REMOTE SENSING FOR NATURAL HAZARD STUDIES

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Lec 8a: Remote Sensing Data Analysis-I Part A

Hello everyone, today we will start Lecture 8, which is on remote sensing data analysis. So, we will continue this course. You might have seen many images when you capture them using regular mobile phones or cameras; even then, you will notice that some of the images are not very clear. The brightness and contrast are not proper. The same thing happens with satellite images also. So, that is why raw remotely sensed images often have a poor visible appearance due to the poor brightness and contrast of the image, So, we will try to understand this photograph.

So, here you see the first image. This is taken from IIT Guwahati. Now the second image is a little bit better; this is again better; this is the last image, So, if you compare all of them together, you will find that this one has poor brightness and contrast, while this one has very good brightness and contrast. So, the quality of this image and how they appear depends on your brightness and contrast, So, you can observe this here. So, this is the first image, then the second image, then the third image, and then this is the fourth image. And here you will easily notice that some of the features available here; let us focus on this

cloud. So, when we have poor brightness and contrast, these things are not clear or visible in our photograph. However, when we improve the image quality in terms of brightness and contrast, we find that clouds are appearing here. So, this contrast is very, very important.

It is the difference in the intensity of the object of interest compared to the background. So, if you draw a line, we are able to see this line because there is a contrast between the background and the color of this line, If I use white color, you will hardly notice, right, because both will have the same color. So, there will not be any contrast. Contrast does not change linearly. So, when I draw a line, the contrast drastically changes here, and on this particular line, that is why we are able to see the edges, it is a function of the logarithm of the difference between the object and background intensity that is obvious.

This means that in the darker region, small changes in intensity can be noticed, but in the brighter region, the difference has to be much greater. Let us take the example of nighttime. So far away, if there is a bulb glowing or a tube light glowing, you will easily see that some light is present. But during the daytime, you will hardly notice if a bulb is switched on or maybe a tube light outside. So, it all depends on what the situation is, how it appears, and what the background condition is.

Image Operators

❖ **Global Operations** do not consider location (x,y) of the image pixels,

$$g=H(f)$$

where 'H' is any operation on the image 'f'.

whereas, local operations also consider pixel location,

$$G_{1(i,j)}=H[f_{(i,j,k)}]$$

where, i,j,k are the position and band information of the pixels.

❖ **Local Operations** are important when the illumination condition is different across the image,

❖ **Point Operations** are used to enhance any particular pixel based on its grey levels,

$$G_{(i,j)}=H[f_{(i,j)}]$$

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So, the darker reason smaller changes in intensity can be noticed. However, in the brighter reason, the difference has to be much greater. So, in the daytime, you will hardly notice any bulbs switched on outside, but at night, we all know that even if it is half a kilometer away and there is no object in between, you will be able to see some bulbs glowing or some light there, So, that is a very good example. Now, referring to this statement, just try to see here. Now you see that when we improve the contrast, this cloud is clearer in this

photograph. So, that means the remotely sensed images do not matter whether they are satellite-based measurements or from your phone or DSLR. Contrast or brightness has to be adjusted correctly, and remember it is only for the visual appearance of the image. I am not talking about the analysis now; the analysis will come later. So, there are different operators. So, in the image, when we have a set of DN values, which is basically our pixel, So, when we have the pixels, let us say 10, this is 20, this is 30, something like that. So, when we have this image, we can have a local operation, a point operation, or a global operation. So, we call them image operators. So, these image operators will help you to enhance the image quality. So, this particular portion is not explained here because it is the limitation of this particular course. So, here we do not have the scope to cover all the basic processing of this.

However, all these details are available in my other NPTEL course, which is Remote Sensing and GIS; if you want, you can refer to those lectures. So, the first one is the global operation; this does not consider the location of the image pixel. So, this will be global. Then next is the local operation. So, here the illumination condition is different across the image. So, suppose this is 1 kilometer by 1 kilometer and part of the area is cloud-covered. So, let us take this particular area that was cloud-covered.

So, this portion needs more improvement, However, in other areas, they do not need that much treatment, So, in such cases, local operation is good if the entire area has the same illumination condition and the weather condition; then this global operation will be a better option. Then the point operation, if you want to enhance a particular object or target in that image, is preferred. So, this is the expression for point operation; you can see this is for the global, and local operations are also considered, and then, this is the point operator.

So, when we talk about the image enhancement technique, there are many. So, we mainly classify them into two classes: one is linear contrast stretching and the other is non-linear. So, when we refer to the linear, the image is enhanced linearly, and when we talk about the non-linear stretching. So, here we have logarithmic stretch, exponential, piecewise, thresholding, density, and there are a few more image enhancement techniques that come under non-linear stretching. So, linear contrast stretching techniques are not very useful in analyzing remotely sensed images. Why? Because when we talk about nature, things are not changing linearly in nature. So, classes are changing dynamically, So, the nonlinear enhancement will be a better option than linear enhancement. So, that is why film, computer monitors, televisions, and the human visual system are the best examples of nonlinear systems. And when we try to represent our ground with the help of remote sensing sensors in the form of images and then use a display system to present our data, a non-linear image enhancement technique will provide a better visual perception of that particular area. Non-linear stretching will become more effective in enhancing digital images.

So, here we have examples of non-linear stretching like logarithmic, exponential, piecewise, thresholding, and density slicing, but we have one more, which is called the lookup table approach. So, here is what happens when you use a particular image. And just apply the logarithmic stretch correctly. So, what will happen is that once you get the output, you will not have any record of the previous data. This is the only output you will have, but when we talk about the lookup table, this lookup table will preserve the original image information.

So, this will be also preserved whenever you want you can go back from here to here. So, that is why it preserves the original image information, which is very, very important because sometimes what happens is that you have to refer to the original value for the analysis. So, let us talk about histogram equalization. So, a dynamic gray range of levels is preferred for better display. What does it mean? Suppose this is the histogram, and let us say this is 8-bit data, so the range is 0 to 255; this is frequency. So, the histogram lets us say one case is this. So, here what is happening is that all the values of my image are concentrated in this particular region. So, this particular region is not used by my data or the display systems. So, here it may be 10 to 50, let us say. So, even though I have the option of having 0 to 255 different classes or the grey labels, our data is occupying only 10 to 50. So, in such cases our image will have poor brightness and contrast. So, when we have this situation, can we use some method to enhance this data so that it occupies the whole range? then we can say this data is occupying the full range which is available to this and then your image will be better right. So, that is why the dynamic range of gray labels is preferred for image display. In the histogram equalization method, the image is transformed in such a way that all the grey levels have an equal likelihood of occurrence. So, what does it mean? When we refer to any image matrix here, basically let us say this is now we have 10, 10, 20, 20, 30, 5, 6, 9, 9, 9, 9, 30, 20, 10, 10.

Now here you see, if I draw the histogram of this, what will happen is I have a unique value of 5, then 6. Then 9, then 10, then 20, and then 30. This is not the actual scale. Now, if we identify the frequency, this is 1, 2, 3. So this may be 1, 2, or 3. So this is coming here. Now for 6, we have 1, 2, and 3. So this is also coming here. 9 is 1, 2, 3; 9 is also coming here. 10 is 1, 2, 3, 4, 5, So this is 5, so 4, 5; so, 10 is here. 20 is 1, 2, 3, 4, so this is here. Now 30 is 1, 2, so this is here. So, if you see, all these have almost equal frequency because they are in the range. But suppose I replace this value with, let us say, 7; now we have 7 here, and 7 has only one frequency. So, in such cases, this value will not be seen in the image because other DN values have high frequency, meaning they are occurring a greater number of times.

So, in such cases, what happens? This histogram equalization method works on the DN values' frequency, and it tries to provide equal likelihood of occurrence to all the DN numbers present in my data. So, in such cases, what will happen is that your image will be enhanced, and this image will have better brightness and contrast. Histogram-based

enhancement technique considers the relative frequency of the occurrence of gray levels. Hope you have understood the previous example. High-frequency gray levels should be given preferential treatment so that they are well separated on the gray scale for better display quality.

I will try to explain this again, let us say, 0 to 255. And this is the frequency. So, let us say my histogram is like this, but this available range is what we are trying to stretch this data. So, it should be like this: it should occupy the full display range, So, in such cases, what will happen is that this preferential treatment will be given so that the data sets will be well separated. So, one value is here, another value is here, but in this case, what will happen is this will be here and this will be here.

So, these two will be well separated, So, that is the meaning of this statement. So, this histogram equalization is one of the best techniques for image enhancement that you will see in the example that I will try to show. Optimize the utilization of the available display range. So, in the case of an 8-bit data or 8-bit display system, the whole 0 to 255 gray range or gray levels will be used to display the data. It also merges the gray levels having very few pixels. So, suppose the image is maybe 10,000 by 10,000 pixels, and here there are a few DN values, let us say 7, which have only 5 frequencies, So, there is a frequency. So, in such cases, this 7 is not a good idea to keep in this image. So, what will it do? It will merge it with the closest value that has a higher frequency. So, let us say 8 has a frequency of 100 or 1000.
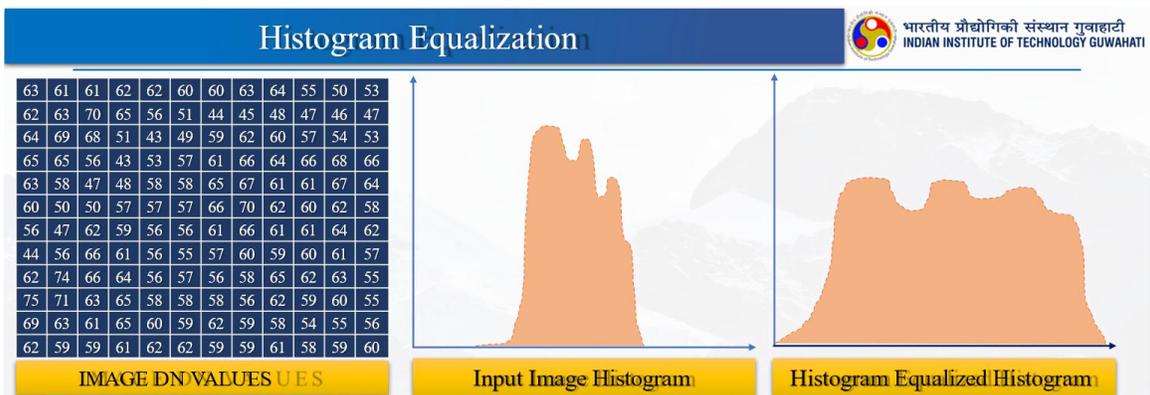
$$h(v) = round\left(\frac{cdf(v) - cdf_{min}}{(M \times N) - cdf_{min}} \times (L-1) \right)$$

where,

cdf = cumulative distribution function,

M×N = image's number of pixels

L = quantization level (e.g. 8bit, 16bit…)

So, these two will be merged. So, this 8 will have the 1, 10,000, or 1,005 frequencies, So, like this it will be treating your data and all this information will be preserved in the lookup table. So that you can go back and refer to the original value, it separates heavily populated

gray levels. That we have already discussed. So, an ideal histogram will have an equal population of all gray labels. So, I have one example: this is the input histogram, and this is the output histogram after the histogram equalization, so you can see how it is occupying this whole range.

Let us say this is 8-bit data; this ranges from 0 to 255. So, this range was not used correctly, but here everything is used correctly. So, this is what we are trying to do with histogram equalization. We will try to provide equal opportunity to all the pixels except for a few pixels that have very low frequency, which will be merged with the closest value. In this example, you can see this is an image matrix. So, the DN value of this image is the histogram of the input one. So, let us say 0 to 255; this is again 0 to 255. So, how do we do that? So, we use this equation to separate this heavily populated data concentrated in a particular range of this histogram, now we will be occupying this full range which is 0 to 255. So, here is the round of the value that you will get from here. So, CDF is the cumulative distribution function, and this MxN is the size of the matrix.

So, you take the total number of pixels in this and this direction; you take this as M by N, and L is your quantization level, which is 8 bits or 16 bits. So, in this case, we have considered 0 to 255. So, this is an 8-bit example, So, the same matrix has been used in this table. So, what we will do first is try to identify the unique value, So, those are the DN values. So, 43 and so on is going up to 75. If you refer to this, the same table has been used here. Now, once you have identified the unique DN values listed in this table, we will proceed with the degrees of freedom in the dataframe. So, what is this? So, 2.43 has occurred 2 times in this particular table or this matrix, So, here you have 2 times, and then 44 has occurred 2 times. So, similarly, we will count it, and then we will prepare this df.

In the next column, which is the CDF (cumulative distribution function). So, here the first minimum value will have the CDF of 2, which will be equal to your degree of freedom, using this image matrix, we will prepare a table, and this table will have DN values. So, here the first column will have the unique DN values from this particular matrix, and they will be listed over here. So, the minimum value, which is 43, and the maximum value, which is 75, are what we have got from that particular matrix.

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

$$h(v) = round\left(\frac{cdf(v) - cdf_{min}}{(M \times N) - cdf_{min}} \times (L-1) \right)$$

Now, we will have the distribution function, df. So, the df is basically the frequency of how many times 43 has occurred in this particular table. So, this distribution function will be listed here for all of these unique values. And then we have this third column, which is the CDF (cumulative distribution function). So, this is the first CDF of 43, which will be the same as your (df) distribution function. Now, what will we do? We will add this 2 to this 2 and then this will become the CDF of 44, and the same thing we are adding here, we are adding like this. And then we are getting the CDF of all these values. So, remember this CDF is very, very important because if you refer to this, we will be using the CDF of a particular pixel, then we will be using the size of the matrix, and whether it is 8-bit or 16-bit data, and the CDF mean, which is here. So, here the CDF mean is 2. So, in the same way, we will be calculating it one by one for all the pixel values, and then we will have the equalized value, So, this equalized value will be based on this equation, and here is the CDF(v) for a particular pixel.

So, in this case, let us say this is 2. So, this value of 2 is used, then the CDF mean is also 2; then M by N will be 144 because this is the sum of all pixels and how many times it has occurred. So, this is a very good idea to cross-check whether this matches your M by N or not. And then you have again that the CDF mean L is your quantization level. So, whether it is 256, 16, or 18 bit, whatever radiometric resolution you want in your data, So, in the same way, we will be able to produce the output image, and remember that this calculation will be preserved in this lookup table, and at any time you can refer to the original value. So, whether this 119 had a value of 43 or 44 that you can refer to at any point in time.

This is one example, and it explains the effectiveness of the histogram equalization method. So, just see this image; this is the raw image that is captured by a particular camera, and

this is the histogram equalized image. So, you can see the difference in how well it is improving the brightness and contrast of the image. In this one, this is a satellite image.

Here you can see how it has been enhanced. I hope the application and the effectiveness can be seen here with these examples. I have one more example so you can see how it is differentiating and how well it is providing equal opportunity for all the pixel values to appear in that particular histogram, I hope these examples have given you an explanation of the histogram equalization method, how it improves the image, and how it can be implemented or applied to any raw remotely sensed image or any camera image or any image that you have taken with your phone. So, with this, I will end part 1 of lecture 8, and we will continue this in part 2 of lecture 8.

Thank you. Thank you for listening.