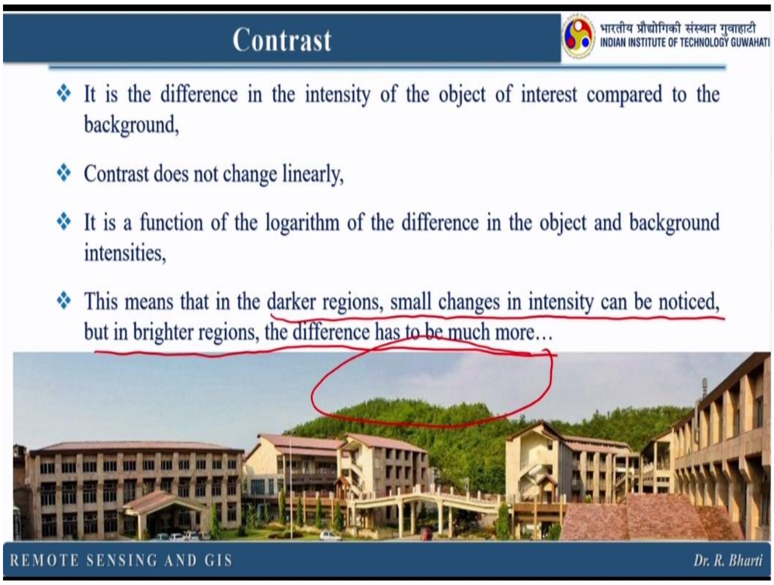

So, what do we mean by contrast? So, contrast is it is the difference in the intensity of the object of interest compared to the background. So, always we say that this is very bright but why do we say it is very bright because the background is very dark. If the background is also very bright, then you will not find that brightness in your target. So, there is a change in the intensity and with respect to background then only this contrast concept is coming into the picture right.

So, contrast does not change linearly. So, if you see any image or when you are saying something some object or in your room then you can see or you can find the edges and those edges are basically because of the contrast, contrast with the background. If you do not have that contrast, you will not find that line or that edge very prominent right and it is a function of the algorithm of the difference in the object and background intensity.

This means that in the darker region, small changes in intensity can be noticed but in brighter regions, the difference has to be much more right, because you just imagine this particular slide is empty, there is nothing written here and then if you draw a line, then you can easily see this line but if the whole background is of the same color then what will happen, you will not find it or if I make this line of little bit of the white shade, white to black shade, then what will happen?

Your visibility or the perception will change. So, that is the point, so it is saying in the darker region, small changes in intensity can be noticed but in the brighter region, the difference has to be much more right. So, here you can see this is one example. Now, here just compare with the first photograph and just observe this particular part of this photograph. In this particular image, there is nothing visible here right in the centre of the circle.

But as you change the brightness and contrast of your photograph, this will be very prominent. So, what it says that if you are having brighter image then you need very strong line or the difference should be more but if it is dark then lighter intensity can be noticed. So, with respect to image how do we apply different logics to enhance the contrast? So that depends on us, what is our decision, how do we perform or how do we want to perform this particular logic. That logic we will discuss after this. So how do we perform?

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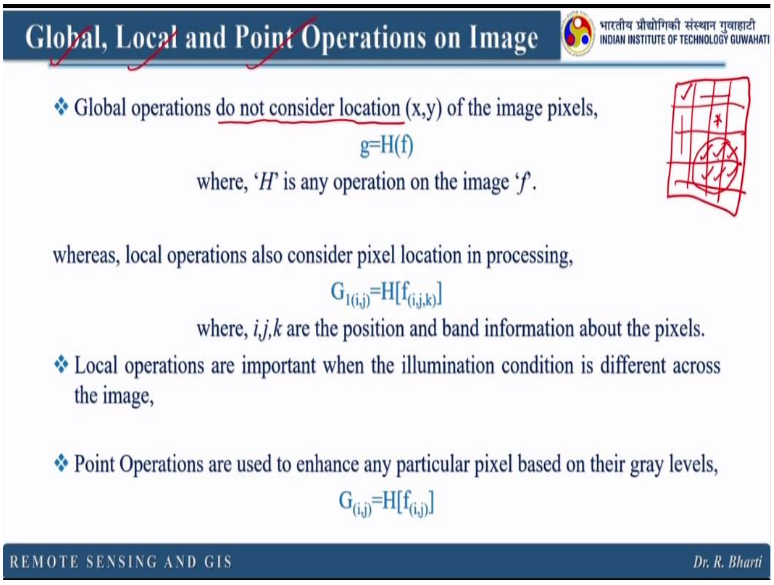

So, either it can be global, local or point operation and that is uniform then it is global. If you want to enhance a particular portion of the image, then that will be local but if you want to perform any enhancement for a particular pixel. Then, that will be point right. So, that is the definition of this global, local and point operation and here you have freedom to use or apply different logics.

So, in global operation, we do not consider location of the image pixel. Location means you are having an image, an image is basically DN number and basically this is a matrix. So, how do we define the position of a matrix element? So, using Cartesian coordinate, so first if we are starting some algorithm here, then if we are moving then we will add +1 in this direction in this direction right.

So, but if you are applying the same logic for the whole image, then we do not consider location right. So, here g=H of f, so here H is any operation of the image f right where local operation also consider pixel location in processing. So, in local operation we need to define which area you want to process or you want to enhance. So, then you need to define what is the location of this, this, this, this, this and this pixel.

Then, only this will qualify under this local operation and local operations are important when the illumination condition is different across the image. So, if you have an image and you find that this particular area is having some haziness or it is not of very good contrast but in this area if you divide this into 3 and this area requires little processing and this area does not require anything right.

So, then what you will do? You will define the pixel's position of this and here and you will say that this logic since this require strong processing, then I will use this location to this location right, but here in this case it will start from here to here and here you no need to process right. So, that is the advantage when you are going for local and global operation. In point operation, basically it is used to enhance any particular pixel based on their gray levels.

So, you can find or you can say that find out those pixels which are having this gray number or digital number and then process it right or if you want to identify a particular pixel and then you want to run an algorithm. So, that is possible only with point operation right.

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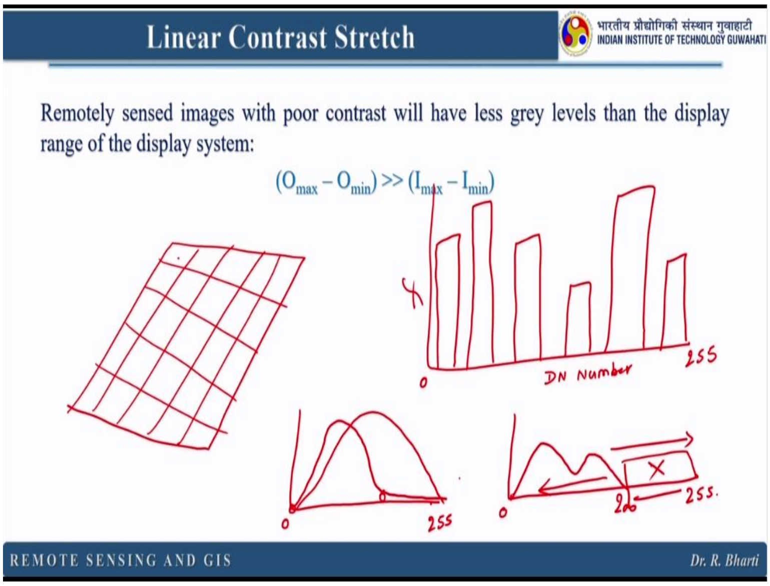

So, in linear contrast stretching basically it says remotely sensed images with poor contrast will have less gray levels than the display range of the display system. So, here when you are having an image and basically this image is a matrix and matrix elements are basically your digital numbers and then for this particular matrix, we can easily generate a histogram. So, here this will be DN numbers and this is the frequency right.

So, you can find out there may be certain unique numbers and this is the histogram distribution right. So, but it is not necessary that you will have or the image will acquire the full range of this display system or full range of the radiometric resolution. So, when you are using this 8 bit data, then this will become 0 to 255. So, it is possible or it is always seen in the remotely sensed image that when you are using this 0 to 255 right your histogram will be something like this or it can be like this right.

So, what is happening here, basically you are not occupying this 0 to 255 full range. So, here this is empty, there is no data here. So, all the values are 0 to maybe let us say 200. So, all the values of your image are basically starting from 0, so what it says is when you are not occupying this particular range, your image if it is this side or this side depending upon the value, it may be lighter or darker right.

So, that, that is the reason you need to perform a linear stretching. So, what will happen? You are going to take this particular value and this particular value and you are going to stretch this whole, so it will appear like this. So, then it will use or utilize the full available range of the display system right.

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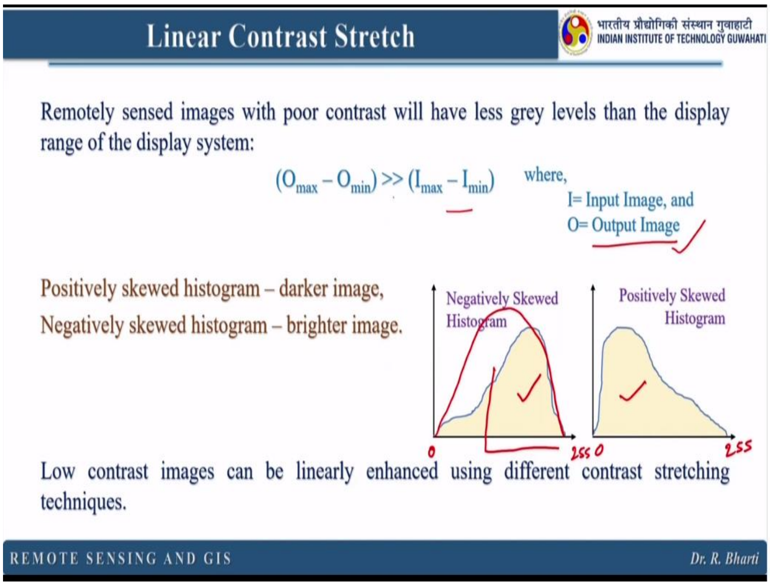

So, if you see here the O max-O min is basically greater than I max-I min where I is input image and O is output image right. So, if this is the condition what will happen? Output image will be like greater than this, so range will be more in this output image. So, there is a concept called positive and negatively skewed histogram. So, here you can see if an image is positively skewed or negatively skewed so what does it mean?

So, basically it says in negatively skewed histogram, the values are actually in the higher range right. So, this is let us say 0 to 255, this is again 0 to 255. So, if the values are more in higher range, your image will be more brighter. If it is positively skewed histogram, then your values are in the lower range, so your image will be darker but in both the cases image is not having a good contrast right.

Why? Because it is not a standard histogram, so if it would have been like this then image will be better. So, here low contrast images can be linearly enhanced using different contrast stretching techniques, so that we will see in subsequent slides.

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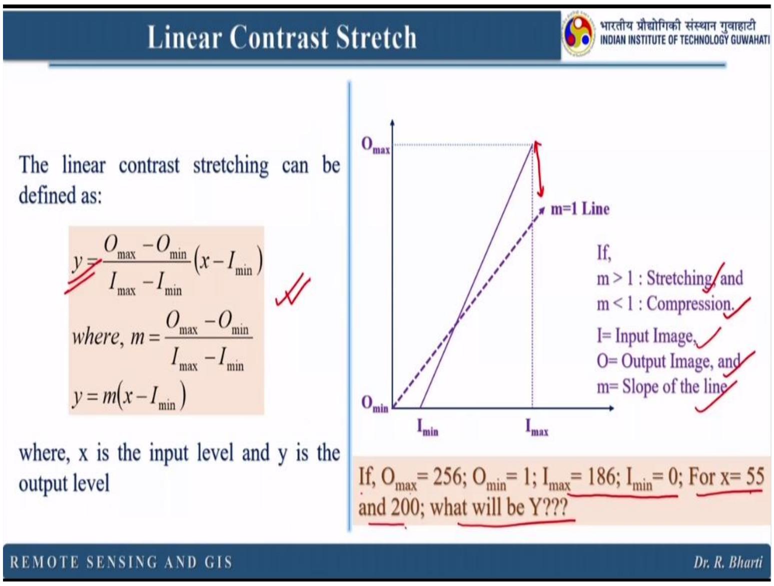

So, the linear contrast stretching can be defined as this where you are using this y we are going to calculate O max-O min, what is your output image range you want and then I max-I min that is your input maximum and minimum DN number value right. So, here if you apply this one, you can easily calculate what is the y value and y is the output value.

Now, if your value, if you plot this O max, O min and I max I min, then if this I min is having this difference right, so then what does it indicate? So, if m is>1 that indicate it is stretching, if m is<1 that indicates compression. So, in both the cases, you need to apply this contrast stretching and I is input image, O is output and m is the slope of the line. So, this is very simple. Just you have to perceive all these information in terms of images and not images, how we perceive images, it is basically a matrix and consists of digital numbers.

Now, this you can try so if O max=256, O min=1, I max=186. I min=0. So, I max and I min has been calculated or estimated from your image matrix for x=55 and 200 what will be the y value. So, you can easily use this particular formula and calculate what will be the y value right. So, y will be the new stretched value for the 55 and 200. So, you will get two values for both of them.

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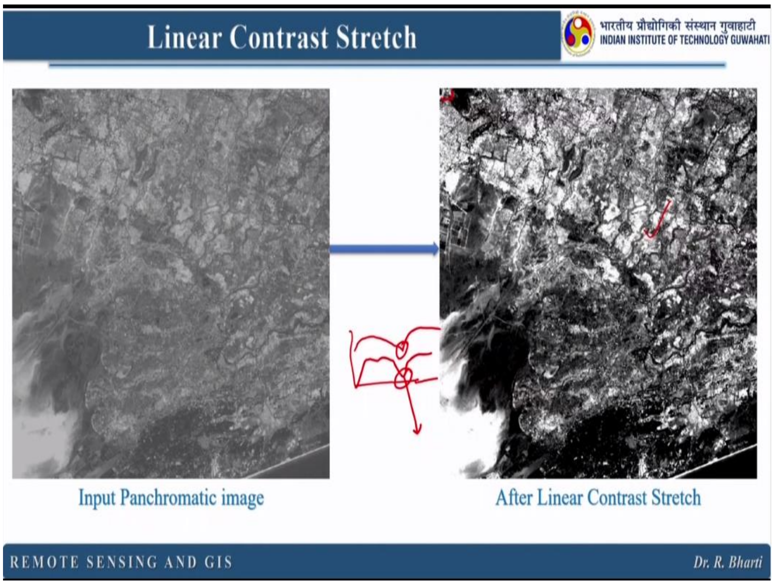

You can see the difference before processing and after processing in these examples, like here you have the input panchromatic image. So, panchromatic or you can call it gray scale image. So, input gray image and when it is linearly contrast right linearly contrast stretching has been applied, then it appears like this. So, you can see easily what is the advantage when you are using linear contrast stretching right.

But remember when you are going for a quantitative analysis, you are not supposed to do this. Why? Because you will be relying on the absorption trough position right, you remember that here suppose this is a spectra for a given pixel in a hyperspectral or multispectral image and based on this particular position, we say that this is x material but what if we have applied the linear contrast stretching, then you will have different number for this right.

Maybe the spectra shape will remain same after processing but the value will change. So, you cannot estimate what is the value or composition of this particular pixel. So, this is only used when you are going for a qualitative analysis.

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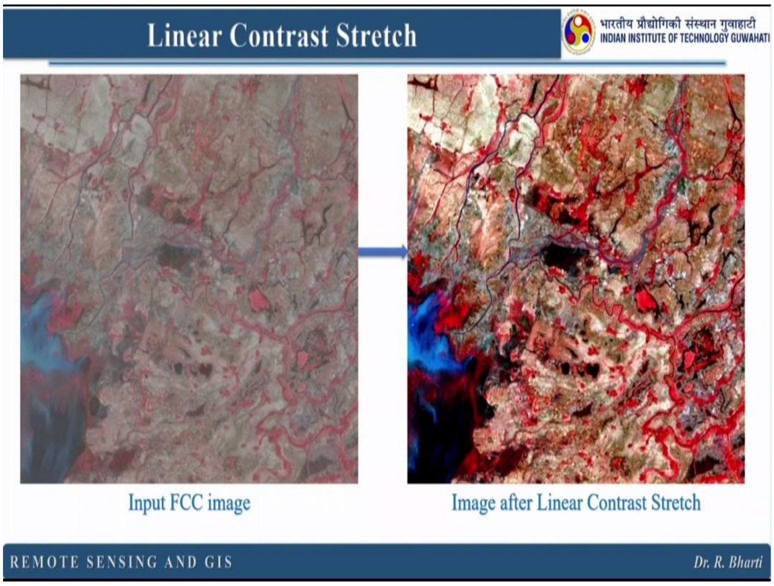

This is another example where you have input FCC image and this is the output linearly contrast image right. So, you can easily see the difference.

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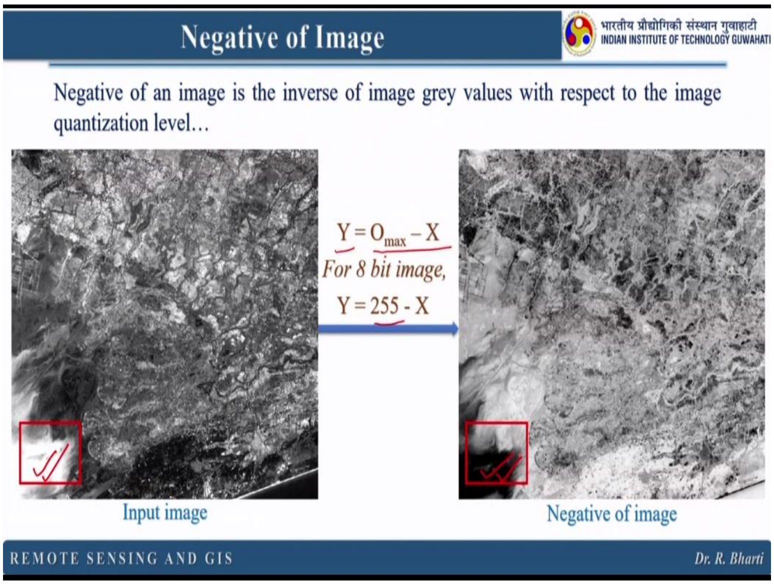

Now, negative of image, so all these are different methods of how we play with this digital numbers. So, negative of an image is basically the inverse of image grey values with respect to the image quantization level. So, image quantization level is basically you have a 8-bit data, then you will use 255 or 256 as your higher value right and here O max-x is equal to your Y, so O max is basically 255 when you are having 8-bit data right.

But in case if your radiometric resolution is different then O max value will be different. So, here you can see the difference and just remember, see the changes here. So, here you can see that in the original image, this particular area was brighter but now here you have darker portion right. So, why it happened because it is just the negative of the image because we are subtracting with the maximum value of your image quantization level.

So, that gives you the inverted image right, not inverted negative of the image, inverted is something like flip.

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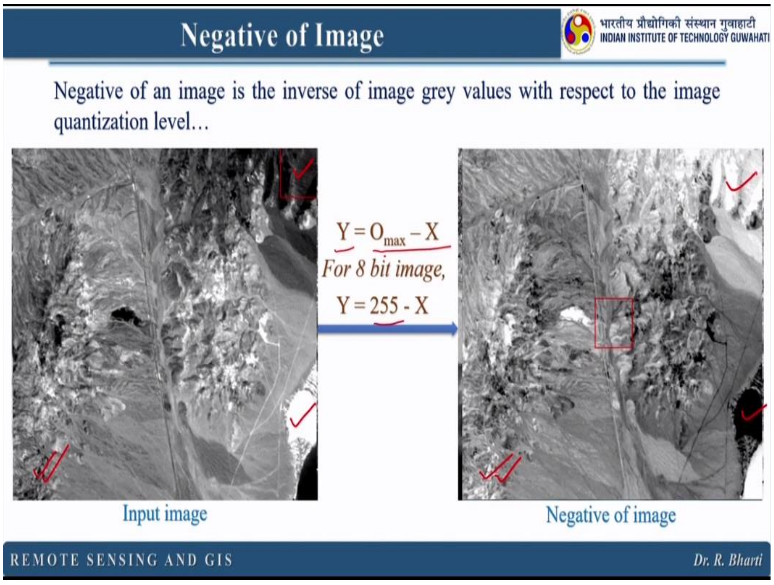

This is another example where you can see the difference. So, here you can see this particular area and this particular area, this and this. It is just negative of each other with respect to highest quantization value. So, these methods are basically linear methods where we are assuming that contrast and brightness are changing linearly but what if we do not have such condition and in nature we always find that we do not have any linear relationship in the contrast or brightness right. So, what we do?

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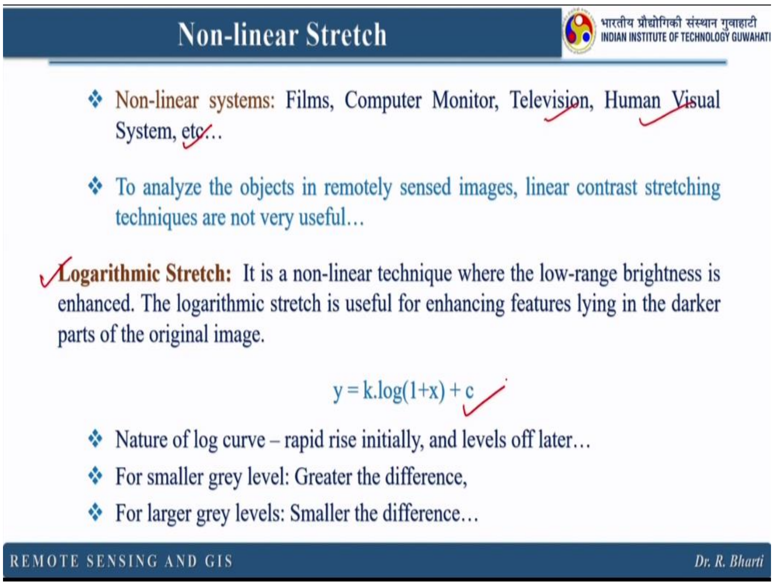

We go for the non-linear stretching and here in the non-linear stretching, there are few good examples like films. So, in films you can see the contrast and then computer monitor, you can see all the lines, boundaries, edges very clearly. So, that means it is giving you good contrast and good contrast in terms of non-linear system and then television, human visual system. So, these are the very good example of non-linear system.

To analyze the object in remotely sensed image, linear contrast stretching techniques are not very useful, so why we have already discussed. Then, let us start the non-linear stretching. So, this is the first method which is called logarithmic stretch. So, it is a non-linear technique where the low range brightness is enhanced. The logarithmic stretch is useful for enhancing features lying in the darker parts of the original image.

So, basically what is happening here, if you want to identify some features which are in the darker area then this logarithmic stretches are useful. So, this is the general expression of your logarithmic stretch and what is the nature of the curve, log curve? So, it rise rapidly and levels off later. So, it can give you very good result in terms, for smaller gray levels greater the difference, for larger gray levels smaller the difference right. So, these kinds of results you can expect when you are applying a logarithmic stretch.

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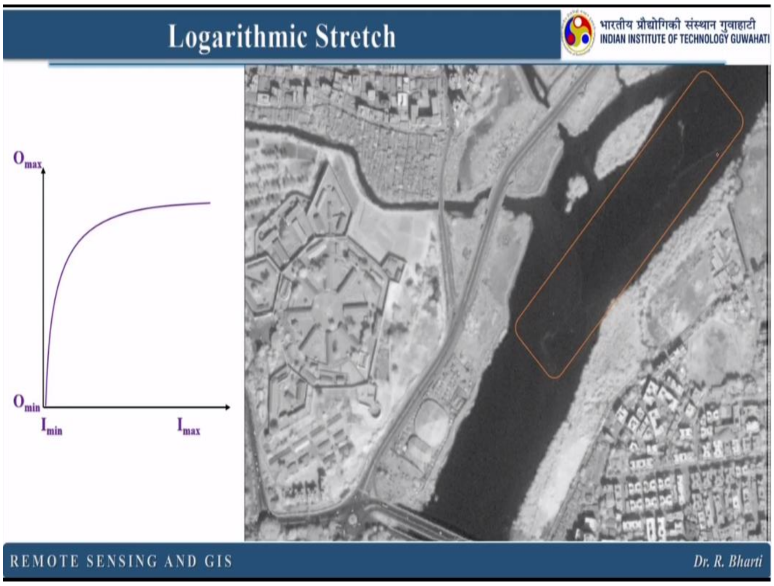

The results of logarithmic stretch can be seen here. So, there are few examples I have put. So, here this is one image which is raw image, directly captured from this satellite and you have this in your system right. So, here you can see this image as of now it looks good but what if we want to identify some features in the darker portion of this image. So, what we will do? We will apply logarithmic stretch and you can see the difference.

So, here previously this particular pattern which is highlighted in this box was not seen, you can see again, so this is the example right. So, here you can see in the darker portion, the information is getting enhanced or you are getting more information in the darker portion of the image. So, in case if you are interested in such areas then definitely you have to go for logarithmic stretch.

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And this is another example. Here you can see after logarithmic stretch and you just compare this and this image and just see that small water body right. Now, I am going back and again see this one, there is a change in the area or the information which is available here right. So, hopefully these examples will help you to perceive the logarithmic stretch results in remotely sensed images.

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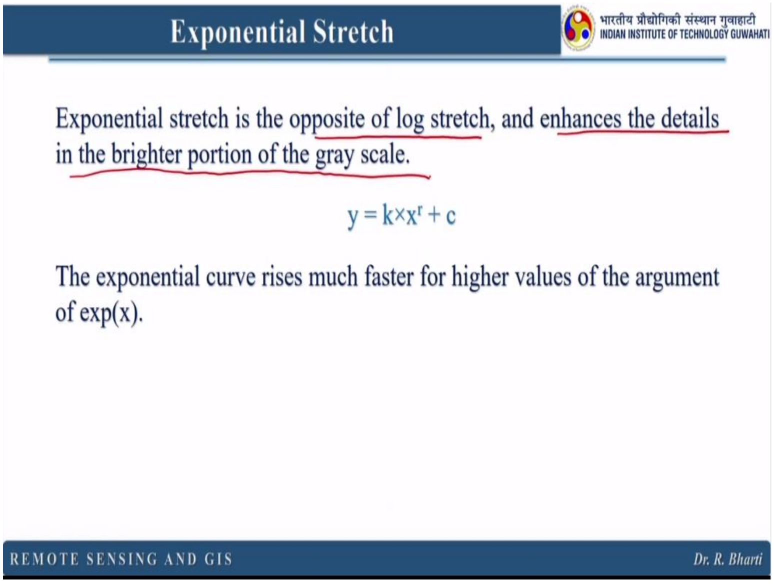

So, next is exponential stretch. So, exponential stretch is the opposite of log stretch and enhances the details in the brighter portion of the gray scale. So, in the previous one what happened, in the darker portion we have highlighted the information but here in exponential stretch, we want to highlight or we want to extract some information which is not available in raw data using this exponential stretch.

So, the exponential curve rises much faster for higher values of the argument of exponential of x right.

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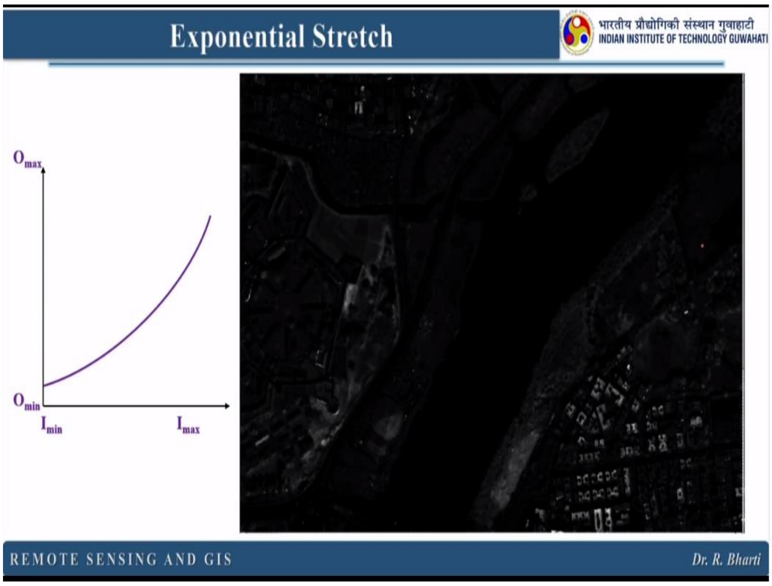

So, here you can see the result of exponential stretch right and see this particular area. So, here basically these were the brighter portion of your image and again it is preserving and highlighting those informations which were hidden in the raw data. So, this is the example of exponential stretch.

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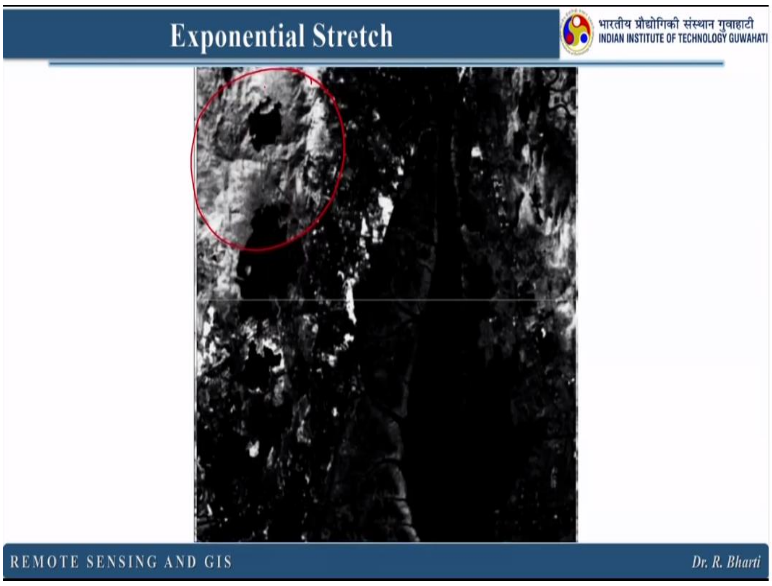

This is another example where you can easily see what is happening here and here you can just see, here you just compare this particular area and here it is brighter and there is nothing seen much. So, if you see this one, there is not more information, so this is the advantage of exponential stretch.

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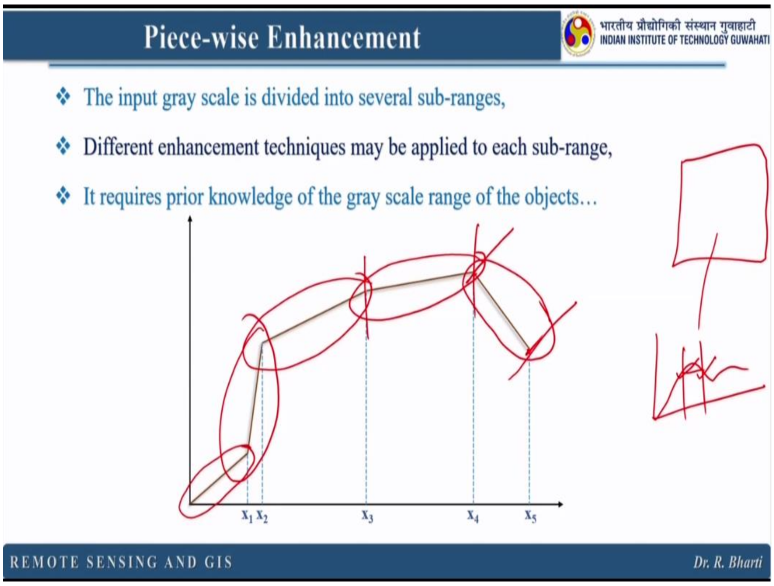

Now, let us see piece-wise enhancement. The image gray levels or image gray scale is divided into several sub-ranges. So, how we can do this? By using histogram. So, different enhancement techniques may be applied to each sub-range, it requires prior knowledge of the gray levels right of the object. This is the histogram generated from a remotely sensed image and here you can see this particular histogram is having different slope in different portion right and which indicate there is a range of values which are starting from here to here right.

So, we can select this to this particular DN values and you can apply either logarithmic or exponential negative right or linear stretching. In this particular, you have freedom to apply, so how you will do that, you have an image, you have generated a histogram right like this and you have selected this is the range of value I want to enhance right. So, when you are doing that you have to write one algorithm.

And you will say that starting are the values ranging between this to this right, this to this, use linear stretching or negative image or exponential image right or logarithmic function and then you will have results accordingly.

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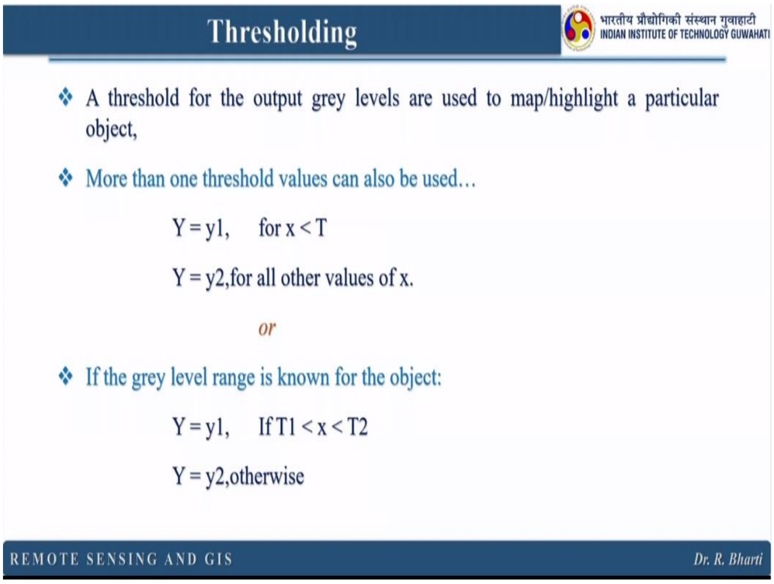

So, in thresholding what we do is we provide threshold of the DN values and we make different classes. So, here a threshold for the output grey levels are used to map or highlight a particular object. So, instead of identifying it using some different techniques, this is one of the techniques where we say that this is my target and the value range of this particular object is ranging from 10 to 70 right.

So, my T threshold value will be like greater than 10 or maybe between 10 to 70 right. So, this kind of logic we are using in thresholding and this flexibility you have because of the different programming softwares and where you can say that in the given matrix you identify the values ranging from this to this and assign them a unique value right.

So, here you can just go through it and you will find that this method is very good when you are having the prior knowledge of the object and you know what will be the reflectance value range for that particular object.

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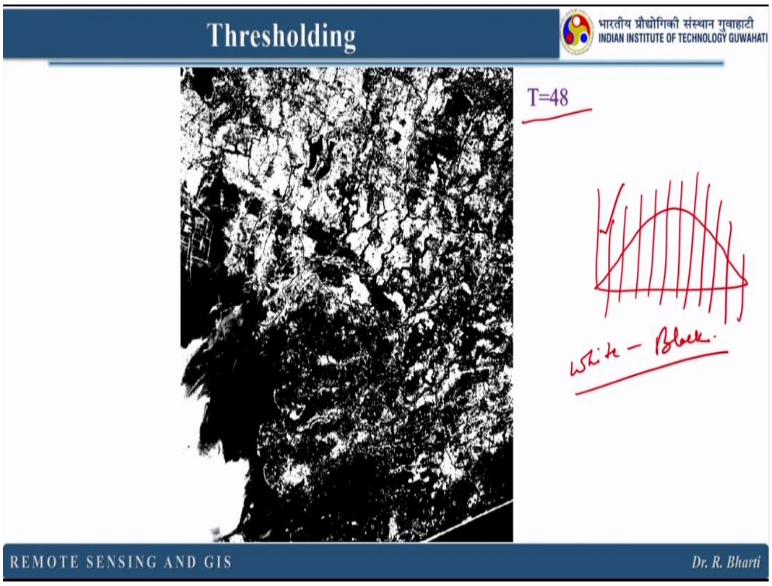

So, this is one example of thresholding where this is the raw data right and when you are applying T=48, so maybe you can select 100, 1000s or 2, 3, 4 T is equal to any number right depending upon your application and the result. Here what you can do is you can select natural distribution and you can say equally distribute this whole value range of this particular image into 48 parts right.

And then accordingly from white to black 48 colors or sets will be generated and each range will be assigned to that color right. So, you can see here I will show you some example in density slicing where you can see how we are assigning different colors for this 48 because 48 assigning color is very difficult for us but system can do it. It can give you different color sets in 48,000s or maybe many more sets.

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This is one image where there is no thresholding has been applied. There is the raw data, now after applying the thresholding so here T=48, so 48 I have given threshold. So, after 48 everything is here right. So, this kind of logic you can use to highlight a certain value range of the DN number or only for that particular DN number right.

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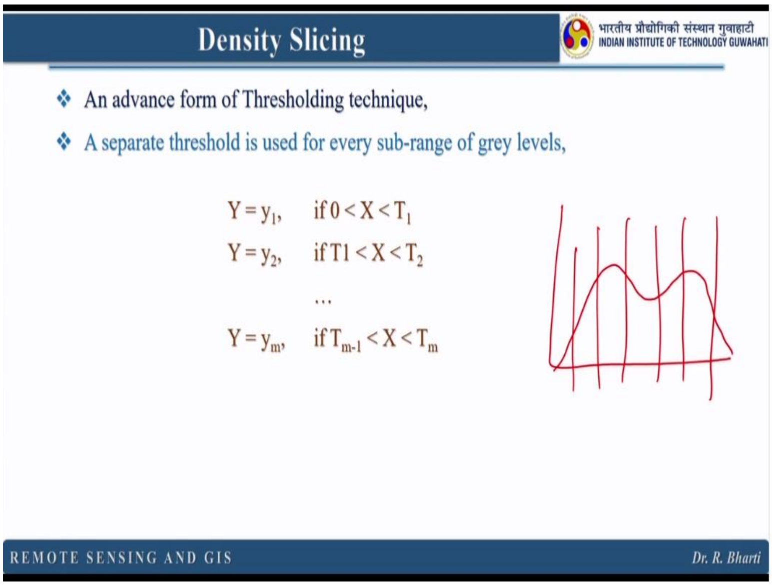

In density slicing, what happens, we provide different ranges like this is the advanced form of thresholding technique. So, what we do, from this particular histogram we can identify different range of the values right and we can simply split them into different classes. So, you can say I want 100 classes from this image right and they are equally distributed. So, depending upon the range of the value, it will be decided or it can be like different ranges and different thresholding technique.

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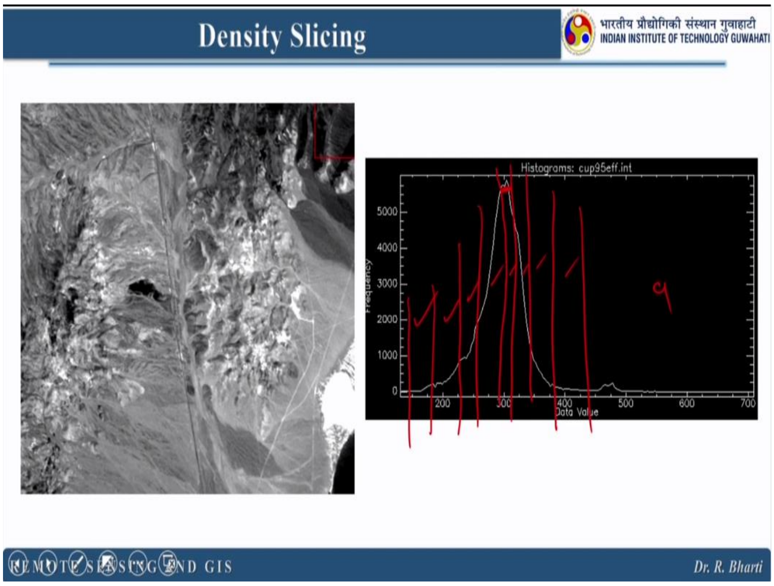

So, here this is one example. This is the raw image where you have this particular histogram and you can see this histogram if you select only this particular value range right, then what will happen, only this value DN values will be highlighted right. So, accordingly you can make different sectors and you can say that this is my first class, this is second class, third class, fourth class, fifth, sixth, seventh, eighth and rest is ninth.

So, you can do that but provided you should have some objective, so you should know what is your intention, what is your application and what information you require from this particular remotely sensed image?

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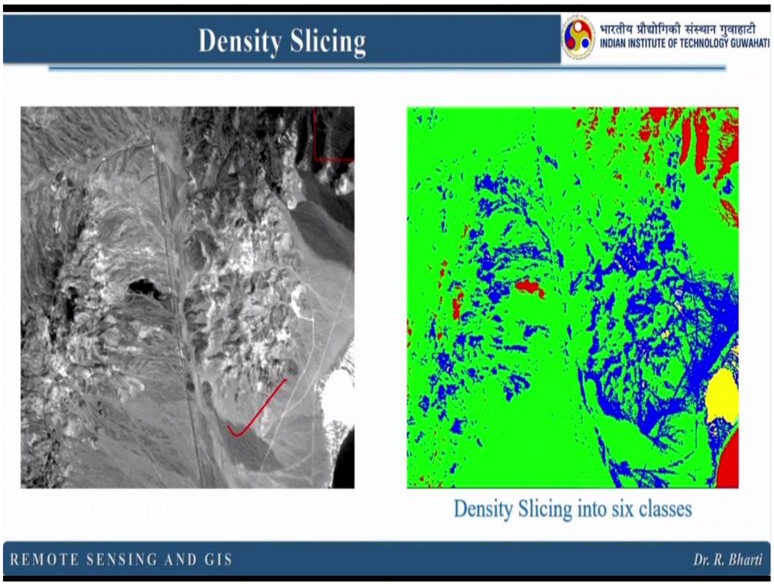

So, here this is the density slicing of this particular image and here I have used 6 classes. So, 6 classes of the same image depending upon my application I have selected some value range and this is the result right.

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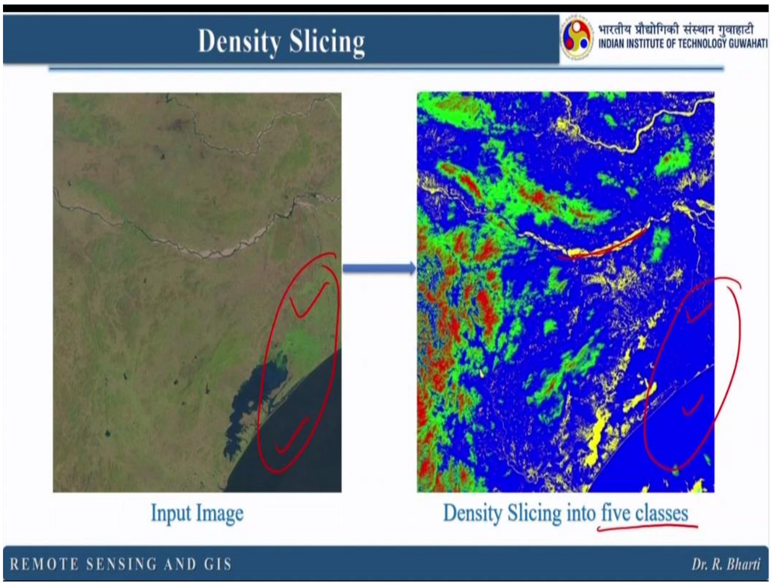

This is another example where you have raw data and this is the density sliced into 5 classes. So, you can see that this particular area and this particular area are getting mixed here, just compare this one right. So, but it is highlighting this particular river channel with floodplains. So, depending upon your application, you may increase the number of classes here and you can get better result.

So, first decide what you want from this and then identify or fix the classes then find out the value range of your objects lying in different classes and then apply this density slicing. So, this is very easy but it will give you very good result.

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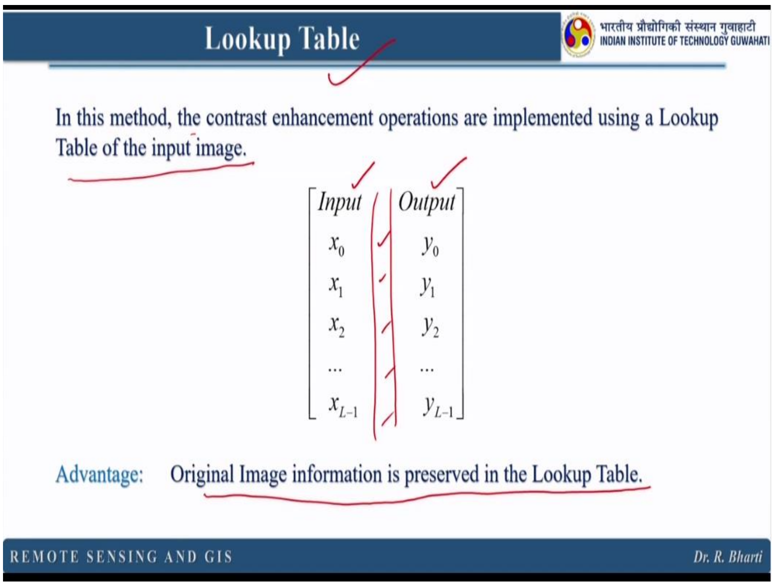

So, all these methods which we have discussed till now, they are basically directly applied on the image. So, we do not have any backup right. So, what we do here in this lookup table, we generate a matrix or we generate a lookup table and whatever calculation you are doing, you do it in the lookup table and then you will have original as well as the output both will be saved there.

So, in any point of time if you want to go back to your original image, it is always possible. So, in this method, the contrast enhancement operations are implemented using lookup table of the input image right and advantage original image information is preserved in the lookup table. So, here you can see that input and output values are saved and in between you have your methods.

So, what methods you have used? So, any point of time you can go back to your original image, so you do not have to keep a backup of your image.

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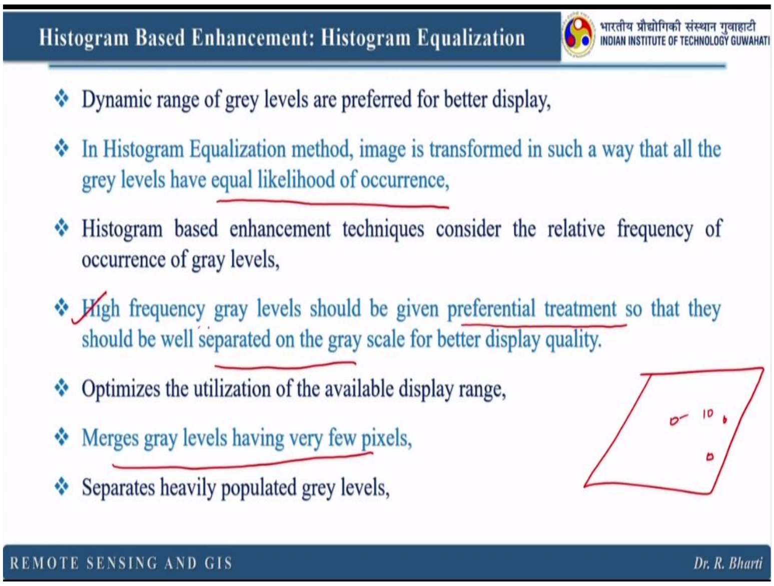

Now, let us see the histogram based enhancement technique. Histogram equalization is one of the best or I would say it is one of the very good methods in non-linear stretching and this is based on the histogram equalization or histogram stretching depending upon the application right. So, dynamic range of gray levels are preferred for better display, so here what it says is you have a histogram like this of your image right.

But it is not showing this particular information, which is missing in the acquisition itself. So, another example you have like in this particular histogram you have occupied the full range of this radiometric resolution and it is having all the peaks and troughs here right. So, it indicates your image will be better. Why better? Because it has first occupied the full range and it is dynamic in nature, it is not constant like truly it is having one peak and it is showing you the result.

So, it is having dynamic range right. The next point is in histogram equalization, image is transformed in such a way that all the grey levels have equal likelihood of occurrence. So, here it says equal likelihood of occurrence. So, all the DN numbers, it does not matter whether they are very low or they are very high, they will have equal chances of getting displayed right.

So, that is the advantage when you are applying this histogram equalization. So, histogram based enhancement techniques consider the relative frequency of the occurrence of the gray level and high frequency gray level should be given preferential treatment so that they should be well separated on the gray scale for better display quality. So, you might be remembering from the previous slides, so in the brighter portion you need high contrast right.

So, you need more value in the intensity so that your difference will be visible but in darker portion, if you are having very less difference that is also seen. So, that is why it gives preferential treatment so that they are separated on the gray scale right for the brighter portion or here it is saying high frequency, optimizes the utilization of the available display range and it optimizes the histogram, so that 0 to 255 the whole range is used in the display right.

And merges gray levels having very few pixels and the very few pixels' value DN values because what happens sometimes in your image there are few pixels only like DN number maybe 10 and the frequency of this DN number 10 is basically maybe 4 or 5. So, do you really need to worry about those 4, 5 pixels. No, out of the thousand by thousand pixel you have four 4 pixels or 5 pixels of DN value 10.

So, that is not going to matter. So, what happens here, it merges the gray levels having very few pixels and separate heavily populated gray levels that is very important right because it is doing the high frequency gray levels separation right.

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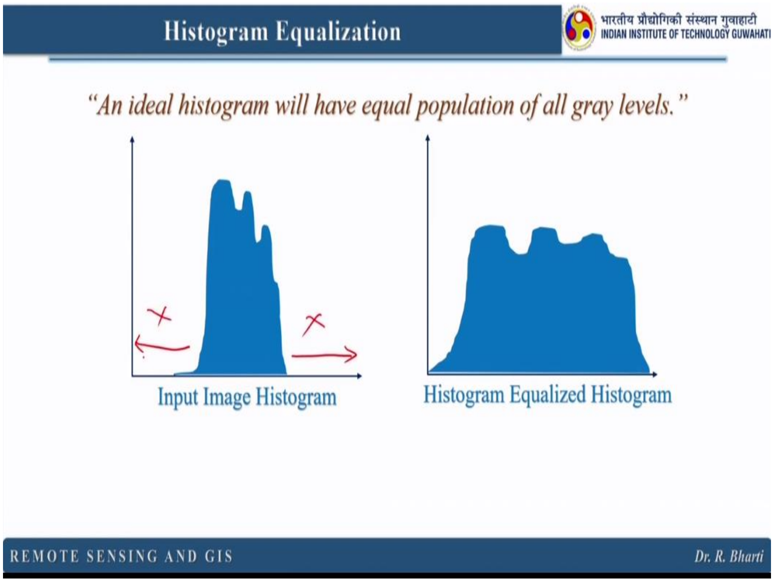

So, an ideal histogram will have equal population of all gray levels. So, if you can get a histogram like this, then it is the best. So, all the DN values are having similar frequency right. This is the frequency but this is not possible in nature and it is not available in nature and it is not possible with any remote sensing instrument or with our eyes because it depends how much energy they have reflected or emitted from the surface right.

So, this is the input histogram before the histogram equalization and this is the output histogram. So, what happened, it is occupied in the output this range has been used which was not used here right. I hope this is clear to you.

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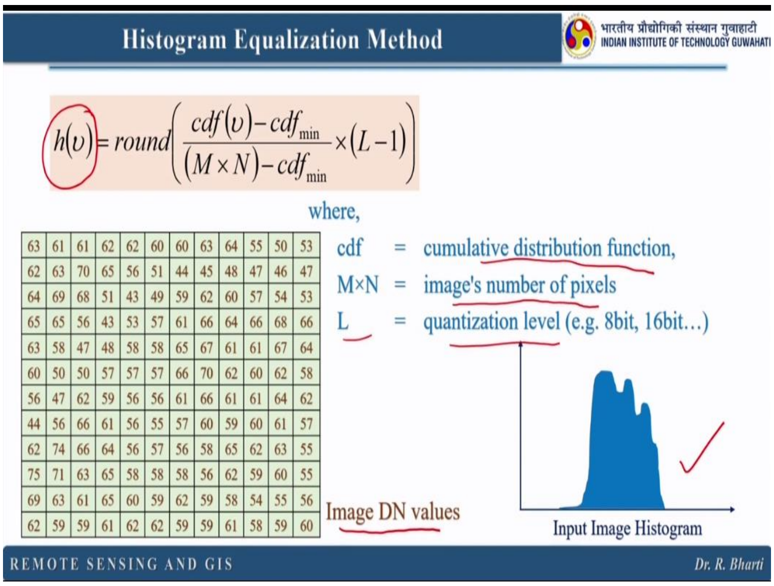

So, here what we do, we use this particular method and we identify the output value right and where cdf is cumulative distribution function and M and N is the image number of pixel and

L is the quantization level. So, in 8-bit, 16-bit this value will keep on changing, so this is one example I am going to show the solution where we are having an image DN value and this is basically an image but I am looking on the values right and this histogram appear something like this.

Now, when we are having this image and this histogram, how we will apply this particular formula right.

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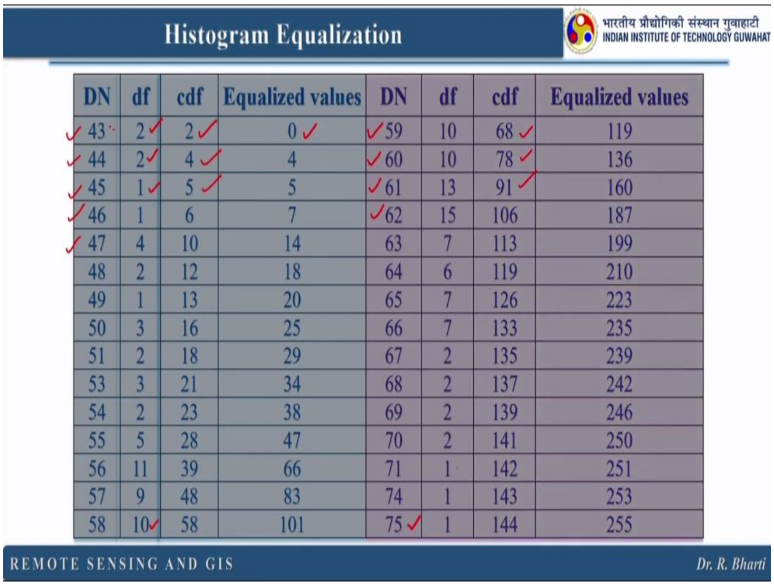

DN	df	cdf	Equalized values	DN	df	cdf	Equalized values
43	2	2	0	59	10	68	119
44	2	4	4	60	10	78	136
45	1	5	5	61	13	91	160
46	1	6	7	62	15	106	187
47	4	10	14	63	7	113	199
48	2	12	18	64	6	119	210
49	1	13	20	65	7	126	223
50	3	16	25	66	7	133	235
51	2	18	29	67	2	135	239
53	3	21	34	68	2	137	242
54	2	23	38	69	2	139	246
55	5	28	47	70	2	141	250
56	11	39	66	71	1	142	251
57	9	48	83	74	1	143	253
58	10	58	101	75	1	144	255

So, what we do, first of all we need to identify unique DN values from the image or from that matrix. So, these are the unique DN values right and here also it is in the continuation right. So, it starts from 43 and ends in 75. So, remember that this is 8-bit data, so your flexibility should be 0 to 255 but it has occupied only 43 to 75 that means 0 to 42 and 76 to 255 is still available to you right.

So, what we do, we identify how many times 43 has occurred in that matrix right. So, 43 occurred 2 times, 44 2, 45 1 and accordingly you can see these values right. Then, cdf is cumulative, so you start from this to then 2 to 4, 4 to 5 like that you have to calculate all the cdf values right and then once you are having that then you can simply use this particular formula and you can calculate your output value right. So, here this is the equalized value.

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This is the example of histogram equalization. This is one image and once we apply the histogram equalization, the image will look like this.

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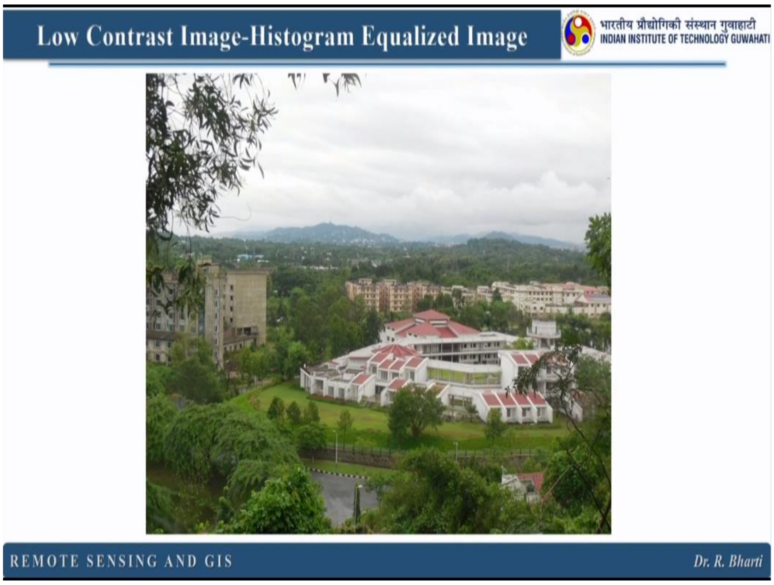

I have some more example for you like this is one image and here this is the output.

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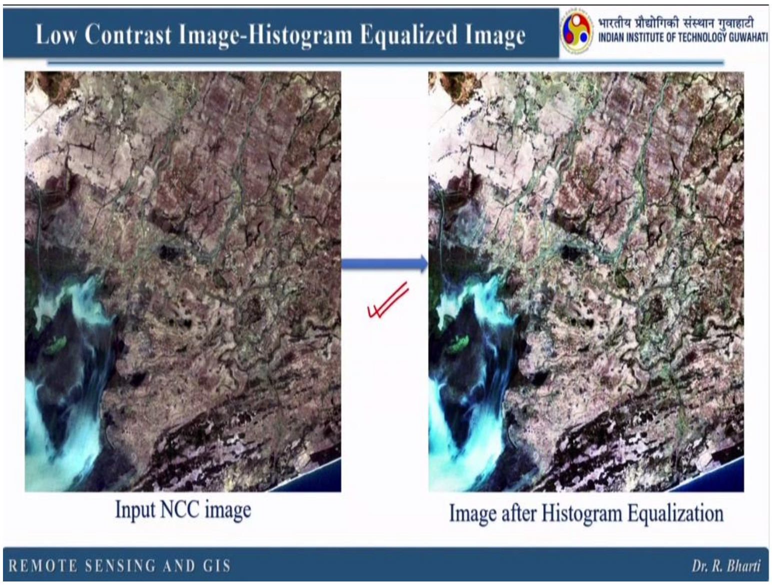

This is another image and this is the output right. So, this is the method which you are going to use in your research also because linear contrast stretching is not very useful always but non-linear algorithms are better because in nature we have non-linear behaviour. So, always you have to go for the non-linear and specifically this histogram equalization method which is based on lookup table approach and this is one of the good method right. This is another example you can see here. That is all for today.

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