**Introduction to Remote Sensing**
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Lecture 14
Basic Image Enhancement Techniques

Hello everyone and welcome to this next lecture on this introduction to remote sensing. And under this topic we are going to discuss the very basic image enhancement technique; how to improve the quality of an image. So far we have seen how to geometrically correct the image and but now in this one we will have discussion on basic image enhancement techniques, very simple one but before that just I would like to recap or refresh your memory saying that remote sensing images are nothing but a two dimensional matrix, say raster data and each cell is having a pixel value and that pixel value is in terms of positive integer values.
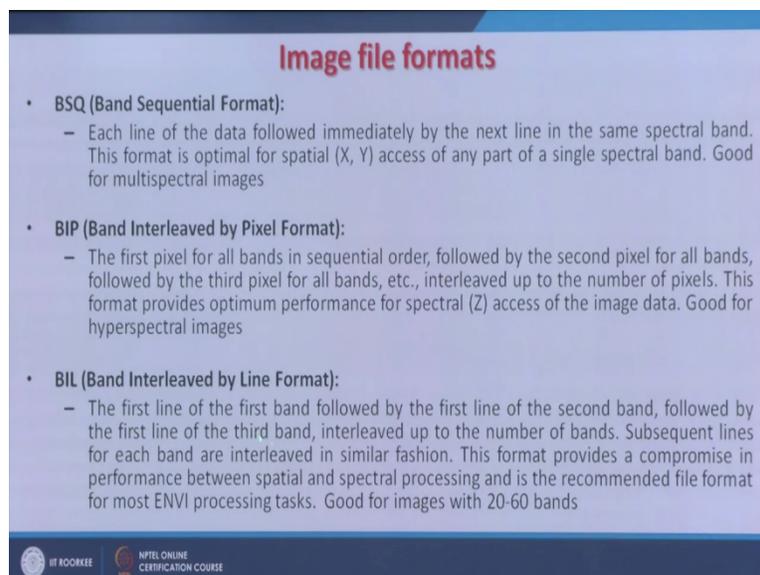
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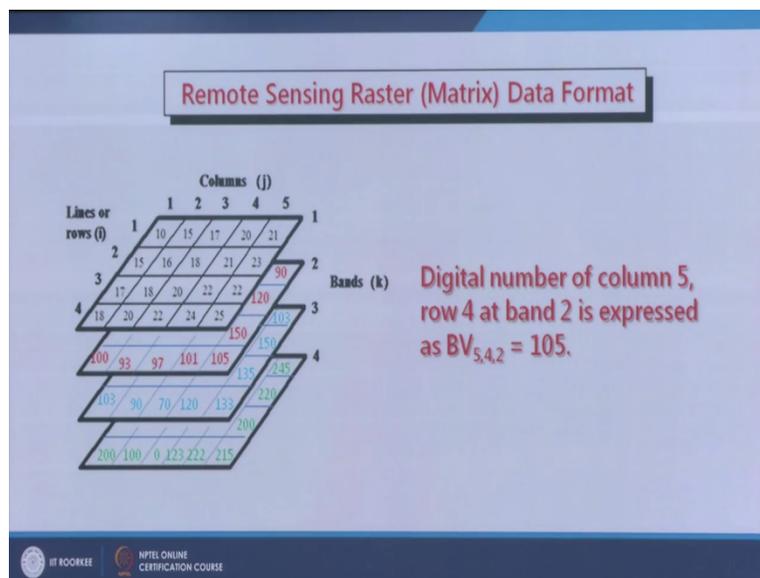
And shape of this cell in this case we call as a pixel would be square shaped, however overall shape of an image or this two dimensional matrix can be either square or rectangular. That means number of rows and columns need to not be same. They can be different but the cell shape has to be, means the pixel shape has to be square in shape and each pixel is having a value and that value is in integers. If I am having more number of bands like here bands K then I may be having

pixel values depending upon the which part of wavelength these bands are representing, they will carry the different value.

In this particular hipstamatic like for green band they are showing some other or blue, red and black. So four bands are together are shown here just is a hipstamatic and the digital number for say column five, row four column 5 row 4 is expressed as V (ah) VB542 and that I want to added or make it something then it is going to be so I can address very easily as well by using column number or row number.

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Now when we get the data from the satellites that is the data acquisition; we will see very quickly about data acquisition part as well. We store the data in certain format. For image there are few formats which are followed world over and nowadays many the images which are available on net, free of cost like Landsat images or other images. Generally they are already geo referenced and if they are not geo referenced, no problem we can do the geo referencing as well. But before that the raw formats which are used are three main most popular one are the three.

The first one in this is the BSQ format. That is in short BSQ but we say Band Sequential Format, so that each line of the data followed immediately by the next line the same spectral band so it is a band by band formatting so suppose it is a Landsat MSS data, now there are 4 bands so the first band would be written in a file then the second band then the third band then the fourth band.

Now they are advantages with writing or making such formats, following such formats that if I am interested to read only band two then I will jump while reading through my program to band two and read the entire data but if I am interested to read all four bands of a particular area, note the entire image area then this type of format is not suitable so people designed another format which is called Band Interleaved by Pixel Format. That means the first pixel of all bands in sequential order so first pixel of first band, first pixel of second brand, first pixel of third band, first pixel of fourth band and likewise if there are four bands then will come second pixel of first band, second pixel of second band and likewise.

Followed by second pixel of all bands followed by the third pixel of all bands and these are interleaved up to the number of pixels so if an image is having say five hundred columns it will go till five hundred twelve. This format provides optimal performance for spectral excess of image data good for hyper spectral images because hyper spectral remote sensing is parallelly very nicely developing and therefore such kind of images, this BIP or Band Interleaved by Pixel Format is going to be very good. And the third type which is very popular is BIL, Band Interleaved by Line; here instead of pixel entire line that means one row is written first for band one.

Then first row or band two is written for second and likewise so the first line of the first band followed the first line of the second band, followed by the first line of the third band interleaved up to the number of bands so if there are four bands then all first lines of all four bands are read in first in sequence then second line of all four bands are written and likewise. So subsequent lines for each band are interleaved in similar fashion. This format provides a compromise in performance between special and spectral processing and is recommended five formats for most NB process task. Good for images with twenty sixty bands.

So this is another issue because now we are also going for large number of bands means our spectral resolution is also improving and for that BIL format, this NV soft image processing software but many software are having their own format and NV is having format which is BIL format. Like ER Adasp is having its own dot Img format or another very popular images format is a Geo Tiff, this was a tiff format now the another version of this tiff format which is called

Geo Tiff, it is also having geographic coordinate written first in the image so that format is very popular.

Many satellite images specially like Landsat and others are already geo references and available in Gio Tiff format and they are ready to go for any image processing software or on GIS platform without any requirement of georeferencing. So first the raw data once comes it is written either in BSQ, BIP or BIL format. As per the requirement, as per the number of bands, as per the size, as per the for what purpose they are being recorded and of course it is possible to change from one format to another means from BSQ to BIL or BIL to BIP can be changed but it requires further reading in checking of accuracy.

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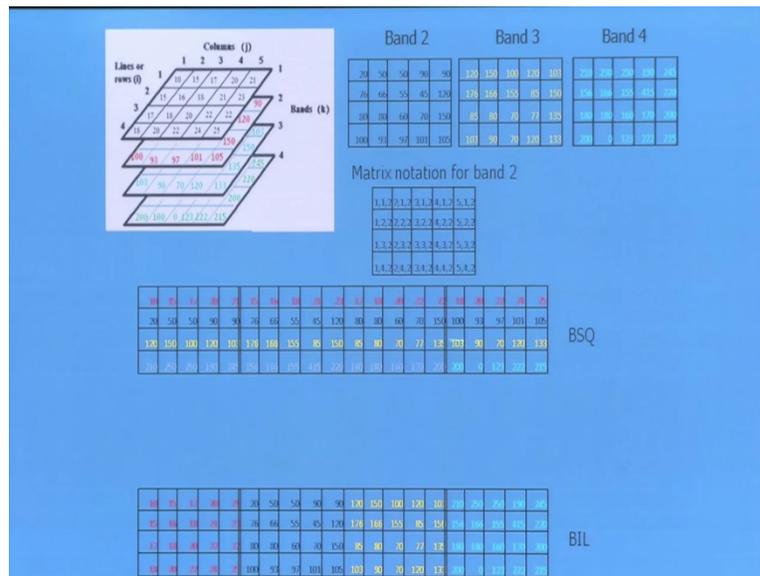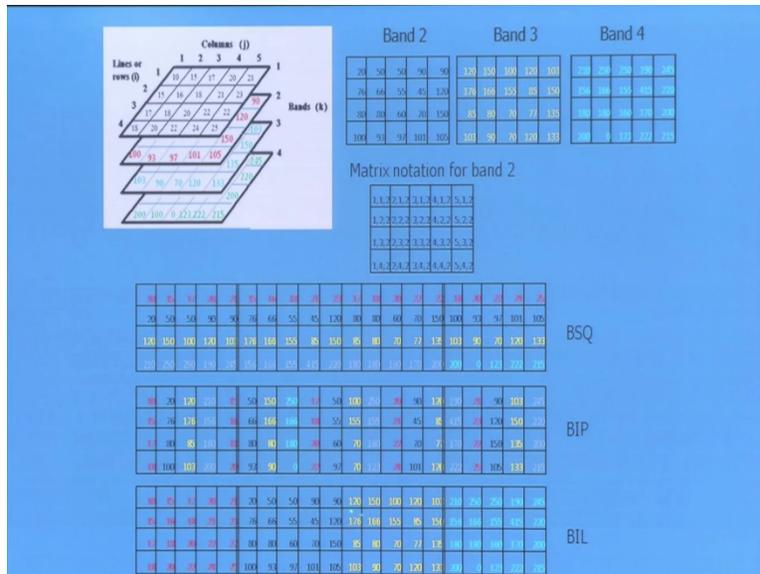
So likewise here in for a different bands this is how we write. We want to write for one combination then probably this is one approach and in case of BSQ, this how the first band, first line, first band one is written then band two is written, band three is written, band four is written in case of and in case of this pixel or BIP then this is how. And then or first pixel of first and, first pixel of second band and likewise, you can check also the values and then the BIL the line by line. So here the first line then second line then second line is the first line of band two then this third line is the first line of band three. The fourth line here is the first line of band four likewise it is written.

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Same thing here that the image one band at time in other words the data of all pixels of band one are stored in this. This is very convenient and very easy to understand that band are written in sequence, the first band is written, first second band is written, second and so on so. But as I mentioned that if am not interested in the entire image area. I am interested only in the part area and my image size is very huge then this format is not very efficient one then probably BIP or BIL are going to be much more.

So band interleaved by pixel that is BIP format is similar to BIL except that each pixel is written band by band and then here this third one is the band interleaved by line, the data is stored pixel information band by one for each line, row an example; I gave three band image, all three bands of the data are written in row one and then so on so forth. So likewise we can write the data as per our requirement we can change from one data format to another as well.

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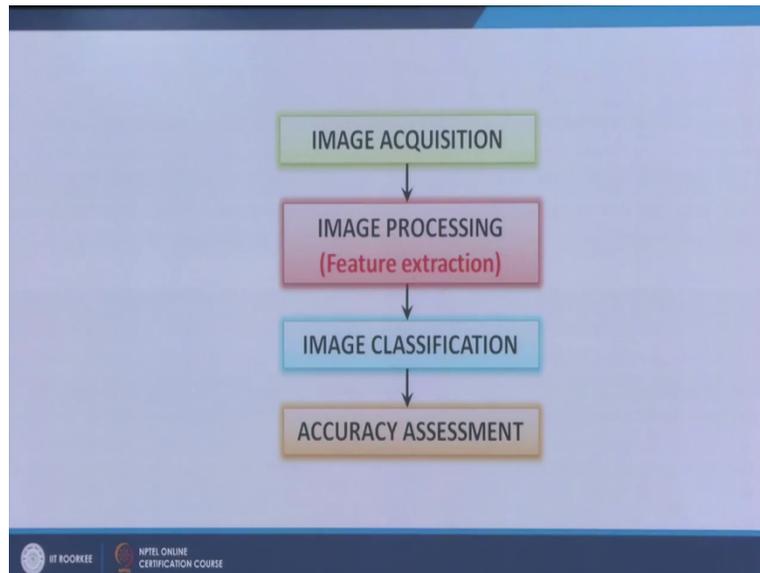
As I mentioned first image is acquired that is the data acquisition. It is done through satellite Earth stations, I will just show you. We have already seen one NOAA AVHRR or Earth station which is operational in IIT Roorkee, that I will show you. So the first thing is the image acquisition. So once the satellite has scanned the part of the Earth, the image has to be acquired by the Earth station and once the data has been acquired then other steps will start that is the image processing.

And basically making geo metrically corrected image, one step. Another one is improving the image quality so that our interpretation visual or machine based becomes highly reliable so for that we go for and the third one is a image classification after enhancement one may go for image classification, creating some output maps like land use map, for as density cover map, a lithological map, soil cover map and so on so forth. And finally one would like to assess the accuracy part after doing image classification so these are the broad four steps; data acquisition, image acquisition as I have said that it can be done satellite Earth station.

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1.2m parabolic disk antenna and rotator of NOAA-HRPT system.
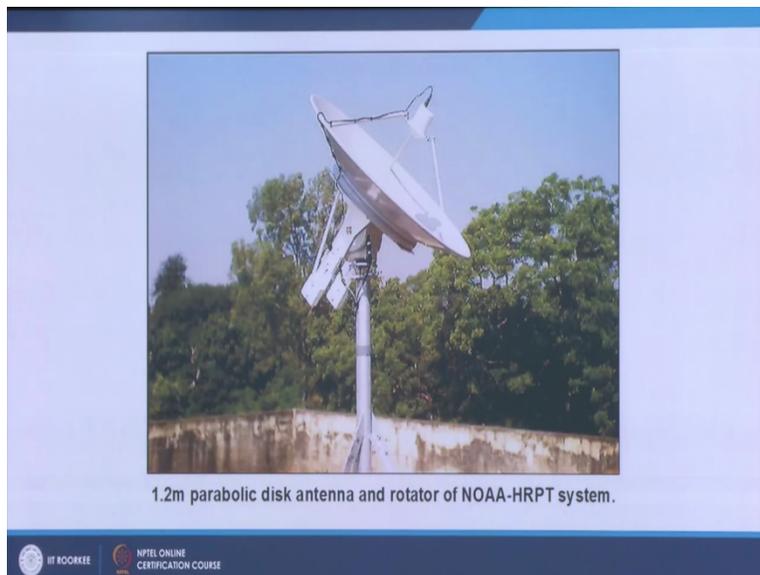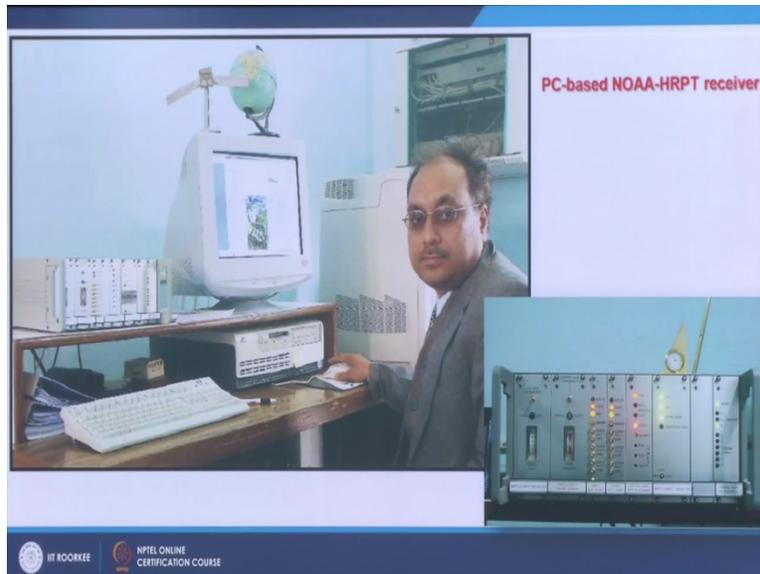
These figures or slides are repeating here just for the completeness I have kept here. He need to have antenna rotating antenna, tracking antenna have shown here. Then you have to have receiver and then computer system which will acquired the data and keep the data as per your desire data format.

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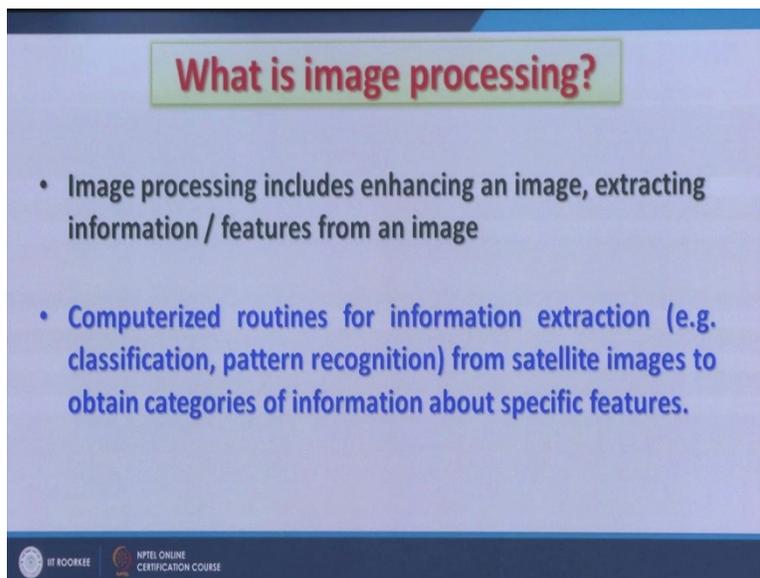
Once the data is in the system then the processing starts so basically if we define, what is basically image processing is? That image processing includes, it should reread as image processing includes enhancing an image, extracting information features from an image. And the

computerized routine for information extraction, that is a classification pattern recognition from satellite images to obtain, categories of information about specific features.

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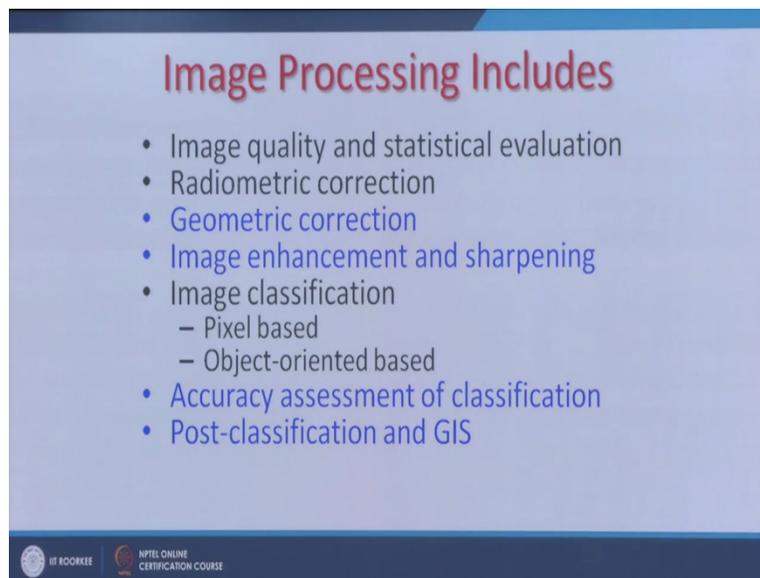
So image processing includes image quality and statistical valuation so we also try to asses, what is the quality of an image. We also try to perform some statistical process on it and before we go for further processing or enhancement of the image we must know what is the minimum value in my image? What is the maximum pixel value? What is the standard deviation? How pixels are distributed? That prior information will help me to decide which enhancement technique would be better for my, that particular image, so this statistic is image dependent. Each scene even of the same area belonging to two different season will have different statistics because images are going to be different.

So that is why before we choose or appropriate image processing technique, image enhancement technique we must first assess or do the evaluation through statistical analysis then of course radiometric correction as haven been saying this is generally done by the operators of the satellites. Geometric correction has to be done by the user itself and specially for higher special resolution data, this has to be done very accurately, very sincerely. Image enhancement and sharpening as per the requirements for what purpose the satellite image is going to be used. For keeping that thing in mind accordingly the enhancement, the image quality enhancement and the

sharpening, that done through the special filtering which we'll discuss in next lecture can be done.

And then finally you reach to the stage where then you can go for feature extraction, that is image classification maybe pixel based, maybe object oriented based. Nowadays very innovative image classification techniques have been developed. But the problem with these techniques is that there might be good for one particular image but if I get the same area image of another season, apply the same way the image classification technique I may not get the same results.

Because not only the season has changed but the entire statistic has changed, entire image has changed and therefore the results may not be that good or accurate for image classification. It becomes sometimes seen dependent image classification but anyway, that will be discussed later and once you go for image classification of course we go for accuracy assessment that how accurately the image classification land use. Suppose if I have classified an area as a bare rocks or bare soils then really on the ground it is there and how accurately I have classified for that quality assessment about the accuracy has to be done.

And then I take that classified output image to in a GIS platform, use it or may create some more products using that is possible. And if I am going for time serious data analysis then I may go for change detection study, for example if I am using thermal images, I have created output that is a sort of image classified output like land surface temperature map, that LST map. If I am having a time series maps, LST map of the same area of different dates then I may see the changes which has occurred between say one month of 15 days or one week.

So that change detection can also we perform. It is need not to be the change reaction has to be only after classification even before classification can be done. So it doesn't matter but change detection is only possible once we are having a time series. At least two images are required. Suppose there has been an Earthquake and looking the ground changes specially on the slopes of the mountains, whether Earthquake induced landslides occurred or not. So need an image just before the Earthquake and probably the same satellite image, same sensor image after the Earthquake.

If the dates of these two images are very close and in between the Earthquake has occurred then change detection do the high reliability, high level of confidence can be done and then I can conclude whatever the changes I am seeing between pre-earthquake image and post-earthquake image are induced by that particular event so that even it might be earthquake that even might be a landslide that even might be flooding, drought or any other thing. So it depends on the phenomena and then the availability of images for change detection. Change detection is becoming very powerful, very useful thing nowadays because of we are having long availability of archive of data.
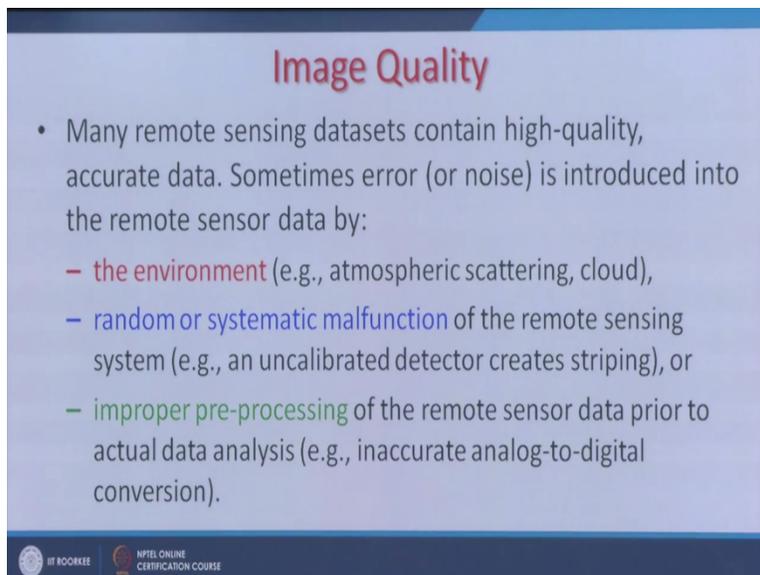
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Now image quality which ultimately if image is good then interpretation will be good, classification will be good, everything would be having better results so many image remote sensing data sets contain high quality accurate data. Sometimes error or noise is introduced in the remote sensing data that might be because of environment and atmospheric scattering, cloud, maybe haze, maybe fog, mist all these environmental factors may deteriorate the image quality. For example if time is not season is not that important then the image which has taken just after the rain specially say for in case of India, specially Northern India wherein winter time you are having generally very hazy scenes.

So if an image is taken just after the rain when Sun is there you would find a very high quality image because the environmental or atmospheric distortions would be minimum, no haze, no fog, no clouds, nothing except the Sun Illuminating the surfaces and therefore high quality image can be acquired but then you need to have orbiting satellite there at that time. Random systematic malfunctioning of remote sensing system we have discussed in previous topic while discussing the geo referencing can be corrected to some extent by involving geo referencing and if there are some random things then probably by human interventions can be corrected and sometimes some errors are so bad that they cannot be corrected and such images cannot be really be used at all.

But one thing one has to remember, generally image processing we divide in two steps. One we call is pre-processing, another one is processing. Not really post-processing but processing. So this pre-processing basically involves the georeferencing and convergence. Earlier we always never had the digital satellite images we used to scan or convert by some means analog to digital and that will consider under the pre-processing. Geo references can also be considered under pre-processing sub heading. So this improper pre-processing may bring some problems later on in your data analysis.

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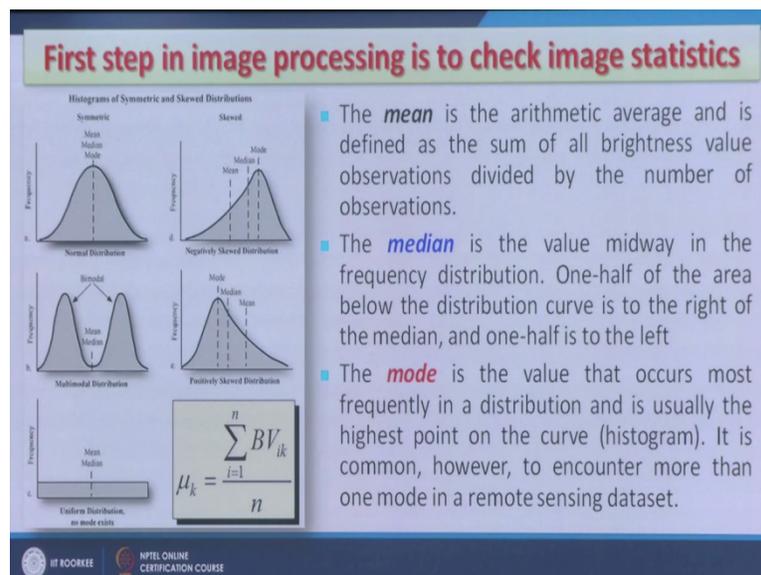
Now as I have mentioned that in this image processing, in image enhancement that is improving the quality of image so that our interpretation becomes easier and accurate, for that we need to

first understand the statistics of all individual images. As I have also mentioned an image of the same area taken in two different seasons will have two different statistics. So statistic of an image depends on that particular scene or image. So if I see here the histograms which is nothing but here I am having the pixel values, suppose this is 8 bits 02 and 255 and I am having frequency and that is a typical histogram.

If it is all well distributed that means the value 127 is going to be in the center and highest then all our mean, median and mode all will be the same. And in, In this condition we call it normal distribution. Though in real images theoretically it is possible but in real images one never gets such kind of a normal distribution in the histogram. You may get a skewed kind of distribution of pixel values and their frequency so mean might be here, median is elsewhere and mode is that is the maximum, is (ah) the threshold might be different and there might be positively skewed, there might be negatively skewed this is negatively skewed the one, this is positively skewed one and there might be multimodal distribution.

So there are a kind of two sets and this is possible because half of the image might be having forest area, half of the image might be having agriculture land. And now both are having vegetation but their signatures in infrared channel are going to be different and therefore I might be having bi-model distribution. So it depends, if it is a desert kind of area I may get a distribution something like uniformed distribution or it is a water body or completely dense forest. So based on this this is the first step as mentioned here in the image processing to check the image statistics.

The mean is the arithmetic average and this defined as the some of all brightness value observation divided by the number of observations. The median is the value midway in the frequency distribution. One half of the area below the distribution curve is right of the median, and the other half on the left and the mode is the value that occurs most frequently in the distribution as shown in these examples in a distribution and usually highest point on the curve store. It is common however to encounter more than one mode in a remote sensing data set as mentioned here is a bi-model and this is very common thing. It is not very rare if depending on the objects which are present within one image.
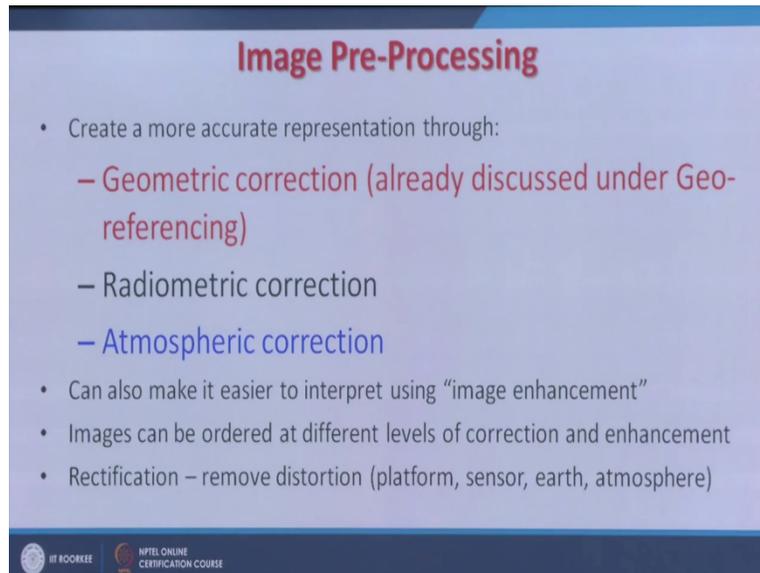
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Now in in image pre-processing steps basically to create a accurate representation through geometric correction, there is always discussed under geo referencing then radiometric corrections. Generally we don't perform, it is done by the operator itself. But if they have not done, we have to find some utility software programs to do it but we need to have a lot of data about the sensor. Atmospheric corrections are also performed, again there are certain models which are used to removed atmospheric distortions from the images but those models will also require a lot of input about the ground conditions when the image was acquired.

And that becomes very very difficult to find, so what we go for? Improving the image quality is to go for image enhancement. That may minimize the atmospheric distortions and other problems of course geometric distortion have to be corrected using geo referencing technique. An image can be ordered at different levels of correction enhancement, the agencies like in India there are NRSA, NDC; National Remote Sensing agency and NDC is National Data Center. They provide data about Indian satellites.

You can order a completely processed data or you can order a raw data. So if you are having a capability of processing by yourself, you can buy raw data at a cheaper rate or a large area and process yourself, so you'll have your own confidence rather depending on others but you don't have the capabilities and the so much set-up you can directly order the complete correction

corrected and enhanced data. Rectification, as we have discussed to remove distortions, here rectifications has also involved, the atmosphere but generally it will be putting in the atmospheric correction.

Initially we when we have this MSS or later on also recently it was noticed in case of Landast 7, this stripping or de-stripping and noise removal so that also we put in this because these are errors due to the sensors. So this radiometric correction is a pre-processing method to reconstruct physically curveted values, correcting the spectral errors and distortion caused by the sensors. But you need to have the information about, suppose I am having, this data has been acquired by linear array so whether this if all this CCTs have been calibrated perfectly then the stripping, de-stripping noise will not come.

If they have not been then this stripping or lines in your image will appear. In order to correct that one we need to have the data about individual CCTs. Once we apply that correction then spectral errors that is creating stripping, de-stripping can be removed. For example here, that this is because of stripping so de-stripping can be done once the data is available about individual CCT and smooth image can be generated. Drop lines, sometimes there might be drop line specially in the thermal data set, it has been observed because of saturation, because of high temperature value objects present on the Earth so it takes some time to cool down the sensor and
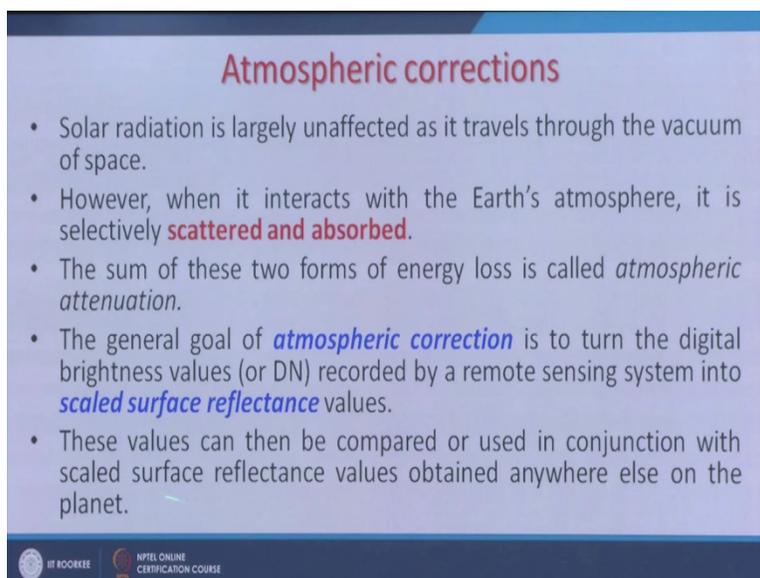
there might be some drop lines are commonly replaced, manually it can be also done if there are not many drop lines then manually perhaps this can also be replaced.

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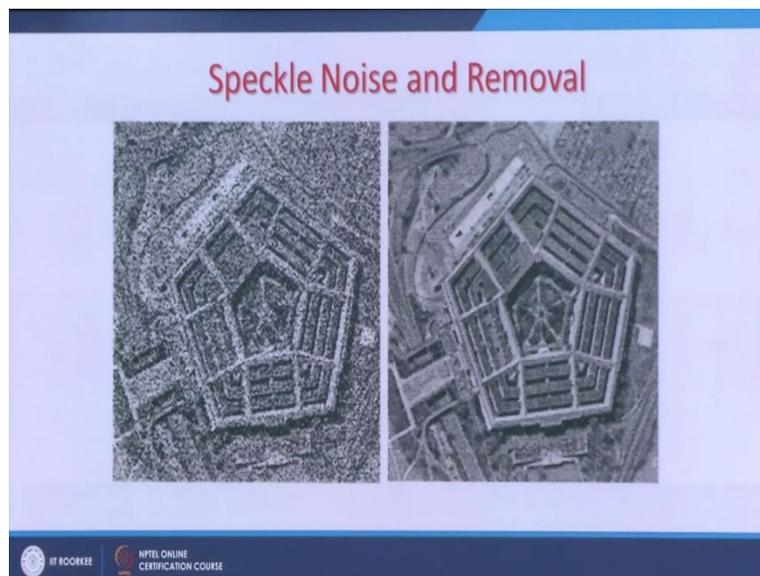
In radar data you will find a lot of speckle or noise, that too can be removed and your image can be made very smooth, so the interpretation of such images can but it will only happen in case of normal passive remote sensing when your sensors have not been nicely calibrated.

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Now atmospheric corrections which requires a lot of input, distortions might come from various reasons so solar radiation is largely unaffected at it travels the through the vacuum of a space. However it interacts with Earth's atmosphere it is reflectively scattered and observed and some of these two forms of energy loss is called atmospheric attenuation, this introduces the distortions in your image. The general goal of atmospheric correction is to turn digital image brightness value recorded by remote sensing system into scaled surface reflectance values. That means removing the entire effect of atmosphere from a image, assuming that there were no atmosphere.

In some earlier lectures I have mentioned that like on the Earth we are having a thick atmosphere, relatively thick atmosphere but on the Moon we are having thinnest atmosphere and therefore atmospheric distortions are also very less and the therefore the images which are coming from the satellites which are orbiting Mar's surface like Mangalyan, are giving a very high quality images because there are no distortions due to atmosphere. We are looking similar kind of image quality then these have to be removed.

Now the atmospheric conditions globally are not the same. In one area they are different, another area they are different. In one time they are different in the same area in afternoon they are different in evening they are different. So when the data is being acquired, all the inputs which will go for atmospheric corrections, the ground data has to be collected from that image area. Then only we can go for high quality atmospheric corrections. If we use some models then a lot of assumptions are involved.

So these values can then be compared to use to conjunction with the scaled surface reflectance values, obtain anywhere else on the planet. So if we go for that kind of thing then that means we are going for modeling, assuming the things are same at two different places or within one image and that kind of assumption for coarser resolution data which covers a very large area may not be very good.

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There are as I have mentioned that if we go in much detail in this part that atmospheric correction required because there are a lot phenomena; scattering absorption, refraction, reflection all are happening at the same time. This is the illumination source is the satellite and signal is going back. All this scattering, absorption, reflection and refraction are occurring and it is a long distance. It has to first pass from atmosphere and reaming in the space, so there are several ways to atmospherically correct remote sensing data.

Some of relatively straightforward while others are complex, being founded on physical principles and requiring a significant amount of ground data to function properly.

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a) Image containing substantial haze prior to atmospheric correction.
b) Image after atmospheric correction using ATCOR (Courtesy Leica Geosystems and DLR, the German Aerospace Centre).
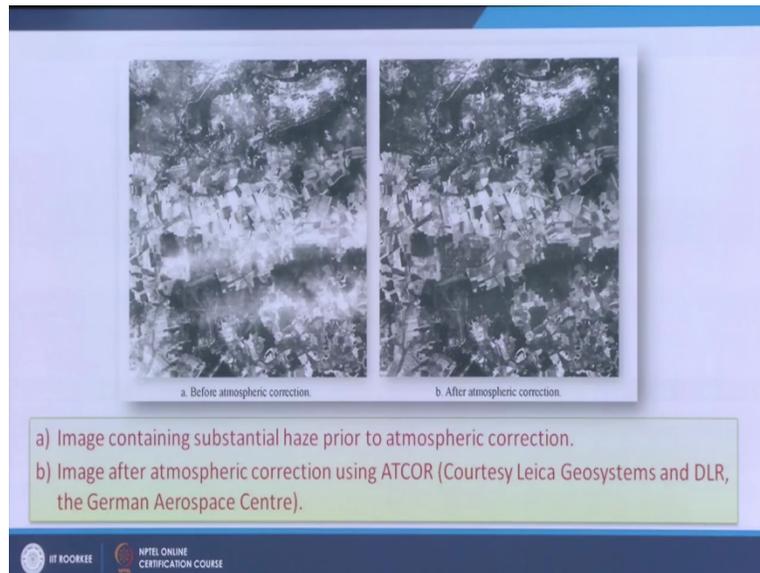
This example is shown as an image which was suffering from some atmospheric distortion like haze and other things. One those things have been removed then an image quality has definitely improved, so after image corrections using this model one can really sometimes can improve the image quality.

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One another way of removing or improving image quality is applying a brute four correction, that is possible by using a simple histogram stretch so if assuming in an image value should have been zero as well as some pixels should have carried value zero, another should have carried 255, if I am discussing an image of 8 bit. Then I can stretch and this is called brute force stretch kind of thing and if through this process and very straightforward manner, I am also removing the distortions which are causing probably by the atmosphere. But this is not a very standard method for removing atmospheric distortions but if there is no other choice available then probably this linear stretch of satellite image can be applied and this distortions due to atmosphere can be removed.
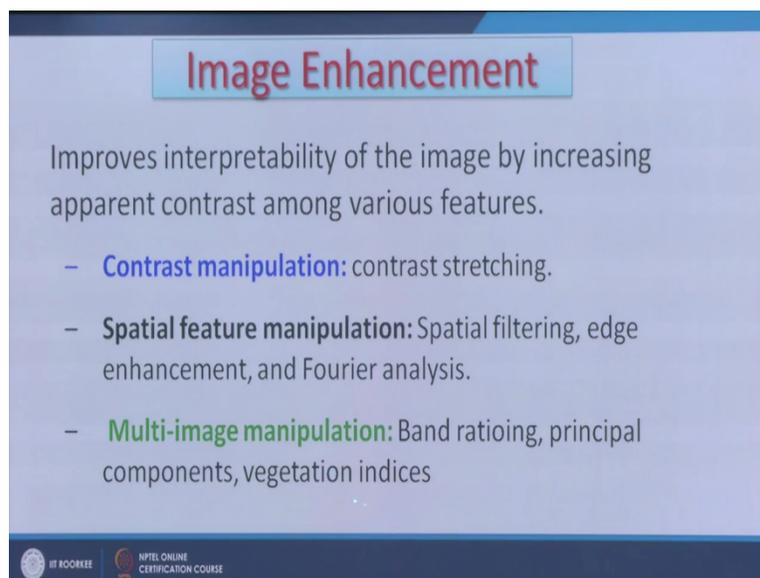
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Now image enhancement further we are discussing that improves interpretability of image by increasing apparent contrast among various features. Basically we are looking more contrast so that indusial object features can be identified very easily. That is the main purpose of image enhancement. Now contrast manipulation that is contrast stretching; maybe spatial feature manipulation that means spatial filtering which we will discuss in next topic. Spatial filtering, edge enhancement, maybe furrier transformations based on this furrier analysis based on fast furrier transformations multi-image manipulations instead of doing only on one image. Generally we are having choices of several bands so we go for multi image analysis.

Maybe some techniques like band rationing, principle component analysis, vegetation indices like normal large difference vegetation index and so on so forth. One variable that is one single band, on multi variable, multivariate analysis can also be performed. So whatever the techniques which are available in mathematical domain for matrix or matrices can be used also in image because after all it is a two dimensional matrix.

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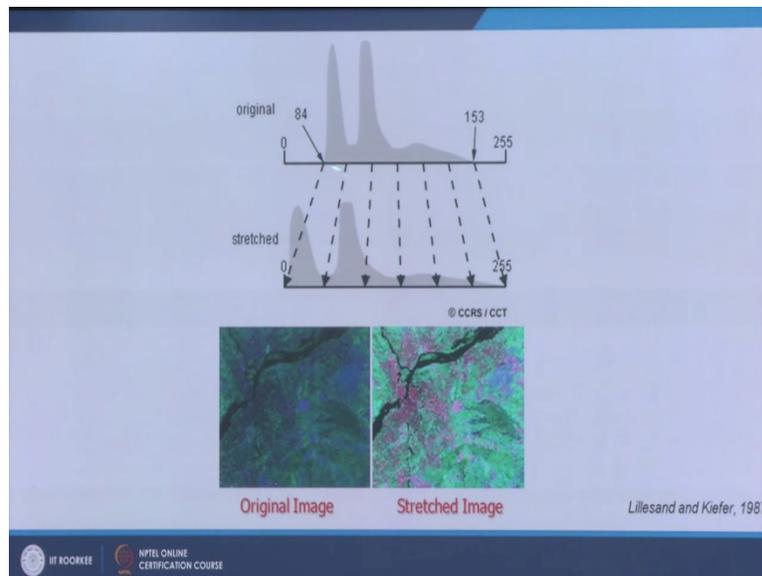
The example here of a removing this thing is like this. This is the original histogram, this is how this image histogram looks, bi-model and the values the minimum value in this input image is 84 and maximum is 153, whereas it is expected that these values should have been zero and 255 may not to be because it is not all the time that you'll have a object in a single image which will have almost no reflection. And as same time you would have an image in your pixel, in your image which will have the perfect reflection in 8 bit image you will achieve 255 value.

If it is not then a simple linear stretch redistributing the values between 84 to 153 into zero to 255 can improve the image quality and this is also called the Brood force and indirectly you are also getting rid of some affects of atmosphere and definitely this is the most common one, very simple one, straightforward one. You are treating each pixel in the same way, a linear stretch will improve image quality very quickly and this kind of image enhancement is called linear stretching.

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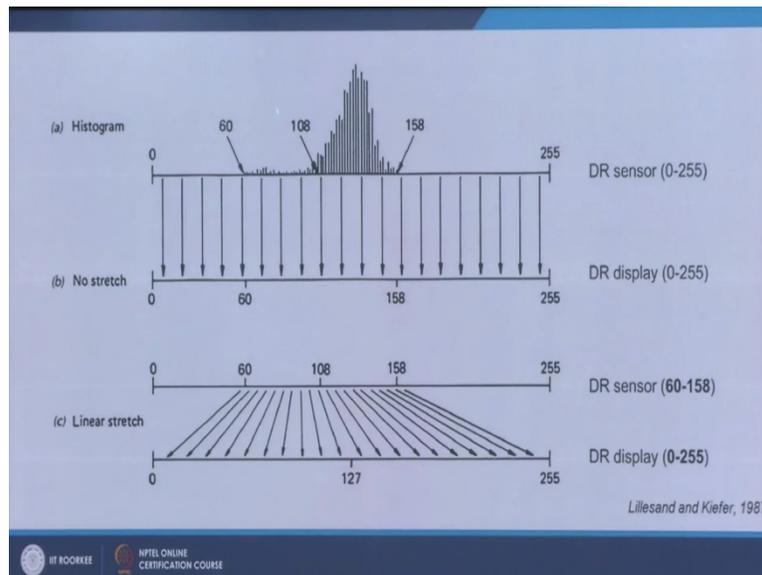
Now same example here that histogram distribution is this, minimum value is 60 158 is the maximum value. If I redistribute without any stretch then it is going to be like this but if I do the linear stretching then I am using whatever the range of pixel available to me, that is between 0 to 255 instead or original which is available between 60 to 158, so when stretch this linearly, like a rower's seat then I am improving the contrast in the image and ultimately image quality by a very quick method, so here the input pixel values are 62 to 158 after stretching they will become so that once their values have been redistributed definitely the contrast among different pixels that means different feature will improve and will be higher.

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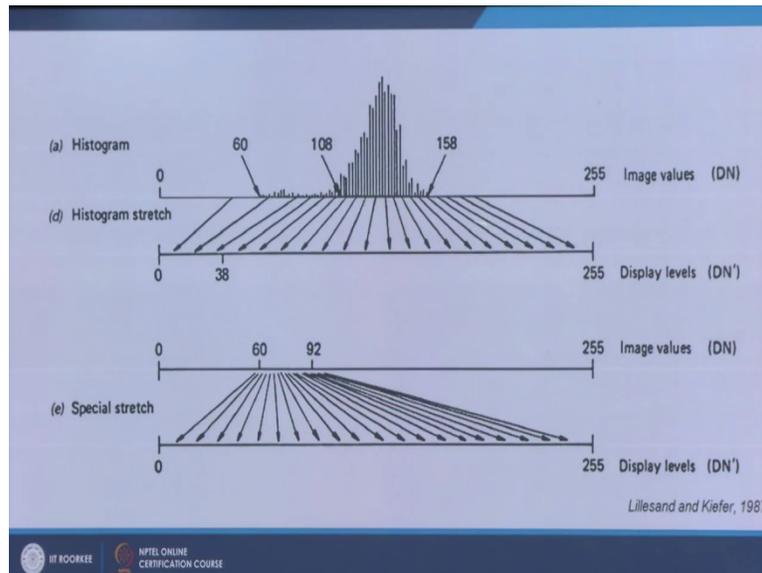
There is a another way of doing is the histogram stretch, now instead of just changing the value along the X axis. Now I am involving the frequency of pixel values occurrence and then histogram is stretched that where the frequency is higher that area those pixel will be stretched more and wherever the frequency of pixel is less those areas will be stretched less and why this we called as histogram equalization and the values which are between 60 to 92 have been stretched between 0 to 255.

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Figure 5 — Contrast Enhancement by Histogram Stretching (Lillesand and Kiefer, 1987)
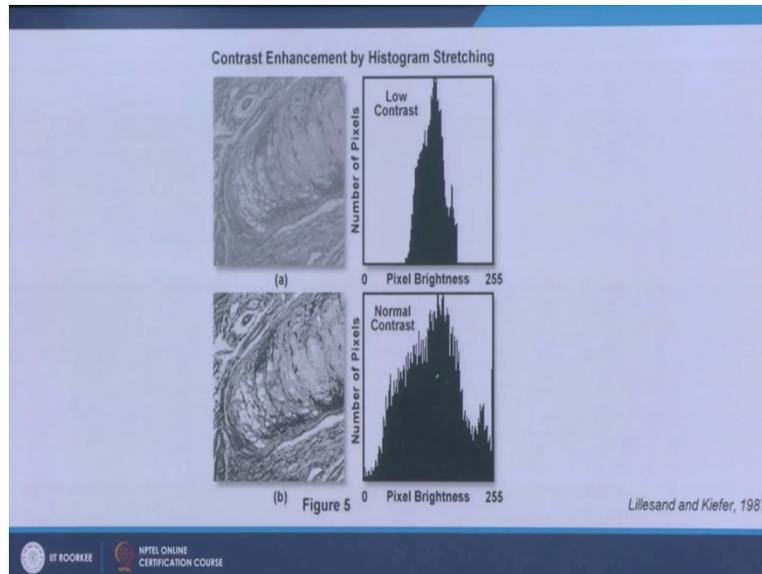
And wherever I had the more density of values are stretched or more frequency of value so this is called histogram equalization and there changes which you can see very easily that how this histogram was stretched then the frequency will change and my image will look altogether different.

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Histogram equalization (Lillesand and Kiefer, 1987)
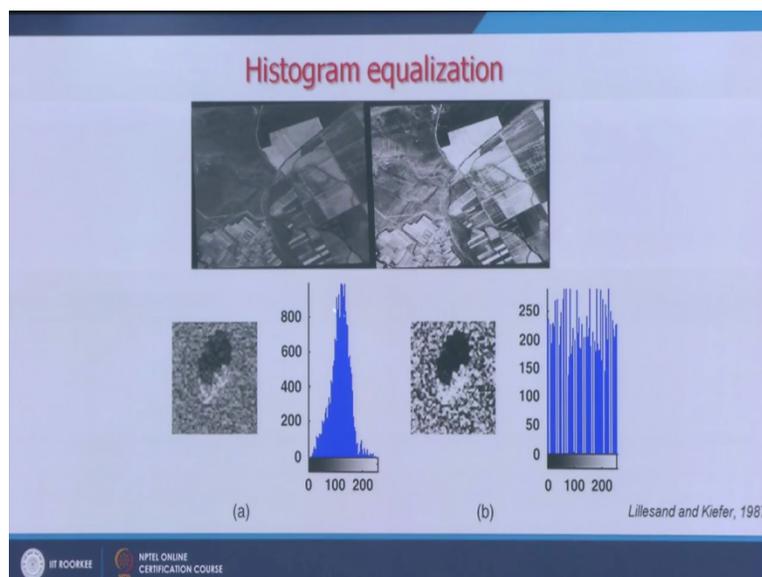
This another example of histogram equalization that I am changing now, playing with the frequency of occurrence of pixels and creating a different kind of contrasting image so here you can see in zoomed part also you can see the distribution, so definitely image quality has

improved. The pixels which has high frequencies are kept as it is but pixels which has the low frequencies are giving more stretching, so it is a in that way one way of doing this so this brings to the end of very simple basic techniques of image enhancement by which you can improve the image quality. Thank you very much.